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Preface

This volume presents the proceedings of CRIWG 2013, the 19th International Conference on Collaboration and Technology, which took place in Wellington, New Zealand, during 30 October and 1 November 2013. The conference is supported and governed by the Collaborative Research International Working Group (CRIWG), an open community of collaboration technology researchers formed in 1995.

Traditionally, CRIWG conferences offer a strong focus on collaboration technology design, development, and evaluation. The conferences bring together researchers from the Americas, Europe, Asia, and Oceania who present papers that report on innovative combinations of technical, human, and organizational approaches to expand collaboration support. Their work is often grounded in theory from various disciplines such as computer science, management science, information systems, engineering, psychology, cognitive sciences, and social sciences.

A total of 34 papers were submitted to the 2013 conference. Of these, 18 were accepted as full papers and 4 were accepted as work in progress. full papers (up to 16 pages) report on completed research studies while works in progress papers (up to 8 pages) report on research designs and preliminary results. All submitted papers were evaluated in double-blind reviews by at least three members of the Program Committee. The reviewing process consisted of two phases, allowing authors to rebut the reviewers' recommendations and resubmit improved manuscripts, which were then reviewed before final acceptance. The papers are organized into six thematic sessions, focussing on various aspects and applications of collaboration technologies: social media, social networks, crowdsourcing, collaborative learning, collaboration technology design, and software development.

The conference would not have been possible without the work and support of a great number of people. We gratefully acknowledge the members of the Program Committee for their valuable reviews, and the Steering Committee for its advice and support. We owe a special debt of gratitude to our local organizing committee, who worked long hours to help make this conference an enriching pleasurable experience. Finally, we honour the authors for their substantial contributions. We are confident that the papers presented at CRIWG 2013 will inspire current and future collaboration technology researchers and warmly recommend them for your reading.

August 2013

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Collaboration Using Social Media: The Case of Podio in a Voluntary Organization

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Abstract. Social media enables a new model of managing knowledge that involves formal and informal communication, collaboration using a variety of applications. Using a case study approach, this article investigates the affordances of such Social Media enhanced Platforms (SMeP) for the management of knowledge work (communication and collaboration). In particular it aims to address the following research questions: What are the affordances of SMeP for the management of knowledge work in a voluntary organization? How do individuals experience the opportunities and challenges of these collaborative platforms?

This paper presents the results of an empirical study on the adoption and use of social media in a voluntary organization. The findings pinpoints towards the potential use of SMeP for shaping new work practices but also towards the issues encountered when social media is introduced in organizations.

Keywords: social media, collaboration, e-collaboration, knowledge sharing, social software, web 2.0.

1 Introduction

Social media enables a new model of managing knowledge that involves formal and informal communication, collaboration using a variety of applications. This model allows managing knowledge at both personal and organizational level, facilitating knowledge sharing and virtual interaction through easy to use collaborative tools [1]. In a knowledge-intensive organization the dynamics offered by Web 2.0 solutions is one way of utilizing the potential that collective intelligence offers and one way of addressing the challenges of the knowledge society and its ability to harness and retain relevant knowledge and stimulate collective creativity. Recent literature emphasizes that collectives are more inventive than isolated individuals because their members bring diverse knowledge related to the shared task and inventions emerge out of their interactions, assuming that synergy between the members of the collective is realized [2]. Social media-enhanced platforms are designed not merely to distribute knowledge but also provide conditions in which knowledge is shared and new knowledge is created or exchanged through collaborative processes using social networks, wikis or blogs.

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The literature suggests that teamwork and collaboration are central for knowledge creation and innovation. Innovation and knowledge creation are two strong interrelated concepts [3, 4]. The design of new innovative ideas which can be further transformed into new products and services or used for problem solving and decision making draws upon collective creative performance. Furthermore knowledge is created through a collaborative effort, relies on team work, and therefore fostering creativity and collaborative innovation are central endeavors for organizations.

Organizations and researchers have started to experiment with the use of social media in an organizational context, hoping to reap the benefits of lightweight informal collaboration among employees [5, 6]. These studies focused on social media participation and how to better engage users using social media within big IT consultancies.

When investigating how motivated are people to use social software, the acceptance of users is a crucial indicator [7]. According to [8] the correct deployment of social technologies in a corporate context will result in better communication and collaboration, more effective knowledge management and faster innovation. The Danish designed Podio collaborative platform founders argue that such platforms will represent "the future of work". This study will take a critical look at the adoption and use of Social Media (SM) in knowledge-intensive organization through a case study method and literature review. In particular, this article explores the affordances of such Social Media enhanced Platforms (SMeP) for managing knowledge processes and collaborative practices. The article focuses on the user experience and aims to understand how and why individuals use Podio and what their collaborative and work practices are. In particular the article aims to address the following questions: What are the affordances of SMeP for the management of knowledge work in a voluntary organization? How do individuals experience the opportunities and challenges of these collaborative platforms?

The article aims to shed light and discuss the opportunities and challenges organizations (the managers' perspective) and employees face in the adoption and use of such tools.

2 Literature Review

Groupware technologies are information and communication tools used traditionally in organizations to support collaborative work processes have started to be increasingly replaced by social media-enhanced platforms. Social media systems apply a network based relationship and resembles to the functionality and design of Facebook while classic applications apply a folder or a group based approach [9]. SMeP apply the same basic concepts as other collaborative systems but with a different adoption creating a different user experience [9].

Some previous studies have already emphasized that social media can help knowledge conversion and team performance [10] or can improve collaboration and communication within most companies [11]. The pooling of knowledge from individuals but also properties of the network of interactions and properties of individual agents (e.g. cognitive capacity) influence the rate of invention [2].

Despite the big success of social media, there are not so many studies on the topic of social media collaboration in SMEs and voluntary organizations. Many studies have been reported by big multinational corporations and in particular big IT consultancies which are at the forefront of adopting social media focusing on specific tools [12-15]. Lots of studies are available on the topic of social media collaboration in an educational context [16, 17]. Researchers have also started to investigate the integrated perspectives between Web 2.0/social media and CSCW [18-20]. CSCW was related to goal and work orientation emphasizing on communication and coordination while social media (Web 2.0) provide a rich user experience and playfulness in their application [18]. “The field of CSCW has an intense interest in studying collaborative practices” [21] .

3 Methods and Setting

This article discusses an in-depth case study of a voluntary organization. Case studies are applicable for studying unexplored emerging fields and thus viable sources of evidence for the development of theoretical implications [22]. The study combines mixed method data analysis, including qualitative data from semi-structured interviews and quantitative data from a questionnaire, with literature review. Data was collected by means of semi-structured face-to-face interviews, questionnaires and participant observation. In total 6 interviews were conducted, 5 with students, aged between 21 and 26, from all the levels of organizations (2 team leaders, 3 executive board members) and 1 interview with an IT consultant and entrepreneur working with Podio. Furthermore 25 questionnaires have been answered. Interviews have been recorded and transcribed verbatim. The focus of interviews was on the interviewees’ perception of Podio as a SMEP. The semi-structured interviews included some of the following questions: How does Podio change the way we work?, How does Podio differ from other platforms?, How was Podio introduced in organisation?, What are the main benefits?, Does Podio increase collaboration and innovation within organisation? Does Podio increase efficiency? What are the challenges?

The short questionnaire included both opened and closed questions such as: Are you satisfied with the use of Podio within AIESEC? What do you think are the main benefits of using Podio within AIESEC? What are the main challenges in using Podio? What kind of applications and features of Podio do you use the most? What features would you like to have in Podio? How often do you check Podio? What are the processes that can be supported by Podio? Furthermore the questionnaire included some additional open questions in order to assess the perception of its users in relation with other mainstream social media tools: Would you prefer to use other platforms, such as e-mail, Google doc or Facebook, instead of Podio? How does Podio differ from other platforms such as e-mail, Google doc or Facebook?

In analyzing the data, the author has tried to identify the perception of individual users and managers of such platforms in terms of both opportunities and challenges.

4 Podio Adoption and Use in AIESEC

4.1 Podio Design as a Working Platform

Podio is an online work platform, which today many companies, organizations and people use to conduct their daily operations. Podio was founded in early 2009 in Denmark by Jon Froda, Anders Pollas and Andreas Haugstrup Pedersen. Later Kasper Hulthin joined the team. Jon Froda describes Podio's vision as "the future of work": "What really sets Podio apart is how it puts people in control of their work tools, rather than the other way around." [23]

Podio is designed to be a 'complete work platform for enterprise' and aims to integrate many different work tasks through one application. Furthermore Podio allows knowledge workers to build easily their own tailored applications. Furthermore, companies can easily customize Podio according to specific business processes and needs. Using the app builder it is easy to create workspaces and add the relevant workers to the space. By providing such a social media-enhanced work platform Podio is designed to support knowledge creation, collaboration, to remove bottlenecks and to increase the overall efficiency. Podio began getting its first customers in August 2009. As Podio gained momentum, the founders worked with others who shared the Podio's vision for the future of work and was acquired by Citrix Systems in 2012. Presently about 200000 organizations worldwide are utilizing Podio [24], and today Podio speaks seven different languages. By March 2012 users built over one million applications [25].

4.2 Characteristics of Podio

Despite strong links to the design of other online social networking sites (e.g. Facebook), the design of Podio is quite unique. The platform provides organizations with professional social media-enhanced collaborative workspaces. The visual design of Podio is similar to Facebook, the most popular social networking site. Users of Podio can also post status updates, comment and 'like' these updates. Podio is a platform that encourages social interaction and transparency in day to day work processes. Podio offers its companies hundreds of applications, which can be utilized for standardized business activities such as project management, recruitment and business development. It also offers additional features such as calendars, task commander, private messages, and chat functionality hence combining communication and work activity on the same platform. Furthermore users can easily customize the workspaces and build their own apps.

4.3 Organisational Background

AIESEC is a global youth organization that provides young people with a leadership platform, and offers students and recent graduates the opportunity to go on international internships. AIESEC is the world's largest student organization, present in over 110 different countries and has over 86,000 members worldwide.

AIESEC in Copenhagen Business School (CBS) has been present at CBS since 1948. Today AIESEC CBS has over 60 members within its local committee who work in the six department areas of the organization; Finance, Communications and Marketing, Human Resources, Incoming Exchange, Outgoing Exchange and Engagement with AIESEC and Alumni Relations.

Despite these distinct departments AIESEC CBS as an organization works cross-functionally to provide students at CBS with the opportunity to volunteer or work overseas, and develop partnerships with local companies. They also provide an internal leadership program for interested members, and organize external workshops and events for CBS students. Due to many levels of management and the high level of activity there is a special emphasis on internal communication, collaboration and information management within AIESEC CBS.

4.4 Podio Adoption at AIESEC

Podio was first introduced into AIESEC at CBS in May 2011, and is an official local sponsor of the organization. The partnership was initialized and in return for unlimited, free access to Podio as a non-profit organization, AIESEC CBS was to provide feedback to Podio.

In the beginning introducing Podio into AIESEC CBS was challenging for the management team. Prior to this AIESEC CBS's primary tool for internal communication was e-mail and Facebook. Projects and processes were done with a variety of tools such as: Dropbox, Google docs, word documents and excel. Within the first year of Podio at AIESEC, people were still communicating via other platforms and members were not checking Podio regularly enough.

One of the main factors affecting the implementation of Podio in the first year was the initial lack of strategy within AIESEC CBS. The former local committee president between 2011/2012 recognized that a major source of failure was a lack of strategy in how the platform should be used. Being new to the platform themselves, the management team was still testing out the various functionalities of Podio:

"We did not have any idea how we wanted to work with it when we got all the new members, so it was a bit confusing in the beginning."

The plan was to have Podio fully integrated within the organization before the new members were joining in September 2011, however this aim was not realized. The president at the time argued that the management did not know what functionalities of Podio they wanted to use and how to formulate an internal communication policy. Furthermore there was no organizational-wide training or introductions to Podio.

In September 2012 the newly elected 2012/2013 management team decided that Podio would be AIESEC CBS's only source of communication and implemented this policy before new members joined the organization. Furthermore new members of AIESEC were given an introduction of the platform, and urged not to use any other device to contact the other members.

Podio was adopted in AIESEC CBS for a variety of reasons. People liked the separation of 'work' and 'social.' People did not like the idea of getting several messages a day about AIESEC work on a social platform like Facebook. According to the survey relating to the satisfaction of Podio within AIESEC CBS, a majority of participants mentioned they liked having a platform devoted entirely to AIESEC.

Management also saw problems with utilizing e-mail for internal communication. First of all, people did not like getting their personal e-mail "spammed" with AIESEC related news. Although, every new member of AIESEC received an AIESEC specific e-mail account, people still did not like getting spammed with internal AIESEC communication. This was seen as a problem because many members were in contact with external members of the organizations, and important e-mails were overlooked or sometimes lost. Essentially the separation of external communication and internal communication was also an important point in the adoption of Podio.

Furthermore e-mail was also perceived as an inefficient method of communication in terms of collaboration and feedback. Often the input and opinions of people were lost in the threads of the e-mail. This was due to the fact that often more than one issue was discussed per e-mail and the layout of e-mail was designed in a way where priority is given to the last person who responded. Podio was seen as a solution for this problem. Essentially each 'post' can be dedicated to a different issue and the comment and 'like' functions also encourage users to give feedback. Furthermore, unlike e-mail this feedback is more visible and clear. This is due to the fact the feedback is targeting an issue specific to the post, and the fact users receive a notification when other users comment on their posts. On top of this, the 'workspace' function allows members to distinguish different teams and projects they are a part of and gives users a natural organizational structure to store their information. The local committee space has also been recognized as a platform for creating a unified working culture. The local committee space is a Podio space that has access to applications and which all AIESEC CBS members are a part of. It is a space where everyone in the organization can interact and collaborate.

5 Discussion and Conclusions

Organizations are trying to embrace social media however despite the potential advantages associated with the adoption and use, organizations and employees are challenged to adapt to new ways of working inherently distributed and collaborative. Using a case study approach, this article has identified new patterns of use, new possibilities for shaping new work practices and has pinpointed towards challenges of adopting SMeP for CSCW.

Podio aims to be a 'complete work platform for enterprise', integrating social media and software as service paradigm. Podio is designed so all work tasks can be organized through customizable apps organized in workspaces. Furthermore Podio allows workers to build their own apps and empowers users to customize their own work processes. Unlike any other mainstream platforms that members of organizations typically use in their private life, Podio offers a plethora of applications and features relevant for organizational use.

One example of Podio use in project management, in AIESEC CBS, was their autumn member recruitment campaign. Essentially all functions of the recruitment strategy were linked to Podio. Discussions of the recruitment marketing campaign were held on Podio, applications were linked to the platform. Furthermore evaluations of the applicants were discussed on Podio and interview feedback was stored on this platform. One particular distinctive advantageous feature of Podio is the fact users can design their own applications. This has led to Podio supporting new work processes. For example, this term the human resource team is now using Podio to track member satisfaction by creating a specially designed application to evaluate members' satisfaction.

In AIESEC CBS Podio applications are used for: communication (room bookings, organizing events), sharing documents, personal calendars, and for project management (assigning tasks, tracking tasks progress). According to the survey conducted at AIESEC CBS, Podio has been primarily used for internal communication (95.8% of respondents), followed by knowledge sharing 83.3%, and collaboration 70.8%. Despite the highly customizable and innovative features in these AIESEC projects, the survey showed that only 8.3% of the respondents recognized the innovation as an associated process facilitated by Podio.

However one of the biggest challenges in ensuring Podio as an effective internal communication tool is making sure all members are active users of Podio. Essentially, Podio loses its value as an internal communication tool, unless all members are active users. Changing the habits of people has been recognized as the most challenging aspect of implementing Podio by both the present and past management team of AIESEC CBS. Getting people to check Podio regularly and use the platform as the only source of internal communication has been a problem identified particularly by the Vice-President of Communication in 2012.

Respondents of the survey have voiced that they are already connected with many other social networking sites/tools and that adapting Podio to their daily routine is a challenge. New members also have problems adapting to the interface of Podio. Certain members have perceived that the platform is not explicitly user friendly and can be confusing at times. This has been linked with management of the Podio system; the existence of superfluous workspaces spaces and complicated applications.

According to the questionnaire, 56% of respondents surveyed are satisfied, 20% are very satisfied, 12% are undecided and only 12% are not so satisfied with the use of Podio in their local committee (0% are unsatisfied with the use of Podio). However, there are still suggestions for the improvement of Podio. In terms of functionality the young professionals use of the platform for coordinating meetings (76% respondents), communication and collaborating in customized workspaces (72%), calendars functionality (40%) and tasks (20%). When surveyed about possible improvements to the platform, respondents mentioned that they would like personal profiles, reminders, chat functions and a graphically illustrated overview of their activity.

Following the first year experience, new members follow an introductory training session about using Podio. These trainings go through the basic functionalities of Podio such as spaces, messages, calendars and how to use some of the applications. Further coaching is then given to specific members who need to learn more about applications. After the basic training, AIESEC CBS promotes Podio as an intuitive, 'learning by doing' platform.

Another major challenge regarding Podio is aligning this local information management platform to the global AIESEC platform. Myaiesec.net is the global information management system and the platform for AIESEC's international exchange program. New members of AIESEC CBS are not only introduced to Podio but the global platform myaiesec.net. Whilst myaiesec.net serves rather as huge database of information, rather than a direct communication platform, it is nevertheless is difficult to ensure members are uploading documents on both Podio and myaiesec.net. The issue of distributing information twice to both the local and global information systems reduces some of the efficiency gains of Podio. Furthermore, the promotion of an internal local information management system essentially isolates AIESEC CBS's entity from the rest of the AIESEC global community. This is an issue due to the fact the entity will be excluding itself from knowledge sharing on a global scale despite the fact knowledge sharing and collaboration may be high within a local setting. Hence, clear promotion of both platforms is necessary for AIESEC CBS in order not to become isolated in a global setting.

The author of this article anticipates the uptake of such platforms by different types of organizations, especially SMEs and voluntary organizations (not only tech-savvy organizations as presented in most of the studies available [4, 5]). The article analyses work related benefits of the use and new patterns of work facilitated by such platforms in a professional context. Platforms like Podio facilitate new possibilities for managing work and collaboration that are different from traditional working and collaborating practices (e.g. using email, traditional groupware technologies or Intranets). Furthermore the article has highlighted challenges that managers and young professionals experience in the adoption of such platforms (including lack of strategy, adapting to a new social media platform, "sense making" of its new possibilities).

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Keep Querying and Tag on: Collaborative Folksonomy Using Model-Based Recommendation

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Abstract. Tags are terms commonly used in collaborative media systems like Flickr, Youtube and Picasa to classify a subject, image, video, music or any related content. Despite its popularity, tagging is a repetitive task and that may affect the quality and reuse of tags in collaborative systems. In this paper we use a model-based tag recommendation approach to perform an experiment and analyze the vocabulary homogeneity of queries (tags provided by users), the recommended tags and their reuse. Results show that the use of recommendation improves the quality and reuse of tags. Furthermore, based on users attribution behavior, we conclude with a proposal for personalized tag recommendation.

Keywords: collaborative filtering, folksonomy, recommendation.

1 Introduction

Having a large amount of information distributed online, the categorization of content became impossible for system administrators. Web 2.0 environments allow users the possibility to categorize items through tags using folksonomy (folk + taxonomy), very popular in social media like Flick, Instagram and YouTube because in photos and videos there is no textual information to be found by search engines.

Despite the advantages of tags, tagging is a repetitive, tedious work and that may affect the quantity of tags and their quality. Sigurbjornsson et al. [1] made a substantial contribution to understanding the long tail on tag distribution: they analyzed how users assign tags, mostly hints to where/who/what and when the photo was taken. In addition, according to Kennedy [2] only 50% of tags provided by users are truly related to the resources. However, collaborative tagging [3] is a powerful tool on social media networks and could be improved by recommender systems [4].

In this paper we present the results from an experiment with queries (tags provided by users during an item classification) and recommended tags (suggested by a recommeder engine) to analyze the reuse and homogeneity of them

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when there is a recommender system involved. We implemented a model-based collaborative filtering (CF) [5] approach to recommend tags and compute the utility of them by probability measures using machine learning techniques. The results show that tag recommendation can improve tag reuse and homogeneity. In the next section we present the recommendation model used in the experiment and its improvements.

2 Reviewing and Improving the Recommendation Model

The tag recommender [6] used in this experiment describes each post P_i in a social tag system as a triple $P_i =< u_i, r_i, T_i >$ where $T_i = \{t_1, t_2...t_n\}$ is a set of tags attributed to resource r_i posted by user u_i. A tag t typed by user is treated like a query for similar recommendations based on its co-occurrence in $P(t) = \{P_i | t \in T_i\}$. To develop the recommendation it is necessary to obtain the k-tags with largest co-occurrence from $P(t)$. The function

$$exist(t, T) = \begin{cases} 1, t \in T \\ 0, t \notin T \end{cases} \tag{1}$$

will signal the existence of t in T and is used to rank the co-occurring tags t_j by $ranking(t, t_j) = \sum_{P_i \in P(t)} exist(t_j, T_i)$. That will produce the preliminary ranking of tags to compute the next three measures to improve the recommendation of a tag t_j.

Co-occurrence: To use the ranking of co-occurring tags and to take a normalized value for each tag, we compute the number of items that have both t and t_j by

$$coo(t, t_j) = \frac{ranking(t, t_j)}{|P(t)|} \tag{2}$$

The $coo(t, t_j)$ value for each t_j ranges from 0 to 1.

Relevance: The relevance measure tries to take from the top of the ranking those tags that do not represent the community vocabulary.

$$rel(t, t_j) = \frac{|users(t) \bigcap users(t_j)|}{ranking(t, t_j)} \tag{3}$$

For example, if a user posts lots of photos from a trip to Paris and the same set of tags is used for all of them, $< Paris, France, Mary, Aaron >$, these personal names will appear with a high level of co-occurrence in the ranking. Computing tag relevance will help us sort out tags that occur many times but are attributed only by a user or few users and its value will be low when this behavior occurs.

Popularity: The popularity measure is the number of users using tags t and t_j divided by the number of users that have t and it measures how popular t_j is to users which have t in their resources.

$$pop(t, t_j) = \frac{|users(t) \bigcap users(t_j)|}{|users(t)|} \tag{4}$$

After computing these three measures, the final ranking of recommended tags is computed for all tags in the list of co-occurring tags by the geometric mean:

$$mean(t, t_j) = \sqrt[3]{coo(t, t_j) * rel(t, t_j) * pop(t, t_j)} \quad (5)$$

Most tag recommendation approaches do not take into account that tags could have ambiguous meaning. *AutoTag*[7] uses information retrieval measures to estimate the similarity between weblog posts and then weigh each associated tag based on its frequency to recommend a list of tags for new content. Also, Sigurbjornsson et al. [1] proposed four approaches to address the problem of tag recommendation, also using tag co-occurrence, but it uses only one tag at a time to recommend others.

To filter a better set of tags from recommendation, our approach was improved to use a set $S = \{t_1, t_2, t_3...\}$ of tags to obtain refined results for recommendation. Thus, it will search the k-largest co-occurrence tags for $P(S)$ using S as query:

$$exist(S, T) = \begin{cases} 1, S \subseteq T \\ 0, S \nsubseteq T \end{cases} \quad (6)$$

This will signal the existence of S in the set T for each item r in the data set and rank the co-occurring tags by the function $ranking(S, t_j)$, compute the measures ($coo(S, t_j)$, $rel(S, t_j)$, $pop(S, t_j)$) and perform the geometric mean as presented.

Figure 1 shows how the algorithm uses more than one tag selected by the user: suppose that a user is categorizing an item, provides a tag used as query NY (a) and accepts the tags “statueofliberty”, “statue”, “nyc”, “trip” and “newyork” (b) recommended by the regular approach (using NY to get recommendation). To get more specific tags based on the context of the item, it is possible to use those tags that are in level b (already assigned to the item as in (c)) to obtain refined tags (e) using the set S of tags (d) that where in level b. For example, the combination between “statueofliberty” and “newyork” in level c will return refined results like “manhattan”, “libertyisland”, “usa”, “statenisland” and “newyorkcity” in level e.

The combination of more than one tag to recommend others helps to filter and avoid tags from distinct contexts such as “Paris” from “Paris Hilton” or “Paris” related to “France”. If the user has the chance to indicate the context using sets of tags to get more tags, the recommendation can be more refined. In the next section we present the results of the experiment performed using the model with its improvements.

3 Experiment

To verify if whether use of recommendation improves the reuse and homogeneity of tags in a collaborative system, we performed an experiment using a training data set from Flickr with more than 600.000 tags and 49.120 distinct tags in total. The engine was freely available online for two weeks and 50 participants classified photos from Flickr that do not require effort in recognizing where/who/what is

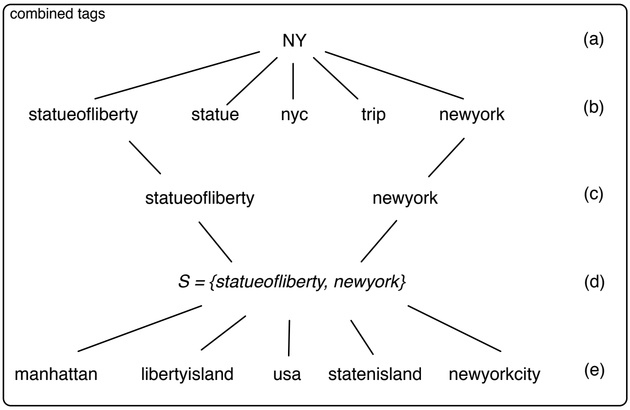

Fig. 1. Improving the model combining tags to get refined results

in the photo. Each tag provided by the users was used as a query to obtain a list of recommended tags (suggested by the engine). We stored all queries used by users and those recommended tags that were accepted by them during the experiment. In the next section, we present the results from the analysis of the data arising from the experiment.

Reuse of Tags. One of the biggest problems in tagging systems is that most of tags are used only one time. The approach presented in this paper tries to provide the best tags for each subject and through its acceptance improve the reuse of tags and the vocabulary homogeneity of items.

Table 1 shows the quantity of queries typed and those tags accepted by users during the experiment. In a total of 891 queries, 182 were distinct and 97 of them were used only one time, showing that 53% of the queries typed by the users were not reused. On the other hand, in the set of 1.235 recommended tags accepted by the users there are 145 distinct tags and 93 of them were reused. Statistically the Z-test of proportion among this sample results in a p-value equal to 0.0484, showing that there is a significant difference in the proportion of reuse of tags accepted by the recommendation comparing to those tags provided by the users and used like queries. In other words, the results show that the reuse of recommended tags is better since 66% of them were reused and only 34% were used a single time.

Table 1. Frequency of tags and queries, the center and spread of dataset resulted from the experiment

Behavior	Total	Distinct	Used Once	Mean	Median	3rd Quartile
Queries	891	182	97 (53%)	4.89	1	3
Tags	1.235	145	52 (34%)	8.51	3	13

Moreover, during the experiment the mean number of queries used was 4.89 and the median was 1.0, showing that at least one half of the queries typed were used only one time. In the other hand the mean of tags accepted by the recommendation was 8.51, almost twice the mean of queries typed by users. Moreover, the median of tags accepted was 3.0. Also, we compute the 3rd quartile of the curve of tags (Table 1) to analyze the spread of the data, with the curve of the queries and recommended tags in Figure 2. The x axis represents each distinct query and recommended tags in the data set and y their frequency.

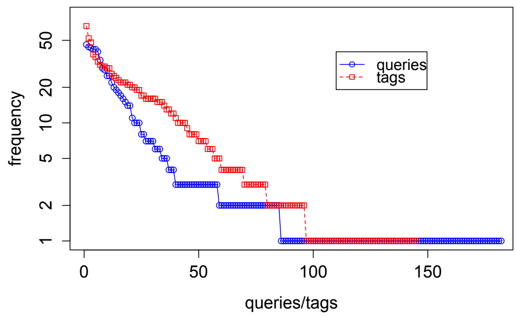

Fig. 2. Long tail of tags provided by the users and recommended tags. Even though the number of recommended tags is higher than the number of queries, the long tail of recommended tags is smaller than queries due to reuse of them.

Comparing the long tail of recommended tags and queries we can better understand the values of the 3rd quartile: for this data the reuse of queries was smaller than the recommended tags. In the next section we report the results from the experiment related to the ranking position of tags during the recommendation and the users behavior related to measures and tagging task.

Tag Ranking Position and Users Behavior. In our algorithm we intend to put on the top of the ranking the most relevant tags through the use of co-occurrence, relevance and popularity measures, thus the ranking position of tags accepted by users is an important point to observe. Figure 3 shows the result of the experiment related to the quantity of recommended tags accepted and their position when they were recommended.

We observe that most of recommended tags accepted are in the first five ranking positions. Moreover, we analyzed the tag recommendation by the tailored precision of tags used in [8], for the first five positions (P@5) compared to the tags presented in the first ten positions (P@10). The precision in five was 0.25 and in ten was 0.18.

However, during the experiment we observed that for one of the images classified by the users, the position of the most accepted tags was not in the five first positions, it was in the eighth place of the ranking. This shows that users choose of tags were not only based on their position on the ranking but in the word itself. Based on these results, the engine frequently brought suitable tags

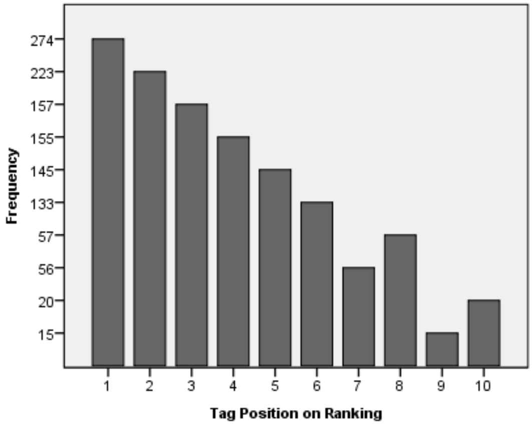

Fig. 3. Frequency and position of recommended tags during the experiment

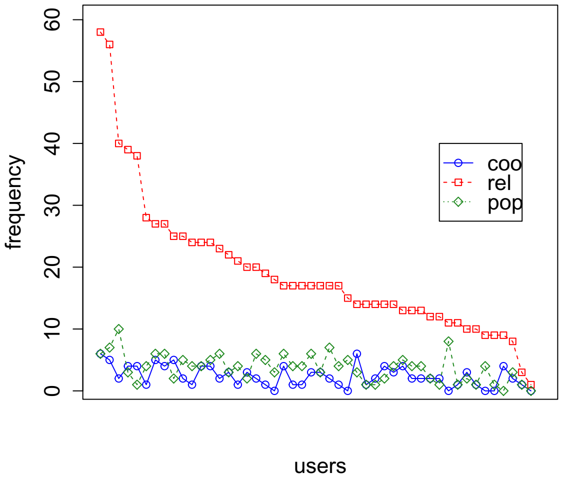

Fig. 4. User's measures behavior by the acceptance of tags

to the top of the ranking. Moreover, the influences of the position of tags it is an important point to be future investigated in comparison with document retrieval approaches.

Also, we verified which tag measures stood out as more important. Each accepted tag has three values (*coo*, *rel*, *pop*) that were used to observe if there is a tag measure that is most significant for each user. Indeed, most tags accepted have a relevance value higher than the co-occurrence and popularity as shown in Figure 4. This observation opens room for personalized measures for recommendation as will be discussed in the next section.

Additionally, we applied a survey to understand what users think about tagging task. The first question was about how frequently users categorize their photos: 48% said that they never use tags to categorize photos. When asked "what are the reasons why people do not tag photos?", most of answers were that "tagging is a hard task" and 99% of them think that recommender tag system helps users to assign tags. Moreover, 41% of users agree that people do not know which tags are good for tagging. This reinforces the importance of collaborative approaches in folksonomy systems and the improvement that can be provided by recommender techniques. In the next section we present a new approach to recommend tags based on the results of this experiment.

4 A Personalized Approach

Based on user's behavior, we may propose a personalized recommendation approach using the measures tied to users' preferences. We still use the three measures for ranking tags, but now their significance is related to previously accepted tags. To personalize the recommendation each profile has a triple $u = < w_c, w_r, w_p >$ where each w is the number of times that the measure was the higher among all measures. For example, to obtain the weight for the relevance we compute w_r by

$$w_r = \sum higher(\text{argmax}\,(coo, rel, pop), rel) \tag{7}$$

where $higher(\text{argmax}\,(x, y, z), x)$ will be 1 if $\text{argmax}\,(x, y, z) = x$ and 0 if it is not. Thereafter, we use the weighted geometric mean where each measure has its corresponding weight to compute the personalized recommendation for each user:

$$mean(t, t_j) = \sqrt[\Sigma w]{coo(t, t_j)^{w_c} * rel(t, t_j)^{w_r} * pop(t, t_j)^{w_p}} \tag{8}$$

Table 2 shows a preliminary result from the personalized approach compared to the recommender approach (non-personalized) used in this paper. To obtain the recommendation we used the weighted measures as $rel > pop > coo$, according to the tags measure users behavior resulted from the experiment. The personalized recommendation approach presents a tag variation that is also suitable for the queries used and it shows that the algorithm can produce distinct and good results using measures based on users attribution history.

Table 2. Comparing the tags recommended using the proposal approaches

Query	Non-personalized	Personalized
nature	butterfly, bird, wildlife	bird, flower, water
ny	statueofliberty, newyork, nyc	usa, policecar, harbor
beach	sand, ocean, dog	sand, boat, ship
venice	italy, gondola, bridge	gondola, water, street
zoo	polarbear, rhino, penguin	rhino, animal, lion

5 Conclusions and Future Work

Results from this experiment show that collaborative filtering approaches can improve tag reuse and have a positive impact in the vocabulary homogeneity. Further, the proportion of recommended tags attributed was higher than the tags provided by users (queries) and most users in the experiment agree that tagging is a hard task and recommender systems can facilitate it. We intend to perform an experiment using the personalized recommendation against the recommendation shown in this paper. Also, we intend to implement gamification techniques in combination with recommender techniques to improve the user experience and encourage users to use tags more frequently.

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Understanding Real-World Events via Multimedia Summaries Based on Social Indicators

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Abstract. We present a novel methodology for creating multimedia summaries of real-world events through social media information. Summaries are generated using selected multimedia data disseminated through Twitter. The proposed summarization technique takes into account social indicators of relevance, which are used to select a set of representative multimedia objects for summarizing the event from a social perspective. In addition, our approach incorporates different news angles by extracting topics within each event.

Keywords: Social Networks, Collaborative Summaries, Multimedia.

1 Introduction

The Web and in particular social networks are characterized for generating and publishing huge amounts of information on a daily basis. In particular, important real-world events (such as recent Boston bombing attacks, for example) overflow social media platforms with millions of messages. Moreover, many of these user-generated messages not only include textual data, but also hyperlinks to external media documents, images, and videos. It is understandable that under this type of scenario the volume of data becomes overwhelming for any human to analyze. Therefore, users searching for fresh information about news events must settle with just browsing a few messages or waiting for traditional news sources to report the information.

One of the most challenging social media platforms in terms of data volume and user adoption, is Twitter[1]. With over 400 million messages (tweets) posted every day[2], its users regularly use Twitter to share all sorts of multimedia. Mostly, multimedia content embedded (as hyperlinks) in tweets consists of text documents (on-line news articles, blog posts, Web pages), photographs (from services like Instagram[3], Flickr[4]), videos (from YouTube[5], Vimeo[6]), or even audio (SoundCloud[7] for instance). Depending on

[1] http://www.twitter.com/
[2] https://blog.twitter.com/2013/celebrating-twitter7
[3] http://www.instagr.am/
[4] http://www.flickr.com/
[5] http://www.youtube.com/
[6] http://www.vimeo.com/
[7] http://www.soundcloud.com/

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the nature of the real-world event, the most significant data can be in the form of text, images or video.

To address the multimedia data deluge on the Web, and in particular that of on-line social media, we propose a methodology for automatically summarizing events. This reduces the load on the user for the task of understanding events. Our approach is based on the incorporation of multimedia data into our summaries as well as text. To achieve this we propose a social based selection scheme for multimedia objects (such as video, images, documents and tweets themselves) that compose the information of an event. The main advantage of our method is the use of social information extracted from Twitter, as a key factor of multimedia document importance. This is, for any event disseminated through the social network, we consider as its most important elements those that have generated the most interest from users (e.g., shares and/or replies). Then, using this selected media we build a comprehensive summary of the event.

Our approach is unique, in the sense that unlike other automatic summarization techniques, we do not create textual excerpts from existing documents. Instead, we create our summary as a composition of the most representative elements of each subtopic of the event from a social perspective. This allows us to generate summaries regardless of the type of the element in the summary, facilitating multimodal element combination.

By taking advantage of all of the information people post in the social Web, we see this approach as a form of implicit collaboration. Since every message conforms the description of an event, summarizing this information helps in understanding particular aspects of it. For example, this type of approach can help journalistic inquiry or the evaluation of sociological hypotheses.

In this article we present our system prototype, which uses Last.fm[8] and Google News[9] as event aggregators for concerts and world news, respectively. For each of the identified events our system gathers related social media information using Twitter. We further expand this dataset by including all of the multimedia elements embedded in each tweet. We model each of these multimodal Web elements using a vector representation. This representation is generated aggregating the text from the tweets that reference the multimedia object, identified by its URL. In addition, we clusterize these elements, to identify subtopics within the event. Then, from each subtopic we extract the most important documents according to social information. Even though this is a first implementation of our approach, our use cases show that it can be a very effective and useful summarization technique. We show promising preliminary results from manually inspected case studies that support the soundness of our approach.

This paper is organized as follows: in Section 2 we present relevant related work; in Section 3 we give an overview of our prototype system and methodology; in Section 4 we show some preliminary results, and in Section 5 we discuss conclusions and future work.

2 Related Work

Relevant literature for our research topic can be classified as follows: automatic generation of summaries based on real-world events and social data, content selection for event representations and measuring relevance from social messages.

[8] http://last.fm

[9] http://news.google.com

There are several works on the topic of content summarization using social information, being that of Chakrabarti and Punera [8] one of the most representatives. In this work the authors summarize sport events based on the frequency of tweets in certain periods of time, whose duration is determined automatically. They then summarize each time window using a similarity approach. Summaries are created based on textual information in tweets, from which they select those with higher scores.

By using multimedia data, Del Fabro and Böszörmenyi [2,3] generate image and video summaries from well-known events, such as a royal wedding. The relevance of each video is measured by its popularity on the social video platform YouTube. These summaries are only generated for selected events and do not consider other types of information (just videos). Another approach is that of Sinha and Jain [4], in which they make summaries from personal photography collections. They use content-based image features to create clusters from which they produce the summary.

Our contribution in this area is that of creating summaries by aggregating information from social networks using data mining techniques. Our summaries are composed of multimodal data, which includes video, audio, images, documents and in some cases social media messages. Our work is related to that of Becker et al. [5,6], in the sense that multimedia information is used for summarization. But it differs in the fact that we base our event representation solely on social data, as well as element relevance. We select social features for event representation using the work of Castillo et al. [7] and Duan et al. [9].

3 Methodology Overview

We propose a methodology for generating real-world event summaries using a unified representation of multimodal documents and their social relevance. The relevance of each document is measured using social indicators that mined from on-line social networks. This is, the more shared or commented document is, the more *relevant* it is considered compared to the rest. The methodology involves several stages, from data extraction for each event, to generating a summary by gathering the most relevant documents from each subtopic of an event representation. In detail, the steps that compose our methodology are the following (shown in Fig. 1):

1. Event metadata extraction from event aggregators, like news or music events
2. For each event: Document extraction by searching on-line social media sources using the event metadata
3. Event modeling phase, i.e., for each event, aggregate and adapt the data for a proper representation.
4. Event subtopic identification (for each event)
5. Event multimodal summary creation, selecting the most relevant documents from each subtopic.

Event Metadata Extraction

In order to obtain descriptive event metadata, we use event aggregators. These aggregators usually have a list of events and their descriptions such as, a title, start and end date of the event, and a short list of keywords or a short description of the event.

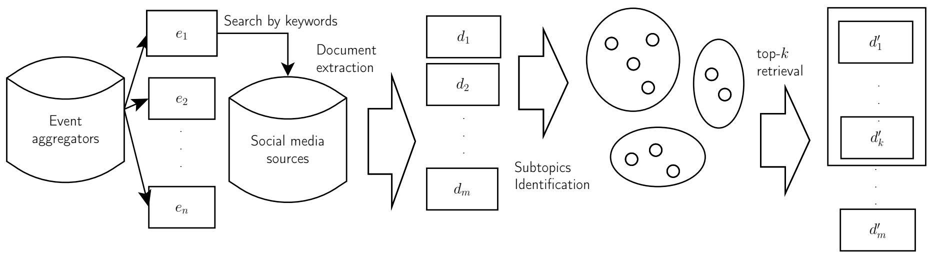

Fig. 1. Methodology overview. The steps of the methodology consist in an event extraction phase, social media search for each event, then subtopic identification and finally the selection of the top-k most relevant documents from each subtopic.

For our initial implementation we only considered two types of events: music concerts and world news. For music events (concerts and festivals) we used the Last.fm API for geolocated events in London, Glastonbury, Las Vegas, Stockholm and Santiago. For news event information in Chile and the US we used the Google News API. Using these public APIs we extract relevant data, such as names of artists participating in music events, and the related news titles. We use this data as keywords for each event for the next phase.

Event Data Extraction and Representation Using Social Sources

In order to model multimodal documents that are part of a particular event we use only social data. Therefore, for each event, we perform a social media platform (in this case Twitter) search using the metadata extracted in the previous phase. This search is time-sensitive, hence we search the time-frame in which the event occurs (start and end date of the event).

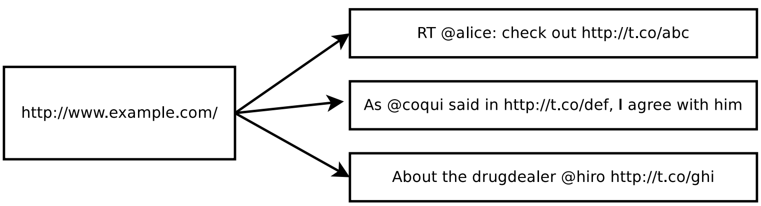

Fig. 2. Example of a document representation. After resolving all shortened hyperlinks contained in the messages, we group every tweet with the same resolved URL into a document, with that URL as its identifier. In this example we do not show the tf-idf scaling of the texts for clarity.

Once we obtain all the messages or tweets that discuss the event, we separate those messages which contain hyperlinks from those that do not. Messages which do not include a hyperlink are added to our multimodal document collection, considering the sole tweet text as the content of the document. On the other hand, if a message contains a hyperlink, then this message is not added to our document representation. Instead, we extract all of the hyperlinks mentioned in messages. Next, we resolve each URL, which in many cases has been shortened, to find duplicate links. Each of these unique hyperlinks may reference several multimodal documents, which can be textual documents, Web pages, images, videos, etc. We add each of these hyperlinks, identified by their URL and use the aggregation all of the tweets which mention this URL as surrogate textual content for the document. Therefore, our implementation does not require that we download or process the actual contents of the multimodal document referenced by the URL. Instead, we use the aggregated short messages that mention the URL as text content for the document. This way, we tackle the issue of processing very short and noisy text messages, like tweets. Figure 2 shows an example of the previously described document representation.

Next, after all of the documents of an event are added to the event collection we apply standard *tf-idf* scaling to their vector-model representation (see [1]).

Subtopic Identification

Once we have the set of multimedia document vectors that compose an event in our system, the next step is to identify subtopics. As a first approach, we use the *K-means* clustering algorithm for this purpose.

K-means requires as an input the number of desired subtopics. As this is not simple to estimate, we approximate this by using the number of related news items and the number of artists, for news and concert events, respectively. It should be noted that it is possible to improve the subtopic estimation of cluster numbers by running K-means multiple times with different number of clusters. This parameter was determined empirically for in the use cases we describe in the following section.

Selection of Relevant Documents

The final step is the selection of the most relevant documents for each event subtopic. In this initial implementation we select the top-2 or top-3 documents of each subtopic. To select the documents, we use a simple method approach consisting of determining relevance by weighting several social features. As a first approximation we use the number of retweets, the number of times the tweets was marked as favorite, the number of followers/followees of the author, the number of lists that the author belongs to. This weighting scheme was built following the conclusions of Duang et al. [9] work, and most of the indicators detailed in the work of Castillo et al. [7].

Therefore, the summary of each event was created by using the top-2 or top-3 elements of each event subtopic, for the purpose of generating a succint summary of each event.

4 Case Studies

In order to assess the soundness of our methodology we inspected two different types of events:

1. `Police arrest suspects in Tel Aviv` (News, 250 hyperlinks, 743 tweets)
2. `New York Philharmonic Dvorak's New World Symphony` (Music concert, 150 hyperlinks, 279 tweets)

We obtain preliminary results for each event, first by determining empirically the appropriate number of clusters. For this we used the inter-cluster and intra-cluster ratio measures.

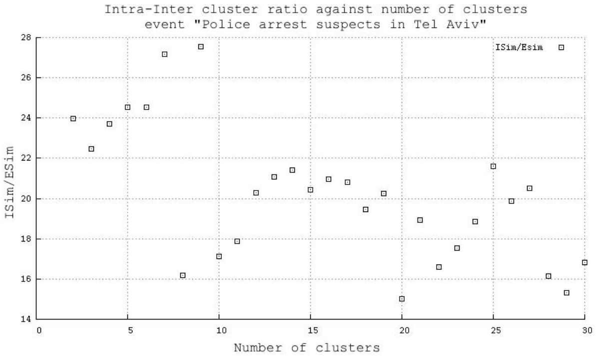

Fig. 3. Evaluation of the clustering solution for the event "Police arrest suspects in Tel Aviv". *ISim* represents intra-cluster measure and *ESim* the inter-cluster one. It can be seen that there is a local maximum at 9 clusters.

For our implementation we used `Cluto` (see [10]) to generate a clustering solution with a fixed number of clusters. This program returns a measure of the intra-cluster and inter-cluster evaluation of the clustering. The inter-cluster indicates how similar the elements are of one cluster to the elements of the remainder of them. The intra-cluster indicates how similar the elements of one cluster are to every other element in the same cluster. We divided the intra-cluster measure by the inter-cluster one, by considering that the higher the ratio, the better the clustering.

The Fig. 3 shows the ratio against various clustering runs for the Tel Aviv event. It can be seen that 9 is a proper number of clusters because the Intra-Inter cluster similarity ratio is a local maximum. Figure 4 shows the most relevant documents according to a methodology applied to this event. The summary is mostly composed of Web documents and twitter status messages. The following links constitute the identifiers of the summary documents of the event:

1. *Arrest announced in Tel Aviv bus bombing — National News - WDSU Home*[10]
2. *Shin Bet, police arrest suspects in TA bus bombing — JPost — Israel News*[11]
3. *Tel Aviv Bombing Suspects Arrested - The Daily Beast*[12]
4. *Twitter / panosharitos: Tel Aviv police chasing after ...*[13]

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[10] `http://www.wdsu.com/news/national/Arrest-announced-in-Tel-Aviv-bus-bombing/-/9853500/17524408/-/m562vn/-/index.html`

[11] `http://www.jpost.com/Defense/Article.aspx?ID=293140&R=R1`

[12] `http://www.thedailybeast.com/cheats/2012/11/22/tel-aviv-bombing-suspects-arrested.html`

[13] `https://twitter.com/panosharitos/status/271204357654077441`

5. *Twitter / 1stNewsHeds: New York (NY) Times: Police ...*[14]
6. *Twitter / MARKETRISER: Israel arrests suspects in ...*[15]
7. *Previous bomb attacks in Tel Aviv - Yahoo! News*[16]
8. *Twitter / BreakingNews: Israel's army spokesman says ...*[17]
9. *Arrest announced in Tel Aviv bus bombing - CNN.com*[18]

Fig. 4. Twitter message with the highest score in the "Police arrest suspects in Tel Aviv" event summary. (Source: Twitter)

For the "New York Philharmonic Dvorak's New World Symphony" event, most of the summary documents are non-textual elements (multimedia). These elements are referenced from Instagram, Twitter (with an embedded photo) or YouTube, as can be seen in Fig. 5.

Fig. 5. Some of the resulting documents from the "New York Philharmonic Dvorak's New World Symphony" summary. (Sources: Instagram, Twitter and YouTube, from left to right)

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[14] `https://twitter.com/1stNewsHeds/status/271752495401934849`
[15] `https://twitter.com/MARKETRISER/status/271758949043298304`
[16] `http://news.yahoo.com/previous-bomb-attacks-tel-aviv-153452046.html`
[17] `https://twitter.com/BreakingNews/status/271718080856592384`
[18] `http://edition.cnn.com/2012/11/22/world/meast/israel-bus-bombing-arrests/index.html`

5 Conclusions and Future Work

We presented a novel methodology for generating automatic summaries from multimedia real-world event information. The main contribution of our work is to exploit social information from Twitter to summarize in a simple way events which are extremely rich in information. In addition, by using social information we are able to combine and select multimodal elements for our summaries. Overall, our preliminary inspection of results shown by this approach are very promising and the resulting summaries give comprehensive descriptions of the events. As part of future work we expect to improve subtopic identification algorithms and document selection and ranking. In addition, as this is a work in progress, we are working on a large scale evaluation which will compare with alternative approaches and incorporate other types of events.

Acknowledgements. Mauricio Quezada was supported by CONICYT grant CONICYT-PCHA/Magister Nacional/2013 - 22131151 and FONDECYT grant 11121511.

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How Do Researchers on Collaboration Technology Collaborate with Each Other? A Social Network Analysis

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Abstract. In this paper we present a network analytic approach for the detection and improved understanding of the dynamics of communities. As a practical example of our own research practice we applied these ideas to the community of CRIWG researchers and checked for the feasibility of our approach. We will present our results on indicators for collaboration and also propose some practices from other fields to intensify scientific discussion and production.

Keywords: Collaboration analysis, Social Network Analysis, CRIWG.

1 Community Research and Its Impact

Community research and scientometry are a growing field to channel research funding, identify trends and future directions in a more and more competitive landscape of research communities. Social Networks are a subject for research in social sciences since the 1930s, mostly associated with the work of Moreno [1]. Later in the 1960s social networks became popular in the field of scientometrics by the citation networks of Solla Price [2]. Crane [3] showed the informal structure of how scientists communicate and the pathways of the diffusion of knowledge in scientific communities.

Collaboration technology is ideally suited for an analysis, because research, software development and practice potentially go hand in hand here: Researchers develop and evaluate tools for collaboration tools and might use it for their own practice for work and teaching. An interesting question is now if this potential is also used in their own scientific production. We will explore this as an exercise of self-reflection on the CRIWG community that will take up some of the insights of an earlier paper of this type [4], but use an approach that is mainly focusing on Social Network Analysis. Thus it can be compared to analyses of other communities, such as the ones on the CSCL community [5],[6] which mainly analysed national and disciplinary aspects, or the recent analysis of communities in technology enhanced learning [7].

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2 Research Questions and Hypotheses

Measuring collaboration is highly influenced by the observable data that can be used. Practically, scientific collaboration can manifest itself in various ways, such as joint workshops, researcher exchange programs (on student as well as staff level), joint projects etc. Yet, it is hard to detect all these activities for a larger community, especially when not directly observing these as an active community member. The most clear-cut manifestation of a collaboration is objectively still the scientific publication of members of two different research teams or institutions. While the nature of collaboration, distribution of efforts between the co-authors, and work performed by technical assistants, experimenters, and coders is not clearly visible, we will consider a **joint publication as an indicator for collaboration**, because it documents at least effort on a joint paper by two or more different actors across institutions.

In addition to this main assumption, we will describe a few more assumptions we make for our research and choice of methods:

number of (co-)authors: usually conference and journal papers in computer science fields have an average author number above two, which reflects the teamwork needed in conceptual design, software development, and evaluation. Collaboration technology usually also involves expertise in user interface design and technical aspects, inciting even more teamwork needed. Theoretical papers, surveys, and doctoral tracks are exceptions and frequently authored by only one researcher, yet, they are relatively unusual for submissions to the main conference track. At CRIWG conference there is the tradition of a separate track for PhD candidates, so this exception will not be relevant for our research. While this is not a very strict assumption, it influences our expectation that in a network analysis we will detect relatively few singular 'bridges' between actors, but rather triangles or quartettes between collaborators. We will explain this in more detail in the hypothetical situations we hope to find in the practical scientific co-authoring network.

time intervals of relevance: while a longitudinal study for the whole time interval of observation is surely interesting in a network - and will be performed by us as well - there is a conceptual limitation to this: When considering a co-authoring network over time by only adding new authors and creating additional links between (old or new) authors the network has a tendency towards increasing density and accumulating to one connectivity component in the long run. Intuitively, this might indicate growing collaboration, but this result can also be reached with constant collaboration (this model is then similar to the Barabasi network model [8]) or even with decreasing collaboration the network grows denser. This could be a methodological problem with studies like [7] that investigate community growth and giant components over time.

Thus, besides the full longitudinal analysis, we will also make partial analyses of smaller time intervals to measure the quantity and progress of collaborations between these different periods. The quantification of a specific period length is difficult, yet we will try to justify our choice with the specifities and practices of academic careers: usually, a young researcher starting a scientific career will need between 3-5 years before finishing a PhD title. After that time she/he will either spend some years as PostDoc at the same university, change to another institution, or drop out of academia. The latter situation explains partially the fact that our colleagues found in their community analyses that only one third of authors shows continuity over time at conferences [5]. Adding PhD and PostDoc times we assume that after approximately six years a researcher is either established in an academic community or will likely leave the field. In consequence we will consider 'time slices' of six years, because an author that did not publish for five years after an initial paper is not very likely to re-join in the seventh year. Considering six year periods across a sliding window might give us insights in the overall development of collaboration over time, which we will evaluate in our study.

With these assumptions in mind we will present several situations that we know from scientific practice, how collaborations between co-authors emerge and happen and also how institutional transitions of an actor can create potential for collaborations or at least effects of connectivity on network level. All these situations also explain the development over time and the hypothetically resulting network structures. In our analysis we will check for these structures and evaluate the hypotheses on concrete cases of in-depth investigation of these situations.

Joint venture research groups having a joint project and publishing about that: this will usually result in a publication that has authors from both (or more if tri-lateral, multi-partner project) teams. If we assume that at least two authors from each team participate, we expect to find a multi-tie bridge between larger clusters as shown in Fig.1. With respect to the temporal dimension it could be expected that both teams had internal publications before and will have in the future, while the joint publishing might be constrained by the project duration.

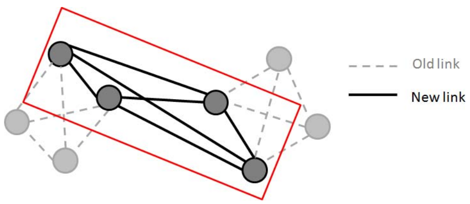

Fig. 1. Schema of hypothetical 'joint venture' collaboration

Visting researcher. A researcher is staying for a visit or sabbatical at another research group: if this results in a joint publication we'd expect that the visiting researcher will create a connection between her/his original group and the hosting group with the visitor as a singular overlapping point, in graph theory a *cutpoint* as visible in Fig.2. With respect to the temporal dimension it could be expected that both teams had internal publications before and will have in the future, while the joint pubishing might be short-lived, but hopefully could develop into a longer-lasting collaboration between the whole groups.

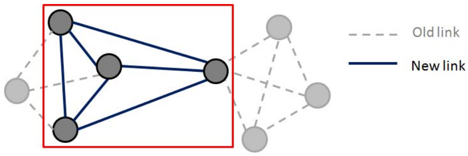

Fig. 2. Schema of hypothetical 'visting researcher' collaboration

Creating a branch one researcher 'grew up' in a research group, maybe as a junior researcher or PostDoc; afterwards she/he moves to a different place and establishes a distinct research group. While the graph structure (without time) resembles the previous case of the visiting researcher, the temporal dimension allows a distinction: Initially the junior researcher publishes in the context of the original research group being part of the social structure there; when leaving and creating the new group, a new clique or other structure will emerge there - the graph structure will have a cutpoint between the original group and the new group with potentially both groups publishing in the future (see Fig.3). Surely, because of joint interests and social connections still rooted with the original group, joint publications and stronger connections are still possible.

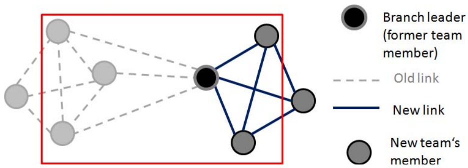

Fig. 3. Schema of hypothetical 'branch'

Marrying to a different village this scenario is similar to the 'branch', yet the moving researcher does find an established group at the new place instead of founding a new one. This means that there have been earlier publication activities of the right group, but now the new researcher is integrated into current publications with part or whole of the right team as shown in Fig.4:

A more quantitative approach similar to our proposed patterns has been described in [9] where the multiplicity of relations is explored across the whole network to identify mesoscopic structures in scientific chemistry communities.

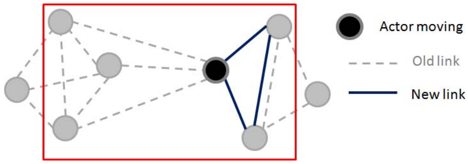

Fig. 4. Schema of hypothetical 'marriage to a different village'

Currently, in this paper we use our method to validate our proposal with our "insider knowledge" of CRIWG before generalizing it to other communities. Yet, since it is built on general concepts as co-authorship relations in temporal dependencies, we plan to apply this to other communities, as in [7] as well.

3 Method

3.1 Data and Processing

As data source for our investigation of the CRIWG community we used the MySQL dump of the DBLP++ publication database of April 13, 2013.[1] From this database all CRIWG publications were fetched, together with the respective authors (identified by the author id of the DBLP++ database). For gathering the publications of the years 1995 – 1998 and 2000 – 2012 this was achieved by using 'CRIWG' as source of publication. In 1999 the source name 'SPIRE/CRIWG' was used as in this year it was a joint event "String Processing and Information Retrieval Symposium & International Workshop on Groupware". To restrict the publications to the CRIWG publications, the page numbers of the proceedings were used, as the CRIWG papers started on page 234.

The information gathered from the DBLP++ database was transformed into an author-publication network. All entities of the network (publications, authors, authorship links) were annotated with the year of appearance. This results in publications and links being annotated with the single year of publication and the authors being annotated with all years in which they authored at least one publication. We interpreted this network as an affiliation network [10] and derived a one-mode network based on joint authorship of papers from it, resulting in a co-authorship network. An overview of the complete network over all years can be seen in Fig.6. We transferred the time information from the affiliation network to the co-authorship network in such a way that we annotated the links with all years in which at least one joint paper had been published by the two involved authors, see Fig.5 for an example case. This time information has further been used to filter the network by time as described in section 2.

We also gathered information about who of the authors have been programme chair of at least one of the conferences. This information has been taken from the webpages of the conferences where available or from the frontmatters of the respective conference proceedings.

[1] The DBLP++ database dump was fetched from `http://dblp.l3s.de/dblp++.php`

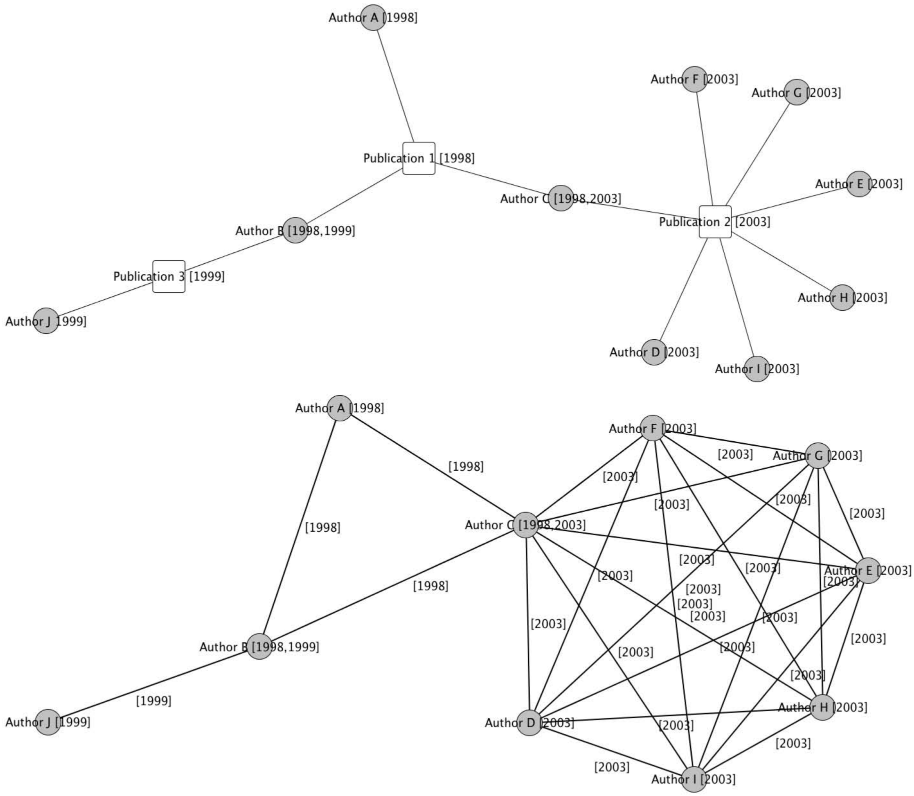

Fig. 5. Transformation of an author-publication network to a co-authorship network preserving time information

A remark on privacy. While the data collected by us is publicly available, the inferences we make and hypotheses we developed might cause privacy issues with respect to the position and importance of individuals of the CRIWG community. Thus, we decided to describe and present all inferences and network visualisations in an anonymous way, protecting privacy as good as possible. Yet, with some in-depth investigation, CRIWG community members might identify themselves (and their peers) based on our elaborations. For interested readers we offer to show each author the position in the network graphs and their ego networks on request.

3.2 A Network Model of Community

Dynamic models of networks have been proposed to explain the growth of real large networks, such as the internet, facebook users etc. over time. One of the best known models is the Barabasi model [8] that incorporated the notion of 'preferrential attachment', which means that actors that are already well connected are more likely to be chosen for a link by a new actor than actors with less connections. The resulting dynamic behaviour and degree distributions are asociated with **scale-free networks**. While the assumption of a growing community might work for a scientific community, preferrential attachment is unlikely to be present to a large extent, because limitations in the number of scientific collaborations an author can keep up as well as the unlikeliness that newcomers to the community will immediately publish with the 'stars' of the community. Additionally, drop-outs of a community are realistic, while the rate between newcomers and drop-outs is likely to reflect timeliness of the scientific topic and maturing effects, i.e. maybe a new topic earns initially strong attention, but will stabilize or saturate over time.

Among the issues to consider on a network-theoretic level, are several aspects that have to do with modelling assumptions and traits that are frequently computed in social network analyses in the literature.

– do we consider strength of relations, e.g. number of joint publications? Focusing on strong collaborations that take place over several years might give different insights to considering all situations of collaboration.
– do SNA measures like centrality and distances have any meaning? E.g. the Erdos number is rather an intellectual game than really representing thematic closeness or transfer of ideas, at least when not considering domain concepts at the same time. Similarly, the k-core measure [11] can also be misleading in the sense that in an author network each author has at least a core value of the maximum number of co-authors for one paper. Shown in Fig.6 the 'ball' in the lower left is produced by a single paper with 10 co-authors, giving each author a core value of 9, despite not being connected to any other autor of the community.

4 The Network View on the CRIWG Community

Fig.6 shows an overview of the 1-mode folding of our raw data into an author-author network. Graphically it can be seen easily that on the one hand there is a large component of interconnected authors in the upper left and a medium-sized component in the upper right while on the other hand the rest of the authors is distributed across small components that are created from a small number of publications. In fact, all of the components besides the first three are constructed from 1-3 papers, thus building a small - otherwise unconnected - author set.

If we take into account information about the 'Top 10' authors [4] and authors serving the community as Programme Chairs at CRIWG conferences we can contextualize major players of the community in the co-authoring network. The Top10 authors referred to in our colleagues' paper can be seen in Fig.7 as the nodes with large diameter in x-dimension. Programme Chairing is represented with a large diameter in y-dimension.

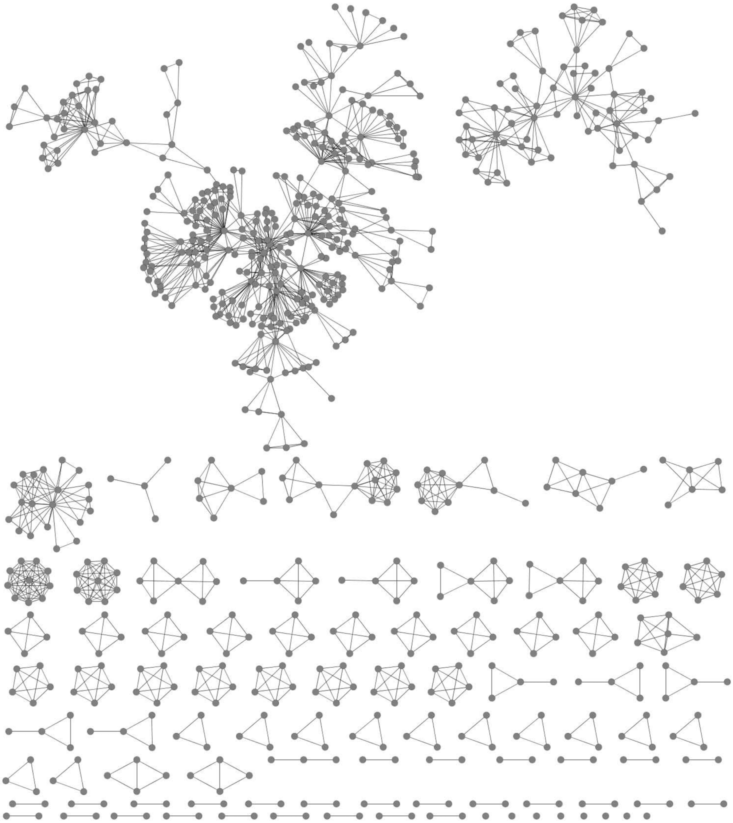

Fig. 6. Network overview (author-author) of CRIWG community over all years

All of the Top10 authors can be found in the two largest connectivity components, while distribution of PC members spans over two additional small components. There is obviously also a strong correlation between Top10 authorship and P, in fact all Top10 autors served as a Programme Chair in at least one conference. This connection between active contribution to publications and organisational contributions is in relatively strong contrast to other community analyses [12] where the connection between chairs and PC members and authors was much less pronounced.

4.1 Collaboration Intensity over Time

When considering the temporal dimension of the network, a more detailed view on the level (and number) of collaborations can be gained than just observing the full CRIWG co-author network. The higher the level of collaboration in the observed time interval was, the lower the SNA metrics of connectivity components will be. Since the number of authors might vary over time the number of connectivity components should be considered in relation to the number of

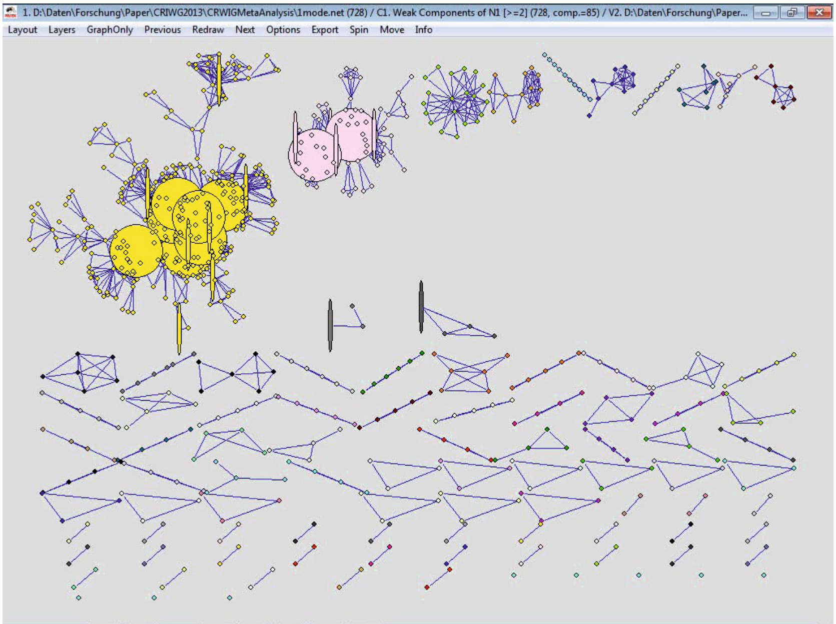

Fig. 7. Network overview (autor-author network) with highlighted frequent authors and PCs of the CRIWG author community over all years

authors. Another interesting SNA trait could be the size of the largest connectivity component, since this value represents the number of authors being connected via co-authored publications in the time interval. As the size of the time interval we gave in section 2 a justification for a length of six years for a researcher to establish herself / himself in a community. Thus, we analyzed six-year intervals starting from 1995 and overlapping with each other by the half duration, i.e. 3 years. So succeeding timeslices have 3 joint years, while every other timeslice is disjunct to the one 2 slices before or afterwards.

Table 1 shows the number of authors, number of components, average number of authors per component, and maximum component size for each timeslice:

– the number of autors increased in the beginning, showing a growing community, and then stablized on a level of approx. 350 authors
– the number of authors per component increases, showing that - on average and given a relatively constant number of authors per paper - authors collaborate with more peers over time
– the size of the largest connectivity component increased during the first four periods, while the fifth decreased, but still is the second highest. This shows that that there seems to be a larger cluster of researchers co-authoring and collaborating with each other than at the start of CRIWG.

Table 1. Measures of collaboration over time

	No. authors	No. components	authors / component	max comp
1995-2000	163	33	4	39
1998-2003	247	53	4	40
2001-2006	345	58	5	62
2004-2009	364	45	8	104
2007-2012	328	40	8	75

4.2 Detection of Patterns for Collaboration

As a next step, we want to put our hypotheses for different scenarios of scientific collaboration to a test: we check if structures in the full network that look like our proposed patterns match with the temporal sequence we expected for the patterns. If we can match this on the substantial network level with episodes of collaboration, we can at least consider our patterns as indicators for scientific collaboration to allow scientometers an informed search in a community without having to inspect the data completely manually.

Fig.8 shows highlighted pattern candidates where the typical graph structures presented in our hypothetical collaboration situations are present. Yet, since the network represents the full CRIWG lifetime, the mere structures might be misleading if the temporal sequence assumed by us does not fit to the patterns. Thus we will inspect when the respective publications have been co-authored to either confirm or reject the hypothetical patterns and check for substantial support of the patterns based on observations of affiliation and job changes for the concrete cases.

For reasons of space we chose exemplarily six patterns shown in Fig.8 that potentially represent all the situations we created hypotheses for. All of the candidates have been chosen from the two largest components of the full network, because the other components show little potential for detecting the situations base on the small number of publications involved (1–3 only for all components but the largest three).

1. this graph structure that connects a large group - presumably a big research team - via a bridge of one cutpoint and an additional cutset of two authors, is a candidate for visiting researcher / branch / marriage. The detailed view in Fig.9 on the decisive publication between cutpoint and cutset and its relation to the dense relations in the left-side subgroup shows:
   While the sequence of the earlier publication in 2003 and then two publications with members of the large group might fit with the 'branch' or 'marriage' type, i.e. a move to another place, the actual substantial investigation shows that the 'cutpoint author' had not changed affiliation between the three publications. This means that the initial cross-institution publication (2003) was not sustainable, but a closer cooperation with colleagues at the same place was sought for and reached. We would also like to mention here, that the usage of our proposed time interval of six years would put the

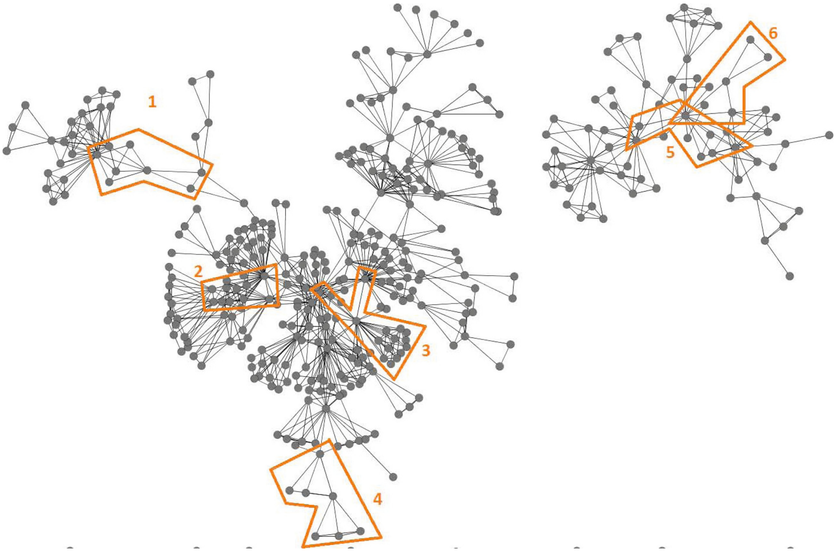

Fig. 8. Pattern candidates for the CRIWG author community over all years)

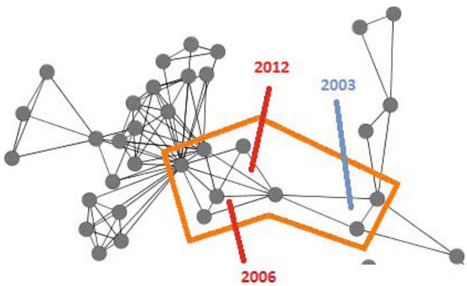

Fig. 9. Detailed look at pattern candidate #1

first and the last publication into different segments, practically meaning that any period after 2003 would leave the large research group on the left in a disconneced component. From that perspective the bridging publication grew outdated and does not contribute anymore to the connectivity of the network.

2. the pattern in in Fig.10 presents a 'multi-bridge' that we also observed at different time points:
   The temporal analysis gives the insight that a quartet of authors from 3 different affiliations collaborated together on publications during a period of 5 years at CRIWG. Both this and the fact that authors continued to publish in the CRIWG community afterwards, but not together anymore, are well compatible with our hypothesis of a 'joint venture' that can have a limited duration, e.g. of a project lifetime.

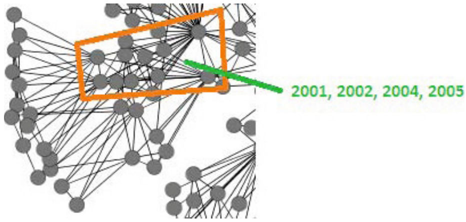

Fig. 10. Detailed look at pattern candidate #2

3. this pattern presents a structure with a cutpoint that is well connected into several directions and a densely connected large group behind the cutpoint. Fig.11 with a focus on the cutpoint shows:

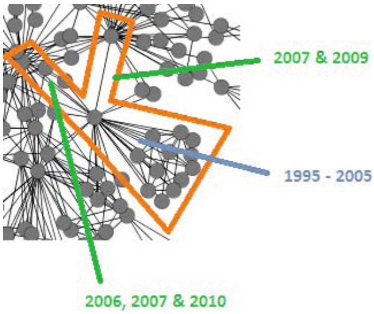

Fig. 11. Detailed look at pattern candidate #3

   Interestingly, the large group is not completely homogeneous but consists of affiliations within one country and mostly one city. While the activity is high, the group is an isolated connectivity component still in an extended timeslice from 1995-2005. Starting from 2006 on, collaborations with persons or teams from other countries are established and are also re-occurring over the years. Yet, the cutpoint functionality still holds, so that we seem not to detect a 'joint venture' here, rather a 'visit and follow-up' situation.
4. two cutpoints connected to each other are a candidate for the visit / branch type. The focus on the publications of the lower cutpoint in Fig.12 shows: The cutpoint originally published in 2006 and 2007 with different co-authors of the same research group. Then in 2012 a publication with previously unknown authors appears where all authors - including the cutpoint – have an affiliation that was not formerly present in the CRIWG community. This is a strong indication for the 'branch' situation, where a researcher moved and built a new group of similar interests. Interestingly, the time interval chosen is critical here: 2006 and 2012 would not fit into the same segment in our six-year-periods, while 2007 and 2012 are close enough to avoid that the new team drops off into a small and disconnected component.

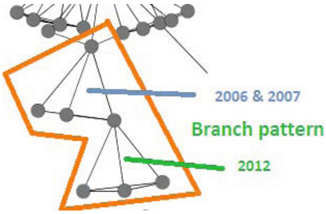

Fig. 12. Detailed look at pattern candidate #4

5. Pattern # 5 shows a structure that potentially could serve as any of our proposed situations, because it contains numerous triangles and cliques. The more detailed view in Fig.13 shows the following:

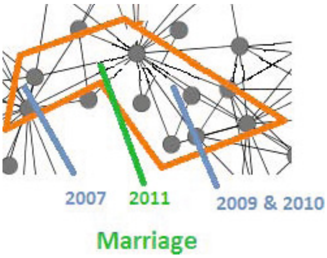

Fig. 13. Detailed look at pattern candidate #5

Publications have been co-autored between researchers on the left side as well as on the right side of the structure. All of these have been homogeneous with respect to earlier affiliations, yet then the publication connecting the left and right in a triangle happens afterwards with a changed affiliation of the focal actor. The new affiliation is the same as that of the left-side actors, which indicates that an instance of 'marriage' was detected, because publications with a previously active team happen at the same site after the move. It will be interesting to observe if the connection to the former team will be kept up for the moving actor.

6. Pattern # 6 shows another typical structure with a cutpoint. The more detailed view in Fig.14 shows the following:
The cutpoint autor has a team publication as well as the authors located at the bottom that have a shared different affiliation. The link between the two groups is established via a joint publication where all involved authors kept their affiliations. This situation is perfectly compatible with our 'visiting researcher' situation. One problem of this concrete structure is that there is neither a followup of the cross-team collaboration nor of the right side team, which we would usually assume, so our hypothesis is only partially supported because of missing evidence for the time after the 'visiting'.

In summary, we can say, that in the combination of network strructures, temporal dimension, and affiliation information, the hypothesized patterns can

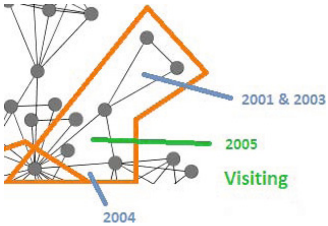

Fig. 14. Detailed look at pattern candidate #6

be detected and can thus serve as indicators for scientific collaboration. This surely does not mean that the set of patterns is complete and neither that this type of analysis can be completely automated without human expertise of interpretation; human 'insider knowledge' is also very helpful for substantive interpretation of these initial indicators. We also gained insights that graph structures alone can be misleading, e.g. in pattern # 1, and that the choice of parameters - such as the time interval chosen for analysis - does not necessarily create robust results. Thus, we will try to refine our methods also with respect to automation to be able to perform an analysis of the whole community network.

5 Discussion and Reflection

Based on our analysis we see some evidence that collaborations across research teams do happen at CRIWG conference. Yet, given the very intense climate of discussion and single track format with extensive time for questions and answers it could still be argued that more cross-team interaction could be stimulated. Partially this is supported by the observation of the full period network that is still divided into several connectivity components, while a constrasting picture of the same authors across other conferences (i.e. beyond CRIWG, we used the DBLP database entries) has a better coverage and coherence than CRIWG alone; this means that authors that did never collaborate for CRIWG papers, collaborated for other venues: the four largest components of the CRIWG network are connected via other conferences; other components are connected, too, with still several islands of author teams not connected to the main component.

We observed in other communities ways for creating interaction and cross-site collaborations that might be taken up for future CRIWG conferences:

Multivocal Analysis of the Same Data Sets: the joint analysis of empirical data by cross-site teams or using and contrasting different methods for analysis is a tradition in the area of Social Network Analysis, e.g. in the 'Viszards' visualisation session at Sunbelt conferences and in the workshops series 'productive multivocality in analysis' in the field of interaction analysis, CSCL, and Learning Analytics. This could be taken up for CRIWG either as focused data analysis workshops with postproceedings or by announcing challenges with the call for papers to tackle a specific data set with analytic methods. The challenge format has been experimented with in the field of Learning Design [13] and brought insights in the comparison and conceptual foundations of educational modelling methods, highlighted by a resulting handbook on visual languages for instructional design [14].

Encourage Cross-Site Experimentation and Tool Usage: the stimulation of cross-site experimentation with the same tools and comparison of the results also with cultural differences in mind and trans-national joint experimentation could bring a new dimension of collaboration between CRIWG research teams. This could benefit especially from a special track or session to submit this type of work to, maybe even with a two-stage set-up, one part for designing these joint activities and one part for reporting about conducted activities, so that each year the 'next generation' of cross-site experimenters can benefit from their peers that just conducted the research. This activity could also help to overcome the 'regional' effects of participation, i.e. that the number of participants shifts radically between the continents (mainly Americas and Europe) with each alternation. Creating multi-continent and multi-cultural research teams could contribute to a larger 'stable' core than the very active and energetic, yet small core the CRIWG community currently has.

6 Conclusion and Further Work

In this paper we presented a network analytic perspective on the CRIWG community with respect to collaborations through co-authorship. We defined hypotheses how to detect different situations of collaboration through specific graph structures and their temporal evolution. We also stressed the importance of considering the dynamics to avoid missinterpretations. We applied our hypotheses and SNA methods to analyse the CRIWG community from 1995 to 2012 and the level of collaboration in this timeframe. We found out that the level of collaboration increased during this time measured by SNA metrics, while the community size stabilized after an initial expansion period. We also gained insights, that our hypothetical collaboration scenarios can be detected by the combination of network analysis with temporal dynamics and affiliation information. While we used various different algorithms and tools for the network analysis, a more complete analysis could be achieved by automated search for user-defined patterns of interest. The advancement of these methods and refinement of suitable sets of patterns will be a topic of future work for us.

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Inferring Hidden Trust Relationships in Social Networks for Encouraging Collaboration and Cooperation among Individuals

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Abstract. This paper presents the T-SWEETS algorithm, a novel approach for inferring trust in social networks and its deployment in a social network knowledge-based management platform, titled *Konnen* (*Knowledge Organization in a Native Network ENvironment*). An objective of trust inference is to recommend trust relationships. The features of T-SWEETS come from an inquiry with a group of 53 people. We also present results obtained from experiment conducted with a group of 57 people during the second half of 2012.

Keywords: Recommender Systems, Trust, Social Networks, Communication, Cooperation, Collaborative Systems.

1 Introduction

Trust is a common phenomenon that is present in society since its beginning and it represents how much a person is trustworthy to another [1]. Trust constantly provides grants that support the society in the decision making task. With the evolution of society and technology, mostly in what concerns the computational context, several studies emerge in this area. These studies are aimed, among others, to understand how trust can be mapped and represented in computing environments. Social network based virtual environments are very propitious to research on trust analysis because they represent the basic structure of the society and provide indicators for such analysis [2].

Furthermore, social networks provide an unrestricted and informal environment, in which people collaborate, in *ad hoc* manner, through unplanned interaction. This behavior assists experiences exchange among people [3]. In this direction there is the 3C Model: communication, cooperation and coordination [4]. The 3C Model considers trust relationships in social collaborative environments as a key element, since trust relationships among people stimulates communication and cooperation. These

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trust relationships may also ease coordination, because the person who coordinates group activities can have information about trust of the group members. As a consequence, people tend to produce larger amount of knowledge that can serve as input for the inference of new trusting relationships.

Considering that the discovery of trust relationships can stimulate the communication and cooperation in social networks, this paper presents a new approach for trust inference in these environments, entitled T-SWEETS. In order to achieve this goal we have done an inquiry with a group of 53 people, aiming to identify and map potential elements to increase the quality of automatic identification of these hidden relationships of trust.

T-SWEETS has been deployed in an organizational knowledge platform entitled *Konnen* (*Knowledge Organization in a Native Network ENvironment*). This environment is being developed and employed experimentally in a university where professors and students are stimulated to create content and new relationships in order to augment the process of learning. The aim of this experiment is to analyze the impacts of a mechanism that recommends trust relationships in social collaborative environments.

2 Social Networks

Social networks, through people and their relationships, build the society's basic structure. There are cases in which these relationships are stronger and more durable, in other cases these relationships are temporary [2]. It is so true that social networks move society, that it is, by decades, object of study of researchers from different domains, such as, Barnes [8] in psychology and Wellman [9], in sociology.

In computing environments, a graph can be used to represent the structure of social networks, in which nodes represent people and edges represent relationships among them. An edge can have labels that explicitly represent the relationships' nature, e.g. if it is reliable or not. Some authors define these social virtual environments as WSBN (Web-based Social Network) like Maamar [10] and Golbeck [5].

The success of web based social networks has attracted a lot of attention, increasing the interest level on the area, and consequently making the term "social network" more flexible. These networks can also be seen as a huge data repository, containing information regarding every single user in it. This information can be used in many ways, like applications that can infer the trust level that a user has regarding any other user on the same social network. Furthermore, these networks allow the emergence of new and complex relationships, creating the need for access to qualitative and quantitative data concerning these connections [5]. In this sense, trust relationships inference use this data to, naturally, stimulate interaction and collaboration among social network members.

3 Trust

Marsh [11] developed a pioneer work on "trust" in computing environment, in which he studies how the concept was used in different science areas, like sociology. Marsh aimed to formalize the concept of "trust" in computing environments and to propose a model for application in artificial intelligence systems, which helps intelligent agents to reason in uncertainty situations.

Golbeck [5] developed another reference research, which studies the concept of "trust" in virtual social networks. This work is based on the definition given by Deutsch [12] that "trust is a bet on future actions of other people". Thus, two main components for the definition of "trust" are taken into account: belief and commitment. The "belief" represents the vision of a person about certain actions of another person classified like reliable. The "commitment" represents the possibility level of a person to perform a certain action.

The studies and the definitions of "trust" available in literature offer subsidies for some properties of trust to be defined. These properties must explicitly represent elements users are familiar to in their social lives (e.g. relationship level) and must be well defined and clear so that they can be used in computational environments.

In computing environments, for application in social networks, Golbeck [5] defines some properties of "trust": *Transitivity*, *Composability* and *Asymmetry*. *Transitivity* is the ability to transfer confidence from person to person. *Composability* is the condition that determines whether a person will search additional information to decide or not decide to trust another person. *Asymmetry* indicates that the trust level of a person relative to each other is one-sided. Considering the peculiarities mentioned above, there are in the literature some algorithms to trust inference in social virtual environments which are presented in the following section.

4 Related Works

The algorithm TidalTrust [5] is one of the precursors of a series of algorithms that explore the structure of social networks relationships for inferring trust. It receives some criticism by researchers because the information loss, for it makes a routine of selecting information sources (i.e. nodes) in the social network before trust analysis. The algorithm SUNNY [6, 7] was developed to improve TidalTrust, but still it presents the problem of information loss. Besides the structure of relationships, SUNNY also considers user ratings on content (such as text and photos) to trust inference. Some works similar to TidalTrust and SUNNY are [13, 14].

To solve the problem of information loss of the previously presented algorithms, [15] developed the FlowTrust algorithm, which uses all the information available on the social network relationships in order to proceed to trust inference. Besides the lossless information behavior, FlowTrust applies the concept of multidimensionality, i.e. it explores more than one element (trust level and confidence level) for inferring trust. However, the information exploited by FlowTrust (data relationships of social network) are all related to the same concept and further information is needed from other sources (e.g. as data on content and context) to increase efficiency in identify whether a user is trusted or not. Other algorithms that exploit information available across the network are RelTrust [16] and CircuitTrust [16].

An algorithm that exploits information from documents and content posted by users in a collaborative environment is available in [17]. This algorithm considers information about the quantity and quality of content posted by users in the social environment.

The study of the algorithms presented above was critical for the understanding of the elements that could be exploited for trust inference in social virtual environment. That study helped to understand that some elements (Similarity between Users´ Profiles, Relationship of Trust User Maturity Level and Reputation) could still be explored with different approaches and, thus, to get more efficiency in the user's trust inference in such social environments (Section 5 presents relations between each element and related works, and their formalisms and definitions). Furthermore, T-SWEETS combines four elements for trust inference between users. None of the related works uses these elements together. We believe that the combination of them can generate more efficient trust inferences.

5 T-SWEETS

T-SWEETS is an algorithm for inferring trust in virtual environments based on social network theory. The deployment of T-SWEETS in a social platform is motivated by the need to promote greater interaction among the users. A contributing factor to this interaction is the need that users may have to contact a particular person, e.g, in order to find a solution to a problem. According to the inquiry applied to a group of 53 people, we found that:

- 56.6% of interviewees help people they have affinity or trust directly or indirectly;
- approximately 77% of interviewees agree that the reputation of individuals also contributes as a decisive factor when a person decides whether to interact with another person;
- approximately 90% of interviewees agree that people's knowledge level about specific subjects is also a factor of strong influence;
- approximately 92% of interviewees tend to collaborate with people whose profiles of knowledge and opinion are similar to theirs.

These statistical results and the absence of an algorithm in the literature that merges all these elements provide background to the T-SWEETS algorithm.

5.1 Prerequisites for Using the T-SWEETS

T-SWEETS analyses the relationships between people and knowledge produced by them in social virtual environment in order to realize trust inference. The first version of the T-SWEETS is available in [18] [**Erro! Fonte de referência não encontrada.**].

The relationships in a social network are represented by graphs, and have characteristics that can be studied in the process of trust inference. In this context, a relationship represents how two people interact with each other – this may assist, for instance, in the identification of how this relationship is positive or not. Moreover, these relationships can take specific labels that determine the relationships nature, e. g., parent and child, boss and employee, or boyfriend (girlfriend), or even more, it may have quantifiers to show how important or confident– a person is to another. These features create information sources that can be potentially studied in order to assist the task of trust inference in social environment.

The knowledge generated by users arises naturally, since the structure of this social virtual environment is useful to the production of knowledge, collaboration and cooperation. The knowledge produced by users becomes another rich source to assist in the process of trust inference.

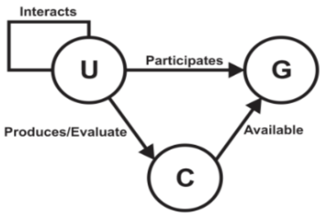

Fig. 1. Structure required of the social virtual environment for the deployment of the algorithm T-SWEETS

From the above features, the algorithm T-SWEETS analyses the direct and indirect relationships between people; grouping among people, and people who share (have) similar opinions and knowledge. Thus, Fig. 1 presents the structure required of the social virtual environment in which the T-SWEETS can be deployed. The environment is required to have production and sharing of knowledge among users.

In Fig. 1 the set of users U performs three main functions: interaction with others users, production of knowledge C, and participation in group G. Moreover, it is also possible to share content / knowledge in groups. In order for T-SWEETS to perform trust inference, the social virtual environment in which this algorithm is deployed should be suitable to the structure shown in Fig. 1.

5.2 Elements to Trust Inference

T-SWEETS analyses also the quality of content produced by people that are in a social network. The definition of the elements used in T-SWEETS was based on the following hypotheses: (**H1**) people related to the same context tend to trust each other in a higher level; **(H2)** people tend to trust people who trust their trusted friends; **(H3)** people who produce relevant content / knowledge are more reliable; and **(H4)** people deemed reliable have good reputations. Thus, the following elements are analyzed in T-SWEETS, whose definitions are as follows:

- **Similarity between Users´ Profiles:** this element has direct relation with H1, since users connected to the same context tend to be more reliable, and it is measured from the similarity between two users - the similarity is determined by common information related to users (*e.g*. tags and content) and based on the context in which they are inserted (*e. g*. a group of people or community). Thus, we estimate the likelihood of greater collaboration among these users with similar profiles;

- **Relationship of Trust:** in society, it is natural for people to seek help from their friends (as H2). However, there are situations in which friends cannot help, in these cases there is the possibility of indicating some reliable third person who can help. In social virtual environments, the relationship of trust can be represented, since is possible the people indicate reliable people to other people;
- **User Maturity Level:** people who produce relevant knowledge to people around them and groups in which they participate tend to be more reliable than people who do not produce quality knowledge (according to H3). To identify the relevance of the knowledge produced by people we analyze the rates of other people on their knowledge. Therefore, we measure the maturity of knowledge of users. The higher the maturity level of the knowledge produced by users, the more reliable is their productions and therefore more reliable is the author;
- **Reputation:** people tend trust more people who have good reputation. Likewise, they tend to trust less people who have bad reputation (H4). The reputation in the T-SWEETS is inferred from the trust rates that users receive from their relationships.

Definition: Similarity between Users' Profiles *is the similarity between knowledge and opinion profiles of the users a and b.*

To measure the similarity between two profiles we consider two questions: (1) user´s knowledge profiles, through their productions in the social network (e.g. production of content), and (2) the user´s opinion profiles, through the rates (e.g. likes or dislikes) given by users to the contents published on the social network. Users with similar profiles have higher affinity hence are more likely to interact among them.

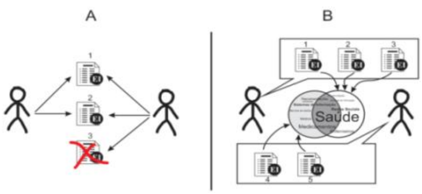

Fig. 2. Process of analysis of the user´s knowledge and opinions

Fig.2A shows the process of similarity analysis of user ratings. This process is necessary because users who evaluate the same contents and have similar opinions are classified as users that have profiles of similar opinions. We consider the rates assigned to all content that have received ratings by two targets users of analysis. Fig. 2B shows the similarity analysis between the knowledge profiles produced by users. Thus, users who produce knowledge similar or related to the same subjects tend to have similar knowledge.

The similarity between the opinions profiles of two users a and b is given by:

$$\rho E(a,b) = \frac{\sum_{\forall\, i \in E(a) \cap E(b)} e(a,i) * e(b,i)}{\sqrt{\sum_{\forall\, i \in E(a)} e(a,i)} * \sqrt{\sum_{\forall\, i \in E(b)} e(b,i)}} \tag{1}$$

In (1), the $\rho E(a,b)$ represents the similarity degree between the opinions of two users a and b; $E(a)$ and $E(b)$ are the contents evaluated by them; while $e(a,i)$ *and* $e(b,i)$ are the user ratings a or b to a content i. We use Vector Space Algebraic Model to represent the users´ opinion profiles [19]. After this representation, it is necessary to use a similarity analysis algorithm to measure the similarity between profiles. In T-SWEETS, we adopt the cosine measure. Other measures could be adopted,, e. g., Jaccard [19].The Equation (1) originates from the equation of scalar product in Euclidean spaces [19]. The term $\rho E(a, b)$ ranges [0, 1]. The closer to 1, more similar are the rates from users, and the closer to 0, less similar are the common rates between the users a and b ($E(a) \cap E(b)$).

In Equation (2), the sK(a,b) represents the similarity degree between the knowledge profile of two users a and b. In (2), K(a) and K(a) are the set of terms extracted from the knowledge (*e.g.* text document) produced by them; while f(k, a) and f(k, b) are the weight of a term k related to a user a or b. The terms are the words identified after the extraction of stopwords [22] (irrelevant terms, such as article, preposition and interjection). The Term Frequency (TF) [22] of users productions define the term weight

$$sK(a,b) = \frac{\sum_{\forall\, k \,\epsilon\, K(a) \cap K(b)} f(k,a) * f(k,b)}{\sqrt{\sum_{\forall\, k \,\epsilon\, K(a)} f(k,a)^2} * \sqrt{\sum_{\forall\, k \,\epsilon\, K(b)} f(k,b)^2}} \tag{2}$$

In (2) also uses the similarity measure cosine. The arithmetic average ($S(a, b)$) of the values $\rho E(a, b)$ and $sK(a, b)$ represents the similarity between the users profiles a and b.

The algorithm SUNNY [6, 7] analyses the concept of similar users, based on the ratings made by users on the social network. While in T-SWEETS we consider the knowledge profiles, which are the productions of users on the social network and the opinions profiles, formed by ratings made by users, to measure the similarity between two users. With this addition, T-SWEETS has more parameters for identifying the similarity between the user profiles.

Relationship of Trust

***Definition**: **Relationship of trust** is the trust of a user a in relation to a user b explicitly assigned by a; or the probability of user a to trust in b given that there is a path relationships of trust between them (e. g. a→b→c).*

In T-SWEETS, relationships of trust take into account the concepts of *Transitivity*, *Asymmetry* and *Composability* whenever the trust inference between two users is performed.

The trust between people is a phenomenon that can be transitive, since people can seek information about other in order to have parameters that assist them in the identification of whether a person is or is not reliable. However, trust is not a totally transitive phenomenon, that is, not every trust of a person might be transferred to another - considering its network of relationships.

This implies that, if a person a, that trusts heavily a person b, and b trusts heavily a third person c - forming the path of relationship $a \rightarrow b \rightarrow c$ – does not mean that the person a trust heavily c. However, we can use information of trust elationships ($a \rightarrow b \rightarrow c$) to infer how much the person a could possibly trust person c.

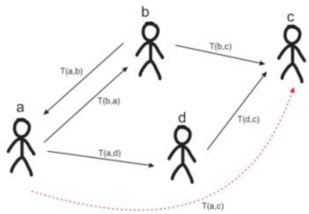

Fig. 3. Trust Graph

Furthermore, if we say that the person *a* trusts heavily *b* does not imply that *b* trusts *a* in the same level. The first information (a→b) do not provides parameters to obtain the second (b→ a). Thus, there is the *Asymmetry* [5]. Fig. 3 presents the concept *Relationship of Trust* in a trust graph.

In Fig. 3, the dotted lines represent trust degree *T(a, c)*, which is the trust degree inferred of the user *a* regarding the user *c*. Beyond *Asymmetry*, the *Relationship of Trust* can also analyses the concept of *Composability.* [5]. The *Composability.* concept defines that if the person *a* trusts more a person who has reliable information about person *c*, then this information may be considered to trust inference. Thus, according to Fig. 3, there are two trust information that can be used in the trust inference process *T (a, c)*: the trust degree assigned by users *b* and *d* to the user *c*.

$$T(x,y) = \begin{cases} T(x,y), if\ there\ is\ a\ trust\ degree\ assigned\ directly \\ \frac{1}{|P(x,y)|}\{\sum_{\forall\ p\ \in P(x,y)}[\prod_{\forall\ \mathrm{adj}(u,v)\ \in\ p} T(u,v)]\},\ \text{otherwise} \end{cases} \quad (3)$$

$T(x,y)$ it is the trust degree of a user *x* in regarding to the user *y,* we used the set of shortest paths *p* between the user *x* and y. In Equation (3), the formula for the trust degree might vary with the following situation: If the user *x* has assigned a trust degree to the user *y*, then this is the trust degree of *x* to *y*, *(T(x,y)*; otherwise we use the second part of formula (Equation (3)). In this formula, *P(x,y)* is the set of shortest paths *p* that can be established between the user *x* and *y* in the relationships graph of social network, and |*P(x,y)*| is the amount of elements in this set. Each element of this set is a pair *(u,v)*, which represents an edge in the graph and the trust information related to it, linking users *u* and *v* on a path *p*.

We define the value 3 of the social distance for the shortest path between two users. The paths length of social distance has been reduced to ensure that the algorithm has more accurate results, although the coverage (recall) is decreased. This approach for path selection was inspired in TidalTrust algorithm [5]. In TidalTrust, besides the shortest paths, it is also established a threshold of trust degree to decide whether or not a path must be considered. In T-SWEETS, we do not use this threshold, because we believe that the quality of the algorithm can be compromised, since low levels of trust were disregarded. If low values of trust are not part of the analysis, there is a natural tendency to increase the trust degree inferred between two users *a* and *b*.

To design the inference of trust relationships in T-SWEETS we adopt the concept of trust transitivity [5], which states that the trust is not a phenomenon totally transitive. Despite this definition, the TidalTrust algorithm makes the trust transitivity fully transitive in some situations. Therefore, the formalism of T-SWEETS solves this problem. Both T-SWEETS and TidalTrust apply trust transitivity based on a probabilistic model. However, there are other algorithms that analyze the trust transitivity based on different theories. For instance, RN-Trust [15] uses the concept of resistivity of circuits and FlowTrust [15], the theory of flow.

User Maturity Level

***Definition**: **User Maturity Level** represents how the users' productions are seen by others users in the social network. For this, we consider all ratings given to the contents produced by a user a in the environment.*

One of the indicators of users´ reliability is the quality of content they produce. This quality represents the knowledge maturity of the authors.

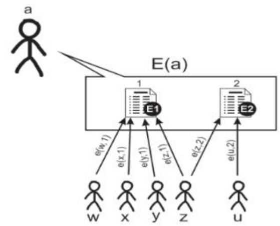

Fig. 4. Analysis of the maturity level of the user *a*

In T-SWEETS, we use the ratings given to a user's contents in order to measure his maturity level. Therefore, we assume that the content that receives positive evaluations has better quality. Moreover, the greater the number of evaluations assigned to a content, the greater may be the accuracy of assessment of such content's quality. Fig. 4 shows the process that determines the user maturity level.

According to Fig. 4 the user *a* has produced two contents *{E1, E2}* that have been rated by some users {w, x, y, z, u}. The ratings of the users for each content and denoted by *e(α, β)* and will be used to determine contents' quality and hence author maturity level. Thus, the user maturity level can be measure with Equation (4).

$$M(x) = \begin{cases} \frac{\log[\sum_{\forall\, i \in E(x)} e(i)]}{\max\{\log[\sum_{\forall\, i \in E(y)} e(i)] : \forall y\}}, & \text{if } E(x) \neq \emptyset \\ 0 & \text{, else} \end{cases} \quad (4)$$

In Equation (4), E(x) and E(y) are the ratings assigned to the content of users x or y; *e(i)* and *e(j) are* the degrees assigned to the rate *i* or *j*; and the $\max\{\log[\sum_{\forall\, i \in E(y)} e(i)] : \forall y\}$ it represents the greatest value of the set formed by the logarithms of the sums of ratings assigned to the contents of users *y*.

According to Equation (4), the users who receive content ratings more frequently have higher maturity level in relation to users who have content evaluated less frequently. Thus, we consider that: the users who have produced most relevant knowledge have greater maturity, *i. e.,* greater trust.

A work that inspired the adoption of the maturity level in T-SWEETS was [17]. In this work, authors use a variation of PageRank algorithm to measure how much the items of users are rated. In [17] the number of rates given by user *x* to the content produced by another user *y* is used to weight inversely those ratings. Thus, the greater the amount of ratings performed by the same user *x* to the contents of user y, the smaller is the weight of these ratings. This approach is an attempt to give less importance to the ratings of people who do not have a default behavior on the social network. However, there is the problem that users who are closer (less social distance), or related to the same context, might be affected. Because, naturally, they have a greater tendency to collaboration and cooperation. This problem does not occur in T-SWEETS.

Reputation

Definition*: *Reputation *is the view that a group of people g have regarding a person p. It is determined by the trust degree of the g regarding to p.*

The reputation considers how much a person is deemed reliable regarding an overview of a group of people. So, it has direct influence on trust among people, because people who have action and opinions more reliable tend to have higher reputation level. In social virtual environment the opinions of all members in the social network is usually considered to determine the reputation degree of a node (i.e. user, person). However, this approach has a high computational cost. To avoid this problem, T-SWEETS do not considers all members of the social network – it is possible to define the size of the social distance *d* of a target user to other social network's users. The ideal *d* – which is, that does not compromise algorithms' performance – has not been defined, more experiments are still necessary to this definition. By default, we use the value 1 for this social distance.

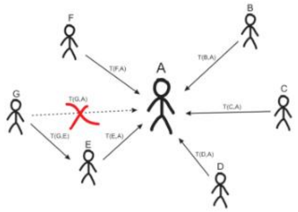

Fig. 5. Trust graph to calculating the reputation of the user *a*

In Fig. 5 the not dotted lines represent the trust degree between users in the trust graph and the dotted line represents an inferred trust degree for an indirect relationship in the graph. As noted previously T-SWEETS uses the trust ratings given to a target user for measuring reputation. Thus, the values *T(G, A)* and *T(G, E)* will not influences the reputation of user *A*. Given these conditions the calculation of reputation can be accomplished by Equation (5):

$$R(a) = \frac{\sum_{\forall u \in adj_1(a)} T(u,a)}{|adj_1(a)|} \quad (5)$$

Equation (5) represents an arithmetic average of trust degrees assigned directly to the user a. The set $adj_1(a)$ contains the users who performed the assignment trust to the user a, where $|adj_1|(a)|$ is the amount of users in the set. The notation $T(u, a)$ is the trust degree of user *u* regarding to the user *a*, as presented in the previous sections.

Likewise T-SWEETS, [17] also uses the same information sources to measure the reputation of a user in the social network. That information sources are the trust relationships between users.

Just as in the measure of user maturity, [17] also give most importance to users who contribute less in the social network. This approach, as already mentioned, affect users that are closer to each other (less social distance), or related to the same context. Thus, these users have a tendency to greater collaboration and cooperation among them. In T-SWEETS, users that collaborate more often in the social network are privileged.

5.3 Trust Inference

The measures outlined above should be considered to obtain the trust degree between two users.

$$C(a,b) = \frac{\alpha(S(a,b)) + \beta(T(a,b)) + \gamma(M(b)) + \delta(R(b))}{\alpha+\beta+\gamma+\delta} \quad (6)$$

In Equation (6) the values obtained for each element of T-SWEETS (Similarity between Users' Profiles $(S(a,b))$; Relationship of Trust $(T(a,b))$; User Maturity Level $(M(b))$; and Reputation $(R(b))$) are used in a weighted average to infer how much a user "a" trust a user "b". We have normalized each of these values by applying an approach from area of information retrieval, called *term frequency* (*tf*). This approach considers the division between the frequency of a term *t1* in a document *d* by the greater frequency of a term in *d* [19]. Thus, we have divided each these values by a highest degree within the set. The values α, β, γ and δ determine the importance of each element considered in the trust inference. The importance of each element has direct dependency on the context in which T-SWEETS is deployed. In this work, we assume equal weights for each element, because we have not done further study to understand the importance of each element. The final trust degree is in a scale [0,1]. The closer to 1, higher the trust of a user *a* in regarding to a user *b,* and the closer to 0, less is the trust degree between them.

6 The *Konnen* Social Network Environment

Konnen is an application based on social network for organizational knowledge management. The current version of *Konnen* is still experimental. It has been in development during the last three years. This environment is been employed experimentally in a university where professors and students are stimulated to create content and new relations in order to augment the process of learning. The important features of *Konnen* to our work are:

- **User´s profile:** part of the user's profile is not filled explicitly by him/her, but inferred by the system. This information includes: (i) the user's activity index, which is calculated through the amount of activities that produce or consume knowledge on the environment; (ii) a set of subjects the user usually writes about, which are inferred through the identification of the most relevant terms posted on the environment by the user. This feature is important to the element *User Maturity Level* and *Similarity between Users´ Profiles* of the T-SWEETS.
- **Objects:** The system also allows adding knowledge through various kinds of objects. In the *Konnen* environment, every file that can store knowledge or be used to enrich existing knowledge is seen as an object, like text documents, papers, spreadsheets, audio and video files, and URLs to external resources. In order to increase user collaboration, any object added to the system can have comments, increasing the probability of surging new dialogues about the knowledge stored within objects. Every member can also act as a reviewer of the content added by his peers, evaluating contributions qualitatively. This evaluation can be done in two ways: (i)

by adding comments to objects, improving them with new knowledge and creating a dialogue around the added knowledge; (ii) giving a rate that positive (like) or negative (unlike). This feature is important to the elements *User Maturity Level* and *Similarity between Users´ Profiles* of the T-SWEETS.
- **Virtual Communities:** In the *Konnen* context, virtual communities can be seen as groups of users who have some interests in common. The system supports the creation of such communities by any WBSN member. A community has a main mechanism to support knowledge creation and sharing between its members: the forum. It allows the members can start new topics about any interesting subject. The communities, in our environment, represent classes and any user may create them. In our experiment, only teachers may create them. The students cannot create virtual communities because our experiment represents a controlled environment.
- **Assigning Trust Degree:** the social network users might assign a trust degree to users that have direct relationships with them. These values are important for inference of trust hidden relationships. It is important to the elements *Relationship of Trust* and *Reputation* previously presented.

7 T-SWEETS at *Konnen*

T-SWEETS is designed to be deployed in any virtual environment based on social network. It allows the representation of direct and indirect relationships between people, the assignment of trust degree of user *u* in regarding to a user *a*, the possibility that there is collaboration (production and knowledge sharing) between people, as well as assignment ratings to the knowledge produced by users (people). T-SWEETS was deployed in *Konnen* (*Knowledge Organization in a Native Network ENvironment*), a social network platform that aims to organizational learning.

Fig. 6. Widget to recommendation justification

The integration of T-SWEETS to *Konnen* aimed to generate recommendations of new trust relationships to the users in such environment. Beyond this integration, we developed a module to explain the recommendations, which present to the users the justifications for each recommendation, as shown in Fig. 6.

We use the 4 elements of the T-SWEETS in explanation widget shown in Fig. 6, so the user has parameters to decide whether or not to accept the suggestion of new relationships. When the user takes the mouse over the user's profile picture recommended the widget is shown. In justification, for each T-SWEETS's element it is presented the equivalent percentage (e.g. the user John was recommended Peter because has 75% of reputation and 68% of maturity in the environment). Only users who have Trust Inference greater or equal to 70% are recommended.

Through an informal interview with some users of *Konnen* we found that they are pleased to understand the reasons why the system is suggesting them new relationships of friendship.

8 Experiments and Results

8.1 Preliminary Experiment

Before the formal definition of T-SWEETS we did an experiment applying a questionnaire with a group of people. This experiment aimed to define and measure some elements that could be used in the process of trust inference. The experiment aimed also to understand the behavior of these people in the network when deciding to collaborate or not with another person. In one of the factors analyzed, we required to understand how people consider the concept of "trust" (e.g., before seeking help from another person about an issue or a problem) and the importance of the trust in collaborative environments – i.e. if trust can be one of the prerequisites to encourage collaboration.

The questionnaire was submitted by two ways: by e-mail and by *Konnen* platform, to a universe of 103 people. 53 people answered the questionnaire. The people selected for the study were from different knowledge areas (e.g. computing, journalism, advertising and psychology) and work daily with a computer.

We found that 43.4% of those interviewed usually seek help primarily with their friends. Among these, as second and third options, 47.8% tend to seek help from a friend of a friend and 43.3% with a coworker. And 22.6% of the people often seek help primarily with a coworker, and friends are the second option. Thus, approximately 66% people usually seek help primarily with people related to their social contexts. The results are understandable, since it is natural for people to seek help in their context of social interaction. Thus, this context provides a social collaborative environment where people have the opportunity to increase their social ties (relationships amount) is an interesting alternative to assist in the resolution of problems.

We found also that 56.6% of interviewees help people who have affinity or trust them directly or indirectly. Moreover, the reputation was another important element considered in this research. The reputation helps to determine how much a person is trustworthy faced with a group of people: 77.4% of respondents consider the reputation when deciding whether or not to trust a person. Another element that helps people to decide whether or not to trust others persons are the knowledge level they have about a particular subject. This was the answer of 90.6% of the respondents.

The respondents were also asked about how much they believe that people who have profiles knowledge and interests similar to theirs are likely to collaborate with them. In response, we obtained 92.4% of the people who have high or very high probability of collaborating with each other if they have similar profiles.

8.2 Experiment of T-SWEETS at *Konnen*

The deployed of T-SWEETS at *Konnen* had the following objectives: (1) use the particularities of social networks to suggest new hidden trust relationships; (2)

discover people´s knowledge and interactions among them in order to assist the process of trust inference; and (3) promote greater collaboration among users of the platform.

The experiment was restricted to 3 classes of a university bachelor's degree programs. We believe that this number is sufficient to measure the impact of the recommendations. These classes had 22, 14 and 21 students. We choose the classes according to the period that students were: one class in the beginning of the course, another one in the midst, and a later at the very end of the course. The goal was to select students who had never met previously. Nevertheless, there were two students who attended of two classes of the experiment simultaneously The period of analysis of experiment was 16 weeks. The experiment was divided into two phases: the first without and the second with the integration of T-SWEETS into *Konnen*. Thus, we would expect measure the impact that this algorithm would have on the environment.

First Phase

249 relationships between users were created during the first phase of experiment. Fig. 7 shows the construction of these relationships regarding time. It is possible to note that more relationships were created during the initial moment – this is natural and expected, because on initial time the users still were not registered on the platform. After the first moment, the emergence of new relationships in the social network gradually decreased, tending to zero.

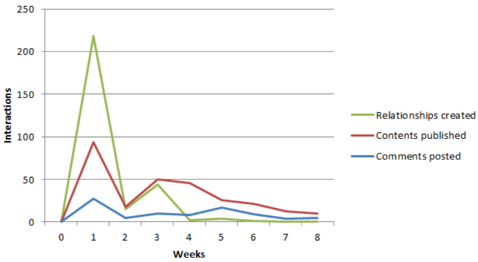

Fig. 7. Interactions vs. Time

From these relationships emerged a set of interactions between the users on the platform. Some data from these interactions are: 278 posts, 131 are type files (e.g. pdf, doc and rtf), 24 are images (e.g. jpeg and png), 16 are links, 134 are texts (traditional posts in discussion forums) and 4 videos. These postings in relation to time can be seen in Fig. 7. Likewise relationships, the initial moment was when there were most postings - also natural, since in this time there was a general contagion of users trying out the tool. At week 2, we note decrease in the amount of publications. Thereafter, only at week 3 the publications amount has increased slightly over 50% compared to the initial moment. After that, the publications amount only decreased, which makes clear the need for mechanisms to encourage collaboration among users.

Fig. 7 shows the amount of comments to postings in relation to time. Similarly to both relationships and postings, there was also a big fall in the comments in the last weeks of the first phase of the experiment. Again, this emphasizes the need for alternatives to keep users motivated to produce knowledge.

Second Phase

The second phase of the experiment (from week 8) was when T-SWEETS deployed at *Konnen*. With the amount of users and existing relationships in the *Konnen*, it would still be possible to create 5256 new relationships. Of all possible relationships, 49.79% were recommended by T-SWEETS, however, we defined a threshold to filter the most relevant recommendations. The threshold defined was 0.7 on a range between 0 and 1. We do not know if this is the ideal threshold. For the definition of an ideal threshold is necessary to conduct experiments and analyze the results carefully for this setting.

By setting this threshold, were recommended approximately 11% of the total trust relationships (49.8%) which could be recommended (Fig. 8). As result, instantly, there was a peak in the increase of existing relationships in the social network. This peak is natural and expected, once there is a natural tendency the people to be excited with new functionality in the environment. The most important is that the relationships continued happening during the time. Although, again, just like at the end of the first phase of the experiment, the new relationships reached zero in end of experiment, but that too is understandable, because this was the time when the classes were being finished and the students hardly accessed the platform. An important fact is that 81.8% of the new relationships created in the second phase of the experiment born from the recommendations of trusted relationships that was suggested to the users by T-SWEETS.

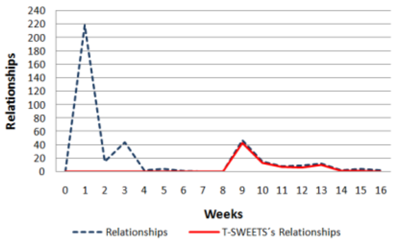

Fig. 8. First and Second Phase of Experiment: Relationships vs. Time

In Fig. 9 we show several scenarios that present the status of the network of relationships at the first 8 weeks (part 1 of each scenario) and at the end of the experiment (the sixteenth week - part 2 of each scenario).

In scenario (Fig. 9-A1) the size of nodes represent the amount of relationships a user has, i.e. the amount of connections defines node size and the node represents the user itself. The node color intensity represents the user connectivity in social network. This connectivity is the average of social distance among users and measures the ease of a user to communicate with others on the social network. There are nodes with high amount of relationships, but with low or medium connectivity, however there are nodes with few relationships and high connectivity. This is justifiable since there are nodes classified as "more centrals" or that have more influence. Although, even if a node has more relationships it does not guarantee that it possesses greater connectivity – crucial in a social network for greater interaction and collaboration. The stimulus to create new relationships can contribute greatly to the increased connectivity of the nodes, as can be observed in (Fig. 9-A2).

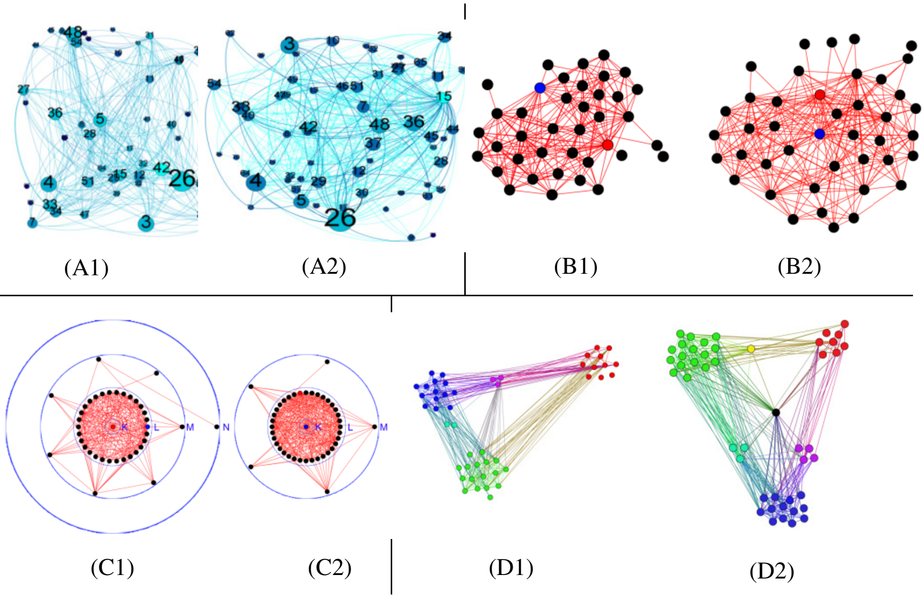

Fig. 9. Relationships´ graph during the 16 experiment weeks: A1, B1, C1 and D1 (before); A2, B2, C2 and D2 (after)

Considering scenario (Fig. 9-A1) again, the explicit identification of users (numbers inside vertices) is important because it shows that the situation of a particular individual in the social network can be modified as new relationships emerge over time. This can also be proven observing that the blue node in scenario (Fig. 9-B1) has greater connectivity, while in (Fig. 9-B2), the red node has more connectivity.

Scenarios (Fig. 9-C1) and (Fig. 9-C2) show a layered organization, in which are emphasized the node that has higher connectivity (central node) and social distance between the network nodes and him/her. The layers amount means the density of connection between users on the network. Therefore, the greater the layers numbers, more dispersed are the users on the network. The nodes in the outermost layer are those that are more distant from node most connected. Scenario (Fig. 9-C1) has more layers than the scenario (Fig. 9-C2). In scenario (Fig. 9-C2) we can mention that the social distance among nodes and among the node that has highest connectivity in network has clearly decreased. Moreover, the amount of users on the layer M in scenario (Fig. 9-C2) decreased with regards to users in the same layer in scenario (Fig. 9-C1). In scenarios (Fig. 9-D1) and (Fig. 9-D2) nodes were clustered according to the groups they belonged to, and then from their relationships. In (Fig. 9-D2) it can be clearly perceived that there is a greater amount of relationships between users that are in different groups, whether we compare to the scenario (Fig. 9-D1). Users previously isolated from the relationships of the groups they belong to have largest connectivity in the network in scenario (Fig. 9-D2), i.e., from the creation of new relationships with users that belong to other groups.

With the increase of relationships amount, there is a natural trend for private messages among users. The comments to postings also increase. The greater the relationships amount, the greater the amount of people accompanying the production and evaluating other people. At the final weeks, there has been a big decrease in the interactions among users. As previously mentioned, it happened because the classes were being closed that time.

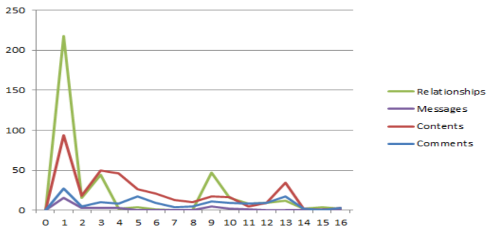

Fig. 10. Relationships emerged, Sent Messages, Content and Comments Posted in Relation to Time

Because of this increment of relationships, we expected that the amount of private messages sent among users will also increase, but this did not happen (Fig. 10) – which was a surprise. To try to understand this result, we conducted an informal investigation with some users. We found that there were some technical problems in the *Messaging* module. Therefore, this was a problem that caused the users with no motivation to use the functionality of messaging.

9 Conclusions

This work presented a new approach for trust inference, entitled T-SWEETS and its deployment in *Konnen*, a platform for knowledge management. Some contributions of this work are: (1) an inquiry with a group of people to identify and validate the elements of the novel approach for inferring trust; (2) a novel method for trust inference in social networks. It is an alternative to stimulate collaboration among the individuals, since trust is naturally a necessary premise in our society for collaboration between people; (3) the materialization of the approach in a social platform, *Konnen*; and (4) an experiment that analyzed the impact of this novel approach deployed in a social platform.

The expectation is that the T-SWEETS can stimulate the users to the collaboration, i.e. contribute to explicit users' knowledge in the environment more frequently, thereby providing background for automatic discovery of knowledge. In the experiment presented in this paper, it is possible to prove this trend, since 81.8% of the relationships created after the deployment of T-SWEETS in the *Konnen* platform emerged from trust recommendations of T-SWEETS.

As future work, we will add new elements to T-SWEETS algorithm to identify the users that do not have a default behavior in the environment, i.e, users rating content and users booth at random, do not obeying any pattern. This behavior might degrade the T-SWEETS performance. We will also develop a performance analysis in the T-SWEETS. Also, we expect to develop an Expert Recommender System (ERS) based on trust. We understand that the ERS can be more efficient since the greater the production of users´ knowledge greater are the chances to identify the users´ experts with more accuracy. Other future work is to investigate the most important factors in the subsequent choices which influence the acceptance/refusal of recommended relationship. Besides, we intend also to analyze whether the trusted relationships has been established, how do they evolve, and what kind and level of collaboration this relationship has permitted.4

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Providing Awareness, Understanding and Control of Personalized Stream Filtering in a P2P Social Network

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Abstract. In Online Social Networks (OSNs) users are often overwhelmed with the huge amount of social data, most of which are irrelevant to their interest. Filtering of the social data stream is the way to deal with this problem, and it has already been applied by OSNs, such as Facebook. Unfortunately, personalized filtering leads to "the filter bubble" problem where the user is trapped inside a world within the limited boundaries of her interests and cannot be exposed to any surprising, desirable information. Moreover, these OSNs are black boxes, providing no transparency of how the filtering mechanism decides what is to be shown in the social data stream. As a result, the user trust in the system can decline. This paper proposes an interactive method to visualize the personalized stream filtering in OSNs. The proposed visualization helps to create awareness, understanding, and control of personalized stream filtering to alleviate "the filter bubble" problem and increase the users' trust in the system. The visualization is implemented in MADMICA – a privacy aware decentralized OSN, based on the Friendica P2P protocol. We present the results of a small-scale study to evaluate the user experience with the proposed visualization in MADMICA.

Keywords: Online communities, Social networks, Social visualization.

1 Introduction

Today, with the enormous growth of Online Social Networks (OSNs) such as Facebook and Google+, millions of users are sharing social updates with friends and followers creating a "fire hose" of data in real-time. The updates vary from personal news (such as what's on their mind, what they are doing, what they are thinking of) to global news (such as news about politics, science, sports, technologies, etc.). If we consider the social data stream of a single user from her friends, only a fraction of it is relevant and interesting and the rest of the stream results in social data overload to the user. Personalized stream filtering mechanisms aim at solving these challenges of social data overload by presenting the user with the most relevant content. Social media sites such as Facebook, Digg and YouTube have already implemented personalized stream filtering which presents the most relevant content to users while reducing

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the social data overload. However, these systems are black boxes and provide no transparency or explanation, so users do not have any idea about what social updates that are hidden in the social data stream by the system and why they are hidden. As a result the user trust in the system can decline. Moreover, while attempting to personalize the stream with relevant content, in a long run the user can be trapped inside a world within the limited boundaries of her interests. This is called "the filter bubble" problem.

There are three key research questions that we are interested in answering by this research.

1. Is Visualization of the Filter Bubble an Effective Technique to Create Awareness, Understanding and Control of Personalized Stream Filtering?

The main purpose of personalized stream filtering is to reduce the social data overload by presenting only the relevant content. But showing what is hidden and filtered away in the stream can increase the social data overload problem. Therefore the main challenge is to find an effective visualization technique that can be seamlessly integrated into the activity stream without contributing additionally to the social data overload. What is the right amount of detail to expose in the hidden filtered social data and its explanation? How do we organize these hidden filtered social data? What type of visualization is effective to display the hidden social data stream? These issues can be explored through theoretical design and experiments with users.

2. Can a Visualization of Personalized Stream Filtering Increase the User's Trust in the Personalized Stream Filtering?

There is the possibility that some of the hidden filtered social data are being wrongly classified as undesirable. We believe that showing hidden filtered social data will provide transparency of the personalized stream filtering to the user and explaining them will build the users' confidence and will increase the user acceptance of the system.

3. Can a Visualization of Personalized Stream Filtering Alleviate "the Filter Bubble" Problem?

As the activity stream is personalized according to the user's interests, the user will ultimately only see activities related to her interest and will have no opportunity of discovering new interests. This will lead to "the filter bubble" problem where the user is trapped in a world filled with only items matching her interests. By exposing (some of the) hidden filtered social data, the user will become aware of the model that the system has of her, and may consciously decide to explore items from other areas by changing interactively her model and it will open the avenue for discovering new interests.

This paper proposes an interactive method to visualize the personalized stream filtering in Online Social Networks to create awareness, understanding, and control of personalized stream filtering to alleviate "the filter bubble" problem and increase the users' trust in the system.

2 Related Work

The social data overload problem is commonly solved by filtering out the irrelevant data. The problem of filtering out irrelevant data and providing personalized recommendation of data are addressed by Recommender Systems (RSs). RSs adapt to the needs of an individual user and provide personalized suggestions of most relevant information [12]. The personalized suggestions help users to make decisions on various types of items such as what book to read, what movie to watch and so on. Tandukar & Vassileva [15] developed an interest based filtering model which recommended relevant social data in the activity stream while filtering out the irrelevant social data to reduce the social data overload problem in a P2P social network. RSs provide recommendations using specific techniques based on background data, input data and algorithm. Collaborative filtering and content-based filtering are the main techniques used in most RSs [1]. Content-based filtering generates recommendations of new information using the history of information and the ratings previously given by that user. In collaborative filtering, recommendations are generated using only information about rating profiles for different users. Peer users with a similar rating history as the current user are identified and used for recommending new information.

Many researchers have worked on developing new RSs and improving the accuracy of their filtering algorithms. However the ultimate measure of success in this area is the user acceptance and trust of the recommendations and with respect to this measure there is still a lot of work that needs to be done [6]. The standard performance measures for RS are good when it comes to testing the recovery of missing data by RSs. But they cannot provide a valid method to test whether recommended data are valuable and previously unknown to the user. Providing a better user experience with RSs can increase user acceptance of recommendations. So user experience is becoming one of the most important current areas of research in RSs. The RSs must adapt and understand the needs of the users at different stages and provide not only valuable recommendations to the users, but also, as proposed by Chen & Pu [10] explanation interfaces which turn to be very effective in building the users' trust in the RSs. Previous research shows that explaining recommendations can increase the transparency of RSs and the users' trust in RSs [4, 18].

Explaining the rationale behind the recommendation is an important aspect of recommender systems. Explanations provide users with a mechanism for handling errors that might come with a recommendation. When we consider how we accept the recommendations provided by other humans, we recognize that other humans are imperfect recommenders. In case of the recommendations suggested by a friend, we might consider the quality of previous recommendations by the friend or we may compare that friend's interests with our interests in the domain. However, if there is any doubt, justification of the recommendation is needed and we let the friend explain it. Then we can analyze the explanation and decide whether to accept the recommendation or not [13].

Tintarev and Masthoff [17] describe three motivations for explanations in recommender systems: (1) transparency, which exposes the underlying logic of forming the recommendation so that the user can trust the system; (2) trust, which enables the user to consider the recommendation regardless of its accuracy level, and (3) scrutability, which enables the user to provide feedback on the recommendation to the system, so that the system can improve the future recommendations. Previous work on expert systems and automated collaborative filtering systems has shown that explanations can provide considerable benefit [13]. Work related to explanations can also be found in many other domains such as psychology, philosophy and cognitive science. Incorporating an explanation feature in recommender systems provides several benefits to users. It removes the black box from around the recommender system, and provides transparency. Herlocker et al. [3], mention some benefits provided by explaining recommendations such as: justification, user involvement, education and acceptance. Johnson & Johnson [4] have done research on explanations in human-computer interfaces.

The way recommendations are presented is critical for the user acceptance of recommender systems. Visualization techniques can be deployed to provide an intuitive "at a glance" explanation for recommendations and can also motivate the user to accept the recommendation. Presenting the recommendations in a ranked list according to their recommendation score is the most simple and commonly used visualization technique. Webster & Vassileva [19] proposed an interactive visualization of a collaborative filtering approach in RSs that allows the user viewer to see the other users in her "neighborhood", who are similar to her, and also to change manually to degree of influence that any of the other users can have on the recommendations of the viewer.

As a result of personalized filtering, the user can be trapped inside "the filter bubble" - a term introduced by Eli Pariser [9] to denote a limited scope of information defined by the user's interests and isolated from anything that doesn't belong to this scope. Resnick et al. [11] discuss the dangers of isolating users in filter bubbles and outline some strategies for promoting diverse exposure.

As discussed above, some approaches for increasing the transparency and the users' trust in RSs involve explanations or making the mechanism of recommendations visible to the user. Yet there haven't been approaches to visualize or explain the filter bubble problem. We propose an interactive visualization that presents a metaphoric view of the recommended and the hidden filtered social data in the personalized stream filtering in OSNs. The purpose of the approach is to alleviate the filter bubble problem and increase the users' trust in the filtered stream. The next sections present the design of the visualization and the results of a small scale user study with exploratory purpose.

3 Proposed Visualization

To achieve the goal of creating awareness, understanding, and control of personalized stream filtering in an OSN to alleviate the filter bubble problem and increase the users' trust in the system, we propose a visualization that metaphorically explains the filtering mechanism and provides means of control over certain parameters of the filtering for the users.

3.1 Visualization Design

The visualization is based on a bubble metaphor to make the effect of the personalized stream filtering in OSNs more understandable for the users (see Fig. 1). It divides the space of the screen in two parts - outside and inside the bubble. The items that are inside the bubble are visible for the user, those outside the bubble are those that have been filtered away and are invisible in the stream (but they are shown in the visualization). The visualization provides two alternative points of view: one focusing on the user's friends and one focusing on the categories of the social data originating from them in the OSN.

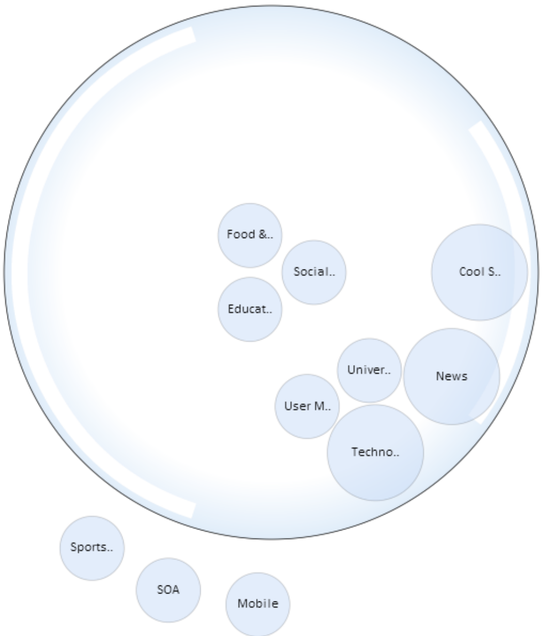

Fig. 1. Filter bubble visualization - category view

Fig. 2. Filter bubble visualization - friends view

Fig. 1 shows the "Category view", where in the bubble are shown the categories of social data that are not filtered away and can be seen in the user's stream (e.g. "Food & Health", "Education", "Cool Stuff", "News"). Outside the bubble are shown the categories of social data that are currently being filtered away from the user stream ("SOA", "Sports" and "Mobile"). The bubble shape design was chosen not only because it fits well with "the filter bubble" metaphor, but because it is scalable to accommodate more circles inside. Making the users aware of the different categories in which status updates are classified provides some transparency of the mechanism, which otherwise users won't be aware of. In essence, the category view summarizes what categories of social data the user is interested in and what categories of social data she tends to ignore in her stream. In addition, the abstract category view scales better than showing the specific updates and does not lead to an overcrowded view and cognitive overload. Upon clicking on a circle representing a given category, a small pop-up window shows the list of social updates from the stream that belongs to the category. In this way, for example, by clicking on the "Mobile" circle shown in Fig. 1, the user can see all the status updates from her OSN stream related to the "Mobile" category, that have been hidden from her. Thus we follow Shneiderman's [14] visualization design principle "overview first, details on demand".

The second view, called "friends view" (see Fig. 2), shows in a similar way the bubble, but instead of circles representing categories of social data, the circles represent the user's friends who have posted the social data. If a friend's circle is inside the bubble, then the social data from that friend are visible in the user's stream, whereas if the friend circle is outside the bubble, the social data from that friend are hidden and not displayed in the stream. Since the filtering mechanism differentiates the filtered data both based on who the data comes from and the category of the data, the friends view displays the relationship that the user has with each of her friends with respect to a given category. Thus the user has first to select a specific category from a drop-down menu on the top of the screen (see Fig. 3), and then sees which of her friends are inside the bubble for this category, i.e. who she is connected with respect to the chosen category. These are the people whose social updates in the selected category the user is seeing in her stream; the updates in this category of the other friends who are outside the bubble are being filtered away from the stream. In order to provide a better understanding of what is happening in the personalized stream, the location of category/friend circle (inside or outside the bubble) represents the visibility of social data in your stream. For both views, the size of the category/friend circle denotes the number of social updates in a certain category or by certain friends, and it helps to understand the relative proportion of social updates that are visible versus those that are hidden as well as who is posting more social data and who is posting less.

Another feature of the visualization design focuses on giving users control over the stream filtering process. This is done by allowing users to drag and drop the category/friend circles inside and outside the filter bubble. Depending on which current view is selected (category view or friend view), dragging a category or friend circle inside the filter bubble enables the users to see updates from a category which appears interesting, but so far has been filtered away, or to strengthen the relationship with a friend whose social data have been not visible in the stream due to the personalized filtering process. In reverse, when users drag a category/friend circle outside the bubble, the social data belonging to that category or from that friend will not appear in the stream anymore. This helps the users to get rid of uninteresting social data and also to avoid spammers who flood the stream with uninteresting and unwanted social data.

3.2 Implementation

MADMICA [8] is an implementation of a privacy-aware decentralized (peer-to-peer) OSN using the Friendica open source framework [7]. MADMICA implements an approach to filtering social data, according to a model of the strength of the user's interests in different semantic categories overlaid over a model of their social relationships, which was originally developed and evaluated in a simulation [15]. The intuition behind the filtering approach is that two people can be friends, but not share the same level of interest in different topics or categories and not trust each other's judgment with regard to these categories. In essence, the filtering approach is based on a model of the user's interest in a finite set of categories of social data that is overlaid with a model of the strength of user interpersonal relationships (over each category). It consists of a matrix of relationship strengths (values between 0 and 1) between the user and each of her friends in different areas of interest. The model is updated based on implicit and explicit feedback from the user, based on the user actions over the social data (e.g. rating, commenting, forwarding or ignoring). The filtering of social data depends on the value of the strength of the relationship between the two users. The current relationship strength between a user and her friend in a given category is compared to a certain threshold value (currently a constant for all users in the OSN, but this could be personalized in the future) by the filtering algorithm to decide whether a new social update from this friend in the given category should be shown in the user's stream, or hidden. More details about the filtering approach can be found in [16].

MADMICA (http://madmica.usask.ca) is built with PHP, jQuery and MySQL technologies. The technology used to implement the visualization is HTML 5 with jQuery. The code can be run by any device on a browser without any plugin and can be adjusted to fit any size screen in a graphically pleasing manner [5]. The visualization is implemented in MADMICA as a plugin. This ensures that the modularized plugin architecture of MADMICA is preserved. So the user of each MADMICA node has the ability to turn off the plugin so the visualization. Users are notified in a side menu next to their stream with a message "Do you know this? N posts from your friends are hidden in your news feed based on your interest. Please, click on the bubble below to see them!". This creates awareness to the users that filtering is happening in the stream and some social data are not shown in the stream. When users click on the small bubble icon, the visualization plugin is loaded. When loading the visualization, all shapes are generated on the HTML5 canvas using KineticJS framework according to the data retrieved from the database. The visualization view is updated instantaneously and it always shows the category/friend circles according to the newest value from the user's relationship model. The default view is category view. Stored procedures have been used in MySQL to speed up the loading of visualization with necessary data.

The visualization can be viewed based on three different filters: bubble view, friends/category, and time period (see Fig. 3). This provides flexibility for the users to choose the desired view, and a time period of interest, since their interests in different categories and their relationships with friends are dynamic. The Bubble view filter consists of a dropdown menu that allows the user to select one of two views: category view and friend view. When the "category view" option is selected, a dropdown list is loaded in the Friends filter containing all the user's friends, so that she can individually select a friend and view all the semantic categories of social data that the user shares with this friend (i.e. shared interest) inside the bubble and those categories with respect to which the user and this friend do not share interest (outside the bubble).

In this view (selected category and selected friend), the circles representing the categories will appear positioned either inside or outside the bubble, based on the relationship strength value with that friend on that category.

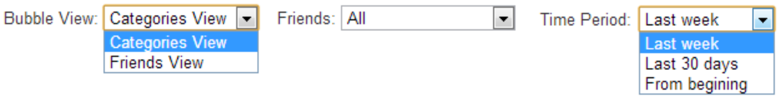

Fig. 3. Filters on the visualization view

To handle the problem of category name not fitting into the small circles, we display only a fraction of text inside the circle and the full text is shown as a tooltip when the mouse pointer is hovered over a category circle. To see the hidden social data for a particular category, the user has to click on the category circles which are outside the filter bubble and a pop-up window is loaded with the individual links to the social data (see Fig. 4). By clicking each link on that menu, the user can see the individual social data items which have been hidden in the stream by the filtering mechanism.

Fig. 4. Screenshot of hidden posts pop-up window

The default option in the Friends filter is "All" which shows just all categories represented inside or outside the bubble depending on the average relationship strength in these categories across all the friends of the user. On the other hand, when the "Friends view" option is selected in the Bubble view filter, the second filter changes to "Category", allowing the user to pick a particular category of interest (the default is again "All"). The circles in this case represent the user's friends and contain the friend's avatar or photo, and the name of the friend appears as mouse is hovered over it (see Fig. 2). In this case, the second filter shows a dropdown menu showing all the semantic categories available in MADMICA. The user can select a particular category and see which of her friends (from those who have posted social data in the selected category) are inside or outside her bubble. Both views can be generated based on a time period filter. This filter comprises several options: "from beginning", "last 30 days" and "last week" as the dropdown list labels. By default "last week" is selected when the visualization is loaded which shows the categories/friends circles in/by which social data were generated during the last week.

To add control of the filtering, we have added the drag and drop feature so that users can drag a category/friend circle inside and outside the filter bubble to show or hide data from this category/friend. When dragging a category/friend circle inside the filter bubble, AJAX (Asynchronous JavaScript and XML) requests are generated from the visualization and the corresponding model values for the interest based relationships are updated in the database. Similarly, when dragging a category/friend circle outside the filter bubble, another set of AJAX requests are generated to save the data. To let the users know about the results of the drag and drop action, a message is displayed to the user informing about whether the social data will be made visible or hidden based on the users' action.

4 Evaluation

A qualitative study was carried out to evaluate the usability and user acceptance of the visualization and whether it achieves its goals of providing awareness, control and trust in the filtering mechanism in MADMICA. The subjects were 11 graduate students from our research lab who used the MADMICA system instead of Facebook to share interesting and research relevant links over a period of three weeks in March 2013. All participants were international graduate students (six female and five male) from various parts of the world (the Middle East, Asia, and Africa), with computer science background and all were very experienced users of social networks (Facebook).

4.1 Hypotheses

The goal of this small-scale user study was to find out if the visualization is usable, if it creates awareness and understanding of the personalized stream filtering mechanism and ability to control it to alleviate the filter bubble problem and if as a result it helps to increase the users' trust in the filtering. So the evaluation aims at testing the following hypotheses.

1. The visualization creates awareness, understanding and sense of control of the personalized stream filtering mechanism to alleviate the filter bubble problem.
2. The visualization increases the user's trust in the personalized stream filtering.
3. The visualization of filter bubble increases the users' satisfaction with the system.

4.2 Experimental Setup

Due to the small number of users and the fact that the users were lab students and knew each other well, privacy wasn't an issue, so for efficiency sake, we hosted only one peer node to support all the participants. Each participant was asked to register and create a profile on MADMICA. Then the participants added each other as friends and started sharing anything they found interesting with their colleagues over the course of 3 weeks. We chose 11 semantic categories to classify the social data (the classification into one of the categories had to be done manually by the user when sharing something new with their friends), but allowed users to create their own categories (subject to approval by an administrator). The categories were chosen based on the main research areas in our lab, such as, education & mentoring, user modeling, mobile technologies, social computing, SOA, and common interest areas, such as food & health, news, sports & games, technology, university news and cool stuff.

To keep the participants engaged and motivated to be active in the network throughout the study period, we provided monetary rewards for participation in the study. Also in the second week of the study, to boost user activity with respect to the visualization, a notification was posted on the main page of MADMICA, to remind users to check the visualization of the hidden and visible social updates.

At the end of the study, the participants were asked to answer a questionnaire. As this was a qualitative study, the questionnaire had mostly open ended questions enabling participants to provide free feedback and describe their own ideas or suggestions. Responses for the few closed questions in the questionnaire were given on a 10-point Likert scale. Both types of questions focused on finding out about the user experience related to the proposed visualization and about the usability of the visualization. All participants completed the final questionnaire.

In addition to the questionnaires results, the usage of visualization of filter bubble was tracked by the system in order to collect data about users' actions on the bubble such as viewing the filter bubble visualization, dragging category/friend circle inside the filter bubble and dragging category/friend circle outside the filter bubble.

4.3 Results

Based on the tracked data, the number of users who performed actions on the visualization, such as clicking on the bubble, dragging a category/friend circle inside, and dragging a category/friend circle outside was plotted for each day throughout the experiment (see Fig. 5). In the first week of the experiment, 19 click actions, 4 drag out actions and 12 drag in actions have been recorded. During the second week when the popup was introduced, the number of click actions has dramatically increased to 28 and while the number of drag outs remained unchanged, the number of drag in actions has doubled as the previous value. In the last week of the experiment, although there is a small decrease in the number of all actions compared to the previous week (21 click actions, 2 drag out actions and 19 drag in actions), the number of actions has increased comparing to the first week.

The questionnaire included a number of closed questions that we asked to get some quantitative data on important aspects of the visualization. A subset of those closed questions focused on evaluating user experience with filter bubble visualization. The results are summarized in Table 1. On average, most of the participants answered above 5 on the scale of 1 (very low) to 10 (very high).

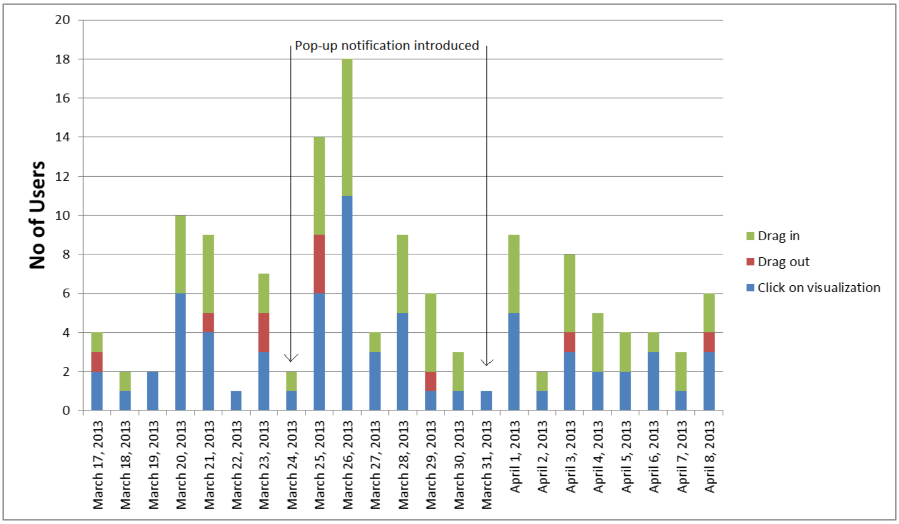

Fig. 5. Number of users performing three types of actions in the visualization

Table 1. Results of closed questions related to user experience of filter bubble visualization (#participants/percentage of all participants)

Question	Results									
Aesthetically pleasing	Very Low									Very High
	1	2	3	4	5	6	7	8	9	10
						1/9	3/27	3/27	3/27	1/9
Friend View	Unhelpful									Helpful
					2/18	1/9	3/27	3/27	1/9	1/9
Category View	Unhelpful									Helpful
					1/9		3/27	3/27	2/18	2/18
Awareness about hidden posts	Inadequate									Adequate
					2/18	1/9		4/36	3/27	1/9
Arrangement of information on screen	Illogical									Logical
		1/9			1/9		4/36	2/18	2/18	1/9
Manipulation of interest/friend circles(dragging in and out)	Difficult									Easy
				1/9	1/9	2/18	2/18	1/9	2/18	2/18
Finding interest not inside your filter bubble			1/9		1/9	1/9	2/18	2/18	3/27	1/9
Discovering new interests					2/18		2/18	2/18	5/45	

Table 1. *(continued)*

Discovering the interests of friends					1/9	1/9	3/27	2/18	4/36	
Discovering the areas your friends are most interested			1/9		2/18		1/9	3/27	4/36	

A set of close-ended questions with Likert scale (1-10) shown in Table 2 were asked to evaluate the users' trust in the system. The results are summarized in Table 3.

Table 2. Closed questions for trust in the system with Likert scale

#	**Question**
Q1	Trust in the System before using the filter bubble:
Q2	Trust in the System after using the filter bubble:
Q3	Trust in the System after seeing the hidden posts:
Q4	Level of transparency in filtering provided by the system:

Table 3. Results of closed questions for trust in the system (percentage of participants who chose on a 10-level Likert-scale)

#	Very Low									Very High
	1	2	3	4	5	6	7	8	9	10
Q1				18	36	9	18	9	9	
Q2					9	18	9	36	27	
Q3				9	18			18	36	18
Q4					9		18	45	18	9

The questionnaire contained a set of questions aimed at evaluating the users' awareness and understanding of the personalized stream filtering mechanism and the filter bubble visualization. Ten (91%) participants reported that they used the filter bubble visualization and one participant reported that s/he didn't use it. To the open-ended question "What do you think the visualization represents?", nine out of the ten participants who used the filter bubble visualization (90%) responded that they thought it represented their interest categories of social data that were displayed in their stream. Some excerpts from the answers follow: "*Shows my interests to different categories (category view) or to posts of friends (friend view)*", "*It represents my* *interest and posts I will receive", "It represents my interest category and that of others that is filtered from me"* and "*It reflects the interest a person showed in certain category of posts*". One participant mentioned specifically about the position of friend/category circles "*inside the bubble is the categories of the news I like while the hidden news belong to the categories outside the bubble, if friend view is selected, the same as category but for friends"* .

For the question "What do you think about the category view in the visualization?", three participants (27.27%) commented on what they understood about the category view: "*Category wise news/posts*" and "*I think category view is useful to visualize my choice of posts and help me to somewhat sort the posts I want to have a look on my wall.*" The remaining eight participants (72.73%) commented positively on the aesthetic aspect of the category view (e.g. *"nice, compact visualization", "good, and easy to use"*).

For the question about what participants thought about the friends view, three participants (27.27%) reported that they didn't use the friends view. Two participants (18.18%) said that it's an unnecessary view and they interpreted it wrongly. Three (27.27%) reported that it was useful to avoid friends' social data in which they were not interested. Three participants (27.27%) said that it was a good and useful visualization. To a control question asking them to indicate a preference to one or the other view, all of the participants replied that they preferred the category view over the friends view. Five participants (45.45%) were happy with the current views and didn't suggest any other useful views. The remaining six participants (54.55%) suggested several other useful views, such as *"a mixture of both", "more subcategories! But I wonder about the tradeoff with the simplicity", "time view! Popular view!", "By Date and week, and popular post -by like and comments"*, and so on.

The last few questions in the series of open ended questions aimed at evaluating the controls given to the user in filter bubble visualization: whether they were used (we could verify the answers as we had collected usage data, shown in Fig. 5), and whether they were considered useful and usable. The first question was about whether participants dragged the category/friend circles inside the bubble. Nine participants (82%) stated that they have dragged the category/friend circles from outside the filter bubble to inside the filter bubble. In a follow-up question, those who answered "yes" for dragging inside, were asked about the effect that they noticed after dragging a category/friend circle inside the filter bubble. Eight participants (88.89%) out of the nine participants said that there is an effect after dragging a category/friend inside the bubble. In particular, four participants out of those eight said that their interest areas expanded and more social data appeared in their stream. Only one participant out of those who tried dragging the circle inside said that there was no effect after the action. Similarly, a question was asked about dragging a category/friend circle outside the filter bubble. Four participants (36%) stated that they had tried dragging category/friend circle outside the filter bubble and noticed a change in their stream; particularly social data got filtered away. Other seven participants (63.64%) stated that they hadn't tried dragging a category/friend circle outside the filter bubble.

4.4 Discussion

The results show that the participants were aware of the filtering. The following results provide enough evidence to support the hypothesis 1: Most of the participants (80%) showed understanding about the representation of filter bubble visualization, knowing that the system is filtering their data stream (82%). The majority (73%) said that the visualization helped them to understand the filtering mechanism and more than 50% of the participants said that the visualization provided adequate awareness about the hidden social data. The participants' understanding of the graphical language of the visualization, i.e. the meaning of circle position and size, however was not uniformly good. The results show that 63.64% of the participants believed that there is a meaning in the position of the category/friend circle with respect to the filter bubble, so it is evident that the majority understood the general metaphor of the visualization. Even though eight participants (72.73%) responded that there is a meaning to the size of the circles, only two participants understood that the size denotes the volume of social data represented by the category or originated by the user represented by the circle. The remaining participants had various wrong interpretations of the size. So the design needs improvement with respect to using the size of the category/friend circles as part of the graphical language.

From the results of the open ended questions related to the category view and the friends view, we can see that the category view was more effective than the friends view in creating awareness and understanding of the personalized stream filtering and also the category view seems to be the most preferred view. So the Friends view needs to be improved, or removed. The results to the open ended questions that aimed evaluating the control given to the user to manipulate the visualization show that the participants felt they had control over their stream and the filtering mechanism. Thus we have sufficient qualitative evidence in support of hypothesis 1.

Hypothesis 1 can also be supported by the results of the user actions graph (see Fig. 5). The graph in Fig. 5 depicts the user actions performed on the filter bubble visualization over the time period of the experiment. The beginning of the graph period can be marked as the learning phase where users get familiar with the drag and drop of category/friend circles. Then there is a sudden spike in user actions in the second week when we introduced a popup window to notify the users that social data are filtered away from the stream and to introduce the visualization allowing them to gain control of the filtering. After one week, when the necessary awareness about the visualization has been created, the popup notification was turned off. Even after the notification was turned off, from the graph in Fig. 5, still we could see users checking the filter bubble visualization and dragging the circles in and out. This shows that the filter bubble visualization has been used to control of personalized filtering. Interestingly, most of the actions were "dragging in" categories or people, which means the participants counter-acted the filtering mechanism. There were a few "drag out" actions throughout the experiment and they were targeted at one particular participant, the most active one in the group, who was probably perceived as a spammer at a certain moments of high traffic by some of his/her friends.

The study results also provide evidence to support the hypothesis 2. Comparing the results of Q1 and Q2 provides more clear evidence to support the hypothesis 2 i.e. most of the participants (63%) rated below 6 (on a scale between 1-very low, 10- very high) for their trust in the system before using the filter bubble visualization. After seeing the filter bubble visualization, 72% of participants rated above 6 for their trust in the system. Moreover, 72% of participants rated high (above 7) for their trust in the system after seeing the hidden posts provided by the visualization and most of the participants (72%) rated the level of transparency as high (above 7).

The results shown in Table 1 provide answers to questions about the general user experience with the system. Following some user experience design guidelines [2], we consider user experience dependent on whether the artifact is aesthetically pleasing, logically composed and easy to use. They support hypothesis 3, because 90% of the participants found that the filter bubble visualization is aesthetically pleasing by rating it above 6; 90% found that category view was helpful, and 72% have found that the friend view was helpful. In addition, 72% of the participants found that the visualization provided adequate awareness about hidden social data, 81% of participants found that the information on the screen was logically arranged, 63% of participants said dragging the category/friend circles in and out of the filter bubble was easy, 72% said finding an interest which is not inside their filter bubble was easy, 81% said discovering new interests and discovering the interests of friends were also easy and 72% said that discovering in which areas their friends are most interested was also easy. So the results in Table 1 suggest that the user experience with the MADMICA was enhanced by the visualization. Moreover, the results showed that users were aware that they are able to find interests outside of their filter bubble and thus discover new interests that they didn't display otherwise in their behavior. This clearly shows that users became more aware of the filtering mechanism due to the visualization and are interested, able and willing to manipulate it to ensure that they will not be trapped inside a bubble world within the limited boundaries of their manifested interests.

5 Conclusion and Future Works

The paper proposes an interactive method to visualize the content-based stream filtering in a P2P Social Network. The proposed visualization helps to create awareness, understanding, and control of personalized stream filtering mechanism to alleviate the filter bubble problem and increase the users' trust in the personalization of the system.

The results of the small scale study show that the filter bubble visualization makes the users aware of the filtering mechanism, engages them in actions to correct and change it, and as a result, increases the users' trust in the system. Future work directions include finding a solution to the limited number of categories, and conducting a large scale user study.

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OurMap: Representing Crowdsourced Annotations on Geospatial Coordinates as Linked Open Data

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Abstract. There is an increasing number of initiatives using Web-based mapping systems that rely on crowdsourcing as a collaborative problem-solving and data production model. In these initiatives, large groups of users can collaboratively annotate spatial things on a map. Ideally, these crowdsourcing initiatives should produce Linked Open Data (LOD) to enable people/systems to share structured data and, consequently, improve distributed problem-solving on the Web. This paper presents an approach for producing LOD from crowdsourced annotations on Web-based mapping systems. In this approach, annotations are represented using the Open Annotation data model and they have as target a geospatial coordinate referenced using the geo URI. Moreover, we combine crowdsourced map annotations with semantic Web technologies to enrich maps with semantic information. To demonstrate the feasibility of our approach, we present the OurMap system, which performs the proposed approach allowing the representation of open and semantic annotations associated with geospatial coordinates independently of the Web map interface adopted.

Keywords: Open Annotation, Semantic Web, RDF, Volunteered Geographic Information.

1 Introduction

According to Brabham [1], crowdsourcing is a production model to solve problems based on collective intelligence and knowledge. There are various Web systems adopting this model in order to obtain needed knowledge or service by soliciting voluntary contribution from a large group of Web users. These systems must provide mechanisms for users to collaborate to build the necessary knowledge, and deal with the problems associated with this voluntary collaboration.

There are various Web mapping services available and some of them adopt the crowdsourcing model. In this work, we distinguish two main categories of user's information associated to Web maps: (i) crowdsourcing geospatial data and (ii) crowdsourced map annotations. Crowdsourcing geospatial data refers to generate a

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map using informal social networks and Web 2.0 technologies [2], producing the so-called Volunteered Geographic Information (VGI). OpenStreetMap (OSM) [3], Wikimapia.org and Google Map Maker [4] are well-known initiatives in this category of crowdsourcing on maps. They allow users to add and edit non-movable and long life places (e.g., roads, parks, businesses, schools, etc.).

This paper focuses on the second category of crowdsourcing on maps, which includes initiatives seeking crowdsourcing to overlay annotations onto a backcloth map. Based on the map, any information can be collaboratively geotagged by users. Annotating or tagging is about attaching tags, names, attributes, comments, etc. to a geographical coordinate. In this paper, we adopt the term "map annotations" to refer to the association between the annotated information and its geographical identification.

There are several examples of systems providing social map annotation functionality using urban zone maps backdrop. These systems allow annotating "things" of a specific domain, such as crimes [5], crisis [6], health [7] and human rights abuses [8]. Additionally to identify non-movable and permanent places, these systems seek to classify several "things" on the maps as events that occurred at some time or that have short life cycle, related to, for instance, crimes and disasters.

Social map annotation systems must deal with the problems introduced by the voluntary collaboration for the knowledge construction. In particular, this kind of system may suffer from problems due to voluntary collaboration of a large group of web users, such as the low quality of the generated content [9]. In general, map annotation systems allow users to create annotations without a semantic rigor, contributing to its low quality. Thus, the knowledge collaboratively generated cannot be more easily integrated and interpreted automatically by the systems.

Regarding knowledge representation, there are several studies pointing the advantages of using ontology-based approaches, such as [10], [11], [12] and [13]. Ontologies can be specified as sets of concepts, individuals, relations, instances and axioms that describe a domain [14]. Ontologies can also be part of a database, known as ontological Knowledge Base (KB). These KBs relies on formalizing the representation of knowledge, enabling enhanced information retrieval, data consistency verification, and increasing interoperability. Therefore, the association of semantics with the annotated content can improve the organization and management of knowledge. Particularly important in map annotations, the semantic tagging allows the verification of location consistency on maps. For example, the annotation of a pothole in a street only makes sense if it is annotated on a geographical coordinate near to a street (a pothole could not be annotable at sea, for example).

The lack of openness is another recurring problem in many map annotations initiatives. Several of these initiatives are closed; the user-generated annotations remain inaccessible for third-party systems. Conversely, interoperable annotations facilitates cross-boundary annotations, allowing multiple servers, clients and overlay services to create, discover and make use of the valuable information contained in annotations [15]. There are several initiatives seeking to offer services or publish useful information for the society. Offering interoperable annotations, these initiatives could use the annotations generated by a larger number of users, enriching the knowledge of incidents and improving the mapping and problem solving.

Let us illustrate this in the context of public safety. There are various initiatives allowing users to report security incident in many cities. Initiatives seeking to publish and to analyze security events in a region, state or country can reuse annotations created using the first ones. Moreover, initiatives offering crowdsourcing travel experience, for instance, can reuse/export annotations related to public safety incidents from/to initiatives in the public safety domain.

A recent effort to enable interoperable annotation is in progress by the W3C Open Annotation Community Group [16] that works towards a common, RDF-based, specification for annotating digital resources: the Open Annotation Model (OA). OA follows the Linked Data principles [17]. MapHub [18], a Web portal for georeferencing and annotating digitized historic maps, under development at Cornell University, is one of the few examples of online application that produces open annotations.

The OA model is not sufficient to guarantee the sharing of the knowledge contained in annotations. Different initiatives can adopt different categorization schema for annotations. For example, a system focused on the public safety domain can have different categories for security-related incidents, such as violence, robbery, theft, etc. In its turn, a system in the tourism domain can categorize these terms as security incident only. This high degree of semantic interoperability requires the adoption of high-level ontologies, allowing the knowledge to be shared through different platforms.

From the above discussion, the paper aims to advance the state of art in crowdsourced annotations on Web-based mapping systems through the following contributions:

1. An open representation of map annotations through the OA model in which the targets are geospatial coordinates referenced in the form of geo URI, as recommended by RFC 5870 [19]. Therefore, the annotated "thing" is the geospatial coordinates, rather than resources over Web. Because of the proposed open representation of annotations and the use of geo URIs, the scheme can create Linked Open Data (LOD) that have the potential to be reused by any application based on any Web mapping services.
2. A high-level ontology to represent knowledge about spatially located incidents. This ontology specifies concepts that are common to all incident domains, such as crimes, crisis and health. The knowledge representation language adopted is OWL [20].
3. Finally, a social semantic tagging approach that associates map annotations with individuals kept in a KB. In this approach, users can collaborate to populate the KB with individuals that semantically describe incidents on the map.

Different from current map annotations adopting ontological approaches, our proposal offers more than a simple semantic tagging of places. Our proposal offers a way to associate spatial things with semantic entities stored in a KB populated collaboratively by the users [21]. When creating map annotations, users implicitly generate individuals to be instantiated in the KB. More specifically, during a map annotation the user identifies the category of annotation, i.e. the class in the ontology, and specifies the property of the individual to be instantiated in the KB. In the sequel, this newly created annotation is semantically tagged with the URI of this instantiated individual (rather than concepts). For example, a map annotation can have a semantic tag that relates a geographic coordinate of a bus stop to an individual in the KB of the abstract concept Bus_stop. The KB can specify a link between this individual with an individual of the abstract concept Road, which in turn can be associated with an individual of the abstract concept Suburb.

Thanks to the inference engines (reasoners), possible inconsistency on KB can be detected. In the previous example, consider that the ontology specifies that a Bus_stop must be associated with a Road. Consequently, a bus stop can be defined only in "places" that can be associated with a road. Moreover, information retrieval is improved by the ability to perform searches that exploit the ontology to make inference about data (using SPARQL [22]). For instance, it is possible to retrieve all bus stops in a particular suburb.

Using the proposed open and semantic representation for incidents, we intend to contribute to different initiatives in social annotations on maps, so it can support each other by exchanging information about incidents in different domains.

To demonstrate the feasibility of our approach, a prototype implementation was developed and tested. This proof-of-concept prototype, called OurMap, allows users to annotate both permanent places and incidents that occur on places at some time. Its architecture has been defined to provide a loose couple relation between Web mapping services and the OurMap annotation service. Therefore, OurMap relies on the services offered by existing Web mapping services, such as OSM and GoogleMaps API, so annotations can be related to a geographic coordinate on a map.

The rest of this paper is organized as follows. Section 2 presents the Open Annotation (OA) data model. Section 3 points out the main requirements for annotation of incidents on maps, and presents the related work. In Section 4 the proposed open representation of incidents on maps is described. Section 5 presents OurMap, our incident map annotation tool adopting our open representation for incidents. Finally, conclusions and future work are presented in Section 6.

2 Open Digital Annotation

Digital annotations allow us to associate content with other resources. There are various motivation for creating annotations. In the context of this work, the annotations are the way used by the users to report incidents or to identify a place on maps. In several systems, the user-generated annotations remain inaccessible for third-party systems. The adoption of open annotation data models allows expressing annotations in a way that they can be shared between different annotation systems, what is particularly important to crowdsourcing initiatives in numerous domains. We consider that the performance in problem solving can be improved if different crowdsourcing initiatives in the same domain share their annotations.

There have been some attempts to establish open data model for annotations, including Annotea [23], Annotation Ontology [24] and the Open Annotation Model [25]. The W3C Open Annotation Community Group aims to conciliate these last two proposals through a common, RDF-based, specification for annotating digital resources: the Open Annotation (OA) data model [16].

In the OA data model, an annotation expresses the relationship between two or more resources, and their metadata, using an RDF graph. The OA model defines a namespaces (http://www.w3.org/ns/oa) for its classes and properties [25].

Fig. 1 presents two annotations (`A-1` and `A-2`) specified with the OA model and therefore instances of `oa:Annotation`, defining relationships between two or more resources. These resources are members of the classes `oa:Target` and `oa:Body`, in which targets are resources being annotated and bodies are comments or other descriptive resources about a target. The relationship `oa:hasTarget` associated with `A-1` defines `T-1` as target of `A-1`. This annotation has two associated bodies (with `oa:hasBody`): `B-1` a descriptive resources about `T-1`; and `Tag1`, which tags semantically `T-1`. In addition to bodies and targets, an annotation can have many properties such as author (`oa:annotatedBy`), title (`dcterms:title`) and date of creation (`oa:annotatedAt`). Moreover, [25] suggests that each annotation should have at least one `oa:motivatedBy` relationship to an instance of `oa:Motivation`. It is important to understand the reasons for the creation of annotation. For instance, the motivation of `A-1` is `oa:tagging`, identifying that this annotation adds a Tag on the target resource (`T-1`). Annotation `A-2` is a questioning about annotation `A-1`.

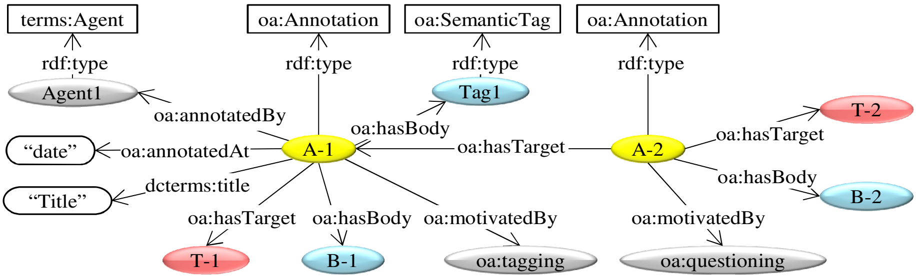

Fig. 1. Illustrating the OA Model

3 Annotation of Incidents on Maps

This section presents the related work, including the identification of some important aspect of Web systems that allow crowdsourced annotation of incidents on maps.

3.1 Describing Incidents

The popular map annotation systems, such as Google Maps Maker, Wikimapia and OSM, allow users to annotate only non-movable places that exist at the time when the annotation is being created. Incident annotations have different characteristics than annotations of non-movable places:

- **Temporal Characteristics**: the reporter of an incident can know the instant or the time interval in which the incident occurred, or he may not know when it started or ended. Moreover, the reporter just may have observed at a given time. Therefore, an incident annotation system should provide flexibility in positioning the incident in time.

- **Location Characteristics**: differently of non-movable places, many incidents may not have a well-known location. Therefore, the system should allow the location to be described not only by precise geographical coordinates, but also by generic spatial relations [26], as to the left of, right of, behind, in front, around, inside and out.
- **Thematic/Semantic Information**: to be more precise and useful, the reporting of an incident should define the type or category of the incident. The annotation system must adopt vocabularies of types of incidents dependent on the application domain.

Regarding the temporal characteristics, in general the existing systems allow users to specify the start and end date/time of incidents (a time interval), as adopted in Ushahidi [6] and Wikicrimes [5]. However, time imprecisions and distinction of period of observation are not supported. Considering the spatial characteristics, the current annotation systems allow the reporter to accurately express the location of the incident (geographic coordinates or well-defined region). Usually this way of location cannot represent the precise location of the incident, which may lead to wrong conclusions.

In terms of thematic information, the current incident/event annotation systems adopt prefixed categories of incidents (thematic information). However, unlike some initiatives of production of VGI, few incident annotation systems offer features of semantic mark-up on maps, making the interpretation and reuse of its content more difficult.

3.2 Open Annotation of Incidents

In general, Web-based solutions seek to identify events/incidents adopting implementation-dependent representations of annotations, and consequently these remain inaccessible for third-party systems. In this case, the crowdsourced information cannot be easily reused by other initiatives.

Wikimapia, a popular GoogleMaps API-based interactive Web map system offers an open-content crowdsourced mapping service, via the Wikimapia API (http://wikimapia.org/api/), allowing third-party systems to receive data from Wikimapia project in various formats (XML, KML, JSON, JSON-P and binary). Similarly, OSM provides a RESTful API in which read and write queries can be formulated in OSM XML format. However, Wikimapia and OSM allow creating annotations only in non-movable places that can be categorized using a fixed category list.

In the context of incident/event annotation systems, the majority of initiatives do not adopt open representation. For instance, [5] and [7] are based on the Google Maps API (http://code.google.com/apis/maps/), and the map annotations are not published under an open content license and cannot be reused in other services. Conversely, Ushahidi and PublicSafetyMap.org offer data in RDF/XML.

Ushahidi is an open source platform that has been designed for geo-located responses to crisis. This platform allows users to create structured annotations that can be categorized and associated with photos and videos. The Ushahidi REST API supports retrieval and report submission of annotations in both XML and JSON output formats. However, Ushahidi (and Wikimapia) does not adopt standardized data model so that these data can be easily shared between platforms. As presented in Section 2, the OA Model is a solution.

In the map annotation domain, MapHub demonstrates how to apply the OA Data Model in the context of digitized historic maps. As already pointed out in this work, we demonstrate how to apply the OA Data Model in the context of map annotations.

In this work, we propose an open representation of map annotations through the OA model in which the targets are geospatial coordinates referenced in the form of geo URI. As previously described, this approach allows users to annotate "things" on geospatial coordinates, rather than resources over Web.

3.3 Knowledge Representation

In addition to adopt open representation of annotations, map annotation systems should allow the semantic tagging of these annotations. This kind of tagging can contribute in the following three areas [27]:

- **Knowledge Representation Sophistication**: Ontologies allow robust representation of entities and relationships that shape tagging activities.
- **Facilitation of Knowledge Exchange**: Ontologies enable knowledge exchange among different systems and users by providing shareable conceptualization.
- **Machine-Processable**: Ontologies and Semantic Web Technologies enable to represent the semantics of data in a machine-processable way, which can be used for data analysis and concept recognition, for reasoning processes and for semantic search.

The GeoNames ontology [28] (available on OWL) models geospatial semantic information. This ontology makes it possible to add geospatial semantic information about places in the GeoNames database. GeoNames is more than a simple semantic tagging of places; it allows users to express properties about named places. Moreover, its data is available through numerous Web Services and also published as linked data. However, GeoNames ontology specifies only general properties valid for all concepts; class-specific data and object properties are not supported.

The OSM project adopts a tagging system that allows the map to contain unlimited data about its elements. Therefore, OSM adopts a metadata (i.e. data about data) provided in the form of `key="values"` pairs. This tagging scheme is being developed into taxonomy of real-world feature classes and objects [3]. The OSM project provides a RESTful API where read and write queries can be formulated in OSM XML format. Similar to the previous proposals, OSM allows only creating annotations in non-movable places that can be tagged using the OSM tagging scheme [3]. The LinkedGeoData (LGD) project [29] provides an integrated and interlinked geographic dataset for the Semantic Web. The majority of this data is obtained by converting the OSM data and is available as an RDF knowledge base according to the Linked Data principles.

MapHub allows users to annotate historic maps and connect these annotations with web resources via semantic tagging. These semantic tags are suggested for the creators of annotations by querying open data sources such as Wikiminer [30] or GeoNames.

All previously cited systems do not aim to specify incidents semantically on the map. In this context, there are some initiatives proposing event/incident ontologies that have potential to be used in the context of map annotations. In [31], the authors provide an overview and a comparison about the existing event ontologies and the way used by each of them to model occurrence time and place.

The Event Ontology (EO) [32] has been developed to be used with music-related ontologies, but it offers high level and minimalist event model that has been widely used by LOD community. EO defines the Event class, an arbitrary classification of a space/time region. An event may have a location, a time, active agents, factors and products. The property time defines the event temporal features and is defined through the class `time:TemporalEntity`, from OWL-Time ontology (http://www.w3.org/2006/time#). Location is expressed using the class `geo:SpatialThing`, from the World Geodetic System 1984 (WGS84) [33]. EO doesn't allow expressing incidents that don't have a known and precise location, only using generic spatial relations with geospatial coordinate or named places.

DOLCE+DnS Ultralite (DUL) [34] is a lightweight ontology that provides a set of upper level concepts that can be the basis for easier interoperability among many middle and low-level ontologies. In this ontology, the Event class is any physical, social, or mental process, event, or state. DUL allows specifying dates for an event (using the datatype property `hasEventDate`) or the temporal interval can be instantiated, through TimeInterval class, and related to an event instance via the `isObservableAt` object property.

The Event Model-F ontology [35] is a formal model for events built on top of DUL. It supports to represent time and space, objects and persons, mereological, causal, and correlative relationships between events, and different interpretations of the same event. The parameter `F:TimeParameter` describes the temporal region when the event happened, being possible to define an instant or a time interval, and the parameter `F:LocationParameter` makes it possible to model location via WGS84 vocabulary, using two properties, for latitude and longitude.

The Simple Event Model (SEM) [36] ontology has been defined to model events in various domains. This ontology considers the loose definition of events. Its definition of time is divided into seven `sem:hasTimeStamp` properties, one of which is for temporal values, two for time intervals and four for uncertain time intervals. In SEM there are symbolic places with location defined by various structures, like `georss:point`, `wgs84:lat` and `wgs84:long`, or `rdf:XMLLiteral` pointed by `georss:where`. Like EO, SEM does not allow to express generic spatial relations.

In this work, we propose an Incident Ontology that groups features that are not found together in the above ontologies. Our requirements include the need of a generic Incident class that allows a loose definition of temporal and location characteristics of incident. The time property from SEM corresponds to our necessity on defining unknown occurrence time and uncertain time intervals for an event.

However, we need an ontology that also supports the usage of a spatial relationship between incidents as data property.

The present proposal adopts the OA model to represent open annotations and OWL for knowledge representation. Different from previous work using semantic tags in map annotations, our approach allows the generation of an ontological knowledge base formalizing the representation of information generated collaboratively during the annotation process. It also allows various systems to make use of the produced annotations, and make possible to use different tools for semantic search, inference, and viewers to OWL representation.

4 Representing Open Annotations on Maps

The purpose of the OA model is to be a common specification for annotating digital resources. In this section, we propose the use of the OA model to represent digital annotation on geospatial coordinates instead of on web resources. In our proposal, the targets of map annotations are geographic locations. The annotation is represented unrelated (e.g. URL pointing a geographic coordinate specific of the web mapping system), making it completely reusable by different map annotation tools.

Moreover, this section presents a semantic approach to represent the collaboratively generated information during the map annotation process.

4.1 Geographic Locations as Targets of Map Annotations

Providing open annotations in Web-based map annotation systems requires special attention in the location identification. We consider important that this identification can be represented independently of any Web resource (like a specific URL in a Web mapping system). The geo URI scheme is a step in that direction of an independent, compact, and generic way to refer to a physical geographic location [19]. The geo URI identifies geographic location (physical resources) through the coordinate reference system WGS-84. The scheme offers textual representation of spatial coordinates of locations.

In this work, we propose the use of geo URIs to identify targets in map annotations represented using the OA data model. Several systems adopting RDF representations for annotation make use of the Basic Geo Vocabulary (http://www.w3.org/2003/01/geo/#vocabulary) to identify location. However, this vocabulary allows the identification to be made as properties and the annotation targets and bodies are Web resources. Using geo URIs and the OA data model, the targets of a map annotation can be physical resources, i.e. geographic locations, increasing the independence of the annotations from applications.

4.2 Incident Ontology

As presented in Section 3, there are several initiatives to establish ontologies that have potential to be used in the context of map annotation. However, none of the analysed ontologies offers a loose definition of temporal and spatial characteristics of incidents. With this purpose, we propose the OurMap ontology, an upper level ontology for Incidents.

Another important point to be considered in crowdsourcing systems is the difficulty to ensure the quality of information voluntarily generated by the community [9]. A semantic approach should guarantee a minimum of semantic consistency in terms of the location of this information. By the lack of an ontology generic enough to cover the basic concepts related to geographical annotations of incidents associated with elements of community life, was defined a high-level ontology, named OurMap.

A simplified view of the OurMap ontology is represented on Fig. 2. The two main concepts are `Place` and `Incident`, both subclasses of `geo:SpatialThing` defined by WGS84. `Place` (http://schema.org/Place) represents something immobile or a location. `Incident` is any incident. The `AdministrativeArea` class (http://schema.org/AdministrativeArea) is any geographic region under the jurisdiction of a particular government, having as subclasses `Country`, `State` and `City` (all defined in http://schema.org). We defined two subclasses of `Place`: `Suburb` and `Road`.

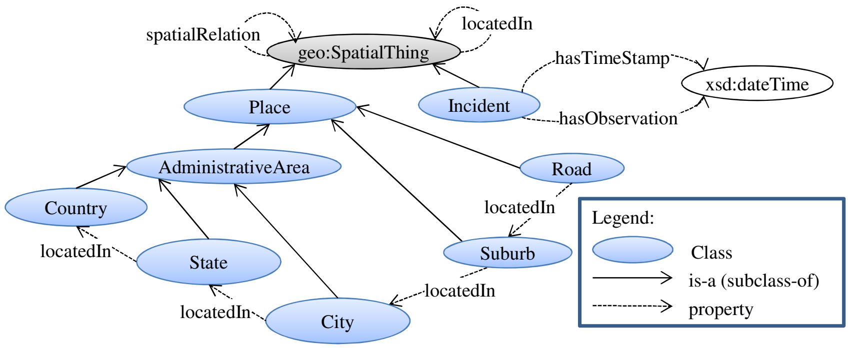

Fig. 2. The OurMap Ontology

The property `locatedIn` allows specifying location relationships between different spatial things, including places. Ontology OurMap defines that `Road` individuals have a `locatedIn` relation with `Suburb`, `Suburb` with `City`, and so on. This ensures a minimum consistency of administrative places, streets and neighbourhoods.

`Incident` may also have a location relation (`locatedIn`) with any other `SpatialThing`. Moreover, an `Incident` may have a generic spatial relation (`spatialRelation`) between other `SpatialThing`: `under`, `isinside`, `encloses`, `near` and `over`. We defined six sub-relations of `near`: `behind`, `beside`, `rightOf`, `leftOf`, `adjacent` and `inFrontOf`. Finally, we defined a sub-relation of `adjacent` called `onTop`. These relations have logical characteristics, like symmetry and transitivity, in order to allow proximity inference between incidents and places.

The data properties `hasObservation` and `hasTimeStamp` of class `Incident` define the instant or time interval of the occurrence and observation of the incident, respectively. Both properties have as literal type `xsd:dateTime`. `hasObservation` used to express the instant of observation of the incident, and its two sub- properties, `hasStartObservation` and `hasFinishObservation`, allow defining intervals of observation. `hasTimeStamp` defines the instant of the incident's occurrence, and its two sub-properties, `hasStart` and `hasFinish`, allow defining a time interval. In its turn, the latter two have sub-properties that allow specifying imprecise time intervals (`hasStartAfter, hasStartBefore, hasFinishAfter` and `hasFinishBefore`). We also defined SWRL rules [37] to assign values to properties `hasStartBefore` and `hasFinishAfter` in incidents with instants or time intervals of observation and without a known time of occurrence. These rules express the consequence that if the incident is observed at a given instant, the beginning of the incident is prior to that moment, and the end is later.

4.3 Creating New Incident and Places Classes

Thanks to the possibility of reuse existing ontologies, it is possible to extend the OurMap ontology to specific domains. All domain-specific categories of incidents or places (possibly defined in other ontologies) that can be annotated by the user on the map must be defined as subclasses of `Incident` and `Place`, respectively. Moreover, each new subclass can have specified location restrictions. As previously presented, the latest is important to ensure the location consistency.

For instance, consider the use of OurMap ontology in the domain of public transportation. In this case, it is possible to use OTN Ontology [38] to specify objects in this domain. All OTN classes classifying places or incidents that can be annotated by the user on the map must be defined as subclass of `Incident` and `Place.` For instance, if incidents can be reported on (or with spatial relations between) `OTN:Stop_Point`, this class must be declared as a subclass of `Place`. Moreover, if the location of objects of class `Stop_Point` is in roads, this class must be defined as a subclass of concepts that have the relation `locatedIn` set to `Road`. This latest allows maintain the location consistency of the crowdsourced annotations.

There are some few Incident/Event ontologies for specific domains. Therefore, because of our semantic approach, it is necessary to create a hierarchy of subclasses of `Incident`. For each subclass, it can be specified restrictions on the location of places. For example, a subclass of incident called `Pothole` (hole in the street) could be specified so that individuals of this class must have a location relation with a `Road`.

4.4 Associating Semantics to Annotations

There are several studies pointing out the advantages of using ontology-based approaches in the Geographic Information Systems (GIS) domain ([10], [11]). These advantages are well known in the Semantic Web area as a possibility to integrate, share and analyse geospatial information. Various ontologies proposed for GIS aim to specify geospatial concepts [39] and [40]. These ontologies specify concepts on the GIS domain, which can be applied to systems that implement the concept of the crowdsourcing in the construction of cartographic maps (so-called crowdsourced maps).

In general, the map annotation systems semantically tag annotations by tagging resources available in external systems, like DBPedia (http://dbpedia.org) and GeoNames. In this work, we propose maintain a KB representing all knowledge explained by the crowdsourced annotations. In this KB, places and incidents are represented as individuals. These objects are expressed as URIs that are used to tag semantically incidents and places.

Fig. 3 illustrates how objects in the KB are used to tag two annotations. A user created `A-3` to identify a bus stop in a specific spatial coordinate. During the creation of this annotation, a `Stop_Point` individual is generated in the KB. Note that this annotation is allowed because its geographic location `(geo:-27.599217,-48.519018)` is near of a road (as specified in the ontology), called Delfino Conti Street situated in the Pantanal neighbourhood of the city of Florianópolis. `A-4` represents a robbery near this bus stop. This robbery is represented in the KB by the *Incident* individual.

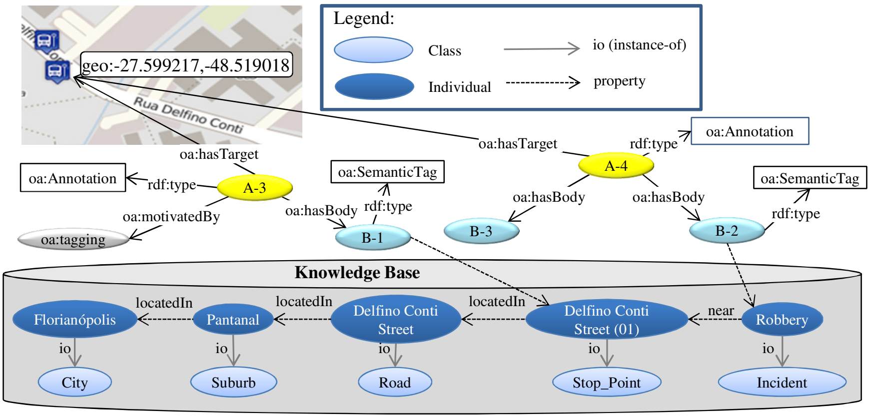

Fig. 3. Semantic tags and the knowledge base

As presented in Section 2, semantic tags in the OA data model are expressed as a URI, the body of the annotation is the URI of the tagging resource. The `oa:SemanticTag` class is associated with this tagging resource. In our proposal, `A-3` and `A-4` have bodies representing semantic tag expressed as URIs identifying the `Stop_Point` individual and the `Incident` individual (or a domain-specific subclass), respectively.

Rather than tagging `A-3` and `A-4` as `Stop_Point` and `Incident` as provided by the current systems, we tag these annotations referencing individuals of these classes. Tagging annotations with individuals in the KB allows us to consider relationships between individuals (as defined in the ontology) and check consistency in terms of location. The maintenance of a KB of incidents allows us to build a repository of information on which more advanced and efficient semantic search can be achieved. Moreover, inference process can be used to generate new knowledge and to verify consistency of the ontology.

5 OurMap: A Map-Based Digital Annotation System

This section presents a general view of our proof-of-concept prototype, called OurMap, implementing the proposal of representing open and semantic annotations of incidents on maps. The main purpose here is to demonstrate the crowdsourcing approach to generate annotations of places and incidents on maps and the management of a knowledge base specifying the knowledge collaboratively generated during the annotation process.

The proof-of-concept prototype OurMap is implemented with Java, OpenLayers [41], OSM geocoding system [42], Jackson Json API to process the information received from the geocoding system. The Jena API [43] was used for programming environment for the semantic aspects

5.1 Customizing OurMap

OurMap can be customized for a specific domain of incidents and places by importing ontologies describing the domain-specific incident and place categories. For instance, in our tests we imported the OTN ontology customizing OurMap for the Public Transportation domain. After importing ontologies, it is necessary to specify the classes whose individuals can be identified on the maps during the annotation process (individuals that will be kept in the KB). Fig. 4 shows the interface used to specify annotable classes. This interface allows specifying the icon associated with the places and incidents, and the allowed place of occurrence.

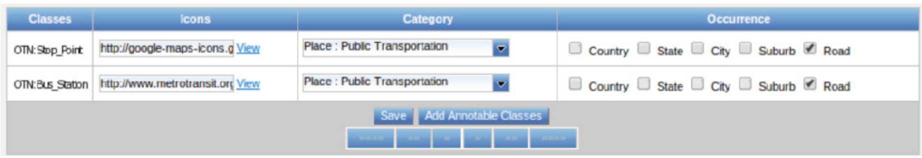

Fig. 4. Specifying Annotable Classes

5.2 Creating Annotations

Annotations can be done in two ways: (i) manually, by users on OurMap User Interface or (ii) automatically, by running mapping scripts to get the open data made available by other initiatives and generate annotation in OurMap. In the proof of concept implementation, we created a mapping script to generated individuals in the KB representing all neighbourhoods, streets and bus stops of the city of Florianópolis from the OSM database. Fig. 5 presents the interface for incident report near a bus stop in which users can describe the spatial and temporal characteristics of the reported incident.

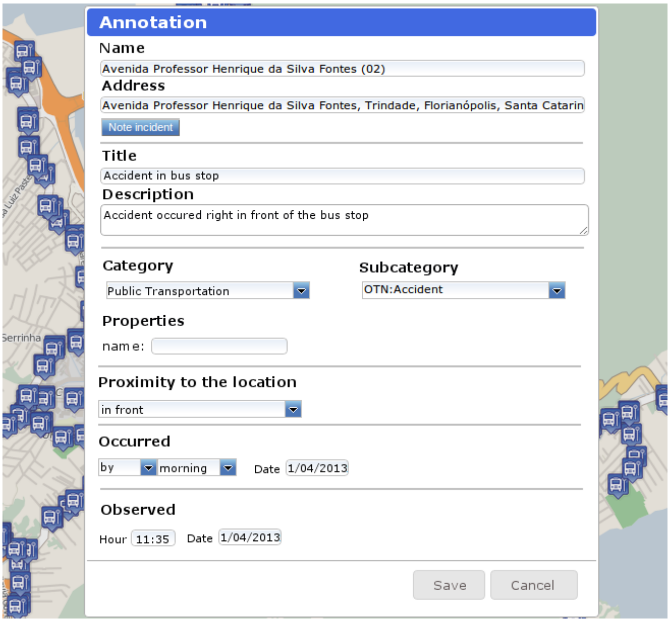

Fig. 5. Incident Report

5.3 Accessing Open Data

We developed a public API called OurMap RESTful Web API, in order to provide the knowledge voluntarily generated via OurMap system. Through this API, it is possible to have access to all data in both the annotation base as in the KB. This API allows the information retrieval by simple requests made through HTTP methods, with the passing of parameters that define the search for information. These parameters refer to location, time and category of annotations so that is possible to recover only relevant information. For example, it is possible to seek the assaults occurred in the suburb Pantanal, at 11 pm. on April 10, 2013.

The OurMap API also supports the language SPARQL in order that more complex queries may be done. In this way, you can make queries relating to different criteria, obtaining even more accurate and complete results than those from HTTP methods. For example, you can search assaults that occurred next to bus stops, in the suburb Pantanal, between 11 pm. and 4 am. every night of last month.

6 Conclusion

The crowdsourcing model of geospatial data is already being used by several communities to allow users to assist in the voluntary production of information. This paper proposes an open representation of place and incident annotations in digital maps following the principles of LOD. For this representation, we adopted the OA scheme and the geo URI to identify geographic coordinates independently of Web map systems. In addition, the collaborative knowledge created during the annotation process is kept in ontological knowledge base. Represent knowledge using the OWL Language allows to perform information search and knowledge discovery based on ontologies, in order to enable improved decision-making.

A proof concept prototype of our OurMap system is presented. This prototype adopts the semantic approach for Incident reports on maps proposed in this paper. Moreover, it uses the open representation of digital annotation proposal.

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A Theoretical Model of User Engagement in Crowdsourcing

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Abstract. Social media technology has enabled virtual collaborative environments where people actively interact, share knowledge, coordinate activities, solve problems, co-create value, and innovate. Organizations have begun to leverage approaches and technologies to involve numerous people from outside their boundaries to perform organizational tasks. Despite the success and popularity of this 'crowdsourcing' phenomenon, there appears to be a distinct gap in the literature regarding the empirical evaluation of the factors involved in a crowdsourcing user experience. This paper aims to fill this void by proposing a theoretical model of the antecedents and their relationships for crowdsourcing user engagement. It is defined as the quality of effort online users devote to collaboration activities that contribute directly to desired outcomes. Drawing from research in psychology and IS, we identify three critical elements that precede crowdsourcing user engagement: personal interest in topic, goal clarity, and motivation to contribute. This paper examines the theoretical basis of these variables of interest in detail, derives a causal model of their interrelationships, and identifies future plans for model testing.

Keywords: Crowdsourcing, engagement, open collaboration, motivation, social media.

1 Introduction

The advent of social web technologies has made it feasible for businesses, non-profits, and the government to engage large numbers of Internet users in performing organizational tasks. This phenomenon is popularly known by the term "crowdsourcing" (Howe, 2006). There are many examples of crowdsourcing initiatives across various domains such as medicine (Norman et al., 2011), journalism (Fitt, 2011), art (Casal, 2011), finance (Belleflamme et al., 2010), and government (Bommert, 2010). The popularity of crowdsourcing can be explained by a number of its perceived advantages. Crowdsourcing provides a low cost and scalable way to access ideas that might be difficult or expensive to obtain internally (Cox, 2011). It can also reduce bias in collective decision making compared with small teams due to the crowd's

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diversity of opinions, assumptions, and beliefs (Bonabeau, 2009). The labor cost paid for freelancers in a virtual crowdsourcing marketplace is much cheaper than that for professionals for the same tasks (Howe, 2006). Companies perceive crowdsourcing as a means to detect trends, recognize customer needs, obtain different perspectives or confirm business intentions (Aitamurto et al., 2011; Dubach et al., 2007). Similarly, the government and public organizations are attracted to the idea of engaging with online citizens since it has the potential to increase the novelty and relevance of ideas and solutions, commitment of the citizens to accept changes, and government transparency (Bommert, 2010; Brito, 2008).

The merits of the crowdsourcing model can be traced back to an important assumption. That is, through crowdsourcing initiatives, organizations can attract an extensive number of online users to help solve problems or issues. Unfortunately, reality turns out to be otherwise – studies show that it often is a challenge to convince people to participate and seriously work on somebody else's problems through the Internet (Brabham, 2008). Consequently, the challenge of user engagement has been repeatedly mentioned in the crowdsourcing literature. For example, Brabham (2009 p. 256) asserts that "how to kick start the crowd that will be responsible for generating needed solutions" is a main obstacle to any participatory public projects. Beyond initiation, Doan et al. (2011) consider user engagement as one of the fundamental challenges in crowdsourcing projects.

Unfortunately, to date research on crowdsourcing engagement is scant (Pedersen, et al. 2013). Therefore, the purpose of this paper is to advance the scientific understanding of the factors that influence crowdsourcing user engagement. We focus our examination in this paper on the *open collaboration* type of crowdsourcing, where the final outcomes are the result of collaborative effort of all crowd members, rather than the independent individual effort in a setting such as a virtual labor market. This focus is grounded in two reasons. First, the open collaboration model has wide application for both for profit and non-profit organizations (Nam, 2010; Vukovic, 2009). Second, among the different crowdsourcing types, we will argue that the open collaboration model is the one that most effectively utilizes the wisdom of crowds.

Consequently, this paper addresses the following research question: *What are the antecedents of user engagement in an open collaboration crowdsourcing initiative?* To answer this question, we have developed a theoretical model that can partially explain the antecedents of engagement on an open collaboration crowdsourcing platform. Even though this model could potentially be applied to explain user engagement in other forms of crowdsourcing, this falls outside the scope of this paper.

Borrowing from the information systems and psychology literature, we propose that user engagement in crowdsourcing is dependent on the alignment of the topics that are being discussed with the users' inherent personal interest. In addition, we also argue that the presence of the interest in the topic is not a sufficient condition to attract and retain user engagement. This interest must be converted into a motivation to contribute. Therefore, we propose that personal interest creates a strong motivation to contribute if the goals of the crowdsourced task are clearly understood by the users and there is no ambiguity in what they are expected to do.

The remainder of this paper is organized as follows. We first discuss crowdsourcing, including the different types of crowdsourcing options that are available for organizations today. Next, we present our model of the antecedents of crowdsourcing user engagement based on studies found in the psychology and information systems literature. Finally, we discuss the theoretical and practical implications of our model and briefly describe future plans to test this model through laboratory experiments and field studies.

2 Crowdsourcing Background

Recently, crowdsourcing has been a buzzword both in public media and academia. Despite the popularity of the term, different understandings of its meaning across the literature exist. Estelles-Arolas & Gonzalez-Ladron-de-Guevara (2012) found 40 different definitions of crowdsourcing in the literature. The most popular definition comes from Jeff Howe, who coined the term. Howe (2006 p. 1) considers crowdsourcing as a special form of outsourcing and defines it as "…the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call. " In contrast, Brabham (2008) perceives crowdsourcing as a collaborative problem solving and co-production model. From the perspective of online workers, Heer & Bostok (2010 p.1) understand crowdsourcing as "a relatively new phenomenon in which web workers complete one or more small tasks, often for micro-payments on the order of $0.01 to $0.10 per task."

While different definitions extend our understanding of the phenomenon, inconsistent conceptualizations of the term can lead to confusion in identifying which applications are crowdsourcing and which are not. For example, Huberman et al. (2009) consider YouTube as crowdsourcing, while Kleeman et al. (2008) do not. Crowdsourcing can also be easily confused with other related Web 2.0 phenomena, such as social networking, communities of practice or social commerce, because on the surface all of them involve interaction and participation of individuals through the Web. It is also necessary to distinguish crowdsourcing from open innovation, user innovation, and open source application development. Compared with open innovation, crowdsourcing has a wider scope of applications (not only innovation processes) and concerns with the interaction between the firm and an online crowd rather than between firms (Schenk & Guittard, 2009). User innovation also differs from crowdsourcing in that it is initiated by users while, in crowdsourcing, it is initiated by a firm (Schenk & Guittard, 2009). Schenk & Guittard (2009) also argue that open source application development is a specific application of crowdsourcing, rather than a theoretical concept in its own right.

In this paper we follow the definition by Howe (2006) because in our opinion, it captures the most unique characteristics of the phenomenon. That is, a crowdsourcing initiative should have the following three elements:

(1) Users are producers, not only consumers: The role of online users as producers in crowdsourcing applications is a critical distinction between crowdsourcing and social commerce (Saxton et al., 2013). A common feature across social e-commerce websites is that online users go to the sites to consume finished products or services offered by firms. For example, online users access nike.com to buy or gain more information about Nike products provided by other users. In contrast, in crowdsourcing, online users contribute to the production process of the firm and the product design. For example, in threadless.com, there are two types of users. First, there are typical

online customers who browse the site to find and buy T-shirts. Second, there are others who contribute their T-shirt designs that, once selected, will be printed as products by Threadless.

In line with Kleeman et al. (2008), we also distinguish crowdsourcing with market creator websites. In market creator websites such as Ebay[1], online users' contributions are in the form of trading finished products. The website only serves as a sales channel for the sellers. In contrast, in crowdsourcing websites, online users' contributions are in the form of resources in a production process. For example, in the case of Threadless, online users participate in the designing stage of the production process. However, unlike Kleeman et al. (2008) who do not consider labor market websites like Amazon Mechanical Turk or Rent a Coder[2] as crowdsourcing, we classify them as crowdsourcing because the crowd offers a labor resource, not finished products.

(2) The number of participants is undefined: The number of participants in a crowdsourcing event is undefined, meaning that the number ranges from one to several thousand or more. Also, this number is unknown in advance but emergent. This characteristic distinguishes crowdsourcing initiatives from virtual team or distributed group work. While both crowdsourcing and virtual teams involve interactions among individuals through information and communication technologies, the number of virtual team members is typically fixed and known beforehand.

(3) Users' contributions are towards completing a specific task: This feature differentiates crowdsourcing from social networking platforms or knowledge/content sharing websites. Crowdsourcing differs from social networking platforms such as Facebook or Twitter in that interactions among individuals on the crowdsourcing platforms are towards fulfilling certain goals, while in social networking platforms, the connections and interactions are just for individuals' socializing purposes. Crowdsourcing is also different from online knowledge and content sharing websites such as Wikipedia, YouTube, or other virtual communities. In crowdsourcing, contributions made by the online users are in response to a specific request ("an open call"), rather than spontaneous or out of contributors' own will as in the online knowledge and content sharing cases.

While all crowdsourcing initiatives share the above three characteristics, not all of them require (the same amount of) collaborative effort among the crowd members. We distinguish three sub-crowdsourcing models - virtual labor marketplace, closed collaboration, and open collaboration[3].

Virtual labor marketplace

The virtual labor marketplace model refers to the online marketplace through which individuals or organizations trade human labor forces for short term projects with a temporary contract. In this marketplace, there are two main types of users: the problem owners and the problem solvers, i.e. the workers. Problem owners are either

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[1] www.ebay.com

[2] www.rent-acoder.com

[3] Besides these three models, some authors also identify crowdfunding as a separate model (Belleflamme et al., 2011). With crowdfunding organizations can mobilize financial capital from a large number of people through an open call for investment. We exclude this type of crowdsourcing from our discussion, as we are interested in how to better utilize the intelligence of an online crowd, not their financial resource.

individuals or organizations who are in need of man power for some tasks. They go to the virtual labor marketplace and post their job requests on the platform so that interested workers can apply. Alternatively, problem owners can browse the list of workers available on the platform to find the ones whose profiles fit their tasks. In contrast, workers are individuals or organizations who are willing to accept job requests from problem owners. They can either search for job requests and apply to them or post their profiles so that problem owners can consider recruiting them. Unlike organizational employees who are tied to their employers by permanent contracts, the relationship between problem owners and workers in the virtual labor marketplace does not last beyond the duration of the tasks. Typically, the workers will get paid right after they deliver the task results to the problem owner.

Freelancer is a typical example of a virtual labor marketplace. On Freelancer, problem owners can search for workers for tasks such as web design, logo design, or sales and marketing. For example, a problem owner may looks for workers for a web design task. He posts the web design task on the Freelancer website with a task description and requirements. Web designers interested in the task bid for it. The problem owner can select among these bidders. Besides Freelancer.com, other popular virtual labor marketplace platforms include Amazon Mechanical Turk, Odesk, and Elance.

Closed Collaboration

In the closed collaboration model, instead of recruiting workers for tasks, problem owners post their problems as an open call for the online crowd to submit their problem solving ideas. The problem owners then determine what are the best ideas internally. In this model, organizational tasks or problems are often represented as challenges in online innovation contests. The contestants who offer the best solutions to these challenges will get rewards. In these contests, the relationship among the contest participants is that of contenders, and therefore there are no interactions between them. Because the quality of the contestants' solutions is evaluated internally by the contest holders this model is called closed collaboration. Typically, the best solutions are not revealed to the public.

InnoCentive or 99designs are typical examples of this model. For example, on InnoCentive, a group of companies operating in oil sands offered a prize of $10,000 USD for the following challenge[4]: "The bitumen produced by the Steam Assisted Gravity Drainage (SAGD) technology in the Athabasca oil sands in Alberta, Canada, is extremely viscous (8-10 API gravity), requiring the use of diluents to aid the flow of bitumen in pipelines. The Seeker is looking for novel, unorthodox approaches to enhance the flow of bitumen through pipelines." The interested contestants can submit their solutions until a specific deadline. After this deadline, the organization will review the submitted solutions and decide the winner. At the end of the contest, the winner receives the $10,000 award and the organization can use the winning solution under a "royalty-free, perpetual and non-exclusive license".

Open collaboration

The open collaboration model refers to crowdsourcing initiatives where the tasks requested by the problem owners are completed through the collaborative effort of the online crowd. "Collaborative" means that the online users complement and improve

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[4] `www.innocentive.com/ar/challenge/9932959` (last accessed on 22 April 2013)

on the contributions of one another towards finishing the tasks at hand, as opposed to competing with one another as in the closed collaboration model. The task outcomes in the open collaboration initiatives, therefore, are determined through the combination and synthesis of multiple contributions from the crowd members. The term "open collaboration" is used to denote the fact that the problem-solving and decision making process is open to all users, not just to the problem owners.

While instances of the virtual labor marketplace or closed collaboration models are very similar to one another, instances of the open collaboration model are diverse. Through the open collaboration model, the collaborative effort of online crowds can be used to build products. For example, in volpen.com, online users can write books together by participating in either one of three major activities: (1) start a new book by writing a 200-400 word paragraph about the main idea of the book; or (2) continue an unfinished book by adding new continuations to the book; or (3) vote on the continuations of an unfinished book. Through this process, a book is made as the aggregation of small writing pieces created and voted as the most interesting from the crowd members. Moreover, the open collaboration model can also be used to make prediction or detect trends. To illustrate, predictions for ticket sales of newly released movies can be made based on the virtual stock prices of movies on Hollywood Stock Exchange (www.hsx.com), a simulated stock market game where players can trade "shares" of upcoming movies, actors, or directors. Finally, the open collaboration model can appear in form of online discussions over specific issues. For example, through MindMixer.com, city halls can utilize online citizens in solving various municipal problems and issues by letting them (1) brainstorm ideas and solutions and (2) comment and vote to reduce large numbers of suggested ideas into a best few ideas worthy of focused attention by the government agency or public entity.

Crowdsourcing generally aims at making use of the intelligence of a large number of Internet users to solve problems. However, the online crowds' intelligence is utilized in different ways across the three models (see figure 1). Specifically, the virtual labor marketplace helps problem owners solve their problems by finding the right people for the tasks at hand. The closed collaboration helps problem owners gather a large quantity of possible solutions so that they can choose the most suitable ones among them. Finally, the open collaboration

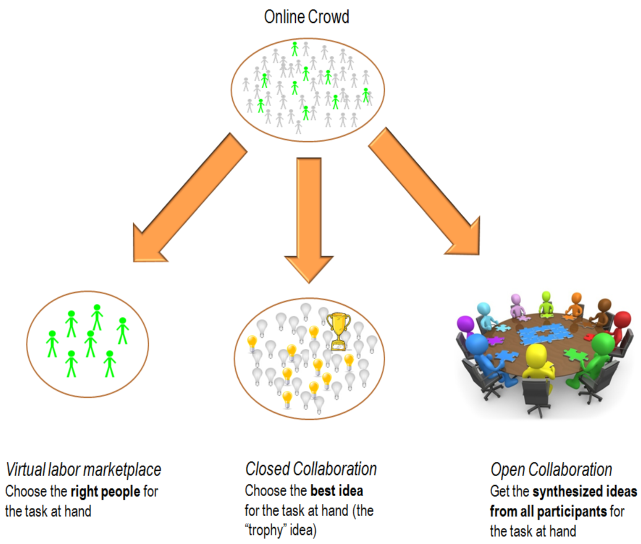

Fig. 1. Types of crowdsourcing

offers problem owners the solutions that are the synthesis of multiple ideas and refinements from the online crowd.

Among the three crowdsourcing models, the open collaboration model exhibits the highest level of sophistication because different people have different, sometimes conflicting ideas and opinions. Synthesizing these ideas and opinions typically is a daunting task. It is even more challenging in the crowdsourcing context where these people are large in quantity and dispersed demographically. However, at the same time, the open collaboration model is also the closest to utilizing the so-called collective intelligence or wisdom of the crowd (Surowiecki, 2004). Indeed, while the best outcome produced by the virtual labor marketplace or closed collaboration is equal to that of the best person in the online crowd, the best outcome produced by the open collaboration can surpass that of any person in the crowd if synergy among the crowd members is created (Surowiecki, 2004). Due to this potential of the open collaboration model, we focus our paper on this type of crowdsourcing only.

3 A Model of User Engagement in Open Collaboration Crowdsourcing

In this section we present the development of our theoretical model. In summary, we propose that crowdsourcing user engagement is driven by motivation to contribute which, in turn, depends on a user's personal interest in a topic. We also propose that goal clarity moderates the effect of personal interest on motivation to contribute.

3.1 User Engagement

Whenever there is an activity that depends on the involvement of individuals, engagement becomes a primary be positive like elation, or negative like disgust or anger. Emotional engagement can be stimulated by addressing important life themes like death, livelihood, and personal struggles. Cognitive engagement occurs when individuals engage in events that are outside their deep emotional range. They are ordinary events that may engage their attention because of the contents or novelty of the text (Wade, 1992). Finally, behavioral engagement can be observed through an individual's set of actions that go beyond what is typically expected (Macey & Schneider, 2008).

Inspite of the interest in engagement in varied disciplines ranging from education (Coates, 2005; Zyngier, 2008) and workplace (Saks, 2006; Towers, 2003) to civic engagement (Pasek, Kenski, Romer, & Hall, 2006) the concept of community engagement has not yet been well-defined (Ludwig & Frazier, 2012). Engagement in a community is usually gauged through the involvement, passion, enthusiasm, and focused effort of community members towards the issues at hand (Bobek, Zaff, Li, & Lerner, 2009). The behavioral component manifests itself as participation in the community whereas the emotional component manifests itself with the sense of identity with the community. Narrowing the focus to crowdsourcing, community engagement can be measured through active participation and identification with the community. Therefore, in this paper we define user engagement as the quality of effort online users devote to open collaboration activities that contribute directly to desired outcomes. This quality will be quantified through (a) the degree of online participation in the form of suggesting ideas and discussing, commenting, or voting for others' ideas through social technology platforms, (b) the amount of time spent on the platform during the visit, and (c) self-perceptions of engagement by users. This engagement measurement approach is typical in the Web environment (e.g. Lehman et al., 2012).

3.2 Motivation to Contribute

Motivation is one of the most studied constructs in psychology (Meyer, Becker, & Vandenberghe, 2004; Mitchell, 1982; Ryan & Deci, 2000). To be motivated essentially means "to be moved" to do something (Ryan & Deci, 2000). It is one of the most common emotions that individuals experience before they actually engage in a task. However, it has been a difficult concept to pin down in terms of a definition. In a multi-disciplinary review of the literature, Kleinginna and Kleinginna (1981) could isolate at least 140 attempts to define motivation. One such perspective relevant to this paper was defined by Pinder (1998 p. 11) about work place motivation: "Work motivation is a set of energetic forces that originates both within as well as beyond an individual's being, to initiate work-related behavior, and to determine its form, direction, intensity, and duration."

This particular definition is significant because it associates motivation with an energizing force to commit an act. It also suggests that this energizing force determines the form, direction, intensity, and duration of the task to be committed. Said differently, this definition takes into account that motivation plays a role in how long individuals work at a task, how intensely they work at it, and the form it takes – extrinsic or intrinsic. According to Deci and Ryan's (1985) self-determination theory, individuals experience an intrinsic motivation to do something only when they find the activity inherently enjoyable, interesting, or attractive for some other reason. Extrinsic motivation, on the other hand, means that the individuals are performing the activity because they expect it to lead to a separable outcome. In the crowdsourcing context, some exploratory findings showed that user engagement was driven by both intrinsic and extrinsic motivators (e.g. Brabham, 2012; Kaufman et al., 2011). However, it is also noted that in open collaboration initiatives, online users are dominantly driven by intrinsic rather than extrinsic motivators (Bondreau & Lakhani, 2009). The literature is replete with studies that illustrate the close relationship between motivation and engagement in a variety of disciplines. In education, for example, it has been observed that students who perform activities either through intrinsic motivation or through internally propelled extrinsic motivation perform better at school work and experience less resentment towards it (Ryan & Stiller, 1991). It was also found that students who exhibited intrinsic motivation towards a task exhibited greater levels of meaningful cognitive engagement (Meece, Blumenfeld, & Hoyle, 1988; Walker, Greene, & Mansell, 2006). In addition, recent crowdsourcing research shows that participation is the highest only when the incentives satisfy the motives of the users

(Leimeister, Huber, Bretschneider, & Krcmar, 2009). Also, a study on crowdsourcing labor markets by Rogstadius et al. (2011) shows that factors that increase the intrinsic motivation of a task – such as framing a task as helping others – succeeds better in improving output quality than extrinsic motivators such as increased pay. Chandler and Kapelner (2013) also found similar results that meaningful framing of the task increases the quality of output. Therefore, we focus specifically on intrinsic motivation as an antecedent to engagement.

Proposition 1: User engagement in open collaboration crowdsourcing is a function of a user's intrinsic motivation to contribute.

3.3 Personal Interest in Topic

Another factor that we argue influences user engagement in crowdsourcing is personal interest in the topic. If users are not personally interested in the topic or issue that they are exposed to, there is little likelihood that they will stick around to make meaningful contributions, irrespective of the absolute importance of the issue. Literature distinguishes interest in a topic into two categories: topic based interest and situational interest (Flowerday, Schraw, & Stevens, 2004). Topic based interest (or topical interest) is one that is developed over a longer period of time. It is content based and stable (Schiefele, 1999). Topical interest is developed through personal experiences and emotions that give it a cognitive/affective quality that individuals carry with them wherever they go (Alexander & Jetton, 1996; Schiefele, 1999; Tobias, 1994). In contrast, situational interest is more transient in nature. It is short-lived, context dependent, and environmentally activated (Krapp, Hidi & Renninger, 1992; Schraw & Lehman, 2001). It results in spontaneous engagement that may fade as quickly as it materializes and is almost always place specific (Schraw & Lehman). This type of interest is based mostly on the novelty of the topic, curiosity, and the salience of the informational content (Wade, 1992). Situational interest may be a good way to "catch" the attention while topical interest may serve to hold the attention over a longer period of time (Hidi & Baird, 1986; Flowerday et al., 2004; Mitchell, 1993).

A review of the literature shows that topical interest has a stronger effect on deeper text processing activities like application and transfer of knowledge and on engagement towards the topic rather than on the shallow text processing activities like recognition of facts (Schiefele, 1991; Schiefele & Krapp, 1996). For example, Schiefele & Krapp (1996) found that interest in the topic results in student engagement which in turn, results in deeper processing of information. Wade et al. (1999) performed an in-depth analysis of the text factors which influence situational interest. They found that imagery, referential coherence created through connective phrases, and the salience of the information presented appeared to have most effect on situational interest. Other researchers (Schraw, 1997; Schraw, Bruning, & Svoboda, 1995) found additional influencing factors like ease of comprehension, text coherence, and relevance of information to the task at hand. These studies also highlight the importance of positive attitudes, like motivation to contribute, as they mediate the relationship between topical and situational interest and personal engagement (Schraw & Lehman, 2001).

Unfortunately, there is little research in the field of crowdsourcing on the relationship between personal interest and engagement. However, in the related field of online engagement in websites, it appears that engagement is strongly related to how personal interests are addressed by a website (Ho, Lee, & Hameed, 2008). Ho et al. found that web surfers were more engaged in activities that conformed to their own religious views than they were in activities that conformed to the traditional institutional religion. Research to date provides a basic foundation for the study of factors influencing user engagement in general. However, it is important to bear in mind that there are additional steps that occur between being interested and actually becoming an engaged crowdsourcing user. This is especially the case since the presence of personal interest does not always translate into user engagement, yet a lack of interest usually results in reduced engagement.

Proposition 2: A crowdsourcing user's intrinsic motivation to contribute is a function of personal interest in topic.
Proposition 3: User engagement in open collaboration crowdsourcing is a function of personal interest in topic mediated by a crowdsourcing user's intrinsic motivation to contribute

3.4 Goal Clarity

Goal clarity refers to the degree to which the objectives of a task are clearly stated and well-defined (Sawyer, 1992). In other words, a clear goal removes ambiguity in the instructions regarding the recipient's future course of action. Goal clarity has been shown to exert its influence on all aspects of interactions ranging from job satisfaction to a sense of well-being. At the individual level, research by Bipp & Kleingeld (2011) shows that goal clarity is positively associated with commitment towards the goal. Their results showed that goal clarity affects the level of commitment employees experienced towards their work. Teams are also more effective in their tasks if they perceive their goals to be clear. For example, Hu and Liden (2011) detected a positive relationship between goal clarity and team performance. They examined team performance and organizational citizenship behavior of bank employees and found that team-level goal and process clarity served as antecedents to team potency, subsequent team performance, and team organizational citizenship behavior. Similar results have been found at the organizational level in the form of a strong relationship between goal clarity and organizational well-being. For example, a study by Hansson and Anderzén (2009) on the organizational well-being of the upper parish management of 500 parishes in Sweden showed goal clarity had a significantly positive effect on the organizational well-being for those who had former work experience. For older employees these positive effects manifested in the form of a higher degree of engagement to work while for the younger employees, it was expressed in the form of a higher degree of perceived influence in the organization.

In the context of crowdsourcing, goal clarity refers to the extent to which instructions make it clear what users are expected to do. Even though scant data is available in the crowdsourcing context, the research on online behavior confirms the results found in the organizational psychology literature. For example, studies examining online shopping behavior revealed that clear goals were positively related to exploratory behavior, sense of control, revisit intentions, purchase intention, and positive attitude towards web sites (Chen & Nilan, 1999; Davis & Wiedenbeck, 2001; Guo & Poole, 2009; van Schaik & Ling, 2003). Similarly, Zheng, Li and Hou (2011) demonstrated that explicitly specified tasks enable crowdsourcing users to be intrinsically motivated to participate in a co-creation process. However, we argue that goal clarity is not sufficient by itself to increase user motivation. If a user has little to no interest in the topic, even a clear goal cannot elicit high levels of participation. Therefore, it is hypothesized that goal clarity will positively moderate the effect between personal interest and motivation to contribute. That is, individuals who have a personal interest in the topic will have a higher motivation to contribute and this motivation will be even higher if the goals are clear.

Proposition 4: Goal clarity moderates the relationship between personal interest in topic and intrinsic motivation to contribute.

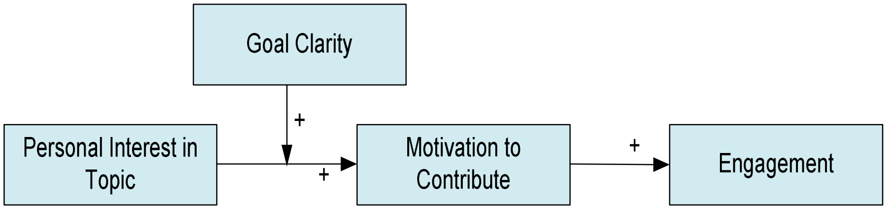

Fig. 2. Model of user engagement in open collaboration crowdsourcing

4 Discussion and Conclusion

Crowdsourcing has become a popular means to take advantage of the collective intelligence of large groups of people. It is likely that organizations soon will be looking on a regular basis towards internal and external crowds to provide solutions to their issues. However, as large as they may be, crowds still represent a finite resource. With the proliferation of organizations that use crowdsourcing, online users will be stretched thin in terms of the time and energy that they can spare towards crowdsourcing activities. Consequently, it will be imperative for organizations to understand what attracts these users and engages them to make quality contributions towards a problem. Understanding the antecedents to engagement will allow organizations to proactively stimulate the level of engagement that they can achieve from users instead of merely putting the problem forward and hoping that crowds will respond.

Interest in crowdsourcing research is on the rise and is a hot topic in many conferences and special issues in management and information systems journals. In addition, many funding agencies like the NSF and IARPA actively encourage research on crowdsourcing. However, there is scant empirical literature on crowdsourcing that focuses on the drivers behind crowdsourcing processes. For such empirical studies to take place, models are needed that describe the constructs and their relationships with respect to key phenomena of interest in crowdsourcing efforts. To the best of our knowledge, the model presented in this paper is the first that exposes the antecedents of user engagement in social web technology enabled open collaboration. The model can guide the empirical assessment of the constructs and their relationships to determine whether crowdsourcing user engagement is, indeed, determined by personal interest, goal clarity, and intrinsic motivation to contribute.

Even though this model is among the first to posit the antecedents to user engagement in crowdsourcing, it has to be borne in mind that this model is not presented as a "complete" model. There may be additional constructs that influence user engagement that can be included in this model. For example, in an introduction to the research stream on persuasive technology, Fogg (2002) noted that the wording of computer instructions could have a persuasive effect on users' behaviors. This finding is potentially relevant to the crowdsourcing context. Thus, the model can be expanded and elaborated in future studies to create a more comprehensive picture of the relationships between user engagement and its antecedents.

Future research efforts will include testing the model in both laboratory experiments as well as field studies. To this end, we first will operationalize the constructs of the model, in particular the dependent variable, user engagement. We will further identify existing instruments or development new ones that measure crowd members' perceptions on the construct in the model. For a laboratory experiment, we plan to invite university subjects to visit a realistic crowdsourcing site, built on a professional crowdsourcing engine. The subjects will be given the impression that their contributions will be used to improve the quality of student life at their university. This will ensure that they have a fundamental level of interest in the topic. After reading the description, the subjects will have time to check the crowdsourcing website out and to leave comments, suggestions, or idea developments for the topics that will be presented to them. The conditions of personal interest and goal clarity will be manipulated. The subjects will be either given an interesting topic or an uninteresting topic. The 'interestingness' of topics will be determined through an assessment of interest levels among a representative sample of the student population with respect to a list of potential topics. The highest and lowest scoring ones will be included. Goal clarity will be manipulated by framing the goal in clear terms with clear and quantified deliverables or in vague, ambiguous terms. For a field test, we will work closely with the open collaboration crowdsourcing company MindMixer. Through an ongoing partnership with MindMixer, we have access to the participation data from users in about 300 existing open collaboration projects across the United States. Furthermore, we will have the opportunity to design interventions to test process structures and facilitation techniques to increase user engagement. As part of these interventions, we plan to collect questionnaires from crowd members regarding personal interest in topic and goal clarity so that we can examine the relationships between the constructs in our model.

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Factors Influencing the Decision to Crowdsource

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Abstract. In order to integrate a crowdsourcing strategy to an organization's business processes, managers need to decide whether or not crowdsourcing is suitable for the organizational context. This study conducted a structured literature review to identify factors related to this decision. These identified factors have been synthesized into a framework for supporting the decision to crowdsource. Based on this framework, recommendations for managers, which were summarized in the decision tables, have been proposed.

Keywords: Crowdsourcing, crowdsourcing decision, business process, literature review, socio-technical system.

1 Introduction

Since its introduction, the term "crowdsourcing" was firstly introduced by Howe [1] to refer to a model that relies on the crowd, a large undefined group of individuals, to achieve specific tasks. Pioneering studies have suggested that this model can bring multiple competitive advantages for organizations, such as more flexibility and responsiveness to business strategy, cost savings [2], and harvesting expertise, information, skills, and labour [3, 4]. Some organizations that successfully utilize this model for their business strategies are Wikipedia for writing and editing articles, Threadless for T-shirt design, and Starbucks, i.e. MyStarbucksIdea project, for collecting customers' ideas.

Given that crowdsourcing can benefit organizations, it is reasonable to expect that crowdsourcing should be potentially integrated with existing organizational business processes. However, this does not seem to have happened. A recent survey [5] reports that only 10% of surveyed organizations have actually deployed a crowdsourcing strategy. If crowdsourcing is such a promising strategy, then why has it not been widely adopted by organizations? One of the possible answers to this question has been suggested by Malone et al. [6], who state that "[organizations] do not know how" to utilize crowdsourcing and advocate more investigation into the "how to" question. In the same vein, Vukovic and Bartolini [4] and Khazankin et al. [7] also suggest further research on this question, especially focusing on how to integrate crowdsourcing with existing organizations' business processes.

The literature addressing this problem shows that integration can be addressed from two different angles: the manager's view, which is responsible for coordinating the tasks; and the designer's view, which is responsible for implementing and

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configuring the crowdsourcing strategy on a particular platform. While many studies [8, 9] have focused on the design issues, currently there is little research focusing on the manager's perspective, including analysis of the multiple issues that managers have to consider when adopting a crowdsourcing strategy [10]. This paper focuses on one of the management issues, which is the "decision to crowdsource or not". This decision requires managers to determine whether crowdsourcing is a suitable strategy for a particular organizational context, rather than with the actual implementation of this crowdsourcing strategy. The "decision to crowdsource or not" is challenging because multiple factors need to be considered and evaluated in order to make an informed decision [11]. This leads to the research question, what factors influence an organizations' decision to crowdsource?

To address the question, this study conducted a structured literature review to analyse the factors influencing the decision to crowdsource. Since crowdsourcing can be seen as a socio-technical system [10], these identified factors will be synthesized to a decision framework including different layers of a socio-technical system. The study contributes to current knowledge by answering the question raised in the literature, "to crowdsource or not to crowdsource" [12]. From the practitioner's perspective, it provides practical recommendations for making the crowdsourcing decision in an organizational context. The recommendations will be presented using decision tables.

2 Literature Review

2.1 Concepts and Terminology

Since crowdsourcing is an emerging research area, different terms were used for this concept, including crowdsourcing, collective intelligence, human computation, mass collaboration and peer production [13, 14]. As a result, researchers have proposed different definitions for crowdsourcing. Some researchers, such as Doan et al. [14], define crowdsourcing as a system, in which the problem owner asks the crowd to solve a problem. Others, such as Howe [1] and Schenk and Guittard [15], have seen crowdsourcing as a form of outsourcing, in which tasks traditionally performed by organizational employees or other companies were sent to the members of the crowd. In some cases a single researcher, such as Brabham [3, 16] and Vukovic [17, 18] may provide more than one definition. In order to conceptualize a definition that captures "any given crowdsourcing activity" [19], Estellés-Arolas and González-Ladrón-de-Guevara [19] recently analysed the existing definitions extracted from literature. A selection of 209 articles was examined and 40 of them, which present original definitions of crowdsourcing, were analysed. As a result, eight common characteristics of crowdsourcing have been identified: clearly defined crowd, a task with a clear goal, a clear recompense for the crowd, the identified crowdsourcer, defined compensation for the crowdsourcer, online process, open call, and internet usage. The authors [19] then integrate these characteristics into a single comprehensive definition.

Although the definition proposed in [19] is comprehensive, it is wordy [20]. Thus the current study simplifies and adapts it for an organizational context. As a result, crowdsourcing is defined as *an online strategy, in which an organization proposes* *defined task(s) to the members of the crowd via a flexible open call. By undertaking the task(s), the members contribute their work, knowledge, skills and/or experience and receive reward, including economic reward, social recognition, self-esteem, or the development of individual skills. The organization will obtain these contributions and utilize the results for the defined goals*. In the following part, two examples to clarify the definition are introduced.

First, Amazon Mechanical Turk (AMT) is a profit platform [21] that allows organizations to crowdsource their simple tasks. After defining tasks and deciding to choose crowdsourcing, an organization creates and publishes these tasks on the platform using the predefined templates. Members (or workers) on the AMT platform browse information of available tasks, including requirements and payments, and may decide to perform these tasks. These tasks are usually performed individually and the results are submitted back to the organization. If these results' are sufficient quality, the organization will pay the compensation to the members who perform the tasks. Second, different from AMT, Brabham [22] introduced a non-profit crowdsourcing competition in the case of NextStopDesign, where the members participate to solve a design task without any concrete award. In this project, the task is published on its own website where anyone who has design skill can submit their design solution. The design solution then was evaluated based on the crowd members' vote. As a result, the three designs, which receive the highest vote, win the competition.

Although these examples show that crowdsourcing activities can be different, ranging from micro tasks to problem solving, from individual to competition, from profit to non-profit projects, the typical process of crowdsourcing can be presented in the following way.

When an organization has tasks to be accomplished, the first step is to decide whether to use crowdsourcing to perform these tasks [23]. Then, if the decision to choose crowdsourcing is made, the organization creates an open call and releases the tasks to the crowd. This step can be done through a platform developed either by the organization (e.g. NextStopDesign) or by a third party (e.g. AMT). Through the platform, the organization can approach members of the crowd. Depending on the organization's requirements, the members can be specific to a particular community, such as designers in NextStopDesign, or anyone willing to perform the task. Accomplishing these tasks individually or collaboratively, the members then submit the results back to the organization which assesses the quality of the results. The payment or other incentives will be given to the members if the organization is satisfied with the results [2, 10]. In practice, this process can vary. For example, a big task can be divided into many smaller tasks with a defined workflow before delivering to the crowd, and thus the results need to be aggregated to achieve the original task [24].

Currently, this process has been used in varied contexts with different applications. Because of this broad area of applications, terminology is not always consistent. For example, the term "task" can prefer to a problem, human intelligence task, micro task, or crowd work while the crowd member is called a solver, worker, labourer, user, or participant depending on the applications. This paper uses "task" and "member" since these terms can be used in a broad sense and are more consistent with the above described process.

2.2 Types of Crowdsourcing

Existing literature has introduced several ways to categorize crowdsourcing. Some researchers choose one dimension to classify crowdsourcing activities, while others suggest multi-dimensional classification. In the former approach, Whitla [2] classified crowdsourcing applied to marketing into three areas based on the purpose of the activity, including product development, advertising and promotion, and marketing research. Similarly, Brabham [25] proposed a crowdsourcing typology for problem solving based on four functions: knowledge discovery and management, broadcast search, peer-vetted creative production, and distributed human intelligence tasking.

In the latter approach, Rouse [11] presented her taxonomy of crowdsourcing with three dimensions: nature of the task, distribution of benefits, and forms of motivation. Geiger el al. [26] identified four dimensions: preselection of contributions, accessibility of peer contributions, aggregation of contributions, and remuneration for contributions. Malone et al. [6] based their classification around four basic questions: what is being crowdsource, who is performing the task, why people do this, and how the task is being done.

According to Nickerson et al. [27], a taxonomy and its dimensions should be evaluated according to its "usefulness". In this study, the main purpose is to support managers making crowdsourcing decision. Zhao and Zhu [10] suggest the complexity of tasks should be clarified before making this decision, and we believe that the nature to achieve tasks individually or competitively can also influence this decision. Consequently, this study employs two dimensions proposed by Schenk and Guittard's [15]: task complexity and the difference between integration and selection based crowdsourcing for categorizing crowdsourcing.

Table 1. Examples of crowdsourcing task types

Participation mode / **Complexity**	Individual (Integrative)	Competitive (Selective)
Simple	**Market place** - AMT - Taskcn	**Simple contest** - Yahoo Answers - Ask Ville by Amazon
Skilled	**Collective intelligence** - Wikipedia - Writing academic papers [28]	**Problem solving contest** - NextStopDesign - Innocentive - Threadless - IStockPhoto

By examining the characteristics of crowdsourcing in practice, Schenk and Guittard's [15] stressed task complexity as the first important dimension. Crowdsourcing tasks can be classified as simple, complex or creative. Simple tasks are jobs that can be accomplished with generic skills. Complex tasks require expertise and problem solving skills. Creative tasks relate to individual creativity such as logo design. It is worth to note that most of the complex tasks also require certain level of creativity while creative tasks' purposes are normally to find solutions for problems. Consequently, the difference between complex tasks and creative tasks is not large, and we combined them to "skilled" tasks in this study. Secondly, the authors [15] suggest the difference between the integrative and selective nature of the process as another dimension, which we named here as the participation mode that represents how tasks can be performed individually or competitively. Table 1 presents examples of different types of crowdsourcing, based on task properties.

2.3 Decision to Crowdsource

The decision to crowdsource has to be made before an organization chooses a crowdsourcing strategy. According to Rouse [11], this decision is significant for the organization since a failed crowdsourcing project can waste the organization's resources. With this in mind, researchers have started to examine closely the factors related to this decision.

Ranade and Varshney [12] propose the question "to crowdsource or not to crowdsource?", but their study was confined to crowdsourcing contests, also known as problem solving contests. Also focusing on a particular type of crowdsourcing, Buecheler et al. [29] examined collective intelligence in scientific method. Using the "three constituents principle" from Artificial Intelligence, they suggested a framework of three factors (environment, agent, and task) to determine the viability of crowdsourcing. Although each constituent principle has detailed variables, the authors did not specify how these variables influence the crowdsourcing decision. More importantly, the framework cannot be fully validated as the authors themselves stated "the data collection was not thorough enough to analyse all the variables mentioned in our framework".

Also focused on problem solving contests, Afuah and Tucci [30] recently suggested circumstances where crowdsourcing could be used. They evaluated the likelihood of crowdsourcing by comparing three alternative ways to solve a problem: internal sourcing, outsourcing and crowdsourcing. Based on behavioural and evolutionary theories of organizations, they identified four organizational factors and one environmental factor that need to be considered before the decision to crowdsource can be made. Four organizational factors that positively influence the probability of crowdsourcing are: characteristics of the problem (ease of delineation and transmission, and modularizability), characteristics of knowledge required for the solution (effective distance, and tacitness and complexity), characteristics of the crowd (pervasiveness of problem solving know-how, and motivation), and characteristics of solutions to be evaluated and of evaluators (experience-good orientation, and number of solution evaluators required). The external factor includes the pervasiveness and low cost of IT, which positively moderate the relationship between aforementioned variables and the probability of crowdsourcing.

Adopting a broader perspective, Sharma [31] provided a framework of several success factors associated with crowdsourcing initiatives, which are necessarily involved in the decision to crowdsource. In this framework, motive alignment of the crowd is the central factor influencing crowdsourcing success since it is "aligned to long term objectives of the crowdsourcing initiative" [31]. This factor is affected by five peripheral factors: vision and strategy, human capital, infrastructure, linkages and trust, and the external environment. However, many factors in this framework need to be detailed [10] before the framework can be used to support managers to make informed decision.

In summary, making an informed decision whether to crowdsource or not requires a comprehensive analysis in which multiple factors should be examined in a systematic way [10, 11]. Although studies highlighted the importance of the decision to crowdsource, most of them have focused on a particular type of task. Therefore, the overall picture of the crowdsourcing decision is still missing. Moreover, these studies offer different lists of factors that should be considered in this decision, and none of them proposes a comprehensive framework to support the decision to crowdsource. Taking that in consideration, this study addresses this gap by synthesizing the accumulated knowledge in the literature to clarify the factors related to crowdsourcing decision for general types of task.

3 Method

Selecting Articles. A structured literature review was chosen as the research method for this study. Following the approach introduced by Webster and Watson [32], this review is concept-centric without being limited by selected journals. In addition, since crowdsourcing is an emerging research field [10], many findings were presented in conference papers which are also included in this study. Consequently, six online bibliographic databases were selected: ACM, IEEE, Science Direct, SAGE, Springer Link and Emerald (as identified by Estellés-Arolas and González-Ladrón-de-Guevara [19]). These databases were searched, using 'crowdsourcing' as the keyword, between February and March 2013. Only English publications available in full text were selected. The results are shown in Table 2.

Table 2. Search results

Document types	ACM	IEEE	Science Direct	Sage	Emerald	Springer Link	Total
Conference paper	274	110					**384**
Journal		33	33	16	8	137	**227**
Total	274	143	33	16	8	137	**611**

After removing duplicates, editorial introductions, conference posters, letters, tutorials, and publications that contain the searching keyword but focus on other issues, the total of 500 papers were left in the initial pool.

Filtering Articles. In an effort to filter the papers which are not related to the focus of this study (the decision to crowdsource), we first eliminated the articles related to crowdsourcing design issues based on the paper' title and their keywords.

This elimination is performed based on the work of Kittur et al. [13], who suggests key topics in designing complex crowdsourcing processes, such as workflow design, task assignment, designing real-time crowdsourcing, collaboration and quality control. 112 articles, which have the titles and keywords related to these topics, were mapped to the design theme. This step also filtered out articles focused on crowdfunding (3 articles) and legal discussion (1 article). As a result, the pool reduced to 384 articles.

Classifying Articles. Since, in our knowledge, there is currently no classification frame or keyword schema that can distinguish the papers related to crowdsourcing decision from the unrelated ones, a classifying procedure is needed. Consequently, we defined the following iterative procedure for classifying the remaining 384 papers.

First, some papers, whose titles are clearly related to the decision to crowdsource, were classified to the crowdsourcing decision group of papers. Examples of these articles are "*to crowdsource or not to crowdsource?*" [12] and "*crowdsourcing critical success factor model: strategies to harness the collective intelligence of the crowd*" [31]. Second, by reading these classified articles, a list of important terms which relate to the decision to crowdsource was identified. Third, unclassified papers were examined, focusing on the papers' abstracts, introductions and conclusions. If a paper has term(s) in the list (or phases that have the equivalent meaning with terms in the list), it was added to the crowdsourcing decision group of chosen papers. Fourth, by examining the new added paper, new term(s) may be added to the list. Steps three and four were performed iteratively until no new term could be found. As a result, the list includes the following key terms: crowdsource or not to crowdsource, crowdsourcing circumstances, crowdsourcing success factors, crowdsourcing success, crowdsourcing decision, feasibility of using crowdsourcing, crowdsource ability, crowdsourcing viability, crowdsourcing alternatives, probability of crowdsourcing, crowdsourcing framework, crowdsourcing factors, and potential risks of crowdsourcing. In the final step, we engaged in detailed reading of the unclassified papers' abstracts, introductions and conclusions, and classified them based on the terms list related to crowdsourcing decision.

As a result, 38 articles related to the decision to crowdsource were identified. Although this number is relatively small, it is consistent with a recent literature review [10], which also reported limited publications on adopting crowdsourcing. Following the forward and backward searching proposed by Webster and Watson [32], additional 10 articles were identified, resulting in 48 papers overall.

4 A Theoretical Framework to Support the Decision to Crowdsource

By analysing the chosen articles, the factors related to the crowdsourcing decision were identified. From a system's perspective, crowdsourcing is a socio-technical system [10, 33], which involves interaction and connectivity between humans and technology. Adopting this perspective, the study adapted the various layers of a complex sociotechnical system from Vicente's work [34] and classified the identified factors to these layers (Figure 1). There are four layers in this framework: the task that an organization wants to crowdsource, the people who perform the task, the management which plans how the task can be coordinated, and the environment. A discussion of each layer in the framework follows.

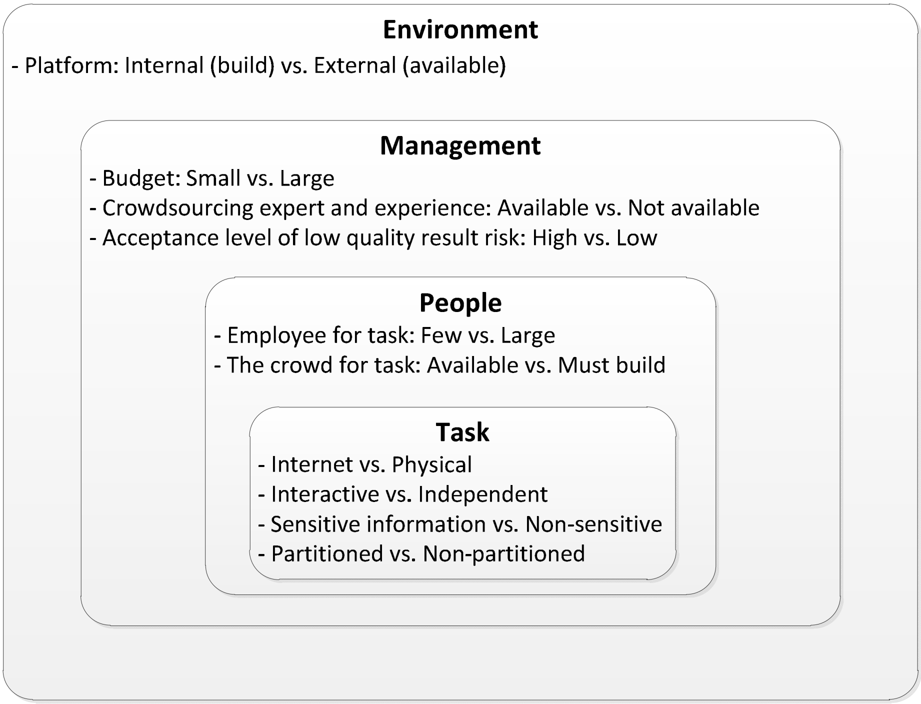

Fig. 1. A Theoretical Framework to support the decision to crowdsource (Adapted from [34])

Task Properties. Existing evidence has highlighted the nature of tasks as an important factor in the decision to crowdsource [12]. According to Kazman and Chen [35], the crowd can be good for certain tasks, but not for all kinds of tasks. Four task properties were highlighted. The first property is whether a task and its corresponding result can be delivered and collected through the internet. Most of the existing literature suggests crowdsourcing should only be used for internet activities, and some of them go further by adding this property to the crowdsourcing definition [15, 19, 36]. Only one exception [37], based on the deployment of tasks through physical kiosks, was identified in the searching papers. However, in this case, the problem solving task could easily be transferred to an online platform.

The second property is the interaction property, focusing on the nature of the relationship between the organization and the members during the crowdsourcing activities. Burger-Helmchen and Pénin [38], for example, suggest crowdsourcing contests are not suitable for tasks that require large interaction between the organization and the members (solvers). This suggestion is logical since the crowd members are usually anonymous to the organization and consequently, it is quite hard to establish the interaction between them. This argument can also be applied to other types of crowdsourcing tasks such as tasks published on AMT and Taskcn [39].

Third, since tasks in crowdsourcing are sent to anonymous members in the crowd, Muntés-Mulero et al. [40] claim that tasks with sensitive information, including privacy, security, and intellectual property, are not suitable for crowdsourcing. However, other believe that with additional actions in defining tasks, these tasks can still be crowdsourced. An action handling sensitive information in crowdsourcing tasks is introduced by Feller et al. [41], who advise organizations to decompose a task into a number of small tasks that conceal the overall picture, thus increasing the ability to protect privacy or intellectual property. Roy et al. [42] present another case of crowdsourcing sensitive-information tasks on digitizing data from scanned images of insurance forms. In this case, the authors [42] describe a sequence of actions "overcoming the security challenges".

Finally, the ease with which a task can be partitioned into smaller pieces of work also affects the crowdsourcing decision. Malone et al. [6], when discussing crowdsourcing in terms of collective intelligence, suggest the crowd should be used for tasks that can be subdivided. Afuah and Tucci [30] noted that "modular problems are particularly conducive to collaboration-based crowdsourcing". This has been supported by other studies [24, 43].

People. An organization should consider who performs tasks in term of its available employees and the crowd members. Malone et al. [6] suggest choosing crowdsourcing when an organization does not have enough employees to deploy the tasks. With tasks, such as transcriptions and image labelling, requiring significant human resources that often exceed an organization's capability, organizations should consider crowdsourcing as an option. For example, a recent project that aimed to transcribe 41 diaries written over 21,000 days and thousands of prints found that "[they] can't do the project with existing human resources" and consequently, crowdsourcing was a good (if not the only) possibility [44]. Afuah and Tucci [30] agreed with this argument, but extended the boundary of the organization's human resources to include outsourcing contractors. Consequently, they recommend using crowdsourcing if "the knowledge required to solve the problem falls outside the focal agent's knowledge neighbourhood".

As key actors in the crowdsourcing system, the nature of the target members will influence crowdsourcing decisions [45]. Since some tasks, such as designing T-Shirts or writing academic papers [28], require the crowd members to have a certain level of skill, crowd member availability will influence the decision to crowdsource. Both Afuah and Tucci [30], examining crowdsourcing contests, and Malone et al. [6], studying collective intelligence, identify the positive influence of the available members, who know how to perform the tasks, on the crowdsourcing probability. Sharma [31] supports this argument by presenting the skills and abilities of the crowd as human capital in her crowdsourcing critical success factor model.

Management. Considering crowdsourcing as a type of outsourcing project, Rouse [11] advises the decision to crowdsource should "only be made" after examining four factors. Besides the production factor, which was discussed in the task section, the other three factors are: costs, coordination and risks. Cost saving is one main reason to choose crowdsourcing [10, 46, 47]. Consequently, the budget of the crowdsourcing project influences this decision. Crowdsourcing has been suggested when a project does not have enough money to hire employees or other companies to perform the task [6]. In other words, project with limited budget should be crowdsourced, and Wikipedia is a typical example of crowdsourcing a huge amount of writing tasks within a limited budget.

However, crowdsourcing activities can only succeed if organizations allocate appropriate expertise and experience to handle the coordination in these activities. Rouse [11] states that poor coordination can lead the project to the drain of resources and substantial delays, while other studies have stressed the importance of expertise and management in different parts of the crowdsourcing process, such as workflow management [48], members management [49], and agreement management [50].

Risk and risk management, as with any project, should be considered in crowdsourcing activities [11, 45]. Since members of the crowd perform the tasks voluntarily, organizations will not have the same level of control over member behaviours as they would have over their own employees [10], and this could lead to poor member contributions to the project. Consequently, the risk of low quality results should be considered.

Environment. The choice between internal or external platforms plays a role in the crowdsourcing decision. In terms of cost, which is one of the reasons to choose crowdsourcing [2, 10, 47], the availability of a crowdsourcing platform can decrease the development cost, which makes the decision to crowdsource become more attractive. In addition, since different platforms include different pools of members, which relates to the probability of the decision to crowdsource, the availability of the platform that is suitable for the defined task is valuable in term of the availability of its members. For example, Amazon Mechanical Turk has approximately 100,000 members [51] who can be utilized to address tasks that organizations would otherwise struggle with.

5 Discussion and Suggestions

Based on the framework, the following implications can be applied for crowdsourcing activities. In order to present these implications in a precise and compact way, the chosen presenting technique in this study is decision table. According to Huysmans et al. [52], decision table is the best presenting technique in term of interpretability compared to decision tree, propositional rule, and oblique rule. The authors [52] conducted an experiment measuring the accuracy, response time, and answer confidence when the participants using the aforementioned presenting techniques for problem solving tasks. The results from the experiment show that decision tables help the participants "answer the questions faster, more accurately and more confidently". Consequently, recommendations for crowdsource decision-making are presented as a series of decision tables. Each layer of the framework is summarised as a decision table, except for the Environment layer, which has only one factor.

Table 3. Decision table for layer 1: Task Properties

Condition: *Task properties*						
Internet	N	Y	Y	Y	Y	Y
Interactive	-	Y	N	N	N	N
Sensitive information	-	-	N	N	Y	Y
Partitioned	-	-	Y	N	Y	N
Action						
Not to crowdsource	X	X				
Should crowdsource			X			
Crowdsource with additional action: defining tasks aiming to hide the sensitive information					X	X
Crowdsource with additional action: only crowd-source as a contest				X		X

Since task is an important factor in crowdsourcing activities, task properties related to crowdsourcing decision were presented in Table 3. On the one hand, managers should only choose to crowdsource tasks that can be performed through the internet [15, 19, 36]. On the other hand, tasks which require a significant level of communication should not be crowdsourced [38]. In addition, if tasks include sensitive information or intellectual property, additional actions to hide the sensitive information are necessary [41]. Examples of these actions can be found in [42]. Finally, crowdsourcing is more suitable for tasks, which can be partitioned into small pieces of work [6]. One can argue that many big contest tasks, which are not necessarily divisible, can still be crowdsourced using platforms such as Innocentive. However, if these tasks can be modularized, "it may be easier for the focal agent to articulate a module" [30]. In other words, the probability to accomplish divided contest tasks is higher compared to the same non-divided tasks.

Table 4. Decision table for layer 2: People

Condition: *People*			
The crowd for task: Available (A) vs. Not available (N)	N	A	A
Employee for task: Few (F) vs. Large (L)	-	F	L
Action			
Not to crowdsource	X		
Should crowdsource		X	
Crowdsource with additional action: consider other factors			X

Table 4 shows the influence of human resources on the decision to crowdsource. Crowdsourcing tasks can only be performed if the organization can approach mass and suitable members. For simple tasks, the number of crowd members is important, while for skilled tasks, the ability of the members is significant. In short, "the constant availability of sufficient quantity and quality, of on-line workers" is a requirement for crowdsourcing [53]. From the organizational context, when an organization does not have enough appropriately skilled labours that are currently possessing by the crowd, crowdsourcing is a good option [6]. Finally, if both employees in the organization and the crowd members have the ability to perform the tasks, other factors, such as task properties, and management factors should be considered.

The factors in the Management layer were summarized in Table 5. Some organizations, such as Wikipedia, and non-profit organizations [54], show that they can employ crowdsourcing with little or no money. Consequently, crowdsourcing should be chosen when the fund allocated for tasks is not enough to perform these tasks in the traditional way [6]. However, it is worth noting that crowdsourcing also needs good expertise and experience in order to organize the activities [11]. As a result, if a project has limited budget, and limited or no crowdsourcing expert, it should not be crowdsourced.

Lack of commitment between the organization and the crowd members creates risks for crowdsourcing activities, including low quality results. In order to address the risk of low quality outcomes, organizations should crowdsource tasks where the results are easy to be evaluated [30]. In addition, different mechanisms that can be used for control quality have been suggested, including checking results by experts, using members of the crowd for evaluating, and evaluating by a third party organization [10].

Table 5. Decision table for layer 3: Management

Condition: *Management*								
Budget: Small (S) vs. Large (L)	S	S	S	S	L	L	L	L
Crowdsourcing expert: Available (A) vs. Not available (N)	A	A	N	N	A	A	N	N
Acceptance level of low quality result risk: High (H) vs. Low (L)	H	L	H	L	H	L	H	L
Action								
Not to crowdsource			X	X				
Should crowdsource	X				X			
Crowdsource with additional action: hire outside experts (due to large budget)							X	X
Crowdsource with additional action: implement mechanisms for quality control		X				X		

Finally, as the lone environmental factor, platform availability should also be evaluated. Although many crowdsourcing initiatives can be done by building their own platforms, the availability of a platform is an important factor when organizations decide to crowdsource, especially for small and medium-sized enterprises which have fewer financial resources and lower technical expertise. The availability of platforms, in some cases, has a relationship with the availability of the crowd members, which is the crucial factor in crowdsourcing decision [6, 30].

6 Conclusion and Limitations

Some studies highlighted the importance of factors that need to be considered when making a decision to crowdsource. Since most of these studies chose a particular type of crowdsourcing to explore the factors, a broader view which can be used for different types of crowdsourcing activities is necessary. Using a structured literature review method, this study developed a framework of identified factors related to the crowdsourcing decision, and proposed decision tables suggesting actions for managers when they make the decision.

There are some potential improvements that can be applied for this study. First, since crowdsourcing is a practical decision, discussion related to it can also be found from organizational presentations, reports, website and news media, such as the discussion in [44] and [55]. Consequently, future research should extend the scope in term of searching sources and keywords. Second, the current study foresees the ability to use these factors, not only in the decision to crowdsource, but also to design and implement crowdsourcing. By doing so, more factors related to each phase in crowdsourcing process should be explored. The results will enable a more comprehensive framework to be built, and provide a tool supporting the organization to decide on, design and implement crowdsourcing activities.

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Data Quality in an Output-Agreement Game: A Comparison between Game-Generated Tags and Professional Descriptors

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Abstract. A novel way to address the challenge of creating descriptive metadata for visual cultural heritage is to invite users to play Human Computation Games (HCG). This study presents an investigation into tags generated by an HCG launched at The Royal Library of Denmark and compares them to descriptors assigned to the same images by professional indexers from the same institution. The analysis is done by classifying tags and descriptors by term-category and by measuring semantic overlap between the tags and the descriptors. The semantic overlap was established with thesaurus relations between a sample of tags and descriptors.

The analysis shows that more than half of the validated tags had some thesaurus relation to a descriptor added by a professional indexer. Approximately 60% of the thesaurus relations were either 'same/equivalent' and roughly 20% were 'associative' and 20% 'hierarchical'. For the hierarchical thesaurus relations it was found that tags typically describe images at a less specific level than descriptors.

Furthermore game-generated tags tend to describe 'artifacts/objects' and thus typically represent what is in the picture, rather than what it is about. Descriptors also primarily belonged to this term-category but also had a substantial amount of 'Proper nouns', mainly named locations. Tags generated by the game, not validated by player-agreement, had a much higher frequency of 'subjective/narrative' tags, but also more errors and a few cases of vandalism. The overall findings suggest that game-generated tags could complement existing metadata and be integrated into existing workflows.

Keywords: Games with a purpose, crowdsourcing, image indexing, cultural heritage institutions, participatory cultural heritage, Output-agreement games.

1 Introduction

This paper aims to evaluate the outcome of the crowdsourcing tool Games with a Purpose (GWAP) or Human Computation Games (HCG) against professionally created metadata. It describes the Royal Library of Denmark's use of an Output-agreement game to index 2079 photographs in 2010 and how the metadata output created via the game compares to the metadata already created in-house at the Royal

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Library. As crowdsourcing is becoming a part of the common toolkit in the cultural heritage sector, an understanding of how the tags can complement traditional knowledge organization systems is needed. While numerous studies have investigated the relation between tags, to the best of my knowledge no previous studies have investigated the relationship between the output of a game and professional index terms.

2 Background

As shown in Figure 1, making cultural heritage digital can be viewed as a 7-step process [1]. In 2010, the total cost of digitizing the content of Europe's cultural heritage institutions (Libraries, Archives and Museums) was estimated to be approximately 100 Billion Euro, which only covers the cost of Selecting, Creating, Describing, Managing and Preserving [2]. This paper covers the task of Describing.

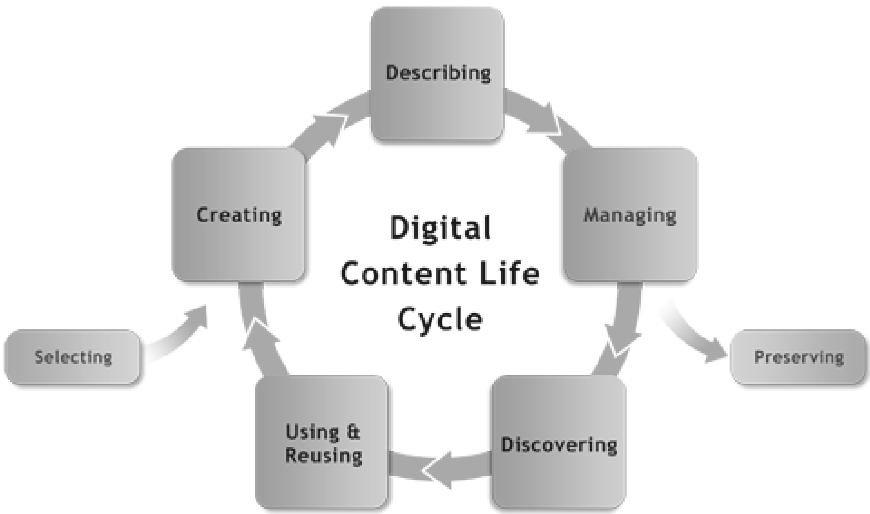

Fig. 1. Digital Content Life Cycle (Source: DigitalNZ)

Describing is mainly a matter of surrogacy i.e. creating data about the content, also known as metadata. The report estimates the cost of metadata-creation to range between 3.5-15 Euro for each object, depending on the state of the object, the type and the organizational context. This covers technical metadata (e.g. file-type, checksum), administrative metadata (e.g. copyright, provenance) and descriptive metadata (e.g. author, title and subject) the latter of which cannot always easily be ascertain via automatic means and often requires human interpretation to assess. The presence of subject metadata (keywords) is essential for content discovery via searching or browsing and represents of one of the challenges facing cultural heritage institutions when migrating into a digital environment: the creation of subject metadata for the rapidly increasing amount of content.

An increasingly popular approach is to rely on user-created index terms, typically by allowing/inviting the users to tag directly in the online catalogs or by publishing the content on external content aggregators with a preexisting social infrastructure already in place (e.g. Flickr or LibraryThing). Both approaches are variations of crowdsourcing tools and make particular sense in the realm of digital image collections in the cultural heritage sector for two reasons:

- Cultural heritage institutions i.e. galleries, archives, museums and libraries have historically been relying on volunteerism [3] and crowdsourcing is a natural extension of this notion.
- Image materials are notoriously hard to index, which is reflected in the literature, to the extent that a more user-driven and 'democratic approach' to image indexing was proposed in 1996 [4] – a decade before the term crowdsourcing was coined [5].

Crowdsourcing in a cultural heritage context can serve multiple purposes. Aside from the rationalization/cost and how the crowd can accomplish things single indexers/institutions cannot - there is another benefit in engaging patrons in some sort of activity, be it describing, digitizing or even co-creating the collection; it can be seen as marketing/dissemination of the library resources. The activities can stimulate interest and lead to discovery and the very notion of inviting the wider public to collaborate is a way for the institution to signal openness and approachability.

One concern, however, when engaging in any kind of crowdsourcing project is the behavior of the eponymous 'crowd'. Cultural heritage institutions have relied on volunteering, but another value embedded in the profession is the notion of authoritative delivery of high quality and un-biased information [6] - an ideal that can be hard to uphold if the institution itself isn't in control of the content it provides. Lascarides states that digital vandalism in crowdsourcing is far rarer than most people expect, but does also note that given the novelty of the field, precious little is actually known about the quality of the output of crowdsourcing projects [7]. An alternative method to tagging only recently applied to image collections in the cultural heritage sector, is HCG, a crowdsourcing tool that uses gamification in the indexing process and relies on user-agreement to create validated tags.

This work aims to investigate the output of an HCG by comparing the user-generated keywords (Tags) to professionally assigned keywords (Descriptors) to deepen our understanding of its feasibility in the cultural heritage sector and is carried out using data from an HCG called 'Make a Difference'[1] developed at The Royal Library in Copenhagen, Denmark and aims to answer the following questions:

RQ1: How similar are the tags of an output-agreement game to the descriptors provided by professional indexers? *Similarity is defined as the thesaurus-derived relations (and strength of those relationships), as the semantic overlap between the*

[1] Translated from Danish by the author.

two kinds of keywords should provide an estimation of the quality of the tags by using the descriptors as a gold standard set.

RQ2: What is the difference in the term-type of the labels assigned by gamers and indexers respectively? *To successfully utilize game-generated tags and how they can complement descriptors, a better understanding of their characteristics are needed.*

3 Related Literature

This section presents the context in which the study takes place. First describing the problems of assigning keywords to images and then introducing crowdsourcing in the cultural heritage context, followed by a description of Human Computation Games in general and the specific type of game created by the Royal Library, Output-agreement games.

Image Indexing is divided into two broad concepts: 'Content-Based Image Indexing' and 'Concept-Based Image Indexing'. The former relates to the picture 'as is it' and refers to computational methods in which a software application decodes an image and returns descriptors [8]. This might be easy for colors or simple patterns, but moving beyond pre-iconographic descriptions presents a computer with significant problems, e.g. describing a mood, identifying a location or interpreting a meaning [6], which is why the reliance on 'Concept Based Image Indexing' still is relevant.

'Concept-Based Image Indexing' presents human indexers with its own unique challenges, as they attempt 'to translate visually coded knowledge into a verbal surrogate' [9]. Indexing images with verbal descriptions is likely to be more subjective than it is when indexing texts [10]. This knowledge led researchers to suggest a 'democratic' approach to image indexing in which users, not indexers, provide the keywords [4]. This was a precursor to the now-widespread phenomenon folksonomies, which is the non-controlled, bottom-up vocabulary that emerges when users tag objects via collaborative information services, such as Flickr, delicious or LibraryThing.

Crowdsourcing is a relatively new concept and is a sort of umbrella term for various practices that involve mass-collaboration on online platforms. The term itself was coined by Howe in his seminal 2006 article in Wired Magazine [5], in which he describes how companies can reduce costs dramatically by outsourcing certain processes to the crowd, rather than having highly trained (and thus costly) professionals perform menial tasks. The approach is highly adaptable, which invariably leads to a plethora of use-cases and makes any attempts at a definition and construction of taxonomies more of an ongoing conversation [11].

In the cultural heritage sector, crowdsourcing is used as a way to collaborate with users via social media platforms, typically centered around a certain collection; has been utilized for correction, contextualization, co-curation, complementing, crowdfunding and classification [12]; and was heralded by Holley [13] as a highly promising approach to problem-solving for libraries in general and image collections in particular. Often, the publication of digitized images is delayed, not because of technical issues such as scanning or publishing, but by the lack of metadata to make the images retrievable via browsing/searching.

Studies of crowdsourcing participants have revealed that they are motivated to work either for extrinsic reasons (monetary rewards, learning new skills or recognition from external parties) or intrinsic reasons (partaking in a community or enjoyment) [14]. When deciding on a platform for a crowdsourcing project, these should be taken into account and since monetary rewards aren't likely to be one of the motivational factors, crowdsourcing projects in the cultural heritage sector should aim to either teach the participants something along the way, build a sense of community or make the experience as fun and enjoyable as possible.

Human Computation Games is a method pioneered by Louis von Ahn and Laura Dabbish in 2004 with the ESP-game, as a way to address the image labeling challenge, i.e. describing the deluge of images available online - both digitized and born digital materials. Rather than relying on content based image retrieval, which doesn't work well enough [15], they came up with the novel idea of getting people do it for free, by taking advantage of their desire to be entertained, and launched it under the moniker Games With A Purpose (GWAP).

The ESP-game is a browser-based game in which two anonymous players are connected and shown the same image. Each of them is then tasked with assigning labels to the image and guessing the labels of the other player. A successful match scores both players points. This part of the game – obtaining multiple labels – has since then become one of the established ways to ensure quality in crowdsourcing projects, i.e. by some sort of defensive design [16]. The validation threshold, i.e. the number of players that have to agree on a term, can be modified according to local preferences.

Figure 2 provides an example from the 'Make a Difference' game where X=3, as three players had to agree on a tag. Unlike the ESP-game, where gameplay is simultaneous, play-sessions can be asynchronous. The three sets of tags from the three players can be added over time, and once three players agree on a given term, it becomes valid. The idea of validation ties into the second innovative gameplay-component from the ESP-game: the idea of Taboo-words. Once a label is validated, it appears in all subsequent games on the screen in grey and the game will no longer accept this exact label, effectively forcing players to provide labels beyond the most obvious ones and makes the indexing process an iterative one as the image runs through multiple play-sessions. In Figure 2, for example, two Taboo words already exist as the three players play the game. Each of the players adds 6 tags to the image, one of which all three agree on ('Statue'). That term then gets transferred to the Taboo-words. Each of the Free Tags and 2Vtags are stored and, should the next player add either 'Summer', 'Sky' or 'Boat', they will also become valid and, therefore, Taboo words.

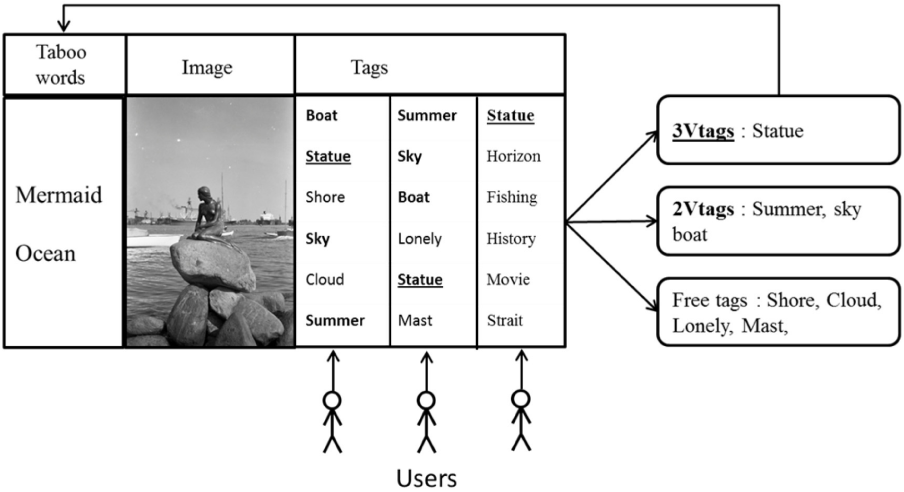

Fig. 2. Example of the Output-agreement gameplay from Make a Difference

Since the inception of the ESP-game, the GWAP platform has developed into a sort of running experiment in HCG, with a wide range of games and media types involved [17]. They are typically very simple, fast and intuitive and can be separated into four fundamental classes [18]:

- **Output-agreement Games**
  All players are given the same input and must produce outputs based on the common input.
- **Input-agreement Games**
  All players are given inputs that are known by the game (but not by the players) to be the same or different. The players are instructed to produce outputs describing their input, so their partners are able to assess whether their inputs are the same or different. Players see only each other's outputs.
- **Inversion-problem Games**
  The first player has access to the whole problem and gives hints to the second player to make a guess. If the second player is able to guess the secret, we assume that the hints given by the first player are correct.
- **Output-optimization Games**
  All players are given the same input and their outputs are the hints of other players' outputs.

The ESP-game as well as the 'Make a Difference'-game investigated in this paper are both Output-agreement games.

Use of HCG as a crowdsourcing tool is not yet a widespread practice in the cultural heritage sector, which can probably be attributed to the fact that developing a game in-house, until very recently, required specialized knowledge. Some examples are the OCR-correction game DigitalKoot from the Finnish National Library as well as the

Dutch 'Waisda?' an Output-agreement game for audiovisual materials. The recent publication of the open source software suite Metadata Games[2], which aims to facilitate local implementation of HCG and is especially targeted towards the humanities, makes evaluation and research into the application of games to create new metadata and complement existing institutional metadata more relevant than ever.

4 Data Collection

In November 2010 The Royal Library of Denmark launched the Output-agreement Game 'Make a Difference' via the social software Facebook, with the stated dual purpose of describing the Danish cultural heritage and collecting money for Save the Children – Denmark. Inspired by the ESP-game, a recently digitized collection of 2079 photographs by the Danish photographer Sven Türck were uploaded, and the crowd was invited to tag the images [19]. For each validated tag (X=3) a donation of 2 DKK was given up to a total of 5000 DKK (provided by external funding). In total, 235 users logged into the game during the ca. two weeks it was open, and they provided a total of 22787 tags, of which 2516 were validated.

The Sven Türck collection had previously been published online by The Royal Library, and the images were already classified by professional indexers to facilitate browsing/searching. As both the professional and the gamer perspective existed, the data generated by the game was suitable for this sort of investigation. The Descriptors were obtained directly from the photo archive via The Royal Library's OAI-server as MODS XML-files, and the game-generated tags were supplied by the developers of the game. The tags were divided into three categories – the non-validated tags (Free Tags), tags validated by two players (2Vtags) and tags validated by three players (3Vtags).

Table 1. Total number of terms for 2079 images

	Free tags	2Vtags	3Vtags	Descriptors
	22787	4743	2516	7306[3]
Average	11	2.3	1.2	3.5

[2] `http://metadatagames.com/about/`

[3] 1950 of the 2079 images contain the Descriptor 'Denmark'. This descriptor is seemingly a prerequisite for adding any location metadata in the system, more than an actual conscious decision from the indexer and is omitted for the analysis. 'Denmark' is meaningless as a search term; as it will result in almost total recall of the entire collection, it does not have any discriminatory power. In order to normalize the data and prepare it for automated analysis, compound descriptors with two words (omitting proper nouns) were split into separate descriptors and subsequently treated as such.

5 Research Design

5.1 Semantic Overlap

To determine similarity, the simplest approach is to look at syntactic overlap, which relies on character-for-character analysis and determining overlap on a completely binary scale. An extension of this is fuzzy matching, an approach that takes orthographical (e.g. British and American spelling) and morphological (e.g. singular and plural) variations into account and can be automated by a stemming algorithm. To deepen the understanding of the relation between the two types of keywords, the scope can be widened by introducing 'related meaning' using the knowledge structure from a thesaurus.

The method was pioneered by Voorbij [20] and was originally used as a way to determine similarity between title keywords and subject descriptors in the OPAC of the National Library of the Netherlands; titles and keywords from 475 records were scrutinized by subject librarians and assigned a score from 1-7, depending on how similar the keyword was to the title. The method was adapted and modified by Kipp [21] to determine similarity between keywords assigned by authors, indexers and taggers, respectively. Since then, the Voorbij/Kipp approach has been used/adapted by the original authors [22-23] and other researchers [24-27]. While each of these studies represent slightly different approaches, the common idea is to categorize term relations according to the knowledge structure from a thesaurus to determine a semantic overlap. The studies in which term comparisons have been done usually use the formal ontology of the descriptors as a 'reference standard' allowing for a certain amount of automatic analysis, e.g. if a tag has a formal associative relation to a descriptor according to Library of Congress Subject Headings, the relation is established, but a looser interpretation of 'associative' has also been adopted [24-25]. Without a reference standard – as was the case in this study[4] - one can either opt for a more exclusive approach in which the associative relations are ignored altogether or choose some external resource as a standard for comparison. As the analysis would be poorer without connecting obvious semantic dots such as 'fisherman' and 'fishing' an external source for comparison between tags and descriptors was chosen. To ensure rigor in the analysis, the Danish lexical-semantic database DanNet[5] was used in cases of doubt to establish the associative relation.

Standard guides for constructing thesauri define three overarching types of relationships, expressed at various levels of granularity:

- **Equivalence** (Same, Equivalence)
- **Hierarchical** (Narrower, Broader, Part-Whole, Whole-Part, Literal-Descriptor, Tag-Literal)
- **Associative** (Associative)

These relationships can then be ranked according to their strength. The concept of semantic strength was introduced by [25] as a way to do exclusive coding of semantic relations:

[4] The Descriptors are not assigned from a controlled set of subject headings, but chosen ad hoc

[5] In particular the visualisation tool of the dataset published at `andreord.dk`

1. **Same**
   A syntactic match between Tag and Descriptor
2. **Equivalence**
   Tag and Descriptor denote identical concept, i.e. synonyms
3. **Narrower Term**
   Tag is more specific than Descriptor e.g. 'villa – house'
4. **Broader Term**
   Tag is less specific than Descriptor e.g. 'sport – soccer'
5. **Part-Whole**
   Tag describes a more specific part of the Descriptor e.g. 'door – house'
6. **Whole-Part**
   Tag describes a term of which the descriptor is part e.g. 'beach – sand'
7. **Literal-Descriptor**
   Tag is a proper noun for an abstract Descriptor e.g. 'street – Bunny Street'
8. **Tag-literal**
   Tag is an abstract term for a proper noun Descriptor 'lady – Queen Margrethe II of Denmark'
9. **Associative**
   Tag has a direct relation to Descriptor according to DanNet, but not one covered by relation 1-8.

Analysis
Due to time-constraints, a subset of the images (n=320) was chosen randomly for analysis. Each tag was compared to the entire set of descriptors assigned to the same image. Coding was done exclusively, only allowing for one relation to be assigned to each tag and always assigning the strongest semantic relation identified.

Table 2. Number of terms in sample (n=320)

	Free tags	2Vtags	3Vtags	Descriptors
Total	2480	746	380	1112

The total semantic overlap is used to determine the similarity between the set of tags and the set of descriptors and is expressed by the frequency of overlap between the two.

5.2 Term-Categories

In order to code the Descriptors and Tags, the unique values from each dataset were extracted to express the vernacular vocabularies of the different datasets.

Table 3. Number of unique terms on vocabulary level

	Free tags	2Vtags	3Vtags	Descriptors
Total	4121	1040	600	905

Preliminary categories, informed by related literature [28-30] on image indexing, were constructed. The crystallization of the final categories however, was the result of an iterative process i.e. they were continually modified during the immersion in the data. No consensus exists among the creators of these frameworks, although some ideas are ubiquitous: Object, event, location, time and interpretation. These informed the initial term-categories:

- **Artifact/object**
  Static objects in the image, e.g. nouns like *man, table, boat, beach.* These terms refer to general things seen *in* the image or its *ofness.*
- **Action/event**
  Something 'happening', e.g. *dinner, gathering, jumping.*
- **Proper Noun**
  Named places, object or people, e.g. *Copenhagen, The Little Mermaid, Ingrid (1910-2000) droning.*
- **Subjective/Narrative**
  Narrating or interpreting terms, e.g. *idyllic, boring, loving.* These terms attempt to express what the picture is *about.*
- **Time**
  Words describing time, e.g. *winter, evening, October*
- **Errors**
  Spelling mistakes and typos. Not a term category per se, but nonetheless worth measuring considering the uncontrolled nature of tags.

These were later supplemented by three other emerging categories found during the first analysis of the Free tags.

- **Modern**
  Slang or neologisms, often in English e.g. *hot, cool, nice, skyline*
- **From Image**
  In a few cases, seemingly non-sense words are lifted directly from the picture, typically from a sign in the image, such as the name of a shop, e.g. '*NEYE*' or 'K133'. This was the only term-category requiring validation by looking at the image.
- **Obscene**
  Malicious tags or vandalism.

'Make a Difference' technically allowed for multiple-word tagging of the images, so a number of compound tags were observed. As multiple-word tagging is useful for Proper Nouns, e.g. 'Frederiksborg Castle' or 'University of Copenhagen', or qualifying tags, e.g. 'Fast car', this option made sense, but also resulted in different kinds of compound tags, not belonging to either of those categories. These compound tags were initially isolated and then subjected to a refinement; four different subcategories of Compound terms were identified and mapped to the overall categories.

- **Two-Term Concepts**
  e.g. ‘Flora_danica’ or ‘fishing_net’. These are counted as ‘Artifacts/objects’.
- **Refining Tags**
  Tags which describe another tag in detail by serving as a qualifier, i.e. adjective-noun pairs like ‘old_man’ or ‘short_hair’. These are counted as ‘Subjective/narrative’.
- **Title Tags**
  Narrative string of tags, often explaining the situations depicted. Examples would be either ‘reading over the shoulder’ or ‘dairyman shows the children the butterchurn, it is a jar of butter’. These are counted as ‘Subjective/narrative’.
- **Multiple Concept-Tags**
  Strings of unrelated tags, usually comma-separated like ‘boys, nature’ or ‘farm, trees, building, winter’. These are counted as ‘Errors’.

Analysis
The term-category analysis was done by listing all tags in a spreadsheet and assigning each tag one of the term-categories described above. In cases of doubt (e.g. the From Image category) the actual images were consulted, but in most cases only the tags were considered.

6 Findings

The Semantic Overlap found between the different categories of tags and the Descriptors is listed in Tables 4-6.

Table 4. Thesaurus relations between Free tags and descriptors

	Free tags (n=2480)		
Relation type	Frequency	% of Total semantic overlap	*M (SD)*
Same (syntactic match)	365	40.24 %	1.12 (1.12)
Equivalence	37	4.08 %	0.11 (0.37)
Narrower	54	5.95 %	0.17 (0.49)
Broader	74	8.16 %	0.23 (0.54)
Part-Whole	9	0.99 %	0.03 (0.16)
Whole-Part	53	5.84 %	0.16 (0.48)
Literal-descriptor	13	1.43 %	0.04 (0.25)
Tag-literal	52	5.73 %	0.16 (0.47)
Associative	250	27.56 %	0.77 (1.34)
Total semantic overlap	907	100 %	0.36 (0.48)

Table 5. Thesaurus relations between 2Vtags and descriptors

	2Vtags (n=746)		
Relation type	Frequency	% of Total semantic overlap	*M (SD)*
Same (syntactic match)	205	54.52%	0.7 (0.78)
Equivalence	12	3.19%	0.04 (0.2)
Narrower	11	2.93%	0.04 (0.19)
Broader	33	8.78%	0.11 (0.39)
Part-Whole	6	1.6%	0 (0.06)
Whole-Part	13	3.46%	0.04 (0.21)
Literal-descriptor	2	0.53%	0.01 (0.08)
Tag-literal	20	5.32%	0.07 (0.28)
Associative	74	19.68%	0.25 (0.61)
Total semantic overlap	376	100%	0.50 (0.50)

Table 6. Thesaurus relations between 3Vtags and descriptors

	3Vtags (n=380)		
Relation type	Frequency	% of Total semantic overlap	*M (SD)*
Same (syntactic match)	132	61.68 %	0.56 (0.65)
Equivalence	5	2.34 %	0.02 (0.14)
Narrower	7	3.27 %	0.03 (0.17)
Broader	17	7.94 %	0.07 (0.28)
Part-Whole	2	0.93 %	0.01 (0.09)
Whole-Part	3	1.40 %	0.01 (0.11)
Literal-descriptor	2	0.93 %	0.01 (0.09)
Tag-literal	8	3.74 %	0.03 (0.18)
Associative	40	18.69 %	0.17 (0.4)
Total semantic overlap	214	100 %	0.56 (0.49)

Overall, the findings suggest that the method of doing semantic comparison yields richer results than merely doing syntactic analysis when comparing metadata for images, as the overlap increased significantly with the inclusion of the thesaurus relations. Even though the players of the game might not use the exact same terms as the professional indexers, there is still a significant overlap in what they see in the picture.

The tags with hierarchical relations were overall on a higher level of abstraction (Broader, Whole-Part and Tag-literal) in the sample. The Free tags had the largest proportion of associative relations and fewer syntactic matches than the validated tags.

Table 7. Percentage of tags with thesaurus relations with descriptors

	Free tags (n=2480)	2Vtags (n=746)	3Vtags (n=380)
Frequency of semantic overlap (%)	907 (36.57%)	376 (50.40%)	214 (56.31%)

As seen in Table 7, more than half of all validated tags and more than a third of the Free tags had some sort of semantic relation to the Descriptors, predominantly the 'Same'-relation. Image indexing being complicated [9], the total semantic overlap must be considered substantial.

The Term-category analysis was initially done on vocabulary level, i.e. the unique terms (Table 8), and the total distribution for all tags and Descriptors was then extrapolated (Table 9).

Table 8. Term-category distribution among unique terms

Category	Free Tags	2Vtags	3Vtags	Descriptors
Artifacts/objects	2345 (56.9%)	829 (79.7%)	505 (84.2%)	469 (51.8%)
Actions/events	392 (9.5%)	82 (7.9%)	45 (7.5%)	31 (3.4%)
Proper noun	316 (7.7%)	91 (8.8%)	41 (6.8%)	382 (42.2%)
Subjective/narrative	380 (9.2%)	21 (2%)	3 (0.5%)	6 (0.7%)
Modern	50 (1.2%)	3 (0.3%)	1 (0.2%)	0 (0%)
From image	11 (0.3%)	1 (0.1%)	0 (0%)	0 (0%)
Time	34 (0.8%)	4 (0.4%)	2 (0.3%)	5 (0.6%)
Error	575 (14%)	9 (0.9%)	3 (0.5%)	12 (1.3%)
Obscene	18 (0.4%)	0 (0%)	0 (0%)	0 (0%)
Total	4121	1040	600	905

Looking at the distribution among non-unique terms, almost 80% of the Free Tags and almost 90% of the 2Vtags and 3Vtags were found to be 'Artifact/objects' - by far the most frequent type of term category observed. The game is set up reward players that guess other players' guesses, so it is not surprising that most players tag what is *in* the picture, rather than what it is *about*, since this is a logical game-play strategy to maximize your score.

The frequency of 'Proper nouns' is stable across all three levels of validation for the Tags. These are typically very recognizable Danish landmarks, e.g. Copenhagen City hall or the Statue of the Little Mermaid. There is a substantially higher ratio of 'Proper Nouns' in the Descriptors. This information can take time and research (beyond looking the photograph) to determine and is therefore less suitable for a fast-paced tagging game. The validation process works, as the error-rate drops from 4.9% to 0.63% for the 2Vtags and further down to 0.5% for the 3Vtags, which interestingly is very close to the 0.3% for the Descriptors and clearly demonstrates the immediate advantage of HCG.

Table 9. Term-category distribution among non-unique terms

	Free tags (*n*=2079)[6]		2Vtags (*n*=1881)	
Category	Frequency (%)	*M(SD)*	Frequency (%)	*M(SD)*
Artifacts/objects	12271 (79%)	5.9 (2.93)	4185 (88.24%)	2.22 (1.3)
Actions/events	831 (5.4%)	0.4 (0.86)	185 (3.9%)	0.1 (0.35)
Proper nouns	909 (5.9%)	0.44 (0.82)	288 (6.07%)	0.15 (0.39)
Subjective/narrative	583 (3.8%)	0.28 (0.61)	39 (0.82%)	0.02 (0.15)
Modern	56 (0.4%)	0.03 (0.17)	3 (0.06%)	0 (0.04)
From image	13 (0.1%)	0 (0.06)	1 (0.02%)	0 (0.02)
Time	71 (0.5%)	0.03 (0.19)	12 (0.25%)	0.01 (0.08)
Errors	762 (4.9%)	0.37 (0.64)	30 (0.63%)	0.02 (0.13)
Obscene	30 (0.2%)	0.01 (0.12)	0 (0%)	0 (0)
Total	15525 (100%)	*7.46 (6.4)*	4743 (100%)	*2.52 (1.33)*

	3Vtags (*n*=1517)		Descriptors (*n*=2062)	
Category	Frequency (%)	*M(SD)*	Frequency (%)	*M(SD)*
Artifacts/objects	2245 (89.2%)	1.48 (0.86)	4479 (61.3%)	2.17 (1.77)
Actions/events	97 (3.9%)	0.06 (0.28)	590 (8.1%)	0.29 (0.59)
Proper nouns	149 (5.9%)	0.1 (0.3)	2062 (28.2%)	1 (1)
Subjective/narrative	8 (0.3%)	0 (0.06)	117 (1.6%)	0.06 (0.23)
Modern	1 (0%)	0 (0.03)	0 (0%)	0 (0)
From image	0 (0%)	0 (0)	0 (0%)	0 (0)
Time	3 (0.1%)	0 (0.04)	37 (0.5%)	0.02 (0.13)
Errors	13 (0.5%)	0.01 (0.09)	21 (0.3%)	0.01 (0.1)
Obscene	0 (0%)	0 (0)	0 (0%)	0 (0)
Total	2516 (100%)	*1.66 (0.87)*	7306 (100%)	*3.54 (1.96)*

A total of 30 Obscene Free tags were found, which shows that vandalism does happen. Most of these were profanity, but a very few cases were racial and sexual slur, which could offend and hurt the users of the collections. These were naturally weeded out by the validation process, but the presence of obscene words in such a short-lived and altruistic project, does demonstrate that vandalism will occur eventually and that we cannot blindly trust the crowd to always have the best intentions.

[6] *n* denotes the number of images in which the tags/descriptors occurred.

Aside from cleaning the metadata, the validation process also cuts off ‘the long tail’ of the dataset, i.e. the marginal expressions and subjective observations not likely to be echoed by another player. The Subjective/narrative, Modern, From image and Time term-category are hardly represented in the 2Vtags or 3Vtags. One of the strengths of the folksonomy is that it can express a multitude of interpretations and viewpoints, an Output-agreement Game with a validation threshold is clearly not be the best way to accumulate these types of tags.

7 Discussion and Outlook

Using thesaurus relations, it was shown than more than half of the validated tags (both 2Vtags and 3Vtags) had some sort of semantic relation to the Descriptors. Considering the complicated nature of assigning keywords to images, this overlap lends credibility to the overall quality of the tags to warrant implementation into the catalog to some extent.

In this case, the validation process prevented errors and the few cases of vandalism. As the errors in the 2Vtags are only slightly more frequent than the errors in the Descriptors, one recommendation would be to set the validations threshold to 2 rather than 3 as it was in Make a Difference, providing almost twice as many tags as access points. An even more radical approach would be to simply use all Free Tags generated in true ‘democratic’ [1] fashion. Circumventing the validation process entirely will result in a much higher number of tags, but also introduce flaws in the catalog, the most prevalent of these being simple typing mistakes or common spelling errors, but also possible obscene tags. While extremely rare, they are in themselves enough to argue against a completely open policy in which every contribution by the crowd should be considered equal. There are two ways to deal with this problem:

Pre-tag screening would entail a mechanism of auto-correction, based on either a dictionary or some existing taxonomy that only allows certain terms to be entered, which might rob the final outcome of some of the more creative tags.

Post-tag screening would happen on vocabulary level rather than object level and would take place at regular intervals before allowing the tags to be introduced as proper metadata in the catalog. Catalogers wouldn’t need to verify images, but simply scan word-lists for errors and obscenity.

Almost 90% of the 2Vtags and 3Vtags belong to the ‘Artifacts/objects’ term category. This is hardly surprising considering the nature of Output-agreement games; as the gameplay rewards users for guessing what other people see in the image, the most efficient and obvious strategy is to describe what is *in* the picture. The term-category ‘Proper nouns’ wasn’t very prevalent in the tags, but it features much more prominently in the descriptors. One possible combination of the two types of keywords would be to let the indexers add ‘Proper nouns’ (mainly locations and personal names) and let the players add information about ‘Artifacts/objects’, as the game lends itself well to those sorts of descriptions.

Make a Difference was only open to the public for a short time, as the goal was to reach approx. 2500 3Vtags. Having an average of just 1.2 validated tags for each image, means that users will rarely have encountered any taboo-words and the images are therefore not likely to have run through many iterations before the target was reached. The relative low sample doesn't allow us to draw any certain conclusion, but does indicate that further exploration of similar games is an avenue worth exploring.

It should also be noted that cataloguing practice can vary from institution to institution, and the Sven Türck collection only consists of a single type of staged black and white photography. Other institutions might have formalized policies, e.g. emphasizing narrative descriptions, and a more heterogeneous sample of images might also have yielded different results.

In this paper, the professional descriptors were used as a gold standard set, but further research into the quality of the game-generated tags could entail comparative assessment by end-users between the two types of labels to determine if the non-overlapping terms differ in terms of perceived relevance. The study is indicative of how closely the tags generated by an Output-agreement game resemble professional descriptors and the overall findings suggests that a game like Make a Difference could potentially supplement or perhaps even replace part of the in-house indexing done at cultural heritage institutions with image collections in need of descriptive metadata.

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Analyzing Two Participation Strategies in an Undergraduate Course Community

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Abstract. Nowadays, information systems, and more particularly, learning support systems, tend to include social interaction features in their design. These features generally aim to sustain the activities of partially virtual communities and help extend the physical presence of the community in the virtual space. In order to achieve a sustainable community, it is important to understand how the strategies used to promote participation influence the way in which community members interact and relate with each other. This article reports a comparative study on two different student participation strategies mediated by a learning support system. The first strategy stressed the quantity of contributions, and the second one promoted both quantity and quality of contributions. By analyzing the resulting interaction networks, we could better understand the interaction patterns among students in their respective communities and conclude ways to monitor interaction and help maintain the community sustainability in time.

Keywords: Interaction patterns, participation, community structure, socio-technical analysis, monitoring, partially virtual communities.

1 Introduction

Social computing has become an important field in the research agenda of the groupware community. In fact, since its 16th edition in 2013, the ACM CSCW conference (one of the most competitive and cited in the field) changed its name to: "ACM Conference on Computer Supported Cooperative Work and Social Computing", thus reflecting a particular interest on socio-technical issues.

Online communities are changing the fundamental way in which people share information and communicate among them. This is affecting the global economy, social interaction, and every aspect of our lives [25]. This paradigm shift changes the main issues involved in the design and development of collaborative systems. It raises a number of questions linking social sciences and human-computer interaction,

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such as stating the relationships between software, social groups, and individuals; managing privacy and security concerns; and also establishing relevant criteria for measuring the success of online and partially virtual communities.

Interaction in these communities can be found in several situations. For example, it can be completely based in the virtual space (e.g. gaming communities), or it may lead to extend the physical presence toward a virtual scenario (e.g. students using an online discussion board outside their class hours) and, conversely, augment the physical space with information brought from the virtual space (e.g. a *Facebook* notification system triggering an alert in a mobile phone when a contact becomes available). Since most physical communities may benefit from extending their presence into an online environment, we are interested in studying in more depth, the dynamics of what Gutierrez et al. refer to as partially virtual communities [8]. In these communities, members have the opportunity to interact through both, a virtual and a physical space. Their members know each other, and this mutual information is useful to understanding the context of the contributions of others.

In fact, when we consider learning communities, today various universities use learning platforms that support interaction among students and instructors, mainly in the form of online asynchronous discussion boards. This form of social interaction is broadly accepted as a way to support different courses, for both instructors and students, [17] and it has led to an understanding of how these tools are used [19].

These communities usually suffer from a lack of user participation at their initial stages of their life cycle. Therefore, it turns out necessary to motivate people to contribute using different strategies that may help the community reach a minimum number of users and content, in order to ensure its sustainability over time [3]. This situation raises a couple of questions: (1) *how do users react to different participation strategies when they get exposed to generate new content?*, and (2) *how do these strategies impact the structure of the community?*.

This article reports the results of a comparative study, where two homogeneous groups of university students were exposed (through the use of a learning platform) to two different participation strategies. The first strategy enhanced the quantity of students' contributions, and the second one enhanced the quantity of contributions, as well as the perceived quality of them by others.

Each group was assigned to a dedicated online discussion board that supported their activities as a partially virtual community, and we gathered data in a monthly basis over a period of 15 weeks, concerning the number of published articles for all users and the number of replies given to the published articles. Afterwards, we built the interaction network for each group, and we analyzed how it evolved over time. The analysis of the results indicates that the participation strategy used to motivate contributions in the community indeed marked a difference on the interaction patterns of their members, and that by performing such an analysis it is possible to monitor the evolution of the community over its life cycle.

Next section reviews participation strategies in online communities, as well as interaction patterns in social networks. Section 3 describes the case study, the participation strategies used, and the metrics used to analyze the community structure. Section 4 shows and discusses the obtained results. Section 5 presents the conclusions and further work.

2 Related Work

This section first introduces reported strategies for fostering participation in online and partially virtual communities. We then present some of the most well known methods, used in Social Network Analysis, for quantifying and analyzing interaction patterns among members of a social group.

2.1 Participation in Online Communities

The problem of improving participation in online communities has been tackled by considering theories derived mainly from social psychology. For example, Cheng and Vassileva proposed a motivation strategy based on persuasion, in order to reinforce the value of quantity and quality in user contributions [2]. Harper et al. studied the effects of social comparisons (i.e., displaying how community members can compare to others in the system, e.g. in terms of performance, participation and interaction) [10]. Janzik and Herstatt proposed a set of incentives to motivate community members (using peer recognition, status, reputation, and identification) [12].

Preece and Shneiderman followed users' life cycles through their evolution in a community and listed strategies for motivating their participation according to their evolving role within the group [20]. Gutierrez et al. proposed a framework for motivating user participation based on intrinsic motivation, which included several strategies such as displaying rankings, proposing challenges, and displaying feedback [7]. In the case of physical and partially virtual communities, Westerlund et al. found out that trust and commitment are multi-dimensional constructs, where their evolution in a social network is dynamic and complex. Typically, trust precedes commitment [28].

Several authors claim that communities have to achieve a certain critical mass, i.e., a minimum number of users in order to sustain activity and information exchanges within the group [1, 14, 21]. Dabbish et al. studied the effects of turnover in online communities, i.e., the dynamics of user entrance and exiting in a particular group. In online communities, both participation and member commitment tend to increase when there is a noticeable turnover. This is understood by the group members as a dynamic evidence of the community activity and it is consequently perceived by them. Therefore, turnover may dramatically impact information exchange and content generation within the group. It turns out to be more important for the sustainability of a community to achieve a critical mass of contributions rather than a critical mass of users [4].

According to Cheng and Vassileva, regulating the quality and the quantity of user contributions, therefore ensuring a sustainable level of user participation in an online community, requires an adaptation of the participant rewards for particular forms of participation, depending on the user reputation and the current needs of the community. Their proposed methodology is to measure and reward the desirable user activities by computing a user participation measure (in order to enhance quantity and quality of contributions), and then clustering users according to this value [3].

2.2 Social Network Analysis

Discussion boards (i.e. a space where users can interact through posted messages, mainly in an asynchronous way) are broadly accepted as a tool for supporting user interaction in online communities. In fact, among all the different forms of computer-mediated communication used to support learning and teaching processes, asynchronous discussion boards are the most frequently used [9].

Researchers and instructors claim that discussion boards reinforce the learning experience by increasing student commitment in their courses, resulting therefore in significantly better results [17]. However, participation and interaction in online discussion boards does not necessarily translate to higher grades at the end of an academic period [6, 19]. In terms of platform support, Vonderwell and Zachariah found that technology, user interface design, content-area experience, student roles and tasks, and information overload, influence online learner participation and their interaction patterns [24].

For better understanding the underlying interaction patterns that emerge in a particular kind of human group, social scientists have historically used techniques from social network analysis [26]. In formal terms, social network analysts work at describing underlying patterns of social structure (based on people interactions), explaining the impact of such social structures on other variables [27]. Since the 1970s, the empirical study of social networks has played a central role in social science, and many of the mathematical and statistical tools used for studying these networks have been first developed in sociology [18].

Social network analysis manages social relationships in terms of network theory. It models individual actors within the network as *nodes*, and the relationships between them as *ties*. For example, Alice and Bob are friends in real life, and they declare this relationship in *Facebook*. This representation is modeled as Alice and Bob as nodes in the network, and they are tied by a relationship that reflects their friendship.

Several approaches for social network analysis have been successfully used in CSCL scenarios to understand participation and interaction aspects during learning processes [11, 15, 16, 22]. Course communities can be understood as graphs where the students represent the nodes and the edges indicate the relationship among nodes. Therefore, social network analysis techniques are mainly expressed in terms of graph theory. Among the main metrics used to characterize and study social networks, we identify: degrees, centrality, density, clustering, cliques, and cohesion [23]. Finally, a visual representation of social networks is important to understand the network data and convey the result of the analysis [5].

Since social networks can be represented as graphs, it is natural to assume that it can be composed by a wide variety of sub-graphs. One important local property of these networks is the so-called *network motifs*, which is defined as recurrent and statistically significant sub-graphs (or patterns) that are present in the network. Although network motifs may provide a deep insight into the network functional abilities, their detection is computationally challenging [13].

3 Case Study Scenario

This section describes the global scenario used for studying the effects of two different participation strategies and how they affect the interaction patterns among its group members. Later, we identify and discuss the key metrics to quantify in our analysis.

3.1 Settings

We worked with two groups of students (30 and 48 people respectively) enrolled in the course *Information Technology* from the Business School at the University of Chile. The first group was composed of 30 students (16 men and 14 women), and they participated in this study between March and June 2012. The second group involved 48 students (19 men and 29 women) that participated between August and November 2012. None of the students was in both groups simultaneously.

Within each group, we put two versions of an online discussion board in service, which runs on the learning platform that students regularly use to support their activities. Both discussion boards offered exactly the same services (e.g. publication of new topics, possibility of replying to others' contributions, notifications concerning user availability and recent activity), except that they used different algorithms to calculate the users' participation. This metric was visible in the user interface of the tool, and it was also used to rank the students according to their participation.

The course lecturer and teaching assistants had also access to the platform, but they had no privileges to moderate content, nor were identified as having a different role. This reduces the pressure on community members and allows them to express themselves. Thus, it was possible to properly identify their interaction patterns.

As part of their mandatory assignments for completing the course, students had to perform three short projects, pass three exams and regularly contribute in the discussion board by including recent news found in diverse media related to the different topics covered in the lecture sessions. In order to make a contribution, students had to select news, cite their respective sources (e.g. a link to the original article found on the Web), and write a short personal opinion on it. Once this contribution is made available in the software platform, other students had the chance to rate the article (according to their own perception on quality and pertinence) and comment on the contribution. It is important to note that ratings could only be made after a student commented on the contribution in order to address the typical free riding situations.

The user interface is divided into two modules: (1) a main page where users can read the different contributions published in the site, and (2) a detailed view of one of these contributions. The first module displays a list of the 10 most recent contributions, a tag cloud and a panel of links pointing to other articles classified by categories and relevant tags (Fig. 1). This element, alongside with the search bar, helps users identify and find relevant documents, facilitating thus the interaction between the author and the reader. Users can access to the detailed view of any contribution by either clicking on its title, content, or dedicated icon at the bottom of the box. Other articles can be found by navigating through different pages at the bottom of the site.

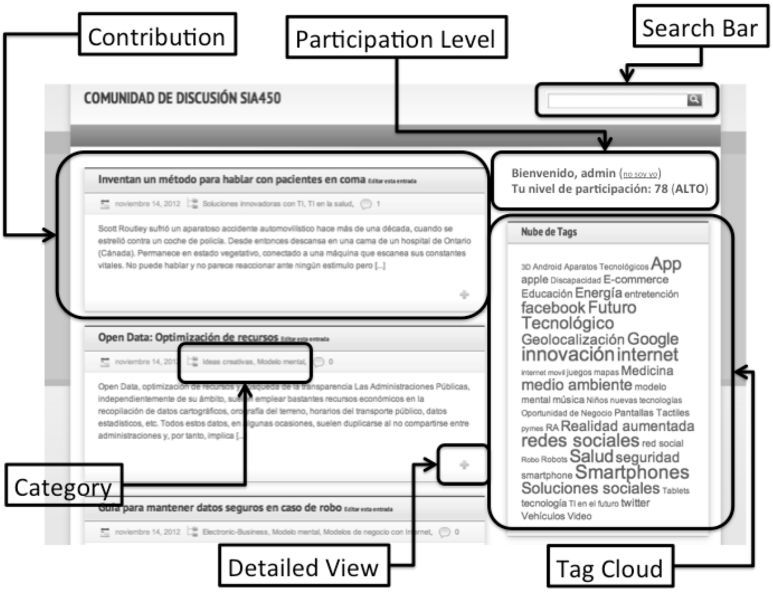

Fig. 1. General user interface of the online discussion board

The detailed view of each contribution displays the complete text (citing the source from where it was taken), the personal opinion of the author regarding the content of the article, and a list of reactions made to the contribution by other students (Fig. 2). Once a student publishes a comment linked to a particular contribution, the system proposes a rating system for grading the perceived quality of the article on a scale of one to seven stars. We chose to set this metaphor, since students are graded in a similar way in their regular courses at the University.

The platform was in service for both groups over 15 weeks. We established three milestones where we gathered the traffic data from the site, and afterwards reinitialized the counters. These milestones were roughly placed every five weeks, in order to make results comparable not only between groups, but also to analyze the evolution of the interaction patterns over time.

In each milestone, we identified: (1) the number of published contributions of each student; (2) the perceived quality of the contributions by other students; (3) the number of comments to other articles made by each student; and (4) the number of comments received by the other students. With these values, we computed a participation metric for each student, according to the strategy used in each situation. Moreover, each student could see his/her participation value in the home page of the platform every time s/he logged in. In this section of the home page, the students could get the computed value for their participation, and a label that situated them within the group. We classified students in three categories: "high participation" (top 20% of the whole group), "low participation" (bottom 20% of the group), and "medium participation".

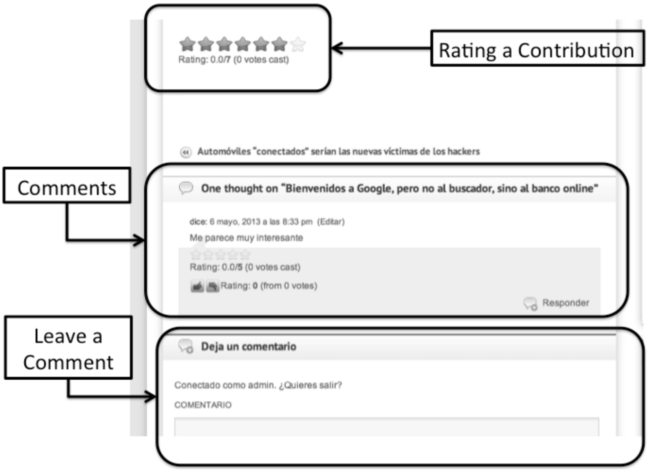

Fig. 2. Detailed user interface for the comments

The maximum and minimum values to set up the three categories were calculated in real time. At each milestone, we published the participation values for all students and we reinitialized the counters for all metrics.

3.2 Measuring User Participation

Every group involved in this study used a particular participation strategy to motivate contributions. We computed the participation function with the values gathered in each milestone, considering the number of published articles (A), perceived quality of the contributions (Q), number of published comments to other students (PC), and number of received comments from other students (RC).

In the first scenario (i.e. the first group), we highlighted the quantity of contributions rather than the quality of them. With this strategy, our aim was for students to increase the number of contributions in time. Considering the four metrics, we computed the value of participation (P) for the first group as follows:

$$P = A + PC\ . \qquad (1)$$

The participation value is in this case a function of the number of published articles and the published comments to other students. We purposely did not consider in Eq. 1 the value of received comments and the perceived quality of the contributions by other students.

On the other hand, the second scenario (i.e. the second group) also included quality as a dimension of how participation is measured. With this strategy, we also aimed to increase the number of contributions, but also to improve the perceived quality of them by the other students of the group. In this case, we computed the value of participation (P) as follows:

$$P = A \times Q / 2 + RC . \quad (2)$$

In this case, the participation value stresses the quality of the contributions, since those that are perceived as more "useful" or "pertinent" by other members, will weigh more in the participation value of a student. The students were pushed to write personal opinions with a minimum length (300 words) before publishing the article, in order to ensure a certain level of quality.

In Eq. 2 we have also considered the number of received comments instead of the published ones. This was done for two reasons: (1) students will tend to comment on those articles that they find interesting or useful, therefore they might be of better quality; and (2) when a student posts a comment on the contribution of another student, s/he helps increase the other's participation value instead of his/her own.

3.3 Relevant Metrics to Analyze

We modeled the interaction network as a weighted directed graph, where the nodes are the students and the edges between nodes represent the number and direction of comments that one student published to another. Figure 3 shows an example of the representation of the network: Alice, Bob and Charlie are students in the course and published at least one article; Alice posted three comments to Bob, Bob commented four articles written by Charlie, but Charlie only returned one comment to Bob.

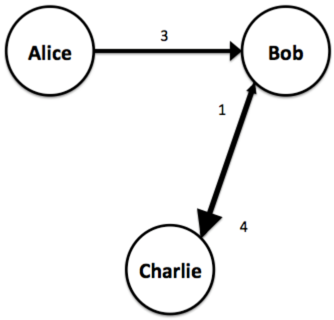

Fig. 3. Example of the interaction network

In order to understand the interaction network, we analyzed these interactions considering the following metrics:

- *Indegree*: This metric represents the number of edges that arrive to a given node. It can be understood as the number of students who write to a particular node.
- *Weighted indegree*: This indicates the number of edges that arrive to a given node, weighted by the number of comments. This metric can be understood as the number of comments that a given student receives.
- *Outdegree*: This metric shows the number of edges that emerge from a given node. It can be understood as the number of students that a particular node is writing to.

- *Weighted outdegree*: This is the number of edges that emerge from a given node, weighted by the number of comments. It represents the number of comments that a student posts in the community.
- *Modularity*: This is a factor between -0.5 and 1.0 that reflects the division of the network into groups within which the network connections are dense, but between which they are sparser. If this value is positive, the number of edges within groups exceeds the number expected on the basis of chance. When this value approaches 1, it means the strength of division of a graph structure is high (e.g. clear and distinct groups within the community).

Finally, we will analyze the different triads that coexist within the network in the form of 3-node motifs. There are 13 different isomorphic 3-node motifs, and they are presented in Figure 4. It is worth pointing out that among these motifs, seven of them are complete (or partially complete), since they tend to form 3-cliques (i.e. a subset of three nodes in a graph, such that every two nodes in the subset are connected by an edge). On the other hand, six of the motifs are partially incomplete, since they represent the interaction between only two out of the three nodes in the triad.

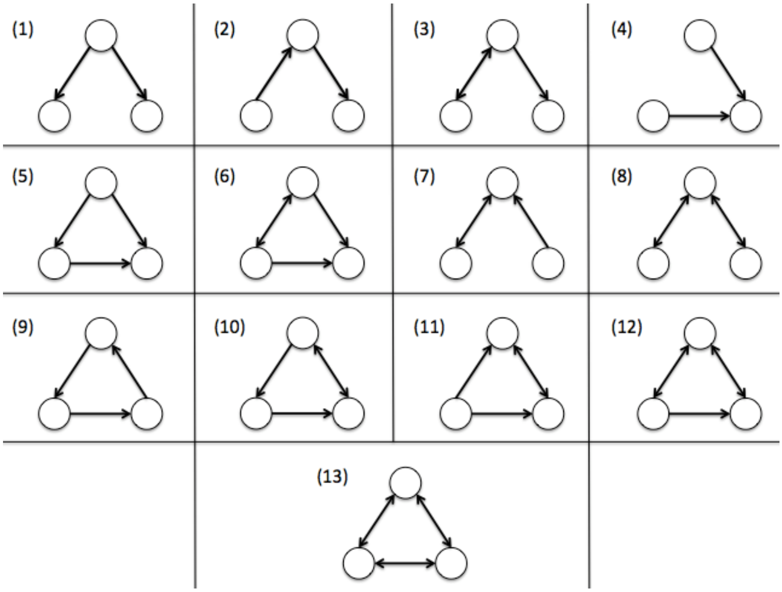

Fig. 4. Isomorphic 3-node motifs

4 Analysis of the Results

This section reports the main results obtained by analyzing participation metrics and the graph structure of the two networks used in the study. For analyzing and visualizing the networks, we used the software Gephi v.0.8.

We first analyze the main participation metrics defined in section 3, and then we show the main structural metrics of the graph. Later, we identify and quantify the different 3-node motifs that compose the structure of each network. Finally, we comparatively discuss these results between both scenarios in order to better understand how the different participation strategies affect both interaction networks (and hence, the interaction patterns among students in their respective communities).

4.1 Participation Metrics

Table 1 presents the mean values obtained for the participation metrics (i.e. number of published articles, perceived quality of contributions, and number of comments) in each scenario. It is worth pointing out that after each milestone, we reinitialized all counters.

Table 1. Participation Metrics (Mean Value)

Scenario 1	Weeks 1 – 5	Weeks 6 – 10	Weeks 11 – 15
Number of articles	11.31	6.41	12.17
Perceived quality	5.89 / 7.00	5.92 / 7.00	5.95 / 7.00
Comments	28.97	13.00	31.97

Scenario 2	Weeks 1 – 5	Weeks 6 – 10	Weeks 11 – 15
Number of articles	3.20	7.15	12.41
Perceived quality	6.22 / 7.00	6.45 / 7.00	6.27 / 7.00
Comments	14.00	23.35	20.15

The results show that the perceived quality of contributions was better in the second scenario than in the first one. This can be a positive response to the participation strategy motivating quality. However, the number of published articles in the second scenario was lower than in the first one, even if there were more students in the second group. This can be explained since in the second scenario it was mandatory for students to submit a personal opinion of at least 300 words before publishing the contribution in the platform. Finally, the mean number of comments per article significantly increased in the second case (3.09) with respect to the first one (2.12). This can be explained because we induced a quality factor in the participation strategy, and this could have triggered more interest to generate better and more appealing contributions. Nevertheless, in order to properly conclude this fact, we need to carry on further research regarding this situation.

4.2 Network Analysis

After building the interaction graph (in each milestone), we quantified the metrics presented in section 3.3 in order to analyze the structure of the community in time. Table 2 presents these results for each study scenario.

Table 2. Network Metrics

Scenario 1 (30 nodes)	Weeks 1 – 5	Weeks 6 – 10	Weeks 11 – 15
Edges	292	282	321
Average degree	9.73	9.40	10.70
Average weighted degree	17.03	25.13	34.53
Modularity	0.12	0.12	0.14

Scenario 2 (48 nodes)	Weeks 1 – 5	Weeks 6 – 10	Weeks 11 – 15
Edges	436	662	429
Average degree	9.08	13.79	8.94
Average weighted degree	13.42	22.38	19.31
Modularity	0.28	0.19	0.40

Despite the differences in the number of nodes (and hence, the number of edges) in these situations, both the average degree (i.e. the mean number of students that are connected through comments) and the average weighted degree (i.e. the mean number of published comments in the platform) remain similar. However, there is a noticeable difference in both scenarios concerning what happened during the last five weeks: the average weighted degree is significantly greater in the first scenario, and the modularity is significantly greater in the second scenario.

Regarding the first situation, this might be a consequence of a “snowball effect”, since the goal of the participation strategy was merely to increase the number of contributions in the community. Therefore, the perceived metric of success is linked to the number of contributions published by the students. In fact, since posting a comment requires less effort than selecting and publishing a new article. This can be a plausible explanation for this particular difference. Moreover, this is linked to the participation metrics for the third period, presented in table 1.

Concerning the second situation, the higher value of modularity is opposed to the closed and homogeneous structure of the community during the whole observation period in the first scenario (when the participation was motivated uniquely through quantity of contributions). It is worth pointing out that greater values of modularity are correlated to the formation of subgroups within the community.

In order to have a closer look at what happened in this situation, Figures 5 and 6 show a visualization of each interaction network at the end of third milestone (i.e. covering weeks 11 through 15). The size of nodes represents the value of the weighted indegree, the colors represent the different modularity classes, and the thickness of the edges represents the number of comments that are posted in that particular sense.

In the interaction network of the second scenario (Figure 6), we can identify a clear subgroup in the community (i.e. black nodes). This subgroup consists of 12 nodes (25% of the network), it has a noticeable central leader (the biggest node in the group), and also a small node that is in between both subgroups. On the other hand, the interaction network in the first scenario (Figure 5) does not display a clear leader within the community, but rather a set of central nodes that gather the attention and drive the interaction of the other students. The structure in this case is rather closed and it does not display clear subgroups.

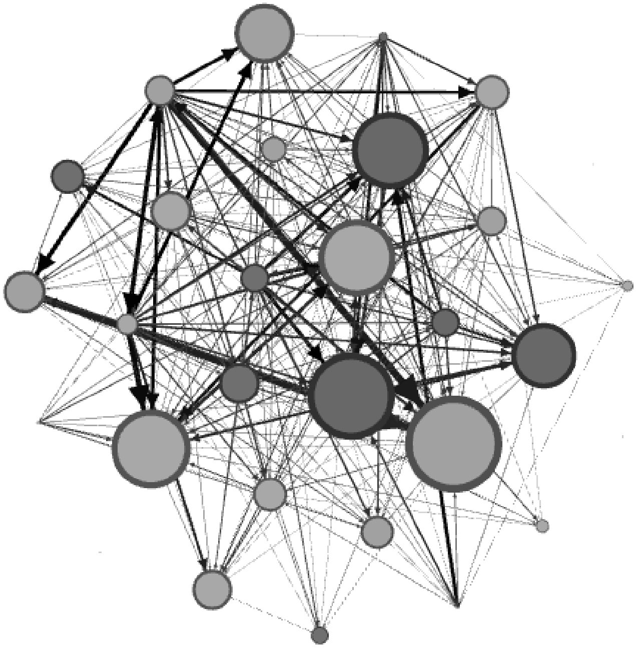

Fig. 5. Interaction network: Scenario 1 – Weeks 11 through 15

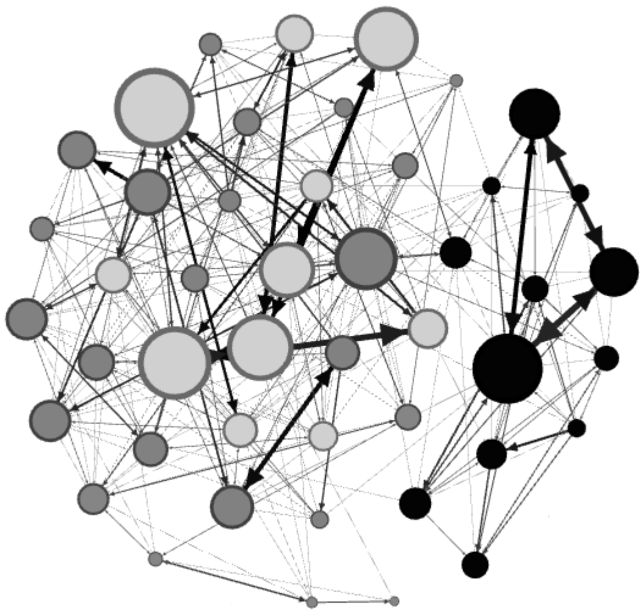

Fig. 6. Interaction network: Scenario 2 – Weeks 11 through 15

At this point, it turns out relevant to analyze if it is worth considering a community structure that is composed of two or more independent subgroups, or if it is better to have a closed and tightly connected group. Both situations have their own pros and cons, and the answer to this dilemma is rather unclear since the answer depends on the context where the community is going to be established. In this case, since we are supporting a small partially virtual community, we would like to benefit from having discussions in small groups. However, to some extent we do have to maintain the size of these subgroups, avoiding that they become independent and generate traffic that will be eventually irrelevant to the rest of the community. Therefore, having a visualization that displays the dynamics of group generation over time would give signs of how the community is evolving, and also if it turns out to be necessary to put some control mechanisms in order to prevent the community break into independent subgroups. In other terms, this kind of analysis can be used for designing strategies for monitoring in real-time the dynamics of a community alongside its life cycle. In relation to this proposition, one way to affect the interaction patterns in the community would be to influence central nodes in the network (e.g. those that gather interest from other members and generate relevant and important traffic). In terms of affecting the participation strategy, this would be related to motivating the activity, aiming to integrate the different groups that appear to be in different modularity classes.

4.3 Identifying and Quantifying Motifs

Figure 7 shows a histogram representing the different isomorphic 3-node motifs in a directed network (as shown in Figure 4). By identifying the different 3-node motifs we can structurally analyze the network representing the community in more depth. In the case of Figure 7, we can see that it supports the results found when analyzing the modularity of the community.

In the first scenario (i.e. where participation was stressed in terms of quantity), the interaction patterns tended to close the group. Thus, the possibility of completing 3-cliques is higher. In this group, motifs 12 and 13 count for about 50% of the total, and they are almost-fully connected (12) and fully connected (13) 3-cliques. Therefore, this is an alternative way to conclude that the community was tightly closed.

Regarding the second scenario, the motifs 3, 7 and 8 count for about 50% of the total, and they all correspond to disconnected 3-motifs. This fact indicates that the community is partially connected (as opposed to what happened in the first scenario), and community managers could take some actions into identifying why this is happening. Eventually they can try to integrate the community, if desired.

In summary, by analyzing the histogram of 3-node motifs, community managers can get an overview of how connected is the community, and how the different interaction patterns are distributed in the whole group. In other words, this technique can be used as an alternative tool for monitoring the evolution of the community alongside its life cycle.

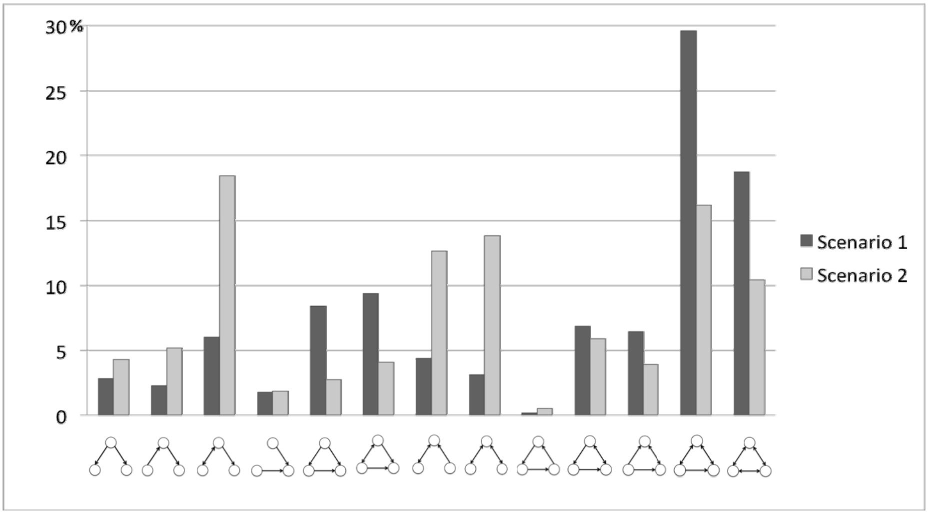

Fig. 7. Three-node motifs found in each interaction network

5 Conclusions and Future Work

This article reports the effects of exposing two homogeneous groups of university students to two different participation strategies in a partially virtual community over a period of 15 weeks. We aimed to motivate contributions in the first scenario by stressing the value of the quantity of contributions, and enhancing the quality of the contributions in the second scenario. We comparatively analyzed the activity within both groups in terms of: (1) participation metrics, (2) structural network metrics, and (3) 3-node motifs that reflect the interaction among members.

Even if we got some relevant observations regarding how participation can be triggered in terms of quantity and quality, it is worth recognizing that neither of both strategies was perfect. In the case of the first scenario, the group tended to follow a snowball effect, where publishing new contributions and generating traffic became the center of the community, rather than the interaction itself. In the second case, the community tended to split into two subgroups that interacted independently. Considering these results, we can say that the participation strategy clearly affected the community structure and the interaction patterns among its members.

By analyzing the different structural network metrics, and more precisely, by having a visualization that displays the dynamics of group generation over time, we can get a first idea on how the community evolves, and also if it is necessary to install some control mechanisms to prevent the community from breaking into independent subgroups. In other terms, this kind of analysis can be used for designing strategies to monitor (in real-time) the dynamics of a community alongside its life cycle. Another alternative for monitoring the activity in the community is analyzing how the community is structured in terms of motifs, which reflect the inner interaction patterns within the group.

There are two major limitations in this study. First, we modeled the interaction network as a directed weighted graph. However, the presented motif classes are based on directed unweighted graphs. Therefore, in the case of detecting weighted edges that outnumber the frequency of a particular motif class, we would need to analyze further in detail the resulting patterns and eventually decide if they need to be considered as independent objects. Thus, the global motif distribution of the network would be altered. Second, some of the presented observations might be due to the differences in the two even homogeneous groups of students. These limitations will be further analyzed in a second stage of this study.

As future work, we are currently studying how we can refine the second participation strategy, in order to better understand the interaction patterns within the community when quality becomes a structural issue in the group activity. In addition, we will carry further experimentation in order to understand how the different triads can be understood as a measure of social cohesion within the network. Finally, we are analyzing which are the correct metrics to consider when monitoring the evolution of a community alongside its life cycle, and how to design visualizations aiming to help community managers understand the dynamics of an online community in real-time.

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Work and Learning across Boundaries: Artifacts, Discourses, and Processes in a University Course

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Abstract. Boundary objects can provide bridges across boundaries and facilitate collaboration between learners with different backgrounds. In this paper, we explore cooperation in a cross-disciplinary and cross-cultural context, focusing on the opportunities for learning that arise at different boundaries and on corresponding boundary objects to facilitate both collaboration and learning. We present and discuss a study we conducted within a Cooperation Technology course. The discussion provides implications for collaboration support across boundaries, including insights on why they are important, how to facilitate their creation, and how to use technologies for that.

Keywords: cooperation technology, boundary objects, collaborative learning.

1 Introduction

Significant part of course assignments and projects at universities are done in groups in order to promote collaborative learning and to prepare students for team-based activities in a workplace. Participants of the collaborative activities often have different backgrounds, e.g., in terms of studied discipline and culture, schedules, level of engagement and interests. On the one hand, this may facilitate a creative process and innovative ideas through the "symmetry of ignorance" [1,2]. On the other hand, cooperation problems among the students are rather common and often lead to frustration and disruptions in the learning process [3,4].

Starting from the core notion of *learning communities*", in this paper we investigate how *boundary objects* can help improving collaboration and learning [5-9] within a university course. In particular, we explore opportunities for collaborative learning that arise when using boundary objects and related challenges.

The paper is based on a Cooperation Technology course at our university that integrates lectures with a group project in which the students had to collaborate in

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different settings to create shared artifacts, and thereby construct new knowledge. Cooperation was supported with a variety of tools that we will hereafter indicate with the generic term *cooperation technology*. Designing the course, we applied the social constructivist approach which implies that learners co-construct their environment and understanding together [10]. In the paper, we discuss the outcomes of the course and our experience, focusing on how students supported their cooperation across boundaries and used specific tools for that. Based on this discussion, we outline implications for cooperation support across boundaries in a social learning system, e.g., why boundary objects are important, how to facilitate their creation and what technologies to choose to achieve more efficient collaboration and learning.

2 Background and Related Work

Boundaries arise from “different ways of engaging with one another, different histories, repertoires, ways of communicating and capabilities” [5]. They are important to consider for supporting ‘social learning systems’[5], because of the learning opportunities they provide and connections they create between different communities and groups. Boundary objects are critical since they provide bridges and have meaning across the boundaries of the individual knowledge systems, groups or sub-communities that join together for some purpose [5-7]. Boundary objects serve groups or communities in situations where each participant has only partial knowledge and partial control over the interpretation of an object [6,8,9]. In this way, boundary objects allow different knowledge systems and communities to interact by providing a shared reference that is meaningful within both parts. Such objects perform a brokering role involving “translation, coordination, and alignment among the perspectives of different Communities of Practice” [6]. Boundary objects are typically negotiated, dynamic and have emergent characteristics.

Boundary objects can take different forms. According to Wenger, boundary objects can be classified into three groups: *artifacts*, *discourses*, and *processes* [5]. *Artifacts* may be documents, models, virtual places [11] that have meaning across boundaries. In our study, shared artifacts can be seen as physical representation of knowledge that a group of students collaboratively create during project work. Such artifacts become boundary objects if they are created by a group or a community and can be understood by all members of the community, and decontextualized. *Discourses* represent a common language that the participants of a collaborative process can use to communicate across boundaries [5]. Discourses are negotiated terms and language constructions that have the same meaning for all the participants. In our study, discourses can be seen as the language the students used to communicate in synchronous discussions and by commenting upon the work done by others. *Processes* include negotiated routines and procedures that allow coordination across boundaries [5], independently by practices established within boundaries. In our case, processes are represented by rules and agreements that allow synchronizing schedules and coordinating work styles of the individual students within and between groups.

The existing literature on boundary objects is typically focused on organizations and communities of practice. For example, Wenger uses examples of specialists and processes at Motorola and Xerox [5]. When discussing boundary objects in Communities of Interest, Fischer talks about cross-disciplinary designer teams (see, e.g., [12]). The concept of boundary objects is rarely used in pure (not corporate or professional training) educational settings (see, e.g., [13,14]). More work is done on exploring boundaries between institutions and communities (see, e.g., [15,16]). The authors are not aware of any systematic attempts to discuss the matter.

3 Study Settings

Our study is based on the data collected during the Cooperation Technology course at our university in autumn 2012. It was conducted with 31 students working in small groups (seven groups of 3–5 students in each) on a group project (counting for 70% of the final grade). Students had the possibility to form a group themselves, while the remaining students were put together randomly. Traditional lectures were used for introducing core concepts. This basic knowledge was intended as a conceptual tool to be used and extended in the group project. The project consisted of three tasks. For each task, the students were required to submit reflection notes. In addition, they submitted a final individual essay counted for 30% of the final grading.

Each task was designed to provide experience with a different form of collaboration, investigating three different types of boundaries. To support exploration and learning of different technologies, we designed the tasks around different cooperation technology, plus students could adopt additional tools at their choice for some of the activities, e.g., writing of the reflection notes. The tools we offered in the course were new for most of the students. This was intended to force discussion on the appropriation of technologies, critical thinking and reflective learning [17].

3.1 Task 1: Collaboration and Boundaries within a Group

The first task was centered on collaboration within a group and it gives us the possibility to explore boundaries between individual participants. The students enrolled for the course were from different computer-science related study programs, including both local and exchange students. Therefore, in most of the groups, the students had different professional and cultural backgrounds.

In *Task 1* each group was asked to create a handbook containing a description of at least 10 tools for cooperation, clearly specifying intended readers and selection criteria, and justifying the overall organization of the entries and their internal structuring. There was no restriction on the tools for internal cooperation and for the delivering format of the handbook. The groups presented their handbooks to their peers and visitors during a virtual seminar (Fig. 1) held in vAcademia 3D virtual world (http://vacademia.com/) and created 3D recordings of their presentations [18]. In such a format, a presentation is a performance and an artifact at the same time.

Fig. 1. Student group presentation in vAcademia

3.2 Task 2: Collaboration and Boundaries between Independent Groups

The second task was centered on collaboration between groups, with each group acting as a single entity, but interacting with other groups by providing feedbacks. The boundaries in this context are between the groups which need to understand of each other's work to make a meaningful annotation or build up on an artifact produced by another group. In order to provide this type of experience and to challenge the students with such boundaries, we designed a task where they could interact with other groups, but producing shared artifacts within their initial groups.

In these settings, the students were working on *Task 2* where they had to use a mobile app LingoBee designed to capture language and culture related content in a situated context (http://simola.org/lingobee/) for producing (a) a dictionary of Norwegian phrases and (b) a glossary of cooperation technology terms (Fig. 2).

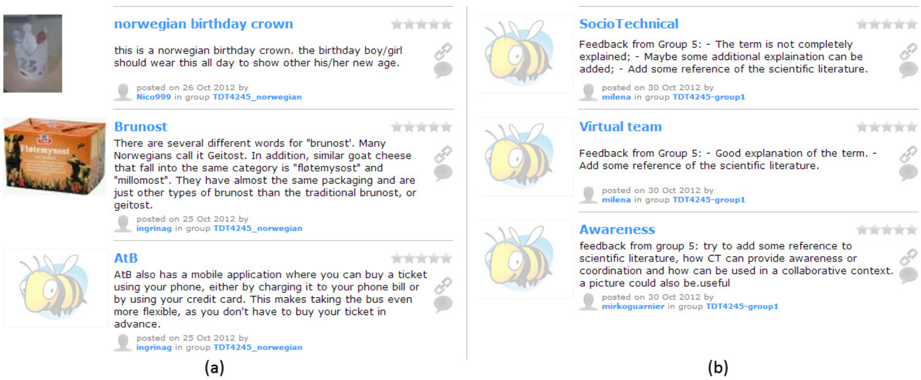

Fig. 2. Boundary Object – artifacts for Task 2 using LingoBee

Task 2 (a) was designed for a startup phase to learn the tool. The students had to create entries individually in a crowd-sourced dictionary and then comment and improve other entries and rank the best ones. For (b), each group had to create an initial draft of the entries in a repository visible only to the group. Then, all the entries were made public, and the groups had to comment on other groups' contributions and revise their own based on the feedbacks.

Sub-task (a) represented a typical scenario of usage for LingoBee (could have benefited from support for mobility); sub-task (b) was purposefully designed to stretch the usage boundaries of the tool. Feedback capabilities were not presented explicitly to the students, as reaching an agreement was expected to be challenging.

3.3 Task 3: Collaboration and Boundaries between Joint Groups

Finally, the third type of collaboration we consider happened when groups were merged into a larger group and worked towards a common goal. In this case, the merged entities need not only understand the work of other entities, but establish a common practice to be able to work together. In order to let the students experience this type of complex collaboration, we designed a task where they could interact with other groups more intensively and produce shared artifacts together with them.

In order to implement these settings, we designed *Task 3* where the students participated in a joint activity that was designed and conducted by CoCreat project (http://www.cocreat.eu/). This activity lasted five weeks and brought 68 students from Tallinn University (Estonia), University of Oulu (Finland), and our University. Our students were expected to apply their knowledge in a domain (education) that was outside their area of expertise. During the course, larger international groups were formed from local groups. All the course activities were conducted distantly.

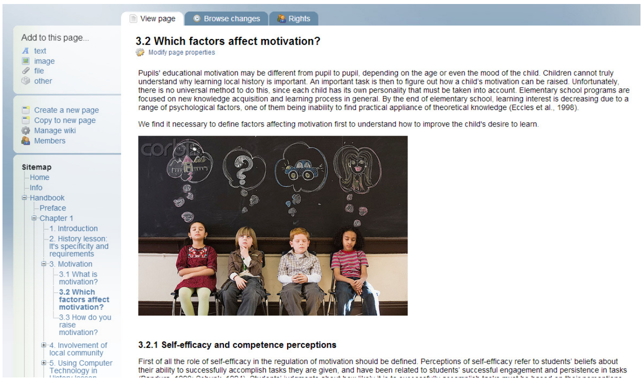

Fig. 3. A screenshot of a media handbook chapter made by the students

The joint activity consisted of several tasks aiming at creating a multimedia book. Each of seven international groups worked on one media chapter. Students were expected to base the contents of their chapter on given scenarios that represented real-life challenges of supporting learning with technology. Each chapter became a deliberate solution to the given challenge (Fig. 3). The quality of the resultant handbook chapters was satisfactory. The main misunderstandings of the task were that students from Finland must lead, as their competence was more theoretical. However, the evaluators were satisfied with the results after their comments were addressed.

3.4 Data Sources and Analysis

The data were collected from the direct observation of students' activities online, the virtual artifacts that they produced in each task (including automatically logged data), and users' feedback in the form of questionnaires, group reflection notes, and individual essays. The main data source for this paper was group reflections notes. Following the reflective learning approach [19], we aimed at promoting rethinking of this experience to learn from it. A template was provided for the notes of each task to scaffold the reflection process, pointing out specific issues to consider, e.g., the flow of work during the task and how it was affected by the technology used, how different technology influenced cooperation, and the tradeoff between creativity and efficiency. The notes were written collaboratively in groups, so that the students had to discuss their experience.

For analyzing the data from the student reflection notes and essays, we use the constant comparative method [20] that was originally developed for the use in grounded theory methodology and is now applied more widely as a method of analysis in qualitative research. It requires the researcher to take one piece of data and compare it to all other pieces of data that are either similar or different. We applied coding to identify the major themes in the student reflections, and later triangulated them with the direct observations of the course staff and with the outcomes of the student projects. Reflection notes for each task were coded separately with some "priori codes" [21] such as challenges and achievements in the process for each collaborative mode, discussions on the products/outcomes, and specific tools and technologies used. We were using a technique close to "cutting and sorting"[22] for identifying the themes.

4 Study Results

In this section, we present the result of our study structured by the types of boundary objects used in the course: artifacts, discourses, and processes. We intend that such decomposition of the boundary objects should clarify the collaborative processes we present and their use for collaboration support. For each type, we present how the students used boundary objects provided by the course, created their own objects, and used cooperation technology tools to support these processes. We present how the students reflected on the boundaries they faced in each task and how they succeeded or failed in overcoming them and learning from experience.

Each student group was using a set of technologies in addition to the ones offered by the course (Fig. 4). These technologies were chosen by the student groups without any specific recommendations from the course staff. These tools performed three major functions corresponding three types of boundary objects. They supported the construction of shared artifacts (e.g., collaborative writing), shared discourses (e.g., communication and reviews), and facilitated cooperation (e.g., group coordination).

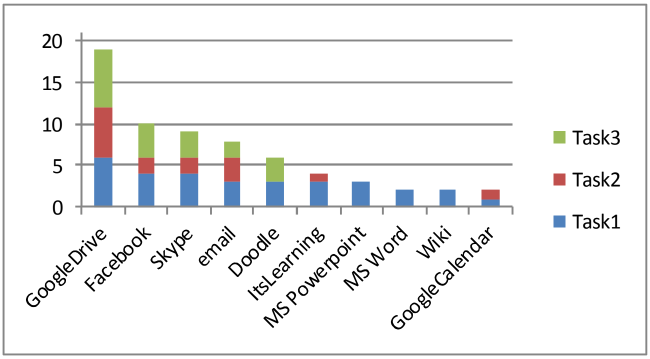

Fig. 4. The number of student groups using specific tools in each task

4.1 Boundary Objects: Artifacts

Shared artifacts have been the central type of boundary objects in this study. In our case, the outcomes of the student group work played the role of boundary objects of the artifact type, being created collaboratively and conveying certain meaning across all types of boundaries involved in the study.

The shared artifacts offered by the course for Task 1 were only the description of the task itself and a template for the expected outcome. The shared artifacts created by the students in Task 1 were the handbooks of tools for cooperation. In addition, technologies that were directly used for constructing shared artifacts can be seen as boundary objects of the artifact type. Microsoft Power Point and Word were used only in Task 1 (by three and two groups correspondingly), when the cooperation required less negotiation and equalization of technological preferences (Fig. 4). Six groups used Google Drive/Docs, as was familiar for all the students and the most appropriate for collaborative writing (Fig. 4).

The handbooks were delivered in different formats, five as documents and two as wiki portals (http://tdt4245.wikidot.com/wiki:handbook-for-group-projects/ and http://ctools.wikispaces.com/Collaborative+Tools+for+Designers+Handbook/). According to task, the handbook had to include the selection criteria for the presented tools and the intended use. Five groups (not necessarily matching mentioned above) dedicated the handbook to the computer science students or professionals, while the other two – to musicians and to designers.

None of the groups reflected upon any challenges directly related to construction of shared artifacts (as all of them were related to discourses and processes). Starting to work on the virtual presentations of their handbooks, six groups found the vAcademia tool too complicated. Nevertheless, all the groups managed to deliver satisfactory presentations (Fig. 1). The recordings of single groups' presentations became boundary objects, as the students had to rethink their handbooks for the new format.

The main shared artifacts offered by the course for Task 2 were the LingoBee app and its repository, which was structured as sub-repositories for each group. The repositories could be accessed through a mobile device or a website which can also be considered as shared artifacts. The shared artifacts created by the students in Task 2 were the crowd-sourced Norwegian terms (Fig. 2a) and phrases and the cooperation technology glossaries (Fig. 2b). Since both these artifacts were created using LingoBee, the artifacts themselves were in the form of LingoBee repositories (the dictionaries are available from http://simola.org/lingobee/index.php?gid=28 and the glossary from http://simola.org/lingobee/index.php?gid=29).

As envisaged, students experienced challenges in using LingoBee for Task 2 and consequently with shared artifacts. The main challenge, as reported by three groups was the lack of familiarity with LingoBee. In addition, all the groups stated that the tool was not fully suited for the Task 2 (b). However, two groups found solutions to overcome the challenges and completed the task using the tool. Three groups reflected that they found different tools to replace the missing (or undiscovered) functionality, thus resulting in new artifacts. The two other groups simplified the task to fit it into the basic functions of the tool and partly failed to complete it.

The main shared artifacts offered by the course for Task 3 were Purot wiki tool and the outline of the media handbook with abstracts for all seven chapters. In addition, the groups were required to use Prezi for creating presentations of their media chapters. The main shared artifacts created by the students in Task 3 were the chapters of the media handbook (Fig. 3). The handbook is an open resource available at http://cocreat.purot.net/.

In all the chapters, our students were responsible for the technology-related parts, as indicated in the reflection notes and the interviews. Six chapters were to some degree reflecting the pattern of a pedagogical elaboration of the given challenge enhanced by a set of technological solutions. Five groups conducted literature studies, and three of them supplemented them with field studies. Five groups (not all are the same as above) provided alternative technological solutions. All groups used various media in their chapters. The final presentations made in Prezi were demonstrated live at the joint meeting, using Adobe Connect for connecting universities.

The challenges and opportunities of the shared artifacts in Task 3 varied greatly. Reflecting upon Purot wiki, all the groups found both advantages and limitations. Three groups learnt to use the tool and mitigate its limitations, while four others preferred to use familiar alternative tools and insert polished pieces into Purot wiki. In fact, all the groups used Google Drive/Documents in this task (Fig. 4) either supplementary to Purot wiki or as the main working environment. In both cases, the student groups were constructing shared artifacts and using them across participants with different cultures, expertise, and roles in the joint groups.

4.2 Boundary Objects: Discourses

An important boundary object for this project has been a common language for negotiating meaning across the borders. In this case, such a ‘language’ needed to be established across different study backgrounds, formed group policies, and different cultures. Establishing shared discourses went very differently in different tasks and different collaborative settings. The boundaries in international collaboration were especially challenging, but as appears from the student reflection, the experience they gained was the most appreciated.

Working on Task 1, students in some of the groups were from the same study program and knew each other well. Six groups out of seven identified their group level collaboration as successful or at least satisfactory. Three groups discussed that the main contributing factors were good atmosphere, knowing each other beforehand, and having similar motivation levels:

– *The group has worked really good together, and we all had the same goal for this course. We have all put in approximately the same amount of effort.*

An LMS “It’s Learning” was actively used only in Task 1, when the groups’ technological environments were not yet fully formed and when the cooperation required less negotiation and equalization of technological preferences. Other groups started using Facebook and Skype for communication and creation of shared discourses (Fig. 4). Face-to-face meetings were also used extensively.

Generally, the students did not reflect on serious problems related to finding a common language within their groups. The only significant challenge was the difference in motivation levels. It was mentioned by two groups:

– *Collaboration is always a bit tricky when you are in a new group with random people. You don’t know each other’s working styles, rhythms, motivations, and interests.*

Establishing shared discourses between the groups imposed more challenges. The students mentioned such challenges 14% more often than benefits in the reflection notes for Task 2, discussing mostly the use of technologies, but also educational and cultural background diversity, lack of shared understanding, and other aspects.

LingoBee is designed to support a shared meaning of an entry through crowd sourcing input from learners and using ideas of social media; e.g., using ideas of wikis, users can enhance an entry by another user, provide feedback as comments, as enhancements or by rating or flagging entries by others. Use of these capabilities in LingoBee could be considered as discourse. The LingoBee repositories from the groups show that the students had enhanced and rated each other’s entries. Task 2 (b) required that students provide explicit feedback (see the term “Socio Technical” on Fig. 2b where the entry says that it is feedback from group 5) to improve the description and thus the common understanding of the term. In such a way, the feedback provided both within the groups as well as across the groups played the role of a shared discourse, where the meanings of terms are negotiated implicitly.

The students discussed around the terms that they entered to the LingoBee repository, using the chat functionality in Google Drive/Docs and face-to-face meetings.

This approach was used for negotiations within a group before passing certain ideas to the cross group level:

– *Before creating the Google document, our group had a meeting where we discussed and commented on the other group's entries before commenting in the shared document.*

The reflection notes generally point out the limitations in LingoBee to support cooperation between groups. This may be due to a lack of understanding of the functionalities in LingoBee or it could be due to a preconceived notion of discourse by the students, either through their perceived expectations for the task or habit. We found a strong tendency in cooperation around creating the artifacts and discourse through explicitly coordinated activity such as face-to-face meetings rather than implicit discourse as supported by LingoBee.

All the student groups discussed cooperation in Task 3 positively and acknowledged its benefits for creativity and learning. The students emphasized the advantage of working with people with different backgrounds (symmetry of ignorance [2]) for creativity and generally the success of the project, as four groups explicitly stated:

– *We […] were able to complete a far more complicated task than we would have been able to by ourselves. Through working with students with very different expertise than us, we were able to gain insight in to another way of looking at our field of study.*

The students were encouraged to learn being tolerant to the cultural differences. The fact that the Finnish and Estonians were more "polite" and appreciated "small talk", while Norwegians were more "straight to the point" and "task-focused", led to a gradual adoption of some joint communication norms (or a shared discourse).

Despite the extensive positive feedback, establishing sharing discourses became very challenging, and six out of seven groups reflected on that. The students mentioned such challenges 135% more often than benefits in the reflection notes for Task 3. This includes educational and cultural background diversity, lack of shared understanding, and other aspects:

– *Since the teams were from different fields of work, we had different understanding for the same topics so it was sometimes a challenge to explain to each other our points of view and to make a unanimous decision which way to go.*

In many cases, the students failed to establish fruitful communication and create appropriate boundary objects to establish shared understanding, adopting a simplified approach to negotiation of meaning:

– *Having only one person from each country meet online over Skype and then informing the rest locally was quite efficient […]. However it was not helpful when it came to knitting the groups closer together and making the participants feel more connected to the project.*

All the groups found both advantages and limitations of Adobe Connect – the tool for communication offered by the course. Five groups used it as the main synchronous communication tool (although, only two groups were satisfied), while two groups switched to more familiar alternative solutions. Purot wiki is the tool for collaborative writing offered by the course for Task 3. Being based on wiki technology, this tool also had functionality for creating shared discourses.

4.3 Boundary Objects: Processes

Shared processes proved to be important boundary object type in the presented study. Based on the study data, we can state that creating the processes type of boundary objects was relatively easy within groups. However, it was much more challenging on the cross groups and international level.

When reflecting on collaboration within groups (mostly in Task 1), three groups emphasized that the main factors for successful collaboration were planning, coordination, and extensive use of online tools for these purposes:

– *That decision [to use Google Drive, Doodle] enhanced the overall effectiveness of the collaborative effort […] and every active member respected the deadlines.*

The students did not identify many challenges for establishing shared processes on the group level. Small local groups were easier to coordinate than any activities between local groups or on the international level. The most common challenge was the differences in time schedules of the members. It was discussed by four groups:

– *Collaboration is always a bit tricky when you are in a new group with random people. You don't know each other's working styles, rhythms, motivations, and interests.*

When reflecting on collaboration between groups (mostly in Task 2), only two groups were discussing how they overcame coordination boundaries between groups. At the same time, five groups were reporting that the problems were too serious to handle. We identified three major types of challenges with establishing share processes between groups. The first one is related to negotiating the procedures of giving and receiving feedback between the groups, as two groups explicitly stated:

– *The review of group 4 gave us better insight in how the entries ought to look, as they had done a better job than us with the first draft. Thus, we were now aware of some of the improvements we could do for our final draft.*

The second type of challenges was related to negotiating how the group would interact with other groups as a single entity (e.g., acting on behalf of the group):

– *Then later that night he had posted his feedback as the entire review, before anybody else had been able to comment. Since we were only allowed to upload one review together as a team, we felt powerless and disappointed.*

Finally, the lack of a leader who would take responsibility for coordinating activities between the groups was explicitly identified by three groups:

– *Coordinating feedback between the groups was hard because there was no natural leader involved. No one wanted to take responsibility for coordinating the groups.*

The collaborative processes supported by LingoBee are sharing entries with other learners; thus browsing, enhancing each other's entries with new ideas, and providing feedback and ratings. Most of the groups elaborated on the flow of work where a group had an explicit task for individuals to collect their terms, then to discuss them within a group, before entering them to the LingoBee repository; i.e. an implicit process of agreeing upon which terms to enter.

When working in joint international groups in Task 3, the students experienced even more challenges with establishing shared processes, as six groups out of seven explicitly identified. When attempting to establish shared boundary processes, the students encountered problems that could be roughly divided into three types. The first type of challenges is related to the lack of group cohesiveness:

– *[We] did not get the same feeling of team spirit and group cohesiveness with the internationally distributed group as the local group. Without social interaction in the same way as local teams we did not get the same feeling of responsibility. […] This resulted in less effectiveness and less motivation for the task.*

The second type in related to negotiating coordination between local groups within international groups. As the students often failed to establish efficient routines for joint meetings, they used "brokers" [5], selected persons from each national subgroup, to negotiate on their behalf:

– *During the project, a clear leader was missed. From Finland and from Norway some people took the responsibility of dividing tasks and making groups but overall a clear feeling of responsibility was missed.*

Finally, the third type of challenges was related to the lack of appropriate tools supporting cooperation in larger groups. The course did not offer specific tools for creating shared processes, but each group selected them while working on tasks 1 and 2. However, for Task 3, they had to start this process again negotiating with international subgroups, often selecting such tools that were familiar to all subgroups (e.g., Facebook, Skype, and Doodle), and used them more extensively (Fig. 4):

– *Another problem was that there are many tools that can support cooperation between four persons but it is more difficult to find the tool that will have good support of cooperation in larger group.*

5 Summary and Implications

In this section, we summarize the results of the study and present our implications for each type of boundary objects. Our analysis shows that boundary objects played an important part in facilitating group work at all levels, but a number of problems were discovered. In particular, when comparing the use of boundary objects in different tasks, we identified the following trends and challenges:

- Successful collaboration in a diverse group requires more complex boundary objects.
- The lack of clear leadership in such a group may lead to breakdowns in collaboration and limited use of boundary objects.
- Initial creation of boundary objects as artifacts will normally benefit from a template or a pre-defined structure.
- Boundary objects as discourses are crucial in international, large, and distributed groups, but challenging to establish.
- Creation of boundary objects as processes requires direct external support on both the intergroup and international levels.
- Cooperation technology tools may play the role of boundary objects as artifacts, discourses, and processes.
- Allowing a certain degree of freedom in constructing boundary objects benefits both learning and group work.

As appears from the reflection notes, students expected that certain facilities/boundary objects being already in place such as “established leader”, “shared spaces”, etc. Some boundary objects had been provided by the course, but they have not always been sufficient. Also, while one of the intentions behind the course was to motivate the students to create own boundary objects, they did not always succeed in that, especially when they did not have anything to start with. Therefore, in the following we discuss what initial boundary objects should be “seeded” and how to facilitate creation of new ones, especially in a diverse, cross-disciplinary setting.

Table 1. Seeding boundary objects as shared artifacts

Observations	Implications and recommendations
Difficulties in starting collaboration in tasks 2 and 3 (using different tools was a common reason)	Creating initial shared artifacts to establish a common understanding between sub-groups or individuals, e.g., tutorials, presentations of study topics, templates, and designated tools and repositories
A single main course environment (LMS) was not used (apart from getting initial tasks and for submissions) as it did not have the necessary functionality.	Establishing shared group spaces / tools / artifacts to mediate activities with one major (serving as ‘nexus’ and the main group space, providing awareness about activities in secondary ones) and several accompanying technological platforms with appropriate means

Table 2. Facilitating creation of boundary objects as shared artifacts

Observations	Implications and recommendations
Use of different tools for working on the same documents (e.g., wiki and Google Docs) and discussing them on other platforms (e.g., Facebook)	Linking and annotating versions of boundary objects across different media, providing mechanisms for organizing objects in repositories
Use of familiar tools even if the new tool was more effective – barriers for investing time in learning new tools	Providing instructions to make full use of its potentials and a list of alternatives

Table 3. Seeding boundary objects as shared discourses

Observations	Implications and recommendations
Materials about the foreign groups were useful, but not sufficient/complete	Introducing boundary objects in advance, including shared curriculum, study materials, and goal descriptions
The joint meetings were useful for establishing shared understanding, but the students struggled organizing them.	Conducting scheduled joint activities, including, e.g., tutorials, workshops, and lectures, especially in the beginning
Problems with understanding their collaborators and explaining own point of view across different disciplines	Establishing designated shared information spaces for reference materials

Table 4. Facilitating creation of boundary objects as shared discourses

Observations	Implications and recommendations
Problems reaching a common understanding of the tasks, roles of sub-groups or individuals, etc. Students appreciated the presence of tutors at the meetings.	Providing moderator assistance during meetings/negotiations
Problems starting collaboration without knowing all the peers and their communication habits. Informal communication is important.	Conducting scheduled "ice-breaking" and socializing activities in addition to purely course-related collaboration, especially in the beginning
Communication improved after introducing technologies that were familiar to all the group members (e.g., Google Drive and Facebook).	Providing mechanisms for mapping workspaces and social networks, e.g., connecting user accounts, or shared artifacts, discussions, and data repositories

Table 5. Seeding boundary objects as shared processes

Observations	Implications and recommendations
Problems understanding the task, especially when international sub-groups were involved	Providing task descriptions with clear instructions on the process, including possible roles for the individuals (or sub-groups) and a timetable
Problems in finding time when all members can meet	Securing time slots when all participants can be available for joint activities
Missing feeling of team spirit and group cohesiveness, esp. in international teams	Conducting regular activities in the designated group spaces
Problems finding a suitable tool for supporting collaboration in larger groups	Providing assistance with complex boundary objects (e.g., groupware tools)

Table 6. Facilitating creation of boundary objects as shared processes

Observations	Implications and recommendations
Use familiar tools for organizing the collaborative process (those who chose learning new tools did not regret)	Providing designated tools that are familiar to majority of the students to increase efficiency, and exposing students to unknown tools to allow them exploring new collaborative processes
Individuals (or sub-groups) had different level of motivation, and this caused problems with participation and commitment.	Motivating and assisting students in identifying roles and developing a set of rules/"working contract"
Problems identifying a leader and subsequent coordination problems	Providing assistance (for, e.g., assigning roles) when no clear leaders available

In order to perform a systematic analysis of collaborative activities across boundaries, we used a classification framework of boundary objects originally suggested by Wenger for organizational contexts [5]. As to our knowledge, this framework has not been used before in educational projects. However, typical student projects exhibit several characteristics of real-life professional projects, which makes the framework applicable for educational contexts. We also apply the framework originally developed for communities to student groups since we consider groups as subjects within a learning community and a part of the activity structure as suggested by Engeström [23]. Our experience shows that the framework we used provides the breadth necessary to cover most of the collaborative activities in diverse student groups.

6 Conclusions

In this work, we have explored how boundary objects facilitate group work and learning across different boundaries in educational context. In particular, we have studied how boundary objects are used in different types of group tasks. Based on our experiences, we identified learning opportunities provided by the boundaries and suggested how to facilitate cooperative processes within and across groups by seeding appropriate boundary objects and supporting their creation during group work.

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Redesigning Collaboration Tools to Enhance Social Presence in Online Learning Environments

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Abstract. This study aimed to investigate through a rapid ethnographic research the behavior of the main communication tools of collaborative learning environments (CLE) to foster students' social presence. Two research questions guided this work: (1) Are there limitations of synchronous and asynchronous collaboration tools in promoting students social presence? (2) Does extending social interactions to external collaborative tools from the CLEs contribute to the improvement of social presence of the students? This research provided support for the redesign of synchronous and asynchronous communication tools for the CLE Amadeus [1], in order to improve students' social presence in online courses.

1 Introduction

In an age where the Internet and web applications are fundamental for the development of human interaction, the landscape of education continues to change due to constant evolution of computer-supported collaborative learning. Collaborative Learning Environment (CLE) diminishes the barriers imposed by physical space and time between learners of online courses by offering ways of interaction, control, coordination, cooperation, and communication between the parties that make up the online learning [19]. The CLEs aren't simply channels for the transmission of information, but environments where users can construct knowledge through conversation and collaboration, providing many possibilities for user interaction through synchronous and asynchronous tools.

According to [2], student interaction in CLEs has implications on learner engagement and collaboration, while [3] associate online collaboration with improved

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volume and quality of student involvement, satisfaction, engagement, and higher-order learning.

One of the most important and popular concepts to describe and comprehend how people interact in a CLE is the notion of social presence, which measures the degree which one learner considers another to be a “real person” within the virtual environment [4]. This degree of awareness can be influenced both by personal features and by tools provided within the environment that transmit social and emotional information about the other [6]. [7], [8] and [20] discuss the influence of social presence on the learning performance, and [3] relate the awareness of social presence with the degree of student engagement, satisfaction, collaboration and facilitation within online courses.

Some recent criticism and fears about the quality of the online courses are related to the significant communication problems between students in CLEs. In this sense, noise in the communication interferes with the quality of information transmission and generates uncertainties and misunderstandings regarding the content of lessons. Although several studies focus the prospects of the increasing number of synchronous and asynchronous tools on CLEs, little attention has been given to the evaluation of these tools: either in terms of usability or verified effective integration of these tools in the instructional design planned by the teacher.

The scant work available in this area includes studies by [9], [10] and [21], which use methods such as Heuristic Evaluation, the Assessment Method of Communicability and student's eye tracking pattern. Few works attempt an analysis from the students’ and teachers’ point of view about the usage of synchronous and asynchronous tools, about the extent of interactions using tools external to the CLE, and about the support offered to the teacher in terms of tracking these social interactions using the tools provided within a CLE.

2 Objective and Research Questions

The main objective of this work were to analyze the behavior of the teachers, tutors, and students using the CLE Moodle on a distance learning course at the Open University of Brazil and on a blended learning strategy using the CLE Amadeus, through a qualitative ethnographic research. From this qualitative analysis, propose a redesign of synchronous and asynchronous CLE communication tools in order to improve social presence in online courses. The research questions investigated in this work were:

1. Are there limitations of synchronous and asynchronous collaboration tools in promoting students’ social presence? What are they?

2. Does extending social interactions to collaborative tools external from CLEs contribute to the increment of social presence of the students?

3 Research Method

The researchers used *quick and dirty ethnography* [11] as the primary method of qualitative investigation over the course of one month's time at the Open University of Brazil, with the goal of understanding the users' culture, motivations, and values, along with the socio-cultural context in which it is inserted. This method diverges from the traditional ethnographic research because it has a more direct focus on relevant activities and covers a shorter duration of time. It also may utilize assistance from key informers to gather multiple viewpoints, and computer assisted qualitative data analysis software to conduct collaborative analyses [12].

Researchers designed and provided a survey for higher education students at the University, and conducted semi-structured interviews with teachers, tutors, and students, besides a Daily Diary written out of observations made during the studies. Subsequently, every document was codified using the qualitative analysis tool NVivo [13].

3.1 Participants, Environment and Procedures

The research was conducted from August 2, 2012, until September 1, 2012 in a center of presence support of the Open University of Brazil. Two researchers performed the fieldwork four hours per day inside the natural environment of the users, in effort to understand the full context of activities. They observed daily interactions on the CLE Moodle, via an administrator's login and password offered by the University. Observations were logged into a diary during the fieldwork, and photos and movies were taken to capture the environment, people and interactions.

The researchers conducted a survey of 89 students: 69 of these were enrolled in eight distance learning higher education courses distributed across five different cities, and 20 were enrolled in a technology course at the university that utilized a blended learning strategy. The CLEs used were Moodle and Amadeus, respectively.

Researchers applied Semi-structured interviews with the coordinator of one of the higher education courses that used Moodle, with the coordinator of a center of presence support, with three teachers (two used Moodle and one used Amadeus), and with five tutors and four students of the Open University of Brazil. To gain a better understanding of the virtual behavior of students using the CLE Moodle, key informers were used and daily tracking was executed and compared with the *in loco* observations.

4 Qualitative Data Analysis

Following one of the principles of the Quick Ethnographic Research, a specific software for qualitative analysis was used, NVivo 10, to encode collected data during the interviews, photographs, videos, and observations. Besides that, an extract of the answers given by the students during the survey was quantified. This analysis was the basis for the redesign process of internal and external communications tools for the CLE Amadeus.

4.1 Survey

The survey was intended to get a general vision of how students interacted with the CLE. The major focus of this research was to identify the tools used for the construction of the social interactions. 95.7% of respondent answered that they used the discussion forum to communicate with other students, teachers and tutors, while 78.2% used the direct message tool to maintain communication. Additionally, 56.5% wanted online social networks integrated with the CLE, in a way to facilitate and promote greater interactions among participants in the distance learning process. 46.4% of the students answered that they felt some need for a synchronous collaborative tool in the CLE, in which the most mentioned was the chat.

63.8% of the students replied that they accessed the CLE daily, 31.9% accessed it at least three times a week, and 4.3% do so less than three times per week.

When surveyed about their usage of online social networks, 85% of the students responded that they used at least one social network, and most of them used at least two. 53.6% used the online social network Orkut, 76.8% used Facebook, 53.2% used Twitter, and 11.6% used MSN.

Of the students that claimed not to use any social network, 20% replied that they do not participate in the discussions proposed by the teacher in the CLE Moodle, versus 5.8% from the set of the surveyed students. 50% of the students that didn't use any social network do not communicate with other students using CLE Moodle during the course, against 43.5% of surveyed students. 30% of the students that didn't use any social network would like to have chat tools available, against 46.4% of surveyed students. And none of the students that didn't use any social network would like to have social network associated with CLE, against 53.6% of surveyed students.

These numbers show that students that use online social network daily also use more CLE synchronous and asynchronous communication tools. Integrating tools external from the CLE, such as online social networks, it can potentially increase the quantity and quality of the interactions, once the member network increases and exceed the limits of the already formed group.

4.2 Encoding Documents Generated in the Ethnographic Research

To analyze the research questions that guide this work, the documents generated in the ethnographic research were encoded using the computer assisted qualitative data analysis software NVivo 10. Pictures, videos, semi-structured interviews transcripts, and observations diary provided a large and rich volume of data. This was complemented by the student survey.

The data was encoded considering five nodes: (i) User experience with tools that promote social interactions in CLEs; (ii) Teaching presence: awareness and mediation; (iii) Extension of the social interactions beyond the CLE; (iv) Social presence of the teacher perceived by the students; and (v) Online teaching Practice to promote social presence. The codes were analyzed considering the research questions.

Reserch Question 1. To examine how collaborative tools on the CLEs can limit the social presence of the students, teachers, and tutors, the researchers analyzed their usage of several different tools. Table 1 provides some excerpts of responses that illustrate teachers' and students' opinions on the limitations of the discussion forum to promote social presence:

Table 1. Excerpts of the interviews with teacher and tutors about limitations of discussion forum to promote social presence

Source	***Excerpts***
Interview: Tutor 5 CLE used: Moodle	"[…] tutors and students use a lot of Twitter, Facebook and MSN, we often have to begin a discussion in a social network and then take it to the discussion forum in CLE."
Interview: Tutor 3 CLE used: Moodle	"They use so much the forum. I believe that some of them do not use this tool in a proper way, as well as other tools of the Moodle. A topic needs to be created when a new question must be done; otherwise you have to leave a comment in an already existing post."
Interview: Tutor 4 CLE used: Moodle	"I see that the students always prefer to create new topics to catch the attention of the teacher, thinking that if they leave a comment on an already existing post, the teacher will not consider it. It's difficult to see so much topics and replies, difficult to identify who had replied who."
Interview: Tutor 4 CLE used: Moodle	"[…] Even a student can begin creating a topics and everything unroll from then. Sometimes it can confuse the head of the students, because they don't know what that topic is about. […] For many times I saw that a question raised in a topic had already been answered in another topic, many times the same question."
Interview: Teacher 1 CLE used: Moodle	"It's difficult to understand the nesting of the posts in the forum (indent style); it's not simple to understand who is replying who."
Interview: Teacher 3 CLE used: Amadeus	"I always have to enter each forum when I login the platform, because there's no notification if there's a new message. […]"

In addition to the discussion forum, the Message tool is one of the most used on the CLE Moodle. The teachers, tutors, and students reported many limitations. Some of them perceived the need for a synchronous communication tool, a feature not found in the Message tool; besides of the impossibility to send a message to more than one person, and users perceived a difficulty communiting during the course, as evidenced in the following excerpts:

Table 2. Excerpts of the interviews and observations diary about limitations of Message Tool to promote social presence

Source	*Excerpts*
Observations Diary: Researcher	"They insisted that there's a lack of a tool in which they can identify exactly who is online on the Moodle in certain moment."
Interview: Tutor 3 CLE used: Moodle	"When the student want to urgently get in contact with the teacher and vice versa, it's difficult to know if he is online, the presentation of who is online is about the last five minutes."
Interview: Teacher 1 CLE used: Moodle	"The access to messages is not so clear and there's no global vision of the messages sent during the whole course."
Interview: Student 1 CLE used: Moodle	"When we want to send a message to another person, the system changes the screen a lot of time, confusing the path back. It should be more practical."
Interview: Tutor 4 CLE used: Moodle	"On the Moodle if I want to send a message to a student of even everybody, I have to do it one by one. […]"
Interview: Student 2 CLE used: Moodle	"I send messages to another online user and usually I don't get prompt reply, I don't know if it was because the user is not online anymore or it's because he didn't see my message."

In many cases, cultural aspects lead online education students, and even teachers, to aim for the immediacy of face-to-face interaction found in traditional classroom courses. In this sense, many users become frustrated with the synchronous tools in CLEs. Students associate this tool with rapid feedback and constantly compare their needs with tools used regularly for communication with friends.

Students reported feeling as though they don't belong, feelings of isolation and distance from the teacher. This could be the result of students' perception of the teacher's inavailability and/or a delay in feedback, whether the result of limitations of the CLE or the teacher's planning and execution. The fact is that, in general, these factors negatively impact student satisfaction and the results of student collaborations and learning.

Many respondents—both in the informal chats with the students and interviews with teachers and tutors—raised concerns regarding the need for immediate feedback from the teacher and tutor. The following excerpts show their perception of the need for new synchronous tools and perception mechanisms in real time:

Table 3. Excerpts of the interviews and observations diary about necessities of new synchronous tools to suporte immediate feedback

Source	*Excerpts*
Interview: Teacher 2 CLE used: Moodle	"The update of the Chat on the Moodle is very slow, you have to keep clicking to update it."
Interview: Teacher 1 CLE used: Moodle	"The students ask my MSN nickname very much, I believe that is because it is a tool that most of them use."

Table 3. *(Continued)*

Interview: Tutor 3 CLE used: Moodle	"When the tutor or teacher wants to get in contact with an student with urgency, there's no way to know if he is online, because it only appears the users that were online in the last 5 minutes."
Observations Diary: Researcher	"The main complaint of the students is the lack of feedback when they need. They claim the lack of a tool in which they can identify exactly who is online on the Moodle in certain moment."
Interview: Teacher 3 CLE used: Amadeus	"The tools on Amadeus have limitations in the forum and chat. There's not a system of messages, so I have to use the e-mail system, that is, log out the platform."

Teachers and tutors feel a need for tools that promote healthy collaboration, especially among students. Many noted that several of the communication tools on the CLEs are not used, and that they prefer external tools that perform similar functions.

Table 4. Excerpts of the interviews about CLE communications tools being preferred by external tools

Source	***Excerpts***
Interview: Teacher 3 CLE used: Amadeus	"Unfortunately the CLE Amadeus does not give us a way for the student and teacher socially interact. I can't send a message for another person; I can't leave a comment on a specific post in the forum."
Interview: Teacher 3 CLE used: Amadeus	"I would like to do a work in group so the student could interact more. Maybe if the Moodle could give us more collaborative tools, the students would be more identified with one of it"
Interview: Tutor 3 CLE used: Moodle	"I think that the student needs to feel comfortable with the environment and with willingness to participate, without obligation, like for example when they use MSN or Facebook."
Interview: Teacher 1 CLE used: Moodle	"The level of interaction between teachers, tutors and students could be better. I believe there's problems with accommodation of some teachers, unconcern of the students and limitations of the CLE tools offered."

Research Question 2. [14] highlights that online social networks have been incorporating virtual communities and the Internet, becoming a "new" form of organizing interactions. The formation of virtual communities is increasingly common both in distance education and in blended learning strategies. Online social networks are also growing in general, and they are being used formally and informally in the learning process.

Teachers tend to ignore social interactions in these external tools, sometimes because of the difficulty in tracking and integrating them with the existing toolset in CLEs, and sometimes because of prejudice or institutional rules that insist on disregarding this important means of promoting social presence in all areas, including education.

Despite this reluctance, and sometimes at the urging of students, teachers surveyed in this study did in fact use social networks like Facebook, Twitter, and MSN in the

Table 5. Excerpts of the interviews about the use of online social networks in the distance learning

Source	*Excerpts*
Interview: Tutor 5 CLE used: Moodle	"I made groups on the Gmail. I always do it every semester. If not the interactions do not meet the expectations."
Interview: Tutor 5 CLE used: Moodle	"[…] unfortunately there are students with a low frequency on the Moodle and every day they are checking their e-mails. […] Obviously that the main way is the Moodle, but if the student do not use it, we have to have another ways to reach the student."
Interview: Teacher 1 CLE used: Moodle	"Next semester I'll use the Skype instead of Moodle's chat."
Interview: Teacher 1 CLE used: Moodle	"The students ask my MSN nickname, I believe that this a tool used by the majority. […] I can't run away from the tools the students are used to use."
Observations Diary: Researcher	"I interviewed two presential tutors and tried to observe how they interact with the CLE, which are their priorities. They use a lot e-mail and social networks."
Interview: Teacher 3 CLE used: Amadeus	"They report they find me much easier through Twitter or Facebook instead of Amadeus, perhaps because the way of perception on the Amadeus is not trivial."
Interview: Teacher 2 CLE used: Moodle	"There's work in groups, but the students prefer to interact among them through another tools instead of the Moodle."

distance learning process. Considering the importance of collaboration, teachers use these tools to build a community feeling, as we can see in the following excerpts:

The teachers and tutors made attempts to integrate online social networks with the CLE, though in ad-hoc way, to transport messages from online social networks to the CLEs and vice versa. We can see this behavior in the next excerpts:

Table 6. Excerpts of the interviews about the transport messagens from online social network to CLE and vice versa

Source	*Excerpts*
Interview: Tutor 5 CLE used: Moodle	"There was a student that sent a message to me; he was online on Facebook, wanting to ask a question. I said to him to copy and paste on Moodle. It's an orientation question."
Interview: Teacher 3 CLE used: Amadeus	"I saw mentions in one of the discussion forum happening through Facebook. Why do not integrate it? Why not use the Amadeus for this discussion?"

In order to break down the barriers between actors in the online education process and encourage students to minimize their social limitations (e.g. fears, shame, and distance), teachers and tutors interact with their students using collaborative tools outside of the formal education process, as shown in Table 7:

Table 7. Excerpts of the interviews about eliminating the barrier among actors in the online education process

Source	***Excerpts***
Interview: Tutor 5 CLE used: Moodle	"Because we create bonds through Facebook, Orkut and Twitter, the students feel more comfortable to ask me some things because they already know me."
Interview: Teacher 2 CLE used: Moodle	"I join some social networks […] and some students have the tutors and teachers as friends on the social networks."
Interview: Teacher 3 CLE used: Amadeus	"I use Facebook and Twitter. Most of my students do not follow me these social networks. I encourage them to use it, but I ask that they post their asks on the CLE

In the informal conversations, teachers and tutors said that since these tools are not integrated into CLEs, they are more difficult to track and monitor. As Teacher 2 stated, "At the same time everything is registered on the log, while other external tools can't be, they are not part of the student's profile on the CLE."

5 Design Method

Activity theory is a key concept in the humam-computer interaction area, as an approach to fill the gap between theory and practice. It provides perspectives about human activity and a set of concepts to describe it. An activity consists of subject(s) and objective(s), artifacts, community and its rules, and the division of labor. In other words, through Activity Theory, human practice is studied locally, inside its context, and incorporating all socio-cultural factor that affect it [16].

Activity theory provides a method to structure, clarify, and comprehend data gained by field observations. It also provides a philosophical and interdisciplinary framework to study different human practices, helping designers to capture the users' current practice and construct models for future activities [5]. This design method utilizes the Engeström Triangle to model activities.

Although countless papers presents solutions for the software design based on the Activity Theory, especially on Engeströn's diagram, there are a few limitations on evidence [15]: (i) propencity to represent only the objects shared through collectivity, leaving aside the other objects on many interaction levels; (ii) human practices are multi-task, in other words, people perfom simultaneous actions and (iii) the non-representation of the activity as it is developed through time and division in more atomical levels like action and operation.

Considering the analyzed data and the elements defined from the Activity Theory, the researchers constructed informal narrative descriptions showing human practice situated as it occurs in the present moment, and created future scenarios to determine the potential impact of their innovation. Those narratives tried to reach different levels of analysis through the Hierarchical Structure of Activity, finding the routine tasks of the teachers and students, in other words, the operations performed without the necessity of consciousness upon it [17]. The design process was finished with the construction of prototypes using the tool Balsamiq Mockups.

5.1 Models and Prototypes

Initially, the Engeström Triangle modeled all the identified activities. Therefore the researchers needed to discern from the collected data what could be considered an activity, according to Activity Theory. Each was then described in terms of subject, tools, objectives, community, rules, work division, and product. This modeling was fundamental to refine, organize and compare the raw data collected. Figure 1 presents the Engeström Triangle of the Social Interaction activity through the asynchronous Discussion Forum of the CLE.

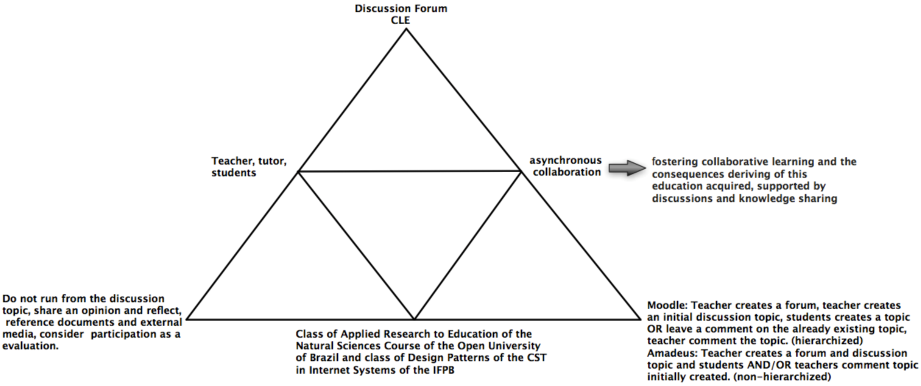

Fig. 1. Engeström Triangle of the Discussion Forum Tool

Figure 2 presents the Engeström Triangle of Social Interactions activity through the synchronous and asynchronous Message tool in the CLE. The Social Interaction activity through the tools externally integrated to the CLE wasn't modeled through the Engeström Triangle because the instances of the investigated CLEs on the ethnographic research didn't offer this integration.

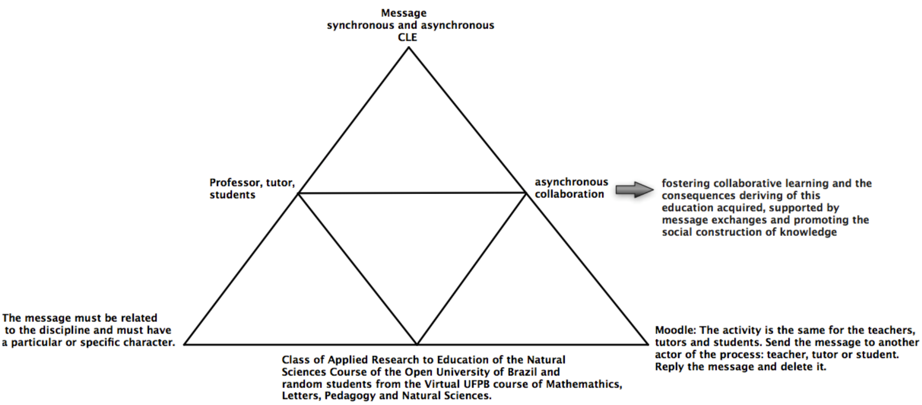

Fig. 2. Engeström Triangle of the Message Tool

The next step was to construct the actual scenarios describing these activities. The aim was to link every identified element on the Engeström Triangle in one informal narrative description to improve the visualization and understanding of the development of the activity and the levels of analysis that activity theory offers. From these actual scenarios, we identified problems and user needs, and built tables in which the necessities corresponded to each phase of the activity (table of user's needs). Table 8 presents an excerpt of the actual scenario and the user requirements of the Social Interactions activity through the asynchronous Discussion Forum in the CLE.

Table 8. Needs and User Requirements of the Discussion Forum tool

Actions	***Needs and User Requirements***
The students create a new topic or comment on in a previous topic as if it was the same action and has the same objective.	[REQ1] Only the teacher and tutor create a topic, initially, the students comment the main topic or the comments of other students, depending on its objective.
The forum interactions was made through the comments to the initial topic or to another comment posted by the teacher, tutor or student, promoting social interaction and collaboration. The visualization of this nesting is indispensable so the student to understand the content of the discussion and participate. The nesting in the Moodle is not easily comprehensible and it does not exist on the Amadeus.	[REQ2] Structuring the forum through the nesting of commented messages, in a way to made clear for the users who replied who. To enable that exclusively the teacher or tutor create the first topic and all the involved ones in the learning process can comment in unrestricted forms any comment made on that forum, providing a maximization of the social interactions.
On the CLE Amadeus, to realize how much messages exists in a certain forum, one has to access it.	[REQ3] Showing in the description of the forum the number of messages still unread on it.
It's possible that one discussion in one forum restricted to the actors involved in a certain subject can be enriched if transmitted also to a social network, where the mediator in this case would be the student building this bridge.	[REQ4] Provide the student or teacher to carry through one single click, a post from the discussion forum to Twitter or Facebook social network. There will be need for a configuration of the association of the login on the CLE with the login of Twitter and/or Facebook.

Table 9 presents an excerpt of the actual scenario and the needs identifies through the Social Interactions activity by the synchronous and asynchronous Message tool of the CLE:

Table 9. Needs and User Requirements of the Message tool

Actions	*Needs and User Requirements*
It was noticed through the observations and interviews a lack of awareness of who is online in the platform, since it gives you the information of who was online for the last five minutes.	[REQ1] Real time awareness of online and offline users. The list might not appear entirely in the screen, it might be reserved a space for a number or names and the others would be seen through scroll bars.
Interviewed users feel the need for a clear and specific space to send messages to online and offline users. There wouldn't be the need of pop-up screens, blurring the user's attention.	[REQ2] Clicking in one of the users of the list, online or not, a message box would be opened under the name of the user allowing the sending of the message. There's a space to enter a title and another one for the body of the message. There should be one Send and Cancel button.
It's not possible to send a message to all users; it has to be done individually.	[REQ3] Possibility to send a message to all users of a course at the same time.
Students reported the need to perceive incoming messages instantly, reporting the idea of instant messaging tools.	[REQ4] Awareness incoming messages instatly. Bellow the opened message there's one Delete and Reply button.

Table 10 presents an excerpt of the future scenario and the identified need for the Social Interactions activity through external tools integrated into the CLE. Twitter was selected for the integration with the CLE Amadeus, though it is adaptable to any tool that provides social interactions.

Table 10. Needs and User Requirements of the integration of the CLE with online social network

Actions	*Needs and User Requirements*
It was noticed that many students, teachers and tutors used online social network such as Twitter, Facebook and MSN to socially interact with subjects related to the course.	[REQ1] Integrate the CLE with online social network tools, offering ways to associate user login of the CLE with logins from the online social networks.
There is a limitation to access online social networks at the same time teachers suggested the social interactions to be done through the internal tools of the CLE. Many students insisted in using online social networks to communicate specially with the teacher and tutor.	[REQ 2] Due to the integration, while entering the CLE the user automatically and individually visualizes the posts related to the registered social network. The update of the visualization inside the CLE must be automatic.

The main purpose of prototyping is to allow some aspects of the future system to be evaluated by real users in an iterative, quick, and cheap way, before the system is formally installed. The CLE Amadeus interface is horizontally divided into three parts: at left is the main menu showing the Twitter feed of the current user. The screen in the middle – the main screen – presents the interface chosen in the main menu, which can be a discussion forum, or can show all the received messages, for example. On the right we see the participants of the course, online or not, and any unread messages.

The prototypes presented in Figure 3 refer to the modeled activities from the ethnographic research: (i) social interaction activity through the asynchronous tool of communication Discussion Forum and (ii) social interactions activity through the external tools integrated to the CLE.

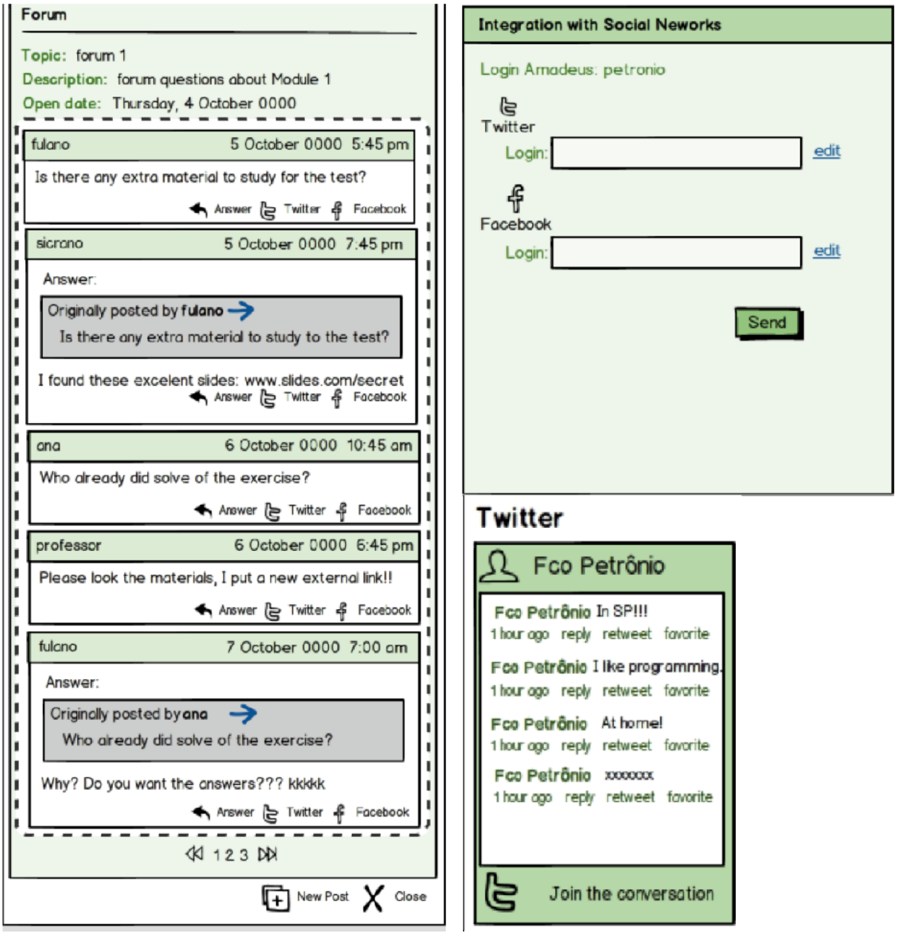

Fig. 3. Forum tool communication and twitter integration prototypes

The prototypes presented in figure 4 refer to the Social Interactions activity in the synchronous and asynchronous communication tool Message of the CLE.

5.2 Social Presence Evaluation

Prototypes were evaluated using the Focus Group technique. Focus groups are usually run with 5-8 people and sessions last about 1-2 hours, including a demonstration (and hands-on) of the prototype or system, followed by a discussion. The discussion is led by one of the researchers based on guidelines, trying to answer important research questions. The advantage is that feedback (e.g., on potential issues) can be provided in very early stages of the design process.

The users of the prototypes evaluation were divided in two groups, the first with a teacher and two tutors and the second one with three tutors; everyone were interviewed for the ethnographic study previously presented. The participants of the evaluation interacted with the prototypes and clearly identified improvements regarding the limitations of the Forum and Message tools, as well as improved facilitation of collaboration from the integration of Twitter with the CLE Amadeus.

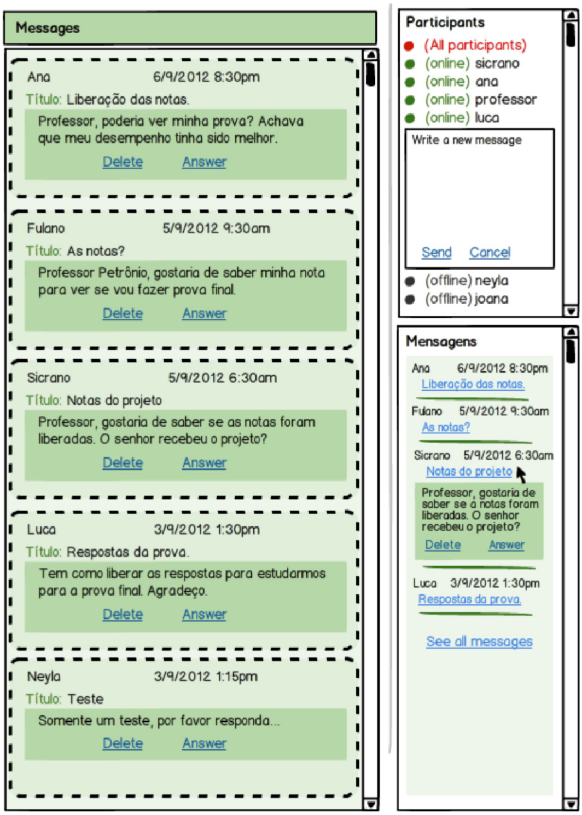

Fig. 4. Synchronous and asynchronous messaging

At the same time, the focus groups identified a few limitations on the prototypes, which could be corrected before the effective recoding, among them: (i) not allow the students to send messages for everyone on the course, otherwise the discussion forum could be avoided. Only the teachers and tutores could send messages for everyone. (ii) Remove from the forum messages, the button which allows a link between the post and the Facebook, since it wouldn't be already integrated with CLE Amadeus. Only the button for Twitter's link would be available, as well as the button for answering the post. The recommendations gotten on focus group were considered on the recodification of the CLE Amadeu tools.

In the recoding process, we have considered the needs identified in the ethnographic study, developed models and prototypes evaluation with focus group. After finalizing the recoding process, an experimental course about Python programming language was offered to 56 students of a college of technology. During the course, which took 45 days, a survey was applied to all the students enrolled at the 30th day. The instrument used was an adaptation of the survey developed for [19] to measure social presence on CLEs.

The results obtained showed a satisfactory degree of social presence among the students of the course on the CLE Amadeus. 84% answered that the online discussions helped them to learn; 96% felt that their classmates and teachers respected their opinions; 80% said that they have perceived the presence of theirs colleagues and teachers, and that in some way it have helped them along the course; 71% felt closeness to their classmates; 73% considered the energy of their classmates and teachers encouraged them during the course; 73% felt satisfied to have socially interacted during the course and 71% have perceived how their teachers and classmates reacted to their comments on the collaborative tools.

6 Conclusions

The methodology used for the development of this project proved to generate insights that led to the ideation for redesigning synchronous and asynchronous communication tools for CLE Amadeus. The qualitative method of quick ethnography offered a rich and complete understanding of usage context and helped to capture the analyzed environment more directly and quicker than would have been possible by other methods. The data were analyzed and encoded in a way to explore and answer the questions of the research, by using key informants, multiple researchers, and computer assisted qualitative data analysis software. It was done in order to minimize the limitations in traditional ethnographic research, such as field work overly long and time consuming, beyond the research focus wide open [18].

From the modeling based on the Activity Theory, we were able to build scenarios for the current observed situations that allowed us to identify user needs and to conceive the redesign of the communication tools. The prototype was developed through an iterative and incremental process, so each cycle could be evaluated and refined by users of the CLE Amadeus.

When finishing the iterative and incremental prototyping process, the redesigned collaborative tools were implemented and integrated into the CLE Amadeus. The researchers conducted a focus group with two teachers and four tutors in three sessions of two hour each. The participants of the evaluation interacted with the redesigned tools and clearly identified improvements regarding the limitations of the Forum and Message tools, as well as improved facilitation of collaboration from the integration of Twitter with the CLE Amadeus. The evaluation through the focus group provided a refinement of the usability of the produced interfaces.

Following this work, the redesign process, including the integration of the Twitter social network, has conformed to Amadeus SIMM, the module of the CLE Amadeus that monitors the synchronous and asynchronous collaborative tools such as Chat, Message and Discussions Forums, and it extends to external tools like Twitter [22]. Through these innovations, teacher can monitor group social behaviors like cohesion and heterogeneity, as well as individual behaviors related to each student such as their degree of interactivity, isolation, intermediation, prestige and engagement.

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The Metafora Design Principles for a Collaborative, Interoperable Learning Framework

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Abstract. In this paper we present the Metafora project for the support of collaborative learning activities in larger problems of science and math topics. We will present the design principles that guided our technical development of an architecture supporting collaboration across different learning tools. Interoperability between the tools mediated by so called referable objects is described, as well as the design issues of awareness and visualisation for the learning groups. We demonstrate the flexibility of our designs and framework in giving example cases for the usage of the Metafora framework with different tools and educational scenarios.

Keywords: Web-based collaborative applications, collaborative workspaces, computer-supported collaborative learning (CSCL), design principles.

1 Introduction - Web-Based Collaboration in Metafora

Over the last decades several collaborative learning environments have been developed for the classroom. The technology used to realise those systems slightly changed but there are still many pros and cons for either web-based or non web-based applications. As web-based systems usually imply restrictions compared to client based applications when it comes to flexibility and adaptivity of user-interfaces, web-based applications are more or less ready to use when opened in a browser.

In the EU funded project Metafora[1] we are bringing together a set of different learning tools for science and math that have been developed in other context and projects. Metafora combines different pedagogical strands, namely constructionism and collaboration, resulting in an approach called *learning to learn together* (L2L2) [1]. Constructionism [2] stresses an active role of the learner who is (re-)constructing knowledge by herself instead of knowledge being delivered by the teacher. Usually this is achieved by direct construction of artefacts,

[1] The Metafora project is co-funded by the European Union under the Information and Communication Technologies (ICT) theme of the 7th Framework Programme for R&D (FP7), Contract No. 257872, http://www.metafora-project.org/

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models, programs etc. Collaboration is another facet to engage students to a more active attitude during learning, stimulating argumentation, negotiation, planning and different kinds of strategic skills referring to management and task solution. This approach is applied to science & math classroom activities of approx. 20 school hours for project groups of 3-6 pupils of ages 12-16. The learning tools are integrated within the browser-based Metafora framework for collaborative and self-regulated learning and organization of the learning process to allow students to make use of the full potential of these tools while working within one integrated web-based environment, using a single login and having central access to all the available tools. Among these tools are constructionist Microworlds for Math and Physics, game-like environments for sustainability (Sus-X, cf. section 5.1) and ballistics (PIKI, cf. section 5.2), and the eXpresser editor for constructing mathematical patterns and algebraic equations [3]. As an umbrella Metafora provides a rich collaborative environment with a shared planning space [4], and – shown in Fig.1 – a group chat and the LASAD argumentation environment[2] as the selected tool tab in the main part on the right side.

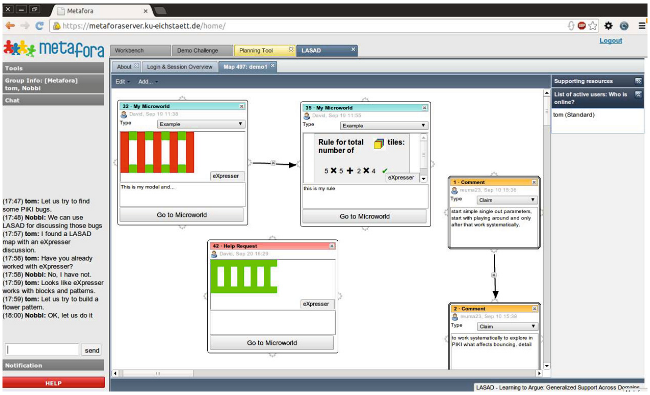

Fig. 1. Metafora system with the LASAD tool visible in the main part

One challenge of web-based collaboration is to overcome a major communication deficit between client and server. While standard web-based interaction is based on the request–response schema, i.e. a web client sends a request to a web server and the server sends a response back, this can only be used to notify a server of a user's action. Other users working on different web clients need to be notified of the same action by the server. One way to realise this update is to change the request–response mechanism and use the so-called *server push* technology which enables the server to actively send messages to web clients. Metafora uses this technology for the distribution of information between the web-based clients: the built-in chat, the graphical *Planning Tool*, and the propagation of updates in the awareness and sharing tool, called *Workbench*.

[2] `http://cscwlab.in.tu-clausthal.de/lasad`

2 Distributed Architecture and Collaboration Framework

Since the Metafora system is intended as a framework for various learning tools, a flexible approach for integration of learning tools is required, as well as a concept how to support learners appropriately in their process by means of intelligent analysis components.

Our resulting proposal for Metafora's architecture can be seen as a modified *blackboard architecture* [5]: several learning tools and analytic components can be used at the same time and do not interact directly with each other (loose coupling). All analytic components will be able to read and take up results from other analytic components and all learning tools will be able to send commands for interoperation between the tools, because a unified language is used between all these components. This allows the required flexible combination of learning tools and associated domain-specific and tool-specific analytic components with cross-tool or domain-independent components and can also be used with already existing indicator-based analyses, as e.g. from the math microworld eXpresser [3].

Our technical implementation to achieve this is to use a well-known and stable communication infrastructure, the *eXtensible Messaging and Presence Protocol* (XMPP), which for example is also used for Google Talk, the Facebook Chat and Whatsapp. Because of the wide spread use of the XMPP technology there are libraries for all common programming languages and frameworks. This is important for Metafora because it allows to easily integrate existing learning tools and microworlds into the framework.

For Metafora we need an open and flexible inter-tool communication between the various tools that do not require knowledge of other existing tools according to the principles of blackboard architectures. For this end we use the extension XEP-0045: Multi-User Chat [3] (MUC) to support multiple clients. We also want semantically interoperating communication between the various tools to generate a better learning experience. Even if XMPP is already an XML protocol we use it only as a (replaceable) communication channel. The messages sent via XMPP are represented in a unified format, called CoLoForm [6], to allow a uniform interpretation across the different analytic components, regardless of where the feedback / analysis was produced. The advantage of using CoLoForm as communication XML format and XMPP only as communication channel is the perfect fit of CoLoForm for our needs and the independence of the XMPP protocol and its implementations. To reduce the message overhead we use three MUCs for Metafora. The analysis MUC contains messages from analysis components and landmarks from microworlds. The command MUC contains the inter-tool communication, which means for example feedback commands which the framework should display for a set of users. The logger channel contains actions for most of the user interaction with the system or components of the system and allows creation of a joint log database. Cross-tool analysis

[3] `http://xmpp.org/extensions/xep-0045.html`

components can subscribe to both log- and analysis-channel and will post their results to the analysis-channel. The biggest advantage of this architecture is that any tool, which can be extended, can interact with the Metafora framework. Figure 2 shows the overview of the Metafora architecture including the blackboard-like approach for the analytic subsystem.

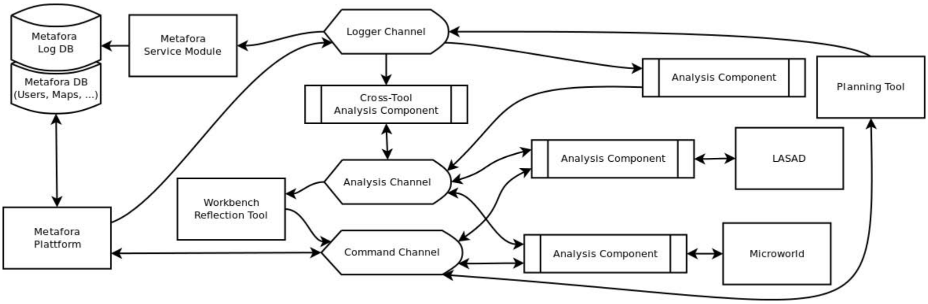

Fig. 2. Architecture overview of the Metafora System

Microworlds and learning tools with a web-based graphical interface can be integrated into the Metafora GUI with the help of inline frames. The technological basis of the tool doesn't matter. The Metafora framework also allows opening of any URL as inline frame with a command message. Most of the currently integrated microworlds use the Unity framework[4], which is a client-only framework like Adobe Flash, and these microworlds use a direct XMPP connection to our server for logging and inter-tool communication. For these learning tools, that do not have their own collaboration server, the file storage feature of the Metafora platform is especially interesting: allowing the client to upload states of the learning workspaces and retrieving them afterwards allows the usage of the tools inside the context of a larger learning activity without the need to create a collaboration server for each tool.

The learning tools for collaborative usage like LASAD[5] and PlanningTool are client-server based and use the *Google Web Toolkit*[6] as technological basis. Both LASAD and the planning tool use only a XMPP connection from the server side component and push the collaboration events to the clients.

The architectural backbone of the Metafora framework with its three channels of communication is fully implemented, while analysis components are currently under development. In this paper we will focus on the cross-tool interactions mediated through the command channel.

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[4] `http://unity3d.com/`

[5] `http://cscwlab.in.tu-clausthal.de/lasad/`

[6] `https://developers.google.com/web-toolkit/`

3 Design Principles for Multi-user Interfaces

Group awareness [7] is a major issue for designing collaborative user interfaces. The goal is to raise a user's awareness of the activities conducted by the other users of the group and to provide an orientation of the social context in which the system is used by the group. Depending on the degree of joint environment and the nature of the collaborative / cooperative task, awareness can manifest itself differently. [8] gives an overview about mechanisms how to support awareness in synchronous vs. asynchronous scenarios and closely vs. loosely coupled task contexts. In our Metafora case of supporting small groups in synchronous collaboration on learning to learn together, we can focus mainly on the synchronous and closely coupled case. We use a relaxed WYSIWIS ('what you see is what I see') approach in a way that the users can have their own view on a joint planning map and also different tools in focus currently. This means that sharing a focus of attention has to be supported by the system design. Among the support functionalities to provide awareness of peer learners' actions we provide:

- awareness of incoming chat messages by giving visual cues, when the user's chat is folded away in favour of other tools
- awareness of incoming notifications sent by intelligent system components or learning facilitators in a similar way to the chat awareness
- display of notifications of different severeness using three levels of intrusiveness (non intrusive, transient messages, model pop-ups)
- overview of group composition, online status and shared resources
- process awareness of the groups activities and achievements over time. The representation designed for this is currently called 'reflection tool' and will be described in detail in the following paragraphs

One other principle for the design of user interfaces for collaborative learning activities that is particularly relevant for long-term and complex activities involving multiple and intertwined tools, such as in Metafora, is a design for visualisations that do not put too much load on the user, yet still keeping the potential to retrieve rich information, if requested by the user. Our approach will be oriented towards the principles known as the 'visual information-seeking mantra' [9] that is cited as 'Overview first, zoom and filter, then details-on-demand'. The designs and proposals we will present for reflection on learning activities in subsection 3.2 will follow this mantra, in giving first an overview that provides visual cues of potentially relevant areas, then interactive zooming, re-focusing and filtering techniques to explore parts of the visualisation in detail.

Finally, in a highly heterogeneous environment as the Metafora system with several distinct learning tools, support tools, and analysis components, a real danger of media breaks when changing between different tools exists. Thus, there is a need to carefully consider aspects of interoperability, seamless transition between tools, and coherent interaction flow between the tools. In the next subsection 3.1 we will introduce the concept of *referable objects* that are one proposal in Metafora to allow the seamless navigation of users between different tools with a uniform mechanism inspired by theory, namely the concept of *boundary objects*, and the technical concepts of hyperlinks in the web and references to objects in programming languages.

3.1 Referable Objects as Boundary Objects for L2L2

Referable objects are not a new concept, but rather were inspired by the concept of boundary objects. Boundary objects are coined by Star and Griesener, who originally used boundary objects to maximize both the autonomy and communication between worlds in their study from 1989. They defined them as objects to depict the divergent use of information in divergent groups. Although they are plastic, a defining characteristic of boundary objects is that they contain enough changeless content to preserve a global identity [10]. In 2004 Hoyles used boundary objects in a classroom context. She wrote "a boundary object provides a generalized mechanism for meanings to be shared and constructed between communities" [11]. We will take up the concept of boundary objects as so called referable objects serving as mediating artefacts between different workspaces explained in the next paragraph.

We found a need for boundary objects in Metafora because students need to share individual elements, or objects, from one tool in another tool to allow discussion about the workings of one tool within another. When a group can share these objects (also with other groups), it is then possible to use the most appropriate tool to discuss and evaluate ideas focused on these objects, rather than being tied to the tool from which the object originates. This ability to visualize and discuss an individual object from one tool within another is powerful and helpful to students, but there is an obvious weakness: viewing an object isolated can cause the loss of context and meaning compared to viewing the object within its original environment. To alleviate this issue, and allow any user to see the full context of the given object, a **reference** in form of an address to the source of a tool where the object was created, is also recorded with the referable object. Through this reference, that has also a visual preview attached to it (i.e. a thumbnail picture of the object in context to allow identification of the object across different tools) learners are able to navigate directly to the place of the element and inspect it. So we can see that our concept of referable objects expands upon the concept of a boundary object, and as such we offer the following definition of a **referable object**: "an individual element or product of any tool that is recorded by the system in such a way as to allow students, teachers and researchers to reference this object for discussion or evaluation at a later point in time."

Referrable objects can be shared as objects to discuss and review in various places of the Metafora system. The students' ability to "discuss in the appropriate place" is one of the subconcepts of L2L2 that shall be supported by the system: thus, both formal argumentation in the LASAD system and more informal or coordinative talk in the group chat can be a place to share referable objects in. The screenshot in Fig.3 shows a referable object shared with the group in both the chat and the LASAD system. In both spaces multiple stakeholders, such as group members, teachers, or peer groups, can follow the reference and

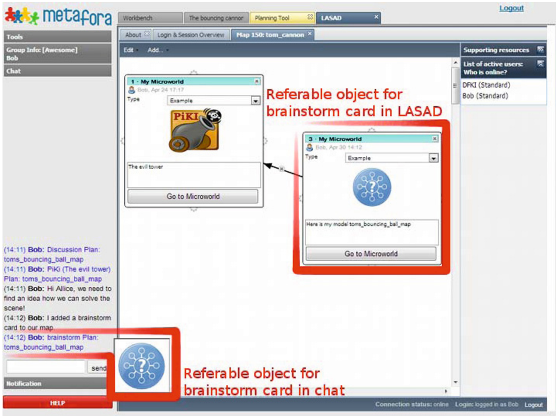

Fig. 3. A brainstorming activity shared from a planning map as a referable object to group chat and the LASAD argumentation system

directly inspect the shared object in its direct usage context, here the specific brainstroming activity in the planning map.

3.2 The Reflection Tool – Combining Principles of Awareness and Visualisation

One of the key factors for learning to learn together in Metafora is the ability to self-regulate, co-regulate and to reflect on others' and own actions during the learning process. In early experimentation we found out that the planning tool is frequently used not only for planning, but also for documenting and reflecting on the current progress and state. To stimulate these very much desirable meta-cognitive processes, we co-designed with some input from our pedagogical partners a visualisation for the support of reflection processes, shortly 'the Reflection Tool'.

Among the information the representation should provide, we identified the following situations and indicators:

– Help requests produced by the members of the group
– The extent to which these requests were responded and by whom, inside the group as well as from the outer community
– How close the group is to reach its goals when comparing plans to enactment
– To what extent the group carried out reflection over their activities
– If the group was confronted with a lot of disputes
– If the group reached consensus at any point

This information could be presented in isolation in table form or some time series diagram as prevelant in current *learning analytics* representations, such as for example the Learning Dashboard [7]. Yet, we believe that on the one hand the representation should be cognitively linkable to the tools, the information originated from, and on the other hand that the concrete visualisation should be designed according to sound information visualisation principles that don't require expertise in 'reading diagrams' as expected from business analysts and statisticians.

On the one hand we follow the argumentation in [12] to embed analytic features into the learning tools to contextualise it with the learning activity, on the other hand we sought inspiration in real-life and everday representations for the concrete visualisations: Based on an analogy of sports tickers (e.g. football, hockey, basketball, rugby) we connect a temporal dimension with the relevant events (goals, ejections, substitutions) happening in relation to timepoints and activities. Our events are meaningful L2L2 situations as listed above, while the time dimension is additionally enriched with information about planning activities happening over time. Each card in the planning tool is represented as a bar scaled according to the duration of the activity associated with the card, allowing an inter-linked interpretation of the reflection tool and the planning tool by the user. The visual representation chosen here shares some features with both Gantt diagrams from project management and also from the representation of a 'down' in American Football tickers. An example presentation of the reflection tool in conjunction with the relevant plan is shown in Fig.4.

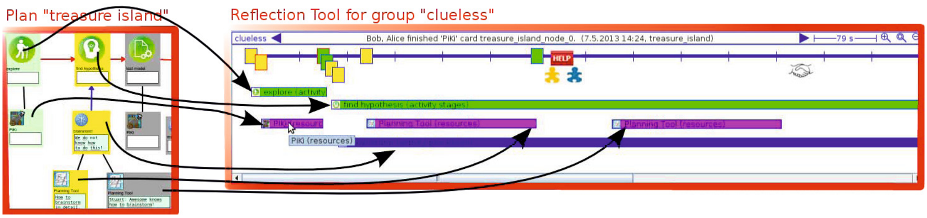

Fig. 4. Reflection tool with iconic representations of important learning events

The picture sketches out how reflection can be supported by means of an interactive visual representation that shows how the students acted and interacted across a temporal dimension shown from left to right in a time axis. Along this line the students can perceive their main activities represented as bars stretching out for their duration, here a green activity stage card started inside of which a resource card (i.e. a tool workspace) has been created and used. Relevant learning events, such as reaching intermediary milestones (shown as yellow and green cards), help seeking (the yellow user asked for help and the blue responded to it) or reaching a consensus (handshake symbol), are represented in relation to their temporal occurrence. The representation provides many interactive features to focus on specific elements, using filters and zooming features, to get overview and

[7] http://learningdashboard.org/

focusing capabilities in tune with sound visualisation principles from the HCI field: similar to the methods in image processing tools or video editing a user can zoom in by marking a rectangle defining the interval to zoom in to. Hovering on the iconic representation of a learning event gives more details, while clicking on it can be combined with an auto-focusing and centering of this event in the temporal dimension.

Since the reflection tool has been designed very recently in a participatory process based on users' needs and preliminary results of our evaluation, the tool has not yet been formally evaluated. We are currently in the process of designing controlled studies that specifically answer research questions about the support of the self- and peer-reflection processes and usability issues with the reflection tool. This is a first step, because the specific evaluation in-vivo will be difficult because of the complexity of the pedagogical scenarios of Metafora and also the system complexity involving multi-tool actions. In a second step we want to explore the role, usage, and aptitude of the reflection tool inside the whole Metafora approach, by adding specific questions on that to our final main experiments in class.

4 Example Case of Collaboration Principles

In this section we give an example how the Metafora framework can be used. One of the central components of Metafora is the Planning Tool. With the help of this component the students collaboratively plan their approach to the learning scenario and get a quick overview of open and running tasks.

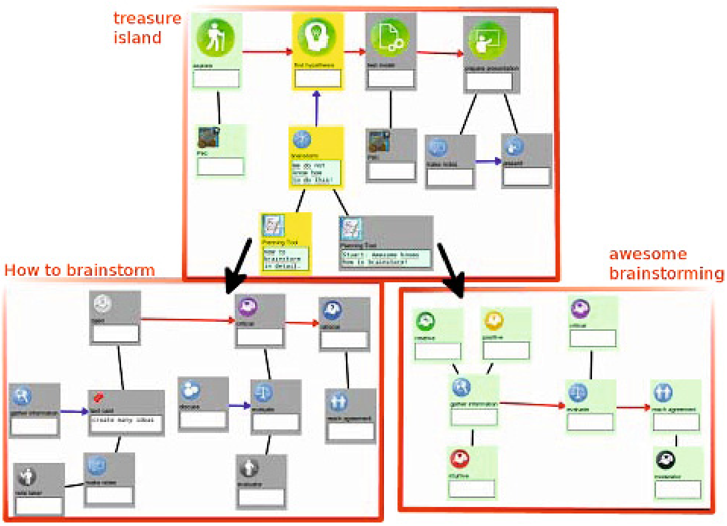

Fig. 5. Alice's and Bob's plan treasure island and both referred brainstorming plans

In our example the two students Bob and Alice get the task to solve a ballistic game scene in PIKI with the minimum number of shots using different bouncing surfaces. Therefore they join a group and create a new plan *treasure island* to approach the task. A screenshot of this plan is shown in the top of Fig.5. First they want to explore the plan to get an idea how the scene can be solved. Afterwards they want to phrase their ideas using brainstorming, test there conclusion and present the ideas to the other students. To explore the scene, they added a PiKI resource card which represents a link to a PiKI workspace. If they consider their playing with PIKI as a success they can checkmark the activity, thus changing the background colour of the card to green. Now they want to find an idea how to solve the scene with the help of brainstorming, but Bob and Alice are clueless how brainstorming works. To overcome this lack of knowledge they decide to create a new plan *how to brainstorm*. They could just create a new plan but they use the Wiki-like feature to add a new Planning Tool resource card. Now they can start using the card to create and link a new Planning Tool plan to this card. Everyone can access the new plan *how to brainstorm* through this Planning Tool resource card from *treasure island*. Bob and Alice can now build a visual model based on their ideas. This plan is also contained in Fig.5 lower left.

When they finish their plan, they are not sure if their brainstorming model is valid and decide to ask for help. The Metafora framework supports asking the own group or others for help. They decide to do a general help request and Stuart, who is member of the group *awesome*, reads their request and decides to help. So he uses the group info panel to switch to group *clueless* and chat with Bob and Alice. Stuart knows of an old brainstorming plan formerly created in the group *awesome* and decides to share this plan with the group *clueless*. The Planning Tool features sharing of plans with other groups. This means other groups get direct access to these plans through the plan selection options. Stuart uses another way to share the plan. He adds another Planning Tool resource card to the *treasure island* plan and links it to the plan *awesome brainstorming*. The Fig.5 contains this plan on the lower right.

Now Stuart can switch back to the group *awesome* and Bob and Alice now have two models for brainstorming. They can revise their model with the help of Stuarts plan and continue with the learning scenario.

5 Practical Usage of the Framework and Integration of External Learning Tools

When developing a technical framework, one of the questions to be answered is if the framework facilitates the re-use and integration of new components. Thus, one hypothesis we wanted to put to the test is if our framework and architecture allows the integration of different types of learning tools and saves time / effort compared to integrating tools directly without a framework.

To test the practical applicability of our Metafora framework, in this section we will present the modifications that are necessary to integrate existing learning tools and some design issues for new tools. First, we will introduce the functionalities that can be used to integrate learning tools semantically and then we present two showcases of successful integration: the first is a pre-existing, formerly not web-based, microworld in the domain of sustainability, the second is a learning game that has been developed from scratch at a time when our technical interfaces had been thoroughly specified already.

Among the important *scenarios* of cross-tool interaction mediated by the platform we consider the following situations / scenarios:

1. creation of a new workspace in a tool by means of the creation of a resource card in a planning map
2. creation of a referable object in a learning tool and making it referable in a space of discussion
3. inspecting a referable object by following the respective reference; this is technically realized by opening a specifically parameterized URL that contains the information to re-create or directly inspect the referable object
4. storing a learning tool model or state into the platform, a feature mainly used by serverless, client-only tools
5. retrieving a learning tool model or state from the platform and using this in the tool where it originated from
6. sending notifications, feedback messages, and analysis results

All these scenarios are triggered by sending XML messages of a well-defined format via the XMPP communication infrastructure. Tools that are able to support these functionalities subcribe to the XMPP command channel and take up the messages, that are relevant for them to be executed. The approach of defining an API for learning tools to react to specific external commands is similar to the 'remote moderation API' [13], yet, our approach is completely transparent to different programming languages and approaches, as long as XMPP is supported, while the earlier approach was using java interfaces, thus being confined to one programming language.

We will demonstrate both the interactions between tools and platform, messages exchanged during this interaction, and the necessary implementations for the two learning tools presented in the next subsections.

5.1 SuS-X, Integrating a Non Web-Based Legacy System

SuS-X is a game template that supports learning in the domain of sustainability. It is a microworld for non technical users, to play and design their own game. The game can be designed by adding content, sites and site properties to the game template. The rules of the game and the end of the game can be defined by setting appropriate values. Thus users can explore, change and reconstruct a model which will then be carried out by players. Figure 6 shows *SusCity*, which is an example microworld template of *SuS-X*, embedded in the Metafora platform, in which users can simulate and experience a sustainable way of living by making a trip in a designed city.

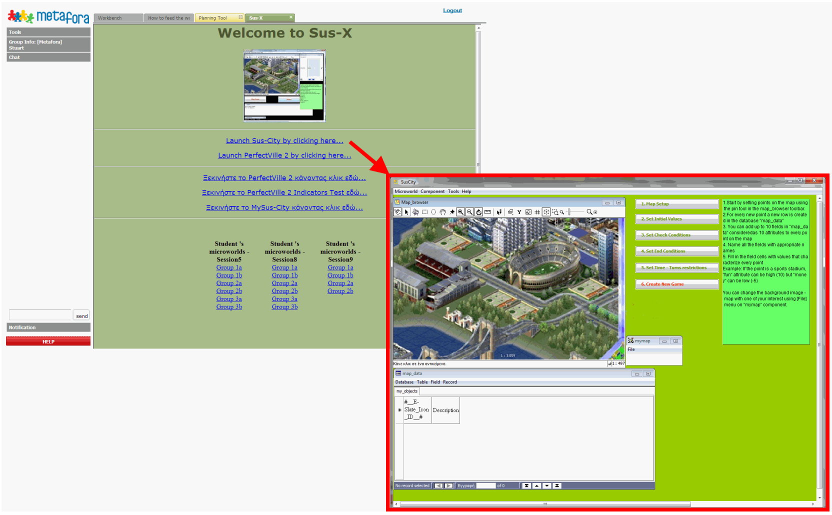

Fig. 6. Intermediate web-page launching Sus-X, here an instance of SusCity

As a pre-existing, client-side and non web-based tool of Metafora developed by our project partners from the Educational Technology Lab (ETL) in Athens, *SuS-X* had to be adapted to the framework. To support the heterogeneity caused by its initial implementation, it was integrated as a standalone application, launchable via an intermediate web-page which is hosted on a server. If *SuS-X* is started through the Metafora framework a website is opened which offers URLs to launch different *SuS-X* learning environments on the client PC. This is realised through an applet which installs the *E-Slate* platform, the technological basis of *SuS-X*. After the installation *SuS-X* is launched, as shown in Figure 6. E-Slate is a learning environment, enabling the visual manipulation of pre-fabricated software elements.

Technically, *SuS-X* is implemented as a Java application, which uses the XMPPBridge with the Smack library offered by the author team. Through this XMPPBridge a *SuS-X* instance launched through a resource card connects to the XMPP channels of Metafora, creates a reference to the workspace (e.g. scenario 1 from the list above) and writes logging information for the analysis components of Metafora (scenario 6). *SuS-X* will also offer a mechanism to store and retrieve saved states, which is currently under implementation (scenarios 4 and 5). If a user decides to save his current work, the microworld will create a file with the modifications and upload it into a database via a standard HTTP fileupload. The fileupload returns a unique ID to this file, through which the stored file can be retrieved at any later point in time. This mechanism will be explained in more detail in the next section.

Although *SuS-X* is a non web-based client application, for the user it appears seamlessly integrated into the Metafora platform and allows interoperable communication with the other tools as well as transitions from and to them.

5.2 PiKI, Integrating a New Unity-Based 3D Microworld

The microworld *Pirates of the Kinematic Island* (PiKI)[8] is an educational game in a setting with pirate flavour which allows students to experiment playfully with parabolic trajectories. PiKI supports two game modes: Students can build scenes where treasures are protected with obstacles and publish this scene as a challenge for other students. Other students can play a published scene and try to collect the treasures with the cannon ball by setting velocity and launch angle of the cannon ball and add surfaces with different bounce characteristics.

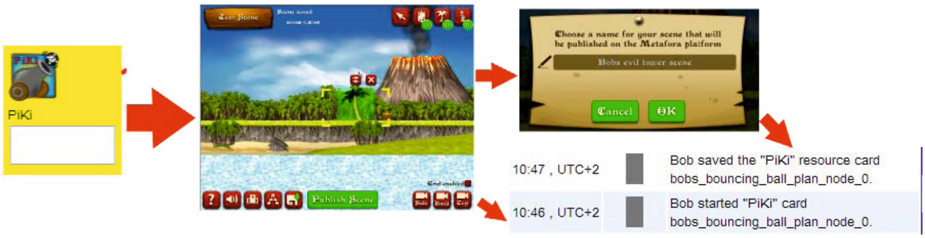

Fig. 7. Creating a new PiKI scene - users' view

PiKI[9] is one of the integrated Unity based microworlds and can be used as a none-collaborative stand-alone game. Through the integration into the Metafora framework most of the none-collaborative disadvantages can be overcome. When, for example, Bob and Alice want to learn something about parabolic trajectories with the help of PiKI they can log into Metafora and create a new plan. Then Bob can add a PiKI resource card and starts using the card (Fig.7 on the left). The Planning Tool sends a command XML message to the framework with the PiKI URL and plan informations (scenario 1 in the list of tool interactions). The framework adds the user informations to the URL and opens it as inline frame on Bobs client (scenario 3). Now Bob and Alice can build a new PiKI scene together if they work on the same client. The scene is stored and refreshed after every change to the Metafora version storage (scenario 4). While creating the scene PiKI logs the users' actions to the XMPP logger channel and generates analysis messages (scenario 6, and Fig.7 lower right) if the scene was changed. After publishing the scene Bob and Alice can split and try to solve instances of this scene, which is now available to all Metafora users.

Fig.8 shows an overview of the flow when Alice and Bob play the scene in parallel: Alice can add another PiKI resource card to their joint plan, start PiKi and select the created scene for playing while Bob can use the old PiKI card. Technically the stored scene is requested from the Metafora storage in its

[8] PiKI has been developed by our project partner Testaluna in co-design with pedagogical input from other project partners; in this paper we focus on the integration aspects that have been coordinated by our author team.

[9] http://test.silentbaystudios.com/metafora_piki/test/piki.php

current state and retrieved. The card is now connected with an instance of the scene (which means that – according to scenario 2 – the scene is now a referable object and the resource card the reference to it) and PiKI sends analysis messages for the new instances. These messages are visible for all students in the same group (again scenario 6 - notifications). Actions during the game are logged to the logger channel and can be evaluated by every attached analysis component. Analysis components can react with feedback messages for Bob or Alice (scenario 6 - feedback). These messages are displayed to the student through Metafora and PiKI. If one of the players hits a treasure PiKI sends a landmark message (scenario 6 - analysis) to the analysis channel, which is shown in Fig.8 in the lower middle. If Bob or Alice want to resume later they can log out from Metafora and resume with their current game state through their resource card (scenario 5). If one of them has problems with the solution or they want to discuss their solutions they can add a LASAD resource card to their plan and start using the LASAD discussion tool (scenario 1, but now with LASAD). Now they can share their PiKI instance as a referable object to LASAD (Fig.8 lower right). To do this, PiKI sends a command message which is picked up by LASAD and triggers the creation of a new discussion node with a reference to the PiKI instance (scenario 2). With this discussion node the saved state of the PiKI instance can be opened using scenario 3. This is also realised with an *open URL* command message.

Fig. 8. Playing a PiKI scene - overview

This example shows how easily even none-collaborative, client-only microworlds like PiKI can be integrated into the Metafora framework and the benefits of this integration. For the integration of PiKI into Metafora a Unity native XMPP library, agsXMPP[10], was used. Since PiKI has been developed from scratch during the Metafora project, all the technical protocols for scenarios 1–6 had already been specified. Thus, the purely technical integegration was achieved with relatively little effort of – to our estimation – a few days of programming. The conceptual design of the granularity of referable objects, appropriate storage formats etc. is considerably higher, but independent from the technical framework and necessary anyway for each learning tool to fulfill its educational purpose.

[10] `http://www.ag-software.net/agsxmpp-sdk/`

As the above scenario showed, PiKI can interact with other integrated tools like LASAD and benefit from more general analysis components, such as cross-tool analysis components that combine information from planning and problem-solving behaviour. With the help of the Metafora version storage it was even possible to transfer the current state of this client-only microworld to other users and clients, using the Metafora storage as a collaboration server.

6 Conclusion and Further Work

In this paper we presented the web-based collaboration framework Metafora and discussed design principles that guided our development of the software framework and the learning tools to be integrated. On the conceptual level we introduced *referable objects* as specific boundary objects that allow communication between peer learners and seamless transition between different learning tools. On the technical level we presented a collaboration architecture with technical interfaces that supports integration of external learning tools also on a semantically interoperable level. To support learners in their reflection about self-regulated learning processes, we designed a tool that integrates awareness and visualisation principles in connection to the collaborative planning tool. This is a specific case of embedded Learning Analytics features [12]. We showed the usage of these design principles with an example from practical usage of referable objects and resource cards in a Metafora learning activity. Additionally, we presented two cases of technical integration of learning tools using our framework's interfaces. These cases supported our hypothesis that a broad variety of learning tools, even non web-based or plugin-based, can be integrated successfully into the Metafora system. The flexibility of our framework has been proven by the cross-tool interoperability achieved when following our technical interfaces and by the possibility to allow client-only learning tools to store and retrieve states in combination with referable objects.

We are currently evaluating the educational effectiveness of our design principles by means of qualitative studies both in-vitro and in-vivo, i.e. in controlled lab settings and in school classrooms. Eye-tracking technology has been used for the lab studies to explore the usefulness of our awareness features, while school classes have been using the system successfully now for 18 months in various educational setups. To create sustainability of the system and invite the integration of additional learning tools into our collaboration framework the platform of the Metafora project is published as Open Source at `https://github.com/metafora-project`.

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Integrating Formal and Informal Learning through a FLOSS-Based Innovative Approach

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Abstract. It is said that due to the peculiar dynamics of FLOSS communities, effective participation in their projects is a privileged way to acquire the relevant skills and expertise in software development. Such is probably the reason for a number of higher education institutions to include in their Software Engineering curricula some form of contact with the FLOSS reality. This paper explores such a perspective through an on-going case study on university students' collaboration in FLOSS projects. The aim of this research is to 1) identify what should be learnt about software development through regular participation in a FLOSS project/community, and 2) assess the didactic potential of this kind of non-standard learning experiences. To this aim we resorted to a participatory research action approach and qualitative methods, namely case studies combining direct observation and interviews.

Keywords: FLOSS, Communities of Practice, Collaborative Learning.

1 Introduction

The International Labor Organization (ILO) report [1] states that "more than 197 million people globally are out of work or 6% of the worlds' workforces were without a job in 2012". According to Jim Lacey, CEO of Linux Professional Institute, "In 2012, 1.5 million cloud computing jobs remained unfilled due to people's lack of skills in Free / Libre Open Source Software (FLOSS) development". In order to build the human capacity required by markets, educational systems need to prepare skillful professionals, combining a broad, informed scientific culture with sharp technical skills in specific domains. The relevance of FLOSS to the world economy singles out as one of such domains.

Due to the peculiar dynamics of FLOSS communities, effective participation in their projects is a privileged way to acquire the relevant skills and expertise in software development. Such is probably the reason why a number of higher education institutions include in their Software Engineering curricula some form of contact with

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a FLOSS environment, either by exploring FLOSS projects in their laboratory activities or emulating them within the academic environment.

But there is much more to be considered. It has been observed that participating in FLOSS communities and projects provides new and unsuspected learning opportunities, with a potential added value to formal education if suitably integrated within more conventional learning contexts [2]. In this paper we explore such perspective reporting on an on-going case study on the inclusion of FLOSS projects activities in a formal learning environment. The research agenda aims at: 1) identifying what should be learnt about the practice of software development through regular participation in a FLOSS project/community, and 2) assessing the didactic potential of this kind of non-standard learning experiences. These two aims can be formulated as research questions: (RQ1) *what* and (RQ2) *how do students learn while participating in a FLOSS project and its community?* The paper is an initial report on a larger case study involving a class of pre-service Informatics teachers at University of Minho, Portugal, along the academic year of 2012-2013. Although only at a latter stage a detailed case study report and consolidated data will be available, it seems worthwhile to share the underlying pilot project and point out a number of issues already detected to call the community attention to this research. Actually, although the use of FLOSS-related projects in formal education is not new, we believe their systematic study, from an educational perspective, is still to be done.

The rest of the paper is structured as follows. Section 2 introduces the background and Section 3 the research methodology. Preliminary results are reported in Section 4; Section 5 concludes.

2 Background: Learning as a Process

Driscoll [3] defines learning as a "persisting change in human performance or performance potential which must come about as a result of the learner's experience and interaction with the world". It can be *formal*, i.e., institutionally framed and hierarchically structured, or *informal.*

Informal learning is a life-long process in which an individual acquires knowledge, attitudes, values and skills while performing daily activity within various contexts. From Jay Cross' perspective, "people informally acquire much of the knowledge they use in their practice. Through the observation of others, by trial and error, and simply working side by side with more experienced people". In his opinion, "formal education contributes only about 10% to 20% of what a person learns in a professional context" [4].

In both settings, the qualifier *collaborative* refers to sets of activities involving a group of people learning or trying to learn something together. The term can be defined more broadly as collaborative teaching and learning [5][6][7], as both activities occur together. Unlike individual learning, collaborative teaching and learning capitalizes on students' resources and skills. For example, individuals learn from each other and teach to each other by enquiring, debating, cross-assessing ideas between members and mutually monitoring work progress. Collaborative teaching and learning encourages knowledge construction, skill development and a deeper understanding by actively engaging students in the learning process.

Behaviorism, cognitivism and constructivism are the three broad *learning theories* [8], most often applied in the analysis and development of instructional environments [9]. However, they pay little attention to the role of context in a learning process and, in general, the relevance of its externalities. This seems particularly critical in modern information societies, in which knowledge is permanently stored and manipulated along complex processes, which affect the way people behave and learn.

A new theory emerging in the so-called digital era is *connectivism*, which recognizes that “learning can reside outside of individuals” and “is driven by the understanding that decisions are based on rapidly altering foundations” [9]. Main assumptions are that new information is continually being acquired, learning is a process of connecting specialized nodes or information sources, and decision-making is itself a learning process.

In this framework, the paper’s starting point is the observation that communities of practice, as FLOSS development networks are, allow knowledge sharing and peer learning on a global scale and at a speed that was unforeseen one or two decades ago. Actually, the relevance of FLOSS to research in education is based on the observation that FLOSS communities may provide unusual, informal learning environments for teaching and learning software engineering skills [2]. As a viable approach to software development, FLOSS provides a model for creation of self-learning and self-organized communities, in which geographically distributed individuals contribute to build software. Well-known software applications, such as Linux, Moodle, MySQL, Firefox are good examples of the effectiveness and success of the FLOSS development model.

3 Research Methodology

Our research is based on a pilot project in teaching/learning software engineering. In general terms, it follows a participatory action research approach analyzed through the construction of a case study. The pilot project involves students, who act both as participants - involving themselves in the activities carried out within the project, and as observers - reflecting about their own practices, behaviors and achievements exhibited and gained through their participation in the project. They are part of a class of pre-service teachers, i.e. students in the last year of a MSc course whose completion will entitle them to teach Informatics at secondary school level. As such, they seem highly motivated to analyze new learning experiences and even test them in their own classes.

By definition, participatory action research aims to understand the “world” by trying to change it, collaboratively and reflectively. Rather than a strict method, it is an approach to what research is in Social Sciences and Education. The pilot project aims to teach students, collaboratively and reflectively, software engineering skills through their involvement in a FLOSS project, using the open and democratic style typical of FLOSS communities. Students are proposed a list of FLOSS projects among which they can choose one to get involved in, but they are also free to choose a project that is not in the list. How students get together in small groups (up to 3 elements) and which role each student and/or small group will play within the project are also free choices. Within each group, leadership may spontaneously emerge and either have an official recognition or just appear as part of the interaction activities.

Along the case study, data is collected through a combination of direct observation and unstructured interviews. Interpretation of direct observation allows us to gather information about the learning and communication skills of the students, their interaction and collaboration modalities, and how roles and leadership emerge from the collaborative process. Unstructured interviews provide a more complete picture of students' behavior by investigating actions and tasks that are not directly observable and fostering the externalization of motivations and expectations. All data collected is stored in the project collaborative platform hosted by Moodle. A weekly meeting of all groups with a member of the research team allows a live interaction and smoothes some difficulties in the project development.

4 Preliminary Results and Analysis

Due to the fact that the pilot project is still running at the time of writing, only preliminary results can be reported at this point. This section focuses on two aspects 1) the project launching and 2) what students emphasize on the experience they are going through.

4.1 Project Launch

The 16 students (10 female, 6 male) joined the pilot project by completing a brief questionnaire on their academic background and previous experience with FLOSS. All but two older students are in their later twenties. However, the group is quite heterogeneous in what concerns academic and professional background. The latter include 3-years bachelor degrees in Computer Sciences, 5-years licentiate degrees in IT Management, or postgraduate studies in Multimedia in Education. This results in a broad range of knowledge that encompasses informatics, communication, multimedia, or management, among others.

An initial questionnaire showed that all but one of the students involved have, on average, a modest background when compared to typical programming skills of members of FLOSS communities. All of them, however, were aware of the FLOSS phenomena and know (or, at least, have heard about) a number of open source projects: the majority mentioned Linux, Open Office, and/ or Mozilla.

Eight groups were initially formed and invited to select a FLOSS project/community to join. Some were suggested, but each group was free to make a different choice (and they actually did). A second group choice was concerned with the role the group would play in the respective FLOSS community. Three roles were proposed and explained in a first live session: analyst, expected to document software, programmer, to develop and integrate code, and tester. Clearly, the choice of FLOSS projects was directly influenced by the academic background. Some students, fearing of their own weak programming skills, opted for more “observational” roles, namely requirements analyst.

4.2 The On-Going Experience

For 3 months now students have been involved in the pilot project. Their global attitude has been pro-active, namely in dealing with difficulties in establishing a connection with the chosen FLOSS community. This was the main initial challenge. In few cases the community was very slow to answer; in others the community had some difficulty in understanding what the group was proposing to do. Typically, the interconnection with the communities, usually through a leading person, was set in a mutual understanding basis, and within 30 to 40 days. This number seems too big with respect to our expectations of a live interaction with “live” communities and is a factor the research team will have to take into consideration when planning similar projects.

In all but one case, the group integration and dynamics went smoothly, probably taking advantage of a previous acquaintance between their members. Differently from what the research team was expecting, however, small groups were quickly to specialize each member in a particular task. In groups of 3 students, typically one was designated to lead the interaction with the community, another assigned the technical task of downloading, installing and configuring the software (namely in the beta-version in which the community was active) and finally another became in charge of documenting the whole process.

The daily supervision of the project platform (based on Moodle) allows us to say that all groups are active in using discussion groups, chats, emails, and forums to exchange ideas, doubts or achievements. They even made a number of suggestions to the research team to improve the collaborative platform. By their initiative an informal workshop, in which each group presented their own experience, was planned as a project checkpoint.

The analysis of the group reports, weekly recorded in the platform, and from live interaction in the weekly meetings, allows us to point out some initial answers to our research questions. We concentrate in just two groups for which more relevant data has been collected so far.

Group 1. This group joined the AnkiDroid community, a popular flashcards application for Android, and opt to act as developers (code.google.com/p/ankidroid). The choice was deliberate: their explicit objective was to learn programming for Android platform. The learning curve was exceptional, much steep than the one we observe in formal lectures for similar classes (RQ1).

With respect to (RQ2) students report very positively on learning-by-doing (‘we learn everyday!’). However, they were initially a bit disappointed with the gap they notice between the community expertise and their own. As pre-service teachers, they were also driven by an educational concern. Actually, flashcards are widely used as a learning drill to aid memorization by way of spaced repetition and the group wants to promote AnkiDroid as a way to 'mobile learning' in their own classes. They become concerned with the practical use of the software by secondary schools students and decide to carry on a number of usability tests. This was done with specific techniques of Software Logging, to digitally record game participation, and Think Aloud, to collect verbal and non-verbal data from observation. The results of the usability tests were communicated to the FLOSS community through a live interaction in the chat and repository. The interaction with the community is understood by the group as the main driving force for their progress. Nuno, one of the students, reports in his project diary: 'it is amazing how we are being pushed by comments from other developers. They even helped with the session [the group organized a one-day long session on AnkiDroid at a secondary school]'. During the workshop João commented on their experience: 'Certainly not in linear way, but the guys there [the FLOSS community] are guiding our learning (…) we face so much technical problems, from the language to version control, that we are being literally forced to make progress.'

Group 2. Another group joined Childsplay, a collection of educational activities for young children, both as tester and developer. Differently from Group 1, the community was small and not very active. Rui reports: 'it seems we were pushing them' … until the moment the group made its first contribution – a complete new game to add to the package – and became the focus of real attention from other developers.

With respect to (RQ1) the group faced a totally new programming language (python), which was mastered in less then 2 months, again with a steep learning curve. But they also acquired a valuable experience in issues like managing API versions and partial compatibility, software interfacing (with SQL) and composing third part software on the fly. This is a major point in favor of this approach: such are not the kind of skills students usually get from formal courses.

For (RQ2) the group points out the impact of being acting both as a 'supplier' and a 'client' of services in distributed development environment. Hélder comments: 'it is the real pressure!' and later 'only after we delivered the first game, the "Tic-Tac-Toe", they start taking us seriously. For the second game, the "Block Breaker", we were even able to ask support from other developers, namely to give us nice graphics to include in the game.'

5 Conclusions

The preliminary results obtained seem quite positive: FLOSS-driven projects do provide a most interesting setting to exercise "learning-by-doing" and, in general, autonomous and proactive approaches to learning. It is still too early in the project to have the "big picture" which may allow extracting more general conclusions and guidelines applicable in other contexts. If our initial intuitions get confirmed, this may open a handful of perspectives for rethinking Software Engineering curricula, in particular in regions of the world were access to formal education at a university level is limited.

The results of the pilot project will be used to design an e-Learning framework to support this approach in teaching software engineering topics. The framework will then be tested in courses at various universities in following semesters.

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Using Geo-collaboration and Microblogging to Support Learning: Identifying Problems and Opportunities for Technological Business

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Abstract. Many services are nowadays offering the use of a (¨Cloud") which allows large groups of people to interact with one another in different ways by means of sharing textual information, to collaboratively constructing complex information objects using text, images, maps, and other multimedia information. Current literature reports a number of works where these services have been used to support collaborative learning. The reliability, scalability and ubiquity are the characteristics that make these services especially convenient in supporting large group collaborative learning activities that require computer support in various settings, in and outside the classroom. In this work we first analyze the use of Google Maps for supporting a learning activity in an urban environment, concluding that some important features are missing. We then propose an approach for taking advantage of cloud computing services for learning activities by integrating different services in a new application. We conclude that this approach may be used for further developing applications supporting large group learning activities.

1 Introduction

It is not uncommon that students of a business degree program have to attend a course in which they are asked to identify situations in real contexts, for which, the introduction of solutions based on Information Technology might be an opportunity to improve the life or solve a problem for citizens that frequently circulate around that area, live or work there. This is also true for students of an Urban Planning program. We can also imagine other situations where students have to geographically identify spots with troubles and/or opportunities and collaboratively propose, discuss and select the most appropriate solutions.

Learning activities taking place in real situations (as opposed to the "laboratory" setting) in which the real context and collaboration among learners themselves and between learners and experts are important clues to the success of the learning outcome. This can be considered as belonging to the Situated Learning theory which states that students have to apply the knowledge they are acquiring in the location and

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context where it is needed. If one adds to this that the geographical location information plays an important role, we can also say that this activity can be classified as a geo-collaborative one, which has been defined as collaborative tasks performed by a group of people involving the contextualization, construction and exchange of geo-referenced data. On the other hand, microblogging has often been used as a means to support decision-making processes, as it helps to comment and rank ideas, which are options to solve a problem.

In this work, we first report on a work done in order to test the hypothesis whether it is possible to use Google Maps “as is” in order to support a rather large group of students engaged in a situated learning activity. This consists in collaboratively identifying opportunities to improve life or solve problems in a certain area of the city where they live which has to geo-referenced in a map. They have to generate, discuss and select the 10 best ideas. After four semesters, according to the feedback given by the students, we concluded Google Maps alone was not enough. We took the comments of the students as input for establishing the requirements for a system which could help them to accomplish the task. We also took some principles of decision-making from the literature in order to complete the requirements. A prototype of a system developed to cope with the requirements was used for one semester and evaluated the same way we did for Google Maps, obtaining positive results and which gave us valuable insight into what the main features are of a system supporting situated learning activities for large groups including decision making and geo-collaboration.

2 Geo-collaboration to Facilitating Context Awareness

According to [1, 2] geo-collaboration is the modeling of collaborative tasks performed by a group of people involving the contextualization, construction and exchange of geo-referenced data based on a human-computer interface that shows the map of the physical zone in the background, where the tasks are being performed and/or spatially contextualized by using mobile devices or desktop computers. The tasks may involve collaborative explorations and mapping meaningful representations [3]; making geospatial decisions collaboratively in situations, like crisis management [4, 5]; building planning [6]; and/or defining strategies [7].

The task may involve the development of pedagogical practices to support learning. According to [8-10], conducting collaborative educational activities using geo-referencing data in authentic contexts enables students to establish significant cognitive relationships between what was seen inside the classroom and what is seen in a real context, [11]. Furthermore, students may collaboratively work by doing learning tasks at the same time and in the same place (by social interaction in a real physical context), at the same time and in different places (social or virtual interaction in a remote context), at different times in the same place (virtual interaction in a real context), or at different times in different places (virtual interaction in a remote context). Geo-collaborative tasks supporting educational practices are based on the **Situated Learning** theory, which states that learning requires theoretical concepts learned inside a classroom to be linked to practical and real situations in authentic contexts where they can be applied [12]. Regarding this, [13] suggest that learning improves when knowledge is presented in a real and authentic context, i.e., settings which normally require that knowledge. They also claim that learning requires social or virtual interaction and collaboration among the students.

The chapter is organized as follows. In section 2.1, we propose a pedagogical learning activity which requires students to identify problems and/or opportunities in an urban area which require innovative solutions based on information technology. In section 2.2, we analyze the advantages of microblogging service to support decision-making process; and in section 2.3 we describe the fundamental requirements of this geo-collaborative decision-making processes.

2.1 Description of the Geo-collaborative Activities for Identifying Problems and/or Opportunities for Technology-Related Business

The geo-collaborative application we present in this work has been developed in order to support students in a scenario where they have to propose ideas, geo-referencing them in a map so the rest of the group can collaboratively comment on and rate them in order to reach a common decision about which are the best. The learning goal is to develop skills in order to identify realistic problems and/or opportunities in an urban area and propose creative solutions based on information technology. Thus, the geo-collaborative tasks follow the basic decision-making model: generate ideas (brainstorming), analyze/discuss them (in a divergence and convergence mode), and select the best ones (in a convergence mode). In such a scenario we will have the following key activities, which we would like to support: a) A student generates a geo-referenced idea at the same place (using mobile devices) or remotely using texts, pictures, and/or any other multimedia material. b) After the idea is published by its author, all students can see and associate comments positive or negative comments to it. It is expected that the interaction for commenting the ideas is done remotely although they can go and physically visit the place where the idea has been geo-localized. c) Students select the best ideas using ranking and/or voting mechanisms, which are expected to be used asynchronously. According to [14], the above described learning tasks, introduce an added value to situated learning applications.

2.2 Including Microblogging to Support Geo-collaboration

According to [15], the use of Twitter – the most popular microblog today, may promote the formation of online communities and facilitate the interaction among learners through the exchange of text messages associated to photographs, documents and videos on the Internet.

Microblogging services have been introduced in various educational scenarios and the evaluations of these experiences report two benefits for the learning process: a) ease of use, and b) the positive impact in various pedagogical practices. In [16], authors report that the complexity level for using microblogs is low and independent of the computer device which is being used. Normally a computer, with browser and Internet connection is enough. Additionally it is available for its continuous use over an extended period of time, allows easier and faster access to information, when and where it is needed. These characteristics allow curriculum designers to focus on the development of the didactics instead of on problems related with the use of the microblogging platform. Various authors have found that its use positively influences important learning aspects like collaboration [17, 18], creativity [17], development of communication skills [17-19], rising ICT Literacy [16], as well as the productivity in the generation of ideas and self-direction [17, 18]. Additionally, it has been found to promote Lifelong Learning [16, 17] and the insertion of users in communities of practice [18, 20].

According to [21, 22], the information generated in a microblog could be efficiently used to support virtual decision-making processes, like the one we are proposing in the section 2.1., according to our understanding. Researchers report in [23, 24] that the reasons people confess why they use microblogging are: a) keeping in touch, b) promoting certain kind of interesting information, c) asking and doing comments. These reasons match with important aspects we consider user should have in order to perform the tasks described in 2.1 properly. Summarizing, microbloging supports collaborative work, communication, creativity, brainstorming, ranking and selecting proposals, all these activities being at the core of the activity proposed in 2.1.

2.3 Models for Decision-Making Process in Geo-collaborative Environments

Group decision-making is a collaborative effort performed by a team of individuals, in order to accomplish certain tasks or attain a goal. It involves series of social interactions, like interaction, communication, deliberation, and other activities such as generating ideas, asking and answering questions, making comments, searching information, or selecting ideas. These interactions may or may be not be mediated by computer technologies. The process of decision-making has been subject of research for decades. The work presented in [25] proposes the Cooperative Decision Making model, which emphasizes the importance of negotiating conflicts (Identification → Processing → Negotiation). The Participatory Decision Making model [26] distinguishes between divergent and convergent collaboration modes (Divergent → Groan → Convergent → Closure). The Collaboration Engineering model [27] synthesizes decision-making as a collection of behavioral patterns that may be "engineered" to respond to contextual situations (Diverge, Organize, Evaluate, Build consensus, and Converge).

As is mentioned in [22, 28], decision-making seems to be organized according to three main decision-making patterns: (1) **information gathering and brainstorming of ideas in a divergent mode;** (2) **find alternatives, information processing and comments of alternatives using divergence and convergence modes;** and (3) **make choices in a convergent mode**. In our case, we consider the following subset of fundamental requirements of geo-collaborative decision-making processes proposed in [28]: **Perception support.** Geo-collaborative decision-making tools should associate changes in geo-referenced data with adequate perception mechanisms, e.g., visualization based on pictures backed with text descriptions, and storyboards to organize in the form of pictures displayed in sequence, for the purpose of facilitate the contextual representation and understanding of an idea [29, 30]. **Retention support.** Retention is a fundamental driver to construct individual and group memory and contributes to enact adequate responses whenever recognizable situations emerge. Geo-collaborative decision-making tools should therefore maintain a repository of the geo-referenced data, and their comments and rakings. **Externalization support.** Externalization is essential to information gathering and brainstorming of ideas, since knowledge is constructed by articulating tacit knowledge into shared explicit expectancies, cues, goals and actions. **Divergent/convergent support.** Decision-making seems to be organized according to intertwined cycles of divergent and convergent activities, where divergent activities favor problem identification and information gathering, and convergent activities promote the negotiation and selection of alternatives. **Task/pattern management.** The decision-making process seems to be organized according with a set of patterned activities such as divergence, convergence, data organization, option evaluation, etc. Geo-collaborative decision-making tools should carefully avoid prescribing rigid structures; they should also support the way of controlling by implementing task/pattern management.

3 Evaluating Google Maps "as it is" for Identifying Problems and/or Opportunities for Technology-Related Business

We made a realistic experiment in order to have some insight about the suitability of Google Maps to support geo-collaborative learning tasks involving all students of an undergraduate course on Information Technology for Business as a single team (see section 2.1). We used the same methodology and experiment design, and applied a similar questionnaires as in the work reported in [31]. However, the results were analyzed for a different purpose: this time the focus was to find out which functionalities were missing or not properly supported to accomplish the tasks. Another difference is that in [31] we reported the results of using Google Maps in one semester, here we present data gathered during 4 consecutive semesters.

3.1 Task Description, Sample, Technical Setup and Data Collect Methodology

The experiment involved students from an undergraduate course undertaking a collaborative assignment which consisted on identifying realistic problems and/or opportunities in an urban area and propose innovative solutions based on information technology. Students were asked to wander around an urban area near the faculty in order to accomplish this "Situated Learning-type" task. They were asked to perform the task using Google Maps because it allows the generation geo-referenced tags annotated with text and it is a highly available and popular tool, which means it requires a minimal amount of user training.

This assignment was applied four times, each semester starting from first semester of 2011 and ending the second semester of 2012. The **sample** consisted of 50, 48, 48 and 46 students, for each semester; 30, 26, 24 and 28 male; average age 23.3, 22.8, 23.1 and 22.3 respectively. They were taking an undergraduate course on Information Technology for Business, in the eighth semester of the Information and Management Control Engineering degree program of Economics and Business Faculty of the Universidad de Chile. It is expected that students taking this course are able at the end of the course to: (a) detect problems and identify opportunities in an organization, that may be supported by Information Technology (IT); (b) manage an IT strategy that can introduce competitive advantages into an organization; (c) design IT solutions for a business project; and (d) develop communication and teamwork skills. These students are good users of computing technology: 55% use notebooks or tablets in classes and most have smartphones, all of them have PC at home. They regularly use popular desktop software; and use social media tools like Twitter, Facebook, and Skype.

Fig. 1. Two Google maps instances collaboratively geo-referenced by the students (2nd semester of 2011 to the left, and 2nd semester of 2012 to the right). The list of ideas is shown on the left side. Geo-references are displayed as icons on the map representing the location for these ideas. Text and pictures describe ideas presented by students. The screenshot on the right shows the interface with a geo-referenced idea showing the comments to this idea.

Regarding the **technical setup**, the task was performed collaboratively outside regular classes. All students were part of a single team. The teacher explained the assignment in the classroom, recommending the students to observe an area and identify problems, opportunities and ideas that may be addressed using IT, which should be geo-referenced in Google Maps. Students were also asked to discuss and give their opinions on the classmates' ideas and collaboratively choose the ten best by mutual agreement. Students had one week to perform the assignment. No instruction regarding the type of hardware to be used or the coordination mechanism to select the best ideas was given. They were just told they should use Google Maps. Consensus rules, task awareness and coordination mechanisms had to be established by the students themselves. Following the instructions, students performed the assignment accordingly. Pictures taken with mobile phones, cameras or even taken from Street View were uploaded in Google Maps. Some documentation of the activities done with Google Maps is shown in Figure 1.

From these experiences, we **collected data** from the questionnaires that the students filled out at the end of the activity, containing questions that required quantitative as well as open answers. For this work, questionnaires and the subsequent analysis were organized in three major categories, namely **information overload**, **usability** (easy to use), and **collaboration support**. As in [31], the strategy we adopted to analyze the results consisted in using open questions to find insights about the suitability of Google Maps to accomplish the proposed task. The responses to these open questions were sequentially analyzed and coded in two rounds. The first one aimed to identify relevant codes and the second one aimed to revise codes and improve the quality of the coding process, [32]. Although the students were instructed to use Google Maps they also used Google Docs (spreadsheet, and text processor) collaboratively in order to support the discussion and convergence process. For this reason we additionally analyzed the students' usage of these tools trying to identify which processes and data structures were the most frequently used in order to obtain additional functional requirements.

3.2 Findings of the Experiment

As we mentioned before, from the questionnaire applied in [31], we only take in account the next three open questions: Q1: "Did you feel information overload during the task?", Q2: "How easy was the software itself to use", and Q3: "How easy to use was the collaboration support?". Students were asked to comment and describe positive and negative aspects of the software they used related to the question. From the qualitative analysis of the data we obtained the results shown in Tables 1, 2, and 3.

According to table 1 the most negative comment about information overload was associated with the difficulty to identify and follow the many ideas generated and the comments associated to them. On average, 16.8 students mentioned this problem each semester. Students mentioned that using only Goggle Maps, as it was instructed, made it difficult to aggregate all comments made for one idea. In the 4 semesters students used additional documents from Google Docs for writing their comments (see figure 2 left). The text editor and the spreadsheet were used to collect the comments. Mechanisms used to associates ideas in Google Map to the comments were: a) repetition of the title and/or description of the idea (see Figure 2 right) b) generation of an identification number for each (see the numbers associated to ideas in Figure 2).

In all cases the number of generated comments made it difficult to follow and read them completely. Many students mentioned they read only a subset of the ideas and comments because they were simply too much. They also indicated that it was difficult to find the new ideas and comments out of the old ones, as well as finding a certain idea or comment previously read again. It was even more difficult to associate the geo-referenced information in Google Maps with the ideas and comments in Google Docs. Only during the second semester of 2012 students tried to associate comments to the corresponding idea in the same document in Google Maps. Students started to write their comments just after the text written as information to the geo-referenced idea, adding their names to the comment. However, additional Google Docs documents were used in order to implement the selection and voting for the best ideas.

Table 1. Qualitative coding of students' answers to the questionnaire and the frequency they were mentioned associated with Q1. Sn = Semester n; Avg. = average

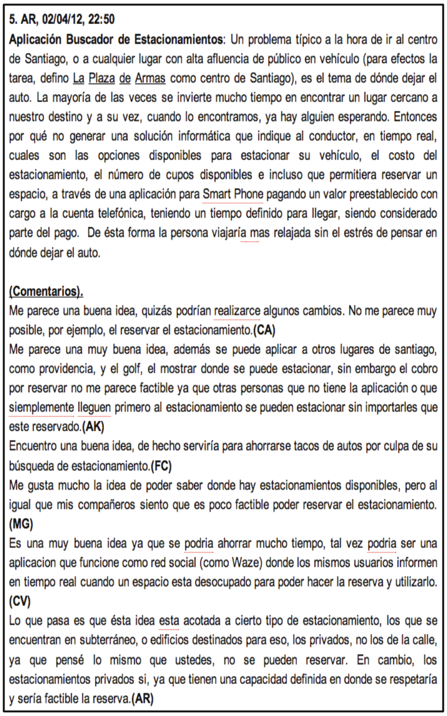
Q1*: Did you feel information overload during the task?*											
Positive comments						**Negative comments**					
	Year/Semester						**Year/Semester**				
	2012		**2011**				**2012**		**2011**		
Avg.	**S2**	**S1**	**S2**	**S1**		**Avg.**	**S2**	**S1**	**S2**	**S1**	
1.8	3	2	0	2	Everyone was available on the computer screen	**16.8**	21	12	15	19	Too many ideas and comments shown at the same time
2	2	2	3	1	Work was performed orderly	**6.5**	5	8	7	6	Some contributions were duplicated
1.5	3	0	1	2	History of ideas was easy to follow	**10.5**	16	14	10	2	Considerable flow of ideas and feedback
						9.3	14	8	9	6	Relation between ideas and comments difficult to establish
						11.5	12	15	12	7	Related ideas are shown apart from each other
						4.8	5	4	8	2	Too many objects shown in the same window at the same time
						7.3	12	9	6	2	Some comments were simply forgotten

The result of having comments separated from the ideas implied that the high flow of ideas and their comments that were created was difficult to follow and easy to forget (10.5 on average); and therefore, the number of repeated ideas was considered high and that they were difficult to detect (6.5 on average); or that it was easy to forget the comments they already read due to the high number of proposals and comments (7.3 on average).Very few positive comments were expressed. The most relevant was that the participants liked having all information available on the computer screen.

Table 2. Qualitative coding of students' answers to the questionnaire and the frequency they were mentioned associated with Q2. Sn = Semester n; Avg. = average

Q2*: How easy was the software itself to use?*											
Positive comments						**Negative comments**					
	Year/Semester						**Year/Semester**				
	2012		**2011**				**2012**		**2011**		
Avg.	**S2**	**S1**	**S2**	**S1**		**Avg.**	**S2**	**S1**	**S2**	**S1**	
8.3	8	9	6	10	Easy to understand	**6.5**	6	7	5	8	Proximate comments are difficult to discern
2.3	4	0	2	3	Immediate visualization of new comments	**7.3**	10	5	8	6	Cannot see who deleted comments
3.5	5	3	4	2	Reference of ideas in geographical context	**11**	12	10	15	7	Lacks coordination support
1.3	2	0	1	2	Using of colors	**10.5**	14	12	10	6	Mapping and chatting unrelated
3.5	6	2	4	2	Using of text and pictures	**1.3**	0	2	1	2	Slow
1.8	1	2	3	1	Use of icons	**6.3**	8	9	6	2	No private working space
1.5	0	2	3	1	Easy access to ideas	**9.3**	13	11	9	4	Had to improvise in order to collaborate
0.8	0	2	0	1	Searching	**8.5**	9	12	8	5	Difficult to merge comments, ideas
						8	11	7	9	5	Communication is not primarily focus

Comments to Q2 reveal several technical issues contributing to the perceived low usability (see Table 2). The most negative comment was related to the lack of mechanisms to easily associate the geo-referenced ideas and the "conversation" associated resulting from the comments given to it (average 10.5). In fact, the lack of this kind of functionality was the reason given by the students for having to use additional documents in Google Docs. From the analysis of Q1 focused on information overload revealed that the most important negative aspect was that it was difficult to follow the ideas and the comments associated. Q2 revealed that from the usability point of view the most negative aspect was the association of the ideas written in Google Maps with their comments in Google Docs. An interesting result of the analysis was that students tried to structure the information in Google Docs in a similar way a microblogging service would do: short messages arguing for or against the proposition (see Figure 2).



5. AR, 02/04/12, 22:50

Aplicación Buscador de Estacionamientos: Un problema típico a la hora de ir al centro de Santiago, o a cualquier lugar con alta afluencia de público en vehículo (para efectos la tarea, defino La Plaza de Armas como centro de Santiago), es el tema de dónde dejar el auto. La mayoría de las veces se invierte mucho tiempo en encontrar un lugar cercano a nuestro destino y a su vez, cuando lo encontramos, ya hay alguien esperando. Entonces por qué no generar una solución informática que indique al conductor, en tiempo real, cuales son las opciones disponibles para estacionar su vehículo, el costo del estacionamiento, el número de cupos disponibles e incluso que permitiera reservar un espacio, a través de una aplicación para Smart Phone pagando un valor preestablecido con cargo a la cuenta telefónica, teniendo un tiempo definido para llegar, siendo considerado parte del pago. De ésta forma la persona viajaría mas relajada sin el estrés de pensar en dónde dejar el auto.

(Comentarios).

Me parece una buena idea, quizás podrían realizarce algunos cambios. No me parece muy posible, por ejemplo, el reservar el estacionamiento.**(CA)**

Me parece una muy buena idea, además se puede aplicar a otros lugares de santiago, como providencia, y el golf, el mostrar donde se puede estacionar, sin embargo el cobro por reservar no me parece factible ya que otras personas que no tiene la aplicación o que siemplemente lleguen primero al estacionamiento se pueden estacionar sin importarles que este reservado.**(AK)**

Encuentro una buena idea, de hecho serviría para ahorrarse tacos de autos por culpa de su búsqueda de estacionamiento.**(FC)**

Me gusta mucho la idea de poder saber donde hay estacionamientos disponibles, pero al igual que mis compañeros siento que es poco factible poder reservar el estacionamiento. **(MG)**

Es una muy buena idea ya que se podria ahorrar mucho tiempo, tal vez podria ser una aplicacion que funcione como red social (como Waze) donde los mismos usuarios informen en tiempo real cuando un espacio esta desocupado para poder hacer la reserva y utilizarlo. **(CV)**

Lo que pasa es que ésta idea esta acotada a cierto tipo de estacionamiento, los que se encuentran en subterráneo, o edificios destinados para eso, los privados, no los de la calle, ya que pensé lo mismo que ustedes, no se pueden reservar. En cambio, los estacionamientos privados si, ya que tienen una capacidad definida en donde se respetaría y sería factible la reserva.**(AR)**

Fig. 2. To the left: extract of a Google Docs document (text editor) with the proposition of an idea and the comments associated. To the right: the upper part shows a screenshot from Google Maps, which a proposal identified with the number 23. The screenshot under it shows a Google Docs document with this number, the same title, some photos and the description of the proposed idea.

The second negative aspect is related with the lacks of coordination support (with a frequency of 11 points on average). In some occasions a coordinator was elected by the students who would establish accords about deadlines for generating idea proposals, number of comments expected and deadlines for generating them, voting mechanisms, etc.; because Google Maps nor Google Docs provide such mechanisms. One of the most cited arguments about lack of coordination mechanisms was that in Google Maps all ideas would look like having the same relevance and only after carefully reading all comments they would find which are the most preferred ones.

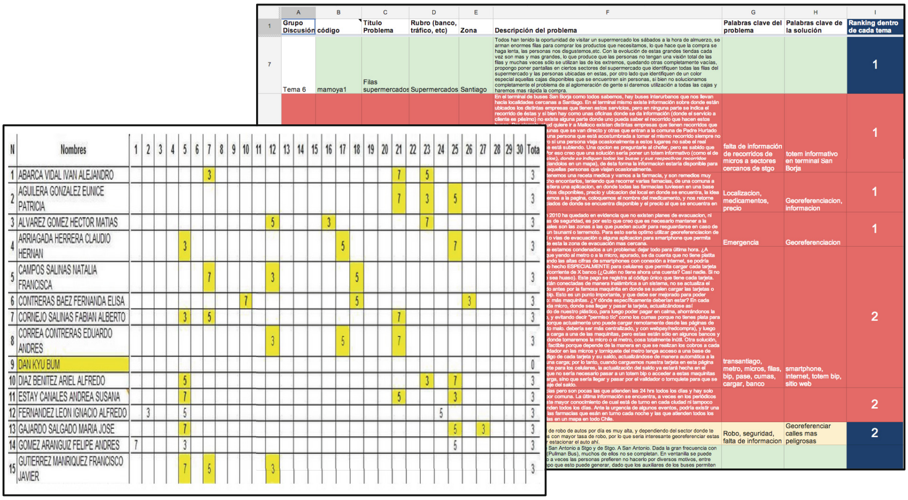


Fig. 3. At the left, a screenshot of the matrix students confectioned using Google Docs. Each row corresponds to an idea and the columns to the rating given by one student to the idea. At the right a screenshot of a text written with Google Docs with a table in which each row corresponds to a student and the columns to a subset of relevant pre-selected ideas which will be ranked; students evaluated each idea with a number from 1 to 7.

The third negative comment with a frequency of 9.3 points is associated with the need to improvise collaboration strategies since the tool does not offer clear support in that area. Students missed a functionality which could help them to count favorable and unfavorable comments given to an idea. In three from the four semesters students used a spreadsheet from Google Docs instead (see Figure 3). In one semester they used a simple table from the text editor (see Figure 3 to the right).

The next negative aspect (average frequency of 8.5) was the difficulty for combining ideas with their comments in a single view. This aspect can be clearly seen from the screenshots shown in Figure 1 showing the geo-referenced proposals and the one in Figure 2 showing the Google Docs document with the comments. Even when in one semester students did write the comments in the same place with the ideas on Google Maps (see screenshot on the left of Figure 1), they were afterwards copied into a document for rating, as seen in Figure 3. This also explains the high frequency

(8.0) of negative comments complaining that there was no simple communication mechanism for commenting the ideas, express preferences and rating.

Other negative aspects mentioned were that any student could modify or even delete the contributions made by another (7.3), difficulties for differentiating comments when their geo-referenced locations in Google Maps was near (6.5), and the absence of private workspace before publishing the ideas (6.3). The most relevant positive aspect mentioned was that Google Maps was easy to use.

An interesting aspect was that many of the ideas which were also presented in Google Docs were extended compared to the one geo-referenced in Google Maps. They were described with more detail sometimes taking the format of storyboards, in order to give better context to the idea [29, 30]. Table 3 shows students' stand regarding to question Q3, i.e. how easy to use was the collaboration support provided by the system, with clear emphasis on the negative side. Two reasons were very prominent: a) the group had to develop coordination and a collaborative mechanism (using Google Docs) since the Google Maps "as it is" does not provide any (12.8); and b) the problem that any participant may modify or delete comments without control or rollback (11.5).

Students mentioned that they had to resort on mechanisms defined by them to synchronize their work, like establishing deadlines for proposing, commenting and ranking them. Despite this agreement many students expressed their preference to work without deadlines. Also many students suggested that the time period for making comments to ideas should be immediately after their publication, otherwise they might forget what they wanted to say after reading it if they have to wait for that. Students expressed that geo-referencing ideas over a map was a good way to give context and with this, more understanding of the problem or opportunity the idea was tackling. They mentioned that using one system for geo-referencing ideas and then another for discussing them was rather inefficient, since they had to manage two systems and input same the information two times. According to the students, the information generated for Google Maps, as well as for Google Docs, should not be collaboratively editable in order to avoid students modifying opinions of their classmates.

Table 3. Qualitative coding of students' answers to the questionnaire and the frequency they were mentioned associated with Q3. Sn = Semester n; Avg. = average

Q3*: How easy to use was the collaboration support?*											
Positive comments						**Negative comments**					
	Year/Semester						**Year/Semester**				
	2012		**2011**				**2012**		**2011**		
Avg.	**S2**	**S1**	**S2**	**S1**		**Avg.**	**S2**	**S1**	**S2**	**S1**	
3.8	6	3	2	4	Shared view of ideas	**12.8**	16	9	12	14	Group had to develop alternatives for coordinating group work
1.3	2	2	0	1	Easies problem understanding	**11.5**	15	11	8	12	Users can edit others' contributions
0.8	2	0	0	1	Facilitates view of task progress	**8.3**	11	6	9	7	Tool inadequate for discussion support
1.8	3	2	0	2	Permits asynchronous interaction	**4.8**	6	3	5	5	Difficult to converge
1.0	2	1	0	1	Easies time management	**8.5**	12	9	7	6	Asymmetric participation
0.5	0	0	1	1	Uses colors	**2.5**	4	3	1	2	Lack of chat tool
						7.3	9	8	7	5	Lacks awareness mechanisms

3.3 Design Requirements Justified from the Findings

From the results described in the previous section we can conclude that that Google Maps “as it is” does not provide all the functionalities to support a collaborative discussion and selection of options (ideas) required for a geo-collaborative activity described in 3.1. Although it provides convenient mechanisms for geo-referencing data collaboratively, it lacks of mechanisms to support decision-making.

From Q1 we can derive the following requirements: a) provide mechanisms for commenting and selecting ideas in the same place where they are geo-referenced (brainstorming); b) provide functionalities supporting the following of ideas and comments associated by means of searching mechanisms which could help a user to follow a certain discussion thread.

From Q2 we can derive the following requirements: a) provide microblogging-like information architecture for commenting the ideas, so it will be easy to identify positive and negative opinions for each idea. b) Provide voting and/or rating mechanisms to support the convergence stage in the decision-making process. c) Provide mechanisms to manage private working spaces whose content can be later published. d) Implement editing rights in order to avoid students modify or delete comments or ideas which are not their own. e) Provide functionalities which allow students to write their idea proposals as “story boards”. f) Design a simple and easy to understand interface which allows to geo-reference ideas informing the physical context where they should be performed, which allows also collaboratively commenting and rating them.

Fig. 4. Two screenshots of the application, the small one taken from a Smartphone, and the big one from a desktop computer screen

From Q3 we can derive: a) provide a collaborative workspace which allows students to propose their geo-referenced ideas enriched by text and images (brainstorming and storyboard), comment them (in divergence and convergence modes); and state their preferences (convergence). b) Include brainstorming, divergence, and convergence processes in an iterative and cyclic way, allowing students to propose ideas, comment them and/or rating them during all the process.

4 Prototype Proposed to Tackle Problems of Google Maps "as is it"

In this section we propose a prototype application which uses geo-collaboration and microblogging to support the situated learning activity described in section 2.1 whose design is based on the requirements presented in section 3.3 which were derived after analyzing the answers given by students to questions Q1, Q2, and Q3 about the usage of Google Maps "as it is" for supporting this learning activity. It also includes design patterns required for a decision-making support system (described in section 2.3). The application has been developed with HTML5, thus users only needs a device with a browser and an Internet connection to run it.

4.1 Description of the Prototype

Figure 4, shows the main view of the proposed prototype as seen on a screen of a Smartphone and a desktop computer. We will describe this prototype according to the three decision-making patterns identified in section 2.3:

(1) **Information gathering and brainstorming the ideas in a divergent mode**. Students can geo-reference concrete physical locations where the proposed idea is going to be put into reality. This will include a title, a textual description and maybe pictures in order to better contextualize the proposal. The description on the left-hand side is always associated to one certain location on the map, which is shown when this location is selected, thus changing the selected location (for example to show another proposal or start creating a new geo-located idea) will also change the description associated. In this way we tacle design requirement a), associated to Q1 in section 3.3. Picture descriptions may correspond to a sequence of situations describing the context of the proposal using a story-board fashion to better understand it (see design requirement e), associated to Q2). The number of pictures is not limited and they may be uploaded from a desktop computer or a mobile device camera, thus allowing a student to create a proposal, write the text and take the picture on the spot and upload it attaching automatically the geo-location using the GPS of the mobile device if present. Pictures will be shown using at most half of the left-hand-side area of the interface in order to leave enough room for the text description and the comments other students make to it (see design requirement a), associated to Q3). At the beginning each proposal of an idea is created in a private workspace or view. When the student completes the proposal, it can be shared with the rest of the students in order to be commented and/or ranked (see design requirement c), associated to Q2). In the

desktop view of the interface shown in Figure 4 there is a geo-reference marked with a () symbol which means that contribution is currently selected by the user to view it and maybe add a comment and/or rate it. The icon showing an open lock beside the proposal's title means it has been made already public. In the Smartphone view of Figure 4 the proposal of the idea is being created, thus is is still private (shown by a closed lock icon).

(2) **Find alternatives, information processing and comments of alternatives using divergence and convergence modes**. In the upper part of the desktop interface view shown in Figure 4 we can see the searching tool which searches for ideas by author's name, associated comments words or date of creation. The result of the search will be shown as a list under the search tool and the corresponding location of all proposals matching the search criteria will be shown on the map. This functionality was designed in order to facilitate the location of proposed ideas which was mentioned as a problem and was the cause for establishing design requirement b), associated to Q1 in section 3.3. Comments associated to the ideas follow a microblogging structure as stated by design requirement 1, associated to Q2, as we can see at the bottom part of the right part of the interface in Figure 4, where two comments made to this idea are shown. The management of the comments is facilitated by the way they are organized and the method of selection/revision based on simple scrolling and options "expand" and "collapse" them. Most recent comments are shown above the older ones in order to facilitate the process discussion process during divergence and convergence phases of a decision-making process.

(3) **Make choices in a convergent mode**. Each comment to a proposed idea has a ranking mechanism associated (see design requirement b), associated to Q2) which allows students to assign points in favor or against the proposal. This mechanism can be seen in the desktop view of the interface in Figure 4, where the last comment shown at the bottom right gives two points in favor for this idea. The sum of all positive points minus all negatives votes given to one idea is shown beside the title of that idea. Beside this, marks on the map showing the location of the proposed ideas will be displayed in three different colors according to the ratings they received from all participants: Green for the better rated, blue for the ones rated in the middle range and red for the worst rated. In order to comply with design requirement b), associated to Q3 ideas can be commented and/or rated as soon as they are made public. Also each comment or idea cannot be deleted or modified according to requirement d), associated to Q2.

4.2 Evaluation of the Prototype

The prototype described in the previous chapter was evaluated under the same conditions regarding the educational objectives, technical setup, methods for data collecting and its analyze, as the one described in the section 3.1; except that this was evaluated for only one semester, which was during the first semester of 2013. The sample consisted of 32 students; 14 male; average age 23.5, taking an undergraduate course on Information Technology for Business, in the nine semester of Accounting career, at Economics and Business Faculty of the Universidad de Chile. These students were also good users of computing technology.

Table 4. Qualitative coding of students' answers to the questionnaire and the frequency they were mentioned associated with Q1, Q2 and Q3. Avg4. = Average of 4 semesters

Q1*: Did you feel information overload during the task?*					
2013	**Avg4.**		**2013**	**Avg4.**	
4	**1.8**	Everyone was available on the computer screen	**4**	**16.8**	Too many ideas and comments shown at the same time
5	**2**	Work was performed orderly	**0**	**6,5**	Some contributions were duplicated
5	**1.5**	History of ideas was easy to follow	**5**	**10,5**	Considerable flow of ideas and feedback
			0	**9,3**	Relation between ideas and comments difficult to establish
			0	**11,5**	Related ideas are shown apart from each other
			3	**4,8**	Too many objects shown in the same window at the same time
			2	**7,3**	Some comments were simply forgotten
Q2*: How easy was the software itself to use?*					
2013	**Avg4.**		**2013**	**Avg4.**	
12	**8,3**	Easy to understand (Google Maps use)	**2**	**6,5**	Proximate comments are difficult to discern
5	**2,3**	Immediate visualization of new comments	**0**	**7,3**	Cannot see who deleted comments
20	**3,5**	Reference of ideas in geographical context	**0**	**11**	Lacks coordination support
6	**1,3**	Using of colors	**0**	**10,5**	Mapping and chatting unrelated
16	**3,5**	Using of text and pictures	**4**	**1,3**	Slow
	1,8	Use of icons	**0**	**6,3**	No private working space
	1,5	Easy access to ideas	**1**	**9,3**	Had to improvise in order to collaborate
	0,8	Searching	**2**	**8,5**	Difficult to merge comments, ideas
			0	**8**	Communication is not primarily focus
Q3*: How easy to use was the collaboration support?*					
2013	**Avg4.**		**2013**	**Avg4.**	
18	**3,8**	Shared view of ideas	**2**	**12.8**	Group had to develop alternatives for coordinating group work
9	**1,3**	Easies problem understanding	**0**	**11,5**	Users can edit others' contributions
4	**0,8**	Facilitates view of task progress	**3**	**8,3**	Tool inadequate for discussion support
19	**1,8**	Permits asynchronous interaction	**1**	**4,8**	Difficult to converge
4	**1,0**	Easies time management	**2**	**8,5**	Asymmetric participation
4	**0,5**	Uses colors	**1**	**2,5**	Lack of chat tool
			2	**7,3**	Lacks awareness mechanisms

Results obtained (see Table 4), were compared with the mean average obtained for the 4 semesters when Google Maps was used "as it is" for questions Q1, Q2 y Q3 in order to find out if students perceived the improvements introduced in order to minimize the drawbacks. We did not tabulate other qualitative aspects than the ones obtained in the previous testing in order to have a more objective comparison process.

Comparing the results obtained when using the new application described in 4.1 for one semester against the average values obtained when using Google Maps (and some features from Google Docs) we can have a first indication that the proposed application performed better. However, we take these as first results, requiring more time to experiment in order to obtain more concluding data. Due to the experimental because we tried to find differences (hopefully improvements) with the negative evaluated aspects of the first experiment but there might be other negative aspects introduced by the second environment which were not present in the first one and therefore were not checked. We will evaluate the usage of the new application at least some other 2 semesters in order to see if there are other aspects that should be positively or negatively evaluated. The fact that results obtained for the 3 semesters following the first application of Google Maps to support the learning activity being studied in this work were not significantly different from the first one may be an indicator that in this case, we may also have no dramatic variations, at least regarding the aspects touched by the questions Q1, Q2, and Q3.

Keeping in mind that these first results should still be confirmed by further evaluation, we can say that according to the numbers in Table 4 many of the negative aspects of using Google Maps combines with Google Docs were solved. We can also say that we do not expect some negative aspects to come up again in future evaluations like duplicate contributions, idea proposals separated from the associated commands and ranking, deletion of ideas or comments by other students, lack of private workspaces, improvisation for supporting the decision-making process, and difficulties because ideas and the associated comments are separated.

5 Conclusions

According to the evaluation using Google Map "as it is" we concluded that it has some very interesting technical features which enable collaboration among members of large groups but it lacked some other also very important in order to properly support the situated learning activity described in this paper. This analysis allowed us to derive some important requirements for designing a more suitable application. We also derived some additional functional requirements from the literature about decision making like: (1) Information gathering and brainstorming the ideas in a divergent mode. (2) Find alternatives, information processing and comments of alternatives using divergence and convergence modes. And (3) Make choices in a convergent mode, described in section 2.3; to which we added the microblogging services, as described in section 2.2.

After defining the design requirements we built a geo-collaborative application which includes microblogging to support the learning activity. After one semester evaluation we obtained positive but still not definitive results when comparing them with results obtained with the previous situation.

Regarding the implementation of the system, it can be regarded as an integration of various types of cloud services into a single one. In fact, it makes use of functionalities provided by Goggle Maps and other cloud computing services and complements them implementing the missing functionalities. Some of the main advantages that authors have mentioned about using Cloud Computing are scalability, ubiquity, and reliability. These characteristics match the requirements of many learning scenarios, especially those in which students have to perform learning activities across various setting, inside and outside the classroom, collaboratively and individually working on generating and analyzing data, using different kind of computing devices supporting this work. We think that one of One of the main contributions of this work is to show an example of the use of cloud computing for learning in a different way as reported by the literature: instead of using services as they are offered we propose to combine them in a new application which can be tailored to meet the requirement of a specific learning activity taking advantage of the characteristics of cloud computing and getting rid of at least some of its drawbacks, hopefully not introducing new ones (this has not been checked so far).

It is clear that we need more evaluation instances of the new environment, which is currently being used by the students. This will allow us to make a more accurate analysis of what is working better and if there are some new problems introduced by the new setting that need to be tackled.

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Ontology-Based Resource Discovery in Pervasive Collaborative Environments

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Abstract. Most of the working environments offer multiple hardware and software that could be shared among the members of staff. However, it could be particularly difficult to take advantages of all these resources without a proper software support capable of discovering the ones that fulfill both a user's requirements and each resource owner's sharing preferences. To try to overcome this problem, several service discovery protocols have been developed, aiming to promote the use of network resources and to reduce configuration tasks. Unfortunately, these protocols are mainly focused on finding resources based just on their type or some minimal features, lacking information about: user preferences, restrictions and contextual variables. To outstrip this deficiency, we propose to exploit the power of semantic description, by creating a knowledge base integrated by a set of ontologies generically designed to be adopted by any type of organization. To validate this proposal, we have customized the ontologies for our case of study, which is a research center.

Keywords: shared resource discovery, ubiquitous collaborative environments, semantic resource description.

1 Introduction

In ubiquitous environments [1], a user would received information and computational services in such a straightforward way that he would not require to make any effort to get such benefits. However, to reach this objective, multiple entities have to be taken into account, not just the user but also the physical space in which this user is located. This challenge gets even bigger when multiple users need to be considered to provide an accurate support. Our research work aims at defining a shared-resource pervasive environment that acts as a base to provide support for collaborative work. Our motivation comes from the difficulties in taking advantages of physical (e.g., hardware and rooms), virtual (e.g., files and applications) and even human resources that could be available and ready to use/contact for a person, but that are usually forgotten or unemployed. Users could be discouraged to try to find a resource they lack if they need to go running around offices, floors and buildings or have to make several phone calls to

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try to localize a resource they do not even know if it actually exists inside the organization. Social relationships also play an important part, since, owners of resources not necessarily want to share their resources with everyone.

Several works have been developed to promote network resource sharing. However, none of these works incorporate in a comprehensive way: 1) the technical characteristics/capabilities of resources, 2) the owner's usage restrictions defined to share resources in a controlled and comfortable way, 3) the ownership and social relationships among users, 4) the resource availability, which depends on the resource and the users involved, and, 5) the current context conditions.

To create the aspired pervasive environment, we argue that a proper descriptive model of such environment would ensure the success of the resource discovery process. Our proposal consists of a semantic model that tackles the description of all the elements involved through an ontological approach. This model is part of the Resource Availability Management Service architecture (RAMS), which provides all the means to retrieve, organize, assess, notify and store information of the entities interacting within the environment.

This contribution is structured as follows. After presenting related work in section 2, we introduce, the RAMS architecture in section 3. Then, the ontologies proposed for describing the shared-resource pervasive environment are presented (section 4) and a real scenario is detailed to illustrate our proposal (section 5). Finally, section 6 presents our conclusions and future work.

2 Related Work

In this section, we successively provide related information about some traditional Service Discovery Protocols (SDP), and some recently developed frameworks that provide context awareness capabilities to the service discovery task.

Service Discovery Protocols

The Service Location Protocol (SLP) [2], developed by IETF, prevents applications from having to know the specific network location of the required services. An application invokes a service by providing its type. In response, this application receives the URL of the service that fulfills its requirements.

Ninja Service Discovery Service (SDS) [3] is an academic proposal that uses predefined XML templates to describe services. Ninja SDS creates representative vectors of the announced/requested services by applying hash functions to subsets of their features. A request is answered by comparing these vectors. If a match is found, the requester gets a XML document with the service information.

Jini [4], introduced by Sun Microsystems considers as a service any artifact able to be represented by a Java object. To process a request, Jini performs a look up among the registered services. If a service satisfies a client request, a Java object representing this service is sent back to the client.

The way the offered/requested services are described constitutes an improvable feature: most description processes limit users to express their needs in terms of service type or minimal features (in the best case). Additionally, SDPs consider neither the environment nor the current states of the services or the users. Thus, the dynamism of pervasive environments is not fully considered.

Frameworks
In order to provide user centric service discovery in pervasive environments, some context-aware frameworks have been proposed. We present two of them.

The AIDAS framework [5] (Adaptable Intelligent Discovery of context-Aware Services) evaluates the users' and registered devices profiles to create a view of accessible services considering the user context. AIDAS does not provide flexibility in service description because it only allows users to provide services characteristics. AIDAS offers semantic matching but just in the sense of the degree of such a match (e.g., exact or subsumption).

The DAIDALOS project [6] (Designing Advanced network Interfaces for Delivery and Administration of Location independent, Optimized personal Services) adds a semantic layer to a traditional SDP in order to include specific technical characteristics of these services. This layer includes an ontology-based description of the services, users and the environment.

Unfortunately, these two frameworks fail at providing means to represent a shared environment in which roles, user relationships, access rights and usage restrictions are so important as in a real scenario.

3 The RAMS Architecture

The RAMS architecture aims to define pervasive collaborative environments for resource sharing by relying on ontologies.

The RAMS architecture is based on the asynchronous publish/subscribe model [7], allowing users to play the roles of producers and/or consumers of events related to the state (e.g., location and availability) of shared resources. Producers publish resources to share them with their colleagues and generate events to change the state of such resources. Consumers subscribe to find out resources they need and receive events about the state of the resources of their interest. To provide support to real collaborative environments, producers grant access rights and specify usage policies to control the sharing of their resources.

RAMS components are identified by services they provide: human interaction (Fig. 1-A), data preprocessing (Fig. 1-B) and human recognition (Fig. 1-C).

The human interaction component is a Broker that provides services for implementing an interaction support between users and RAMS-based applications. The Publication Service (Fig. 1 step #1) allows producers to provide all information regarding their shared resources (i.e., technical characteristics, usage policies and access rights). This information is sent to the Topic-based Filter (Fig. 1 step #4), which classifies it into the right ontology according to the resources type. Afterwards, the Publication Preprocessor structures the classified information (Fig. 1 step #5) to be stored into the Knowledge Base (Fig. 1 step #6).

Consumers use the Subscription Service (Fig. 1 step #2) to describe the type of resources (or a specific resource) they are interested in. The Subscription Preprocessor structures such information (Fig. 1 step #7) to be understood by

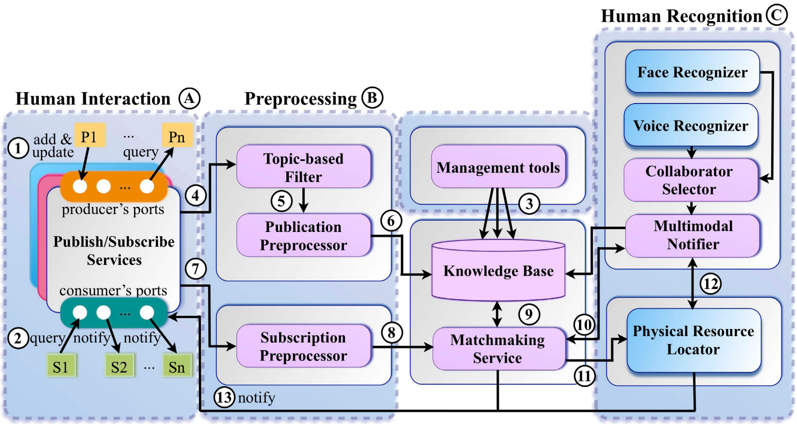

Fig. 1. RAMS Architecture

the Matchmaking Service (Fig. 1 step #8). This service determines the best resource available for each request by assessing information retrieved from: a) the Knowledge Base (Fig. 1 step #9), b) the up to date dynamic information from the Multimodal Notifier (Fig. 1 step #10), and c) the Management Tools (Fig. 1 step #3), which get the location and availability of a user respectively.

In case of a physical resource request, the available-suitable resources selected by the Matchmaking Service are sent to the Physical Resource Locator (Fig. 1 step #11), which asks the Multimodal Notifier for the consumer's current location (Fig. 1 step #12) in order to determine the closest resource and the path he should follow to reach it. The results produced by either the Physical Resource Locator (when looking for a physical resource) or the Matchmaking Service (when searching for a human or virtual resource) are finally delivered to the consumer (Fig. 1 step #13).

4 The RAMS Ontological Collaborative Environment

The RAMS architecture adopts a semantic approach to modelize all the resources involved in the sharing environment. Through the analysis of the behavior of different types and sizes of organizations (e.g, design agencies, research centers, and hospitals), generic elements (e.g., types of resources) were identified to provide flexibility (extension and customization) to the model. Here, we first present the ontologies [8] defined to support this semantic model. Then we introduce a study we carried out to identify the data properties, which are the most representative characteristics of resources. Finally, the context ontology is explained.

RAMS Ontologies
In order to make easier the reuse, adaptation, and extension of the RAMS architecture, a set of ontologies is proposed instead of just one big ontology.

1. *Human Resource Ontology.* Collaborative environments should help users to share their competences and characteristics in order to obtain results that are better than the sum of their forces. So, people inside an organization may share information about themselves and the roles they act within.
2. *Physical Resource Ontology.* This type of resources may assume different forms, from traditional hardware (e.g., projectors or computers) to the environment itself (e.g., classrooms or meeting rooms).
3. *Virtual Resource Ontology.* This ontology allows the description of resources represented by individuals[1] categorized in the following subclasses: `File`, `DriverPlugin`, `Database` or `Software` classes.
4. *Institution Information Ontology.* It holds specific information of the organization that can be customized according to its structure and requirements.
5. *Meta-Ontology.* It relates all the ontologies described above and the context ontology by defining object properties.

Object properties give meaning to an ontology as they relate instances of classes that otherwise are independent. In our semantic model, these properties are specified to represent the interaction individuals have in the real world. As the meaning of such properties can be enhanced by specifying their behavior, their characteristics (e.g., inverse, functional and transitive) were determined. Besides, closure axioms were set to create universal and existential restrictions over those object properties (cf. Section 5).

Data Properties

To identify the features (e.g., size and speed) allowing to define the best description of the resources the RAMS architecture manages, a survey was designed and applied to 100 potential users. The online and paper-based version of this survey presented technical characteristics, obtained from vendor specifications, of 18 different hardware devices and 17 types of virtual resources. Potential users chose the features they considered the most relevant for each resource.

The study was conducted into two institutions: 1) a university, in which 50 undergraduate students answered the survey; and 2) our research center, in which administrative staff, researchers, master and PhD students participated. The data properties were selected as those important for over 50 respondents.

Context Ontology

Our proposal main objective targets to perform shared resource discovery considering the environment and its changes. Several authors [5] [6] already proposed to represent context information [9] using ontologies. However, according to Najar et al., [10] most of the context representations are user-centric, limited to physical aspects (e.g., location and device capabilities). These representations do not consider the user in his/her collaborative environment. Yet, other authors [10] [11] [12] have pointed out the importance of organizational information on the context definition. We aim at providing the bases for collaborative work by

[1] In the ontology domain, an individual referers to an instance of a class in OOP

defining a pervasive environment for resource sharing. Thus, context representation should evolve to include both physical and organizational aspects.

Organizational Context
To model the organizational context, we consider Kirsch's work [12], which includes five features: space, tool, community, time and process. Its model provides awareness information for a set of activities (process) performed asynchronously (time) by a group of users (community) using a tool (device and application) in a physical location (space). However, the RAMS objective is not as fine grained as this model [12]. So, RAMS follows this model only to provide a contextual response when resources are required for reaching a goal.

This model is then adopted by adding the next classes to the `OrganizationalContext` one in the context ontology:

1. `Process.` Each individual belonging to this class is related to a final goal (e.g., meeting) that can be reached by a user or a group.
2. `Activity.` This individuals represent activities performed in a process.
3. `Group.` Each individual from this class represents a set of users.
4. `Role.` An individual from this class is a part a user plays when performing an action. A role affects the access rights/restrictions of a user.
5. `Calendar.` Individuals from this class represent the schedule of a process.
6. `Time interval.` This class holds individuals representing a period of time.

Physical Context
To represent the conditions of the physical environment in which resources are shared, two subclasses belong to the `PhysicalContext` one:

1. `Restriction.` This class holds individuals representing the usage restrictions defined by a producer. Each individual from this class is related to data properties that define its metric, an allowed and a consumed value.
2. `Task.` This class represents actions users can actually perform over virtual or physical resources (e.g., use, fix and move).

The modeled data properties are:

1. *PhysicalLocation.* It holds the coordinates of a resource location.
2. *DeviceCharacteristic.* It keeps current situation properties of an individual from the `Hardware` class (e.g., available memory and running applications).
3. *EnvironmentCondition.* This group of properties represents the actual conditions of an individual from the `Building` class (e.g., temperature).

5 Ontological Description Scenario

To explain in detail the designed model, let us consider Rachel's case of study. She requires an interactive whiteboard to give a conference in an auditorium which does not have such a resource. Since, for Rachel is really important to keep the audiences attention, she takes advantages of the pervasive environment that the RAMS architecture provides by requesting a UBoard portable whiteboard.

She is open to different brands, but she prefers the UBoard, cause she has used it before and the required software is already installed in her laptop.

Considering this request, three individuals representing portable whiteboards are found in the knowledge base. From the static information, the following relations (created by object properties) between individuals are known:

1. a **UBoard** *isOwnedBy* **James** from the `Researcher` class;
2. an **ONfinityCM2** *isOwnedBy* **Kate** from the `Researcher` class;
3. an **eBeam** *isOwnedBy* **Lauren** from the `ResearcherAssistant` class.

The `Researcher` and the `ResearcherAssistant` classes are subclasses of `HumanResource`. The *isOwnedBy* property is part of the *resourceRelationProperty* set of object properties, which groups properties related to the ownership and guarding of a physical or virtual resource by a human resource.

Regarding permissions and access rights, it can be known that Rachel is able to use the three devices, but she has to satisfy the following restriction:

1) **Rachel** *hasToSatisfy* **resRachel** 2) **resRachel** *isAssociatedTo* **UBoard**
3) **resRachel** hasAllowedValue 5 4) **resRachel** hasConsumedValue 1

This restriction is determined through the *hasToSatisfy* object property. **Rachel** needs to fulfill **resRachel**, an individual from the `Restriction` class. This restriction is related to the **UBoard** whiteboard. The hasAllowedValue is a data property denoting the allowed number of hours (per week) the resource can be used. Finally, the hasConsumedValue is also a data property linking **resRachel** to the amount of hours already consumed.

Some characteristics of the *isOwnedBy* property are: 1) it is not functional. Since, a physical resource can be owned by several human resources; 2) its inverse is the *isOwnerOf* object property. So, **Kate** *isOwnerOf* **ONfinityCM2**; and, 3) it is not transitive. Thus, **Kate** cannot be owned by **ONfinityCM2**.

From observing the conditions of the users and the environment when Rachel's request is made, the following information can be known: 1) James is available and inside his office, the UBoard is then available; 2) Kate is in the lunchroom, so, she would not be able to give access to her resource; and, 3) Lauren is working in a contiguous office; but Paul, a PhD student, is inside her office. Paul is then able to give access to the resource.

This information is essential to provide resource discovery at the RAMS architecture level objective, which involves not just a type of resources and its features, but also users' current context and their environment.

6 Conclusion and Future Work

The deployment of the RAMS architecture in any type of organizations would provide resource owners with full control on their resources by restricting their access and usage. So, the safety of resources would not be compromised.

The principal contributions of this work is the design and implementation of a knowledge base integrated by ontologies, which provides an accurate representation of all the elements involved in a real shared-resource environment.

We state, we have gone one step further from related work by providing a full semantic description model. This is important, cause, any change registered in an individual would automatically affect all the entities related to such individual, which does not happen in syntactic approaches as another algorithm will have to give meaning to the mentioned change. We also succeeded at considering organizational and physical context. These two types of context acknowledge the dynamism of the environment and of the people, by taking into account their roles and the tasks people perform inside an organization.

The proposed ontological approach for describing shared resources was designed in a generic fashion to be easily implemented in any type and size of organizations. So, the current state of our research leads us to deploy this ontological approach in different environments to validate its versatility and to measure its deployment easiness. Also, as part of the future work, we highlight the importance of conducting usability and system acceptance studies.

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Identifying the Awareness Mechanisms for Mobile Collaborative Applications

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Abstract. The complexity of modeling collaborative systems has been broadly recognized by the CSCW community. Mobile collaborative applications are a particular case of those systems, where design requirements and constraints are even more complex than in stationary solutions. Design complexity in mobile application increases because mobility changes the interaction requirements of nomadic users and the capabilities of devices to support them. Consequently, the awareness support provided by these systems should also be adjusted according to the nomadic users' context. This article presents a method that helps identifying the awareness mechanisms required by nomadic users to support a certain activity. The method, named Awareness Identification Method for Mobile Applications (AIMMA), suggests particular awareness components embedded in mobile collaborative applications, which will increase the interaction possibilities of users participating in a collaborative process. AIMMA can be used by software developers as a design guideline. This article reports the results of a proof of concept where the proposed method helped identifying suitable awareness mechanisms to improve the collaboration support of a mobile application. This method could also be extended to help identify, e.g., the services required by mobile workers to support their interactions.

Keywords: Mobile collaboration, awareness mechanisms, software design, users interaction, system evaluation.

1 Introduction

The complexity of modeling collaborative systems has been broadly recognized by the CSCW community. The success of a collaborative system depends on multiple factors,

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such as the group's characteristics, the work context, and the effects of technology on the supported collaborative activity [1]. Besides modeling, the design of these systems is also complex [14]. One reason is that most developers have experience implementing single-user applications, but little experience with multi-user applications. This single-user bias has been shown to affect the developers' intuition on what makes an application successful [10, 11]. When the system under development is mobile, design complexity increases because users' mobility changes the physical, task and interaction contexts. In particular, this means that a mobile application should dynamically self-configure its services to the new conditions and constraints.

Frequently, mobile collaboration happens in a loosely coupled way. This suggests that groups have low interdependence, high differentiation, low integration, and that these characteristics remain stable over time, resulting in groups that work autonomously and weakly depend on each other [24]. As a consequence, multiuser interaction is sporadic, occurring only when users require it. Collaborative systems should ease multiuser interaction at these moments, providing awareness mechanisms to understand the collaborators' activities and whereabouts, while promoting participation and collaboration.

Unfortunately there are few guidelines to identify which interaction services should be made available to increase coupling under certain adverse conditions, and also what awareness mechanisms could trigger such interactions. Herskovic et al. state that the selection of multiuser interaction services and awareness mechanisms depend on the supported task and also the interaction context [13]. The task dependency cannot be addressed in a transversal way (e.g. using a "fixed" set of Questions, Options and Criteria), because each task has its own particularities. However the second aspect, i.e. interaction dependency, can be addressed as a transversal design issue. Let us illustrate this statement. Assume for simplicity that only two mobile users are collaborating mediated by their communication devices. Their interaction context may be one of four possibilities, which depend on 1) the simultaneity of the presence of the two users at the moment they decide to interact, and 2) the capability of a user to reach the other user [14]. This classification opens up the opportunity to develop specific suggestions about what awareness mechanisms to support in each scenario. Note that these suggestions must be dynamic because people on the move can change their connectivity, which has implications on the interaction context.

Trying to contribute to reduce the design complexity of collaborative systems, this article proposes an Awareness Identification Method for Mobile Applications (AIMMA). The method highlights what awareness mechanisms developers should consider when tailoring technology support to mobile collaborative activities. AIMMA can be used both in the systems development and task/process reengineering cycles, and may even contribute to bring these two important tasks together. This method can be used, with minimal adaptations, to identify other services that must be embedded in a mobile collaborative application; for instance, services to support users' interactions and data sharing.

Next section discusses the challenges posed by awareness support in mobile collaborative applications. That section also presents some related works. Section 3 describes the proposed method. Section 4 presents the tool that supports the AIMMA method. Section 5 describes a case study where AIMMA was used and discusses the obtained results. Section 6 presents some conclusions and further work.

2 Identifying Awareness Mechanisms for Mobile Applications

Identifying which multiuser interaction and awareness mechanisms should be embedded in a mobile collaborative application is a difficult task. According to Herskovic et al., the difficulty in making these choices is a consequence of the iceberg effect [14], i.e. lack of visibility of groupware features, especially for designers and developers with little experience in collaborative systems.

The systems' functional requirements (i.e. those that are focused on single-user interactions and have a representation on the application user-interface) usually tend to be clearly visible for users and developers. They represent the visible part of the iceberg (Fig. 1). On the other hand, groupware requirements (i.e. those involving multiuser interactions) are often known by users but not clearly visible for most developers. One reason is that collaboration support is absent in most common systems, which results in a lack of familiarity for regular software developers. Another reason to ponder is that users often just tacitly know how they collaborate and may find it difficult to describe all details involved in their collaborations. As a consequence, the elaboration of groupware requirements may have to involve people with some experience in the design of collaborative tools.

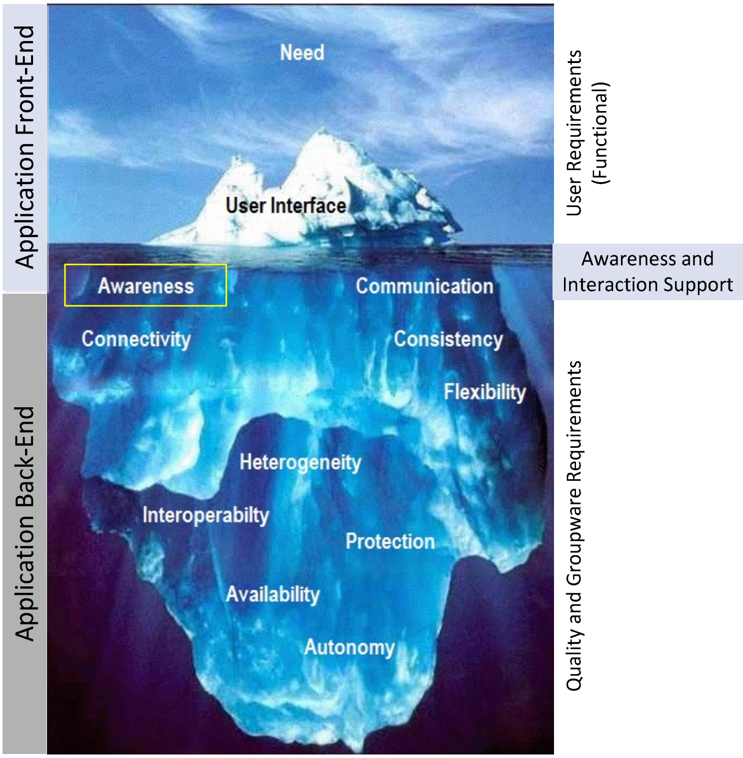

Fig. 1. Representation of the Iceberg Effect, from [14]

In the lower part of the iceberg we include a set of non-functional requirements that often impact collaboration support but may only be identified almost exclusively by groupware experts. The proposed method is focused on identifying those awareness mechanisms that are potentially useful to support multiusers interactions in mobile collaborative applications. This is a quite new research area, in which several initiatives are currently under way.

The research by Edwards et al. [4] concerned asynchronous work by a group of collaborators. They developed a platform called Bayou, on top of which collaborative applications can be built. Application developers can use Bayou to describe the semantic constraints of their applications. Developers can define data-integrity constraints, conflict detection and resolution procedures, and data propagation policies. Izadi et al. [17] propose their own middleware—called FUSE—to help developing mobile collaborative applications. FUSE provides a number of pre-packaged awareness widgets for gathering, distributing and presenting context information to application instances and their users. Each widget manages a set of context information, which helps individuals identifying other group members and coordinating their tasks.

When transforming single-user into multiuser applications, workspace awareness can be obtained as a result of Transparent Adaptations (TA), which are based on the Operational Transformation (OT) technique [28]. In the case of collaborative web-based applications, Heinrich et al. proposed a generic infrastructure promoting the accelerated, cost-efficient development of awareness widgets, as well as non-invasive integration of awareness support with existing web applications [12].

A very interesting paper by Oulasvirta et al. [23] addresses the provision of awareness in a mobile collaborative environment. They assert that "*instead of basing design on trial and error, we aim to reduce uncertainty in design choices by grounding them on findings in social psychology… Our starting point is that the usefulness of a situation cue in inferring another party's current situation depends on two processes: 1) on the individual's correct inference of a situation cue, and 2) on the social interaction afforded by that situation cue*". With that in mind, they developed 11 design requirements based on an equal number of social interaction scenarios. They used those requirements to build *ContextContacts*, a contact book that provides cues about the current situation of other users.

3 Awareness Identification Method for Mobile Applications

The AIMMA method was designed to help developers identify awareness mechanisms that could be useful for supporting mobile collaboration, depending on the users' interaction context at the time they decide to collaborate. Thus, this proposal contributes to reduce the systems' design complexity. AIMMA has three main steps: (1) modeling the multiuser interactions supported by a collaborative mobile application; (2) identifying the list of awareness components which are likely to be included in the application; and (3) reviewing the application to check whether it already includes the suggested awareness mechanisms, and if not, suggesting their integration in the application. Next sections explain these steps in detail.

3.1 Modeling Multiuser Interactions

During this step the designers use the Mobile Collaboration Modeling (MCM) language [13] to build a MCM graph. This graph identifies the roles of users participating in the collaboration process, describes the relationships among these roles, and determines the multiuser interaction contexts that are present in the mobile collaboration scenario. This modeling task must be done by observing and interviewing users.

The specification of this model allows developers to evaluate the completeness and correctness of the interaction scenarios that should be supported by a mobile application. This ensures that the awareness mechanisms to be analyzed are those potentially relevant according to the considered interaction scenarios. The visual representation of this model contributes to reduce the effort required for its evaluation.

Figure 2 shows an example of an MCM graph that describes the roles participating in a collaborative classroom activity, such as a teacher assigning students to teams, defining a leader, sending teams to collect plant specimens, collaborating to build a report, and having the group leader present some conclusions to the teacher. The MCM graph displays roles and how they interact by showing the types of multiuser interaction contexts in which the users can be when they decide to interact. The black squares characterize the arcs between nodes (roles), specifying which multiuser interaction contexts must be supported by the mobile collaborative application, as explained below.

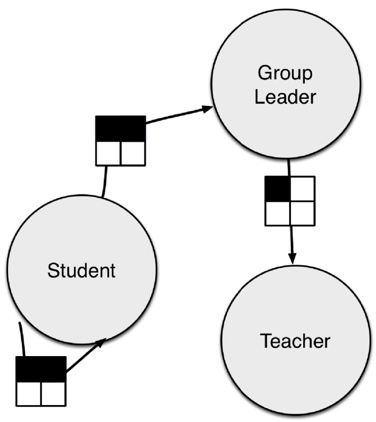

Fig. 2. MCM interaction graph among participants in a collaborative classroom activity

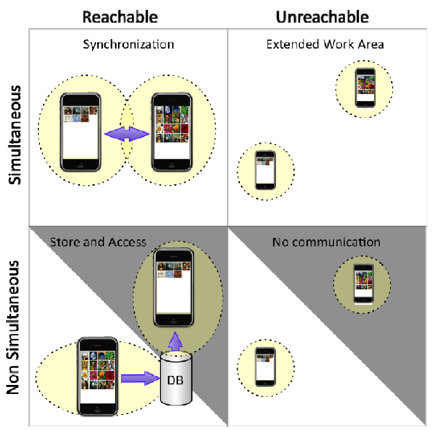

Fig. 3. Multiuser interaction context between two mobile users

The MCM graph depicted in Fig. 2 shows that users play one of the following three roles (light gray nodes): teacher, student, and group leader. In the case shown, interactions can be established when users are in one of the following quadrants: “reachable-simultaneous”, and “unreachable-simultaneous”. Fig. 3 presents the general multiuser interaction context in the four quadrants of this taxonomy. Note that the labels on the arcs in the MCM graph (Fig. 2) correspond to the interactions shown in Fig. 3.

According to the taxonomy, whenever a user decides to interact with another, that makes them *reachable* if there is an available communication channel between them. In other cases we say that both users are *unreachable*. For instance, two users are unreachable if one of them is unavailable to collaborate or disconnected. Moreover, considering the simultaneity dimension, we can say that two users are *simultaneous* if they are present in a virtual or physical space at the same time. In other cases, we say that both users are non-simultaneous. This is an updated version of the classical space/time CSCW matrix [2], since the ubiquity of mobile devices available today allows users to continuously move between places, making their simultaneity to do work a more relevant distinction. Typically, non-simultaneity occurs when the users collaborate in different shifts. Multiuser interactions between roles can change from one quadrant to another, e.g., because of users’ mobility, network access, or changes in their availability. It is important to note that unreachability and non-simultaneity are different: reachability refers to an accessible communication channel and availability to work, which can happen when the users are simultaneous (e.g. face-to-face) or non-simultaneous (e.g. e-mail).

Knowing which roles are participating in multiuser interactions, the relationships among them, and the quadrants in which those interactions take place, allow us to move to the second step, as explained below.

3.2 Identifying Candidate Awareness Components

The second step attempts to identify what types of awareness support are required in each multiuser interaction quadrant. Awareness support is mostly needed when users are working autonomously and at some instant in time they need to interact. Such interactions are typically eased if the application provides awareness about the other users’ location, activities, and communication possibilities.

Table 1 summarizes the types of awareness considered by the proposed method, which were obtained from literature and product reviews, using a previous study as a starting point [15]. For each type of awareness we considered the *time* dimension as a transversal factor, i.e., whether the awareness mechanism works with *past* or *present* activities and locations. We do not consider predicting future activities and location, since this would be forecasting, not an awareness mechanism—rather, we expect users to be able to predict what the other users are doing by studying their present and past activities (e.g. “*if John was at the cafeteria working on our paper 10 minutes ago, he might still be there and might want to talk to me about the paper”*).

The list of awareness elements was then classified according to the multiuser interaction contexts shown in Fig. 3. Table 2 shows the result of this classification, indicating also when the awareness mechanism should provide present information (labeled as “Pres”), past information (labeled as “Past”), or both of them.

Table 1. Summary of awareness types to support mobile collaboration.

Awareness Type	Definition	Examples
Physical Location	Location of a user in a map.	Google Latitude [8]
Physical proximity	Whether the user is in the same physical place as another.	Hummingbird [16], Rococo [25]
Distance	Location of user in relation to other users.	Loopt [19]
Place	Location of user in a place (e.g. "cafeteria", "library").	Foursquare [6]
Movement	Direction and speed of a user with regards to other users.	Waze [31]
Profile	Shares the user profile information with other people, including the user role.	Facebook [5], Gatsby [7], LinkedIn[18]
Visibility	Indicates if the presence of the local user is visible or not to others.	Skype [27]
Availability	Indicates whether the user is busy or available to collaborate with co-workers.	Skype [27]
Activity	Indicates the activities the user is engaged in at his device.	ConNexus [29], CenceMe [20]
Connection	Indicates whether the user is connected or not.	MSN [21], Google Talk [9]
Network connectivity	The system informs when the network connectivity is lost or recovered.	Skype [27]
Message delivery	The system informs the user when her/his messages are received by the target users.	WhatsApp [32]
View	Provides visual information from a remote environment.	Skype [27], Tango [30]
Resources Accessibility	Indicates whether a resource is shared for a group, public or private.	Dropbox [3]

To perform this classification, we used as a starting point a questionnaire that asked 170 engineering students about what presence awareness mechanisms were most useful in the four different quadrants [15]. The students' strongest preferences for each quadrant are highlighted in boldface in Table 2.

Then, we interviewed over 60 people to ask them what types of awareness are most useful in each multiuser interaction situation. Based on previous experience in the design of mobile collaborative tools, as well as using the results of the questionnaires and interviews mentioned above, we developed the final classification of awareness types in the proposed four quadrants. Overall, we note the second step of the AIMMA method analyzes the multiuser interaction situation specified in the first step and suggests awareness components that could be useful to support the collaborative process (i.e. quadrants in Fig. 3).

Table 2. Recommendation of awareness components to support interaction in the four quadrants

	Reachable	Unreachable
Simultaneous	- Physical location (Pres) - Physical proximity (Pres) - Distance (Pres) - Place (Pres) - Movement (Pres) - Profile (Pres) - Visibility (Pres) - Availability (Pres) - Activity (Pres) - **Connection** (Pres) - Network connectivity (Pres) - Message delivery (Pres) - View (Pres) - Resources accessibility (Pres)	- **Physical location** (Pres-Past) - Physical proximity (Pres-Past) - Distance (Pres-Past) - Place (Pres-Past) - Movement (Pres-Past) - Profile (Pres-Past) - Visibility (Pres) - Availability (Pres-Past) - Activity (Pres-Past) - Connection (Pres-Past) - Network connectivity (Pres) - View (Pres) - Resources accessibility (Pres)
Non-simultaneous	- Profile (Pres) - Visibility (Pres) - Activity (Past) - **Connection** (Past) - Network connectivity (Pres) - Message delivery (Pres) - Resources accessibility (Pres)	- Profile (Past) - Visibility (Pres) - Activity (Past) - **Connection** (Past) - Network connectivity (Pres)

3.3 Analyzing the Collaborative Mobile Application

The *third step* involves implementing the proposed awareness mechanisms in the application under development. Naturally, in case some awareness mechanisms have already been incorporated into the application, we must first review it to determine whether the suggested awareness components are already present or not. To do that, developers will have to simulate/theatricalize the multiuser interactions that may occur during collaborative activities (i.e. those indicated in the MCM graph) and determine if in those situations the system provides any awareness mechanisms suggested by the AIMMA method.

In case a particular awareness component is not present in the application, the method suggests in which context the component should be made available. Thus, the method aims to improve contextualized collaboration support. However, the developer should ultimately decide if a certain awareness component should be included in the application or not, taking into account other factors such as, for instance, the implementation cost. In order to reduce the effort applying the proposed method, a software tool was developed. Next section briefly describes this tool.

4 A Tool for Applying AIMMA

We developed a tool supporting the AIMMA method. The tool helps software developers to create an MCM graph that describes the collaboration processes they are trying to support. The tool also allows users to generate a list of awareness requirements for the relationships defined in the MCM. For example, Fig. 4 displays a collaborative process for construction inspections we developed with the AIMMA tool. If the user chooses the "*Analyze awareness requirements*" option, the tool automatically generates the corresponding awareness requirements for each role relationship.

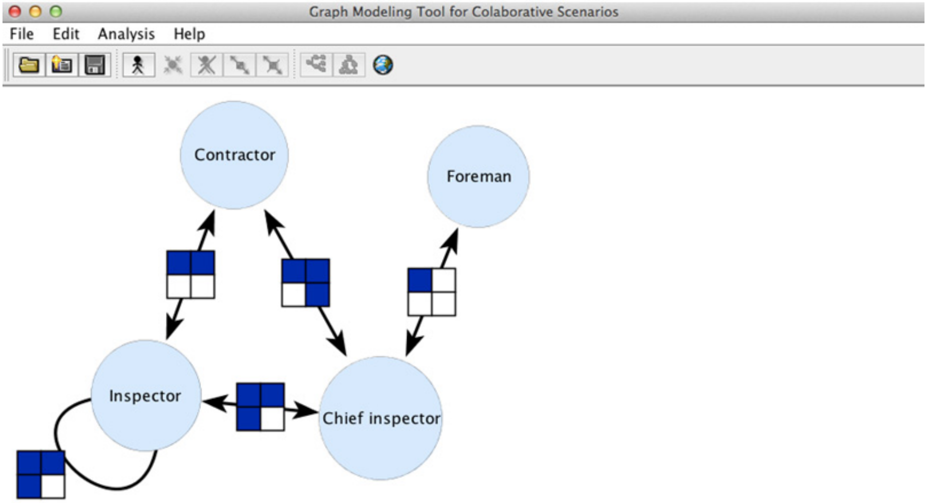

Fig. 4. Example mobile collaborative process

Fig. 5 displays the list of requirements generated for the Foreman role, which, according to the MCM graph, only interacts with the Chief Inspector. The tool shows the suggested mechanisms and allows adding other mechanisms or disregarding some suggestions by unchecking a box.

Then, the developer must review the application (or the requirements specification if the application is under development) to identify which recommended awareness mechanisms are already included in the application. The developer may indicate whether the awareness mechanism has been implemented or not, by checking the "done" box. It is important to note that each pair of multiuser interactions will generate its own list of awareness requirements. For instance, the *message delivery* requirement applies to the Foreman and Chief Inspector interactions but not to Contractors and Inspectors.

Concerning the awareness mechanisms that have been suggested by the tool but are not implemented in the application, the developer must decide if it is convenient or not to include them. To do that, the developer can use his/her own criterion and also ask the users/clients for their pertinence.

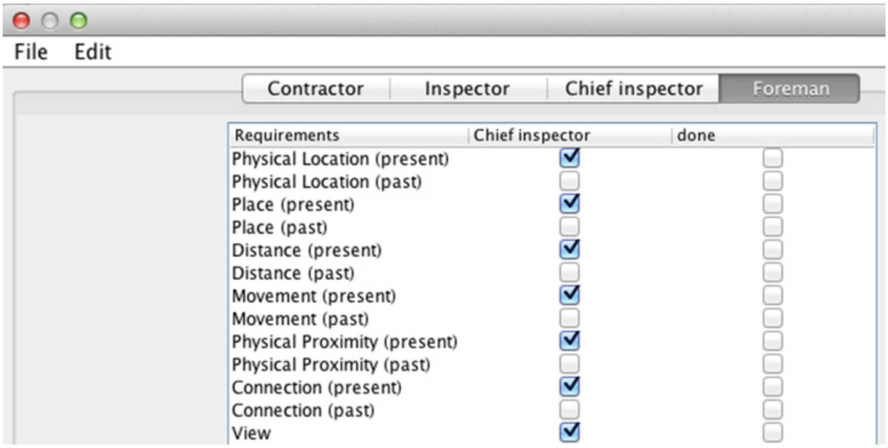

Fig. 5. Recommendation of awareness components to support users interaction

5 Case Study

The AIMMA method was used to improve the collaboration support provided by a mobile collaborative application used to perform construction inspections. The application, named COIN (Construction Inspector) [22], had a development team in charge of evolving the solution according to the users' requirements and also the opportunities identified by AIMMA. AIMMA was applied to COIN v1.5, and the obtained feedback was considered in the development of COIN v2.0. Next sections describe the initial COIN, the results obtained after applying AIMMA to COIN v1.5, the new version of COIN and some preliminary results.

5.1 The Initial COIN Tool

COIN allows a team of inspectors to record incidences in digital blueprints that represent the physical facilities of a construction project. These records are shared and discussed by several inspectors to determine whether incidences must be sent to the main contractors or subcontractors. Figure 6 shows the main user interface of COIN v1.5. The user list (also known as "buddy list") shows that two inspectors (Juan and HP-PDA) are participating in the inspection process of a building. Moreover, we can see the users' current location on the digital blueprint they are using to record incidences. This allows them to perform quick face-to-face interactions when they have to discuss an incidence record or have to coordinate their activities.

COIN also includes an instant messaging tool that allows exchanging messages among the participants in an inspection process. Connectivity among the participants is provided by a Mobile Ad hoc Network (MANET). Therefore, a wireless communication infrastructure is not required to connect the team members. A user can set his/her connection mode as “collaborative” if he/she wants to remain connected to the MANET. However, a user can set the connection mode to “stand-alone” and in that case will be disconnected from the other team members.

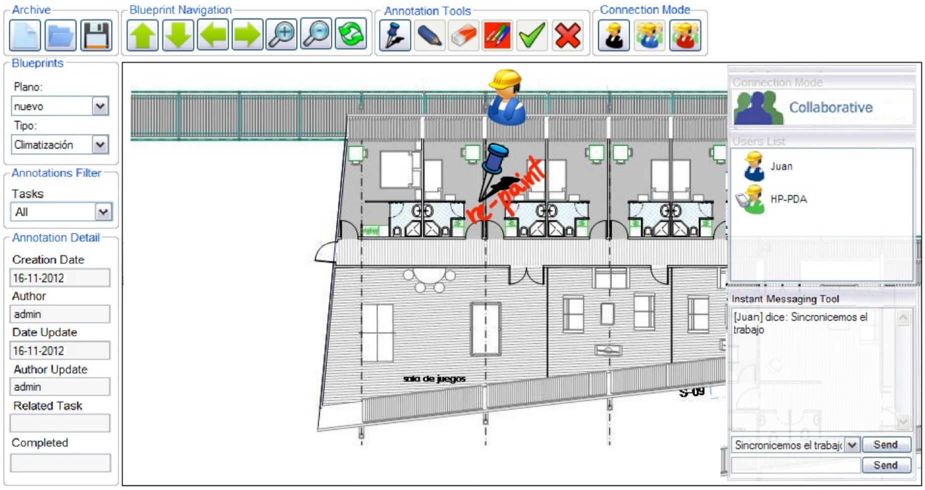

Fig. 6. Main user interface of COIN v1.5

5.2 Analyzing COIN’s Awareness Support

To determine how suitable the awareness support of COIN v1.5 is, a developer created and validated the multiuser interaction graph for the inspection process (i.e. performed the first step of AIMMA). The graph is presented in Fig. 4.

Using the AIMMA tool, the developer obtained a list of awareness mechanisms that could be used to ease the multiuser interactions among specific pairs of roles. Fig. 7 shows part of the recommendations related with the Inspector role; and also shows what awareness mechanisms are already supported for that role.

AIMMA gave 23 recommendations for the Inspector’s relationship with the other 3 actors. Eighteen of them were found appropriate by the developer. The awareness on place (present and past), view (present), profile (past) and resources’ accessibility (present) were not considered suitable to support the construction inspection process. Four of the suggested awareness mechanisms were incorporated into COIN: physical location (present), connection (present), profile (present) and visibility (present).

Moreover, it was found that the current version of COIN does not provide awareness about the interaction between Inspectors and Contractors. After analyzing the recommendations not included in COIN, the developer decided to support the interactions among Inspectors and between Inspectors and the Chief Inspector. The resulting application is detailed in the next section.

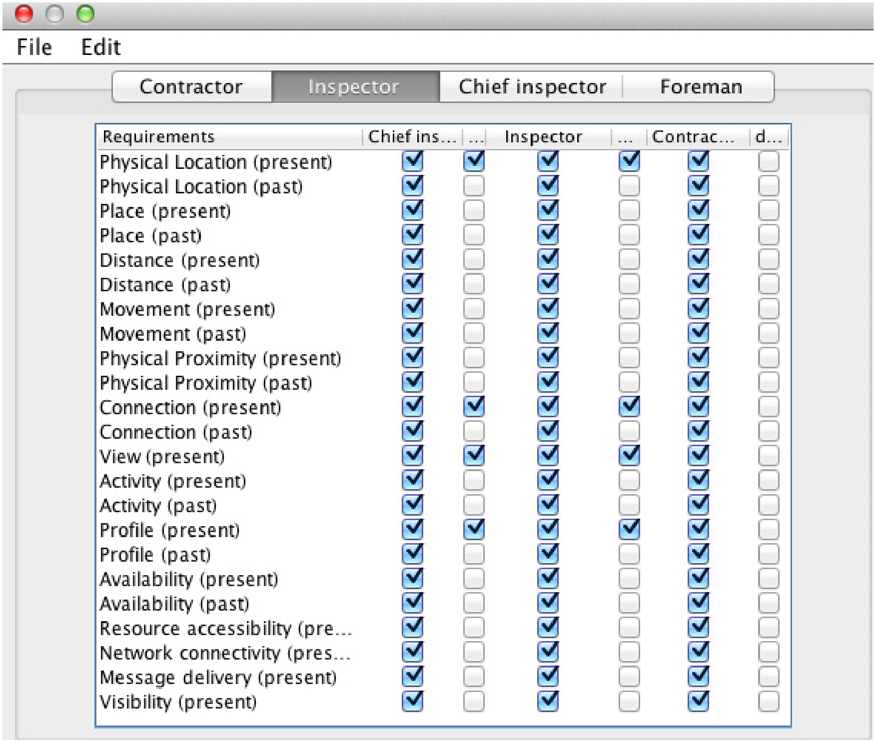

Fig. 7. Awareness support of COIN v1.5 for a user inspector

5.3 The Current COIN Tool

Figure 8 shows the user interface of COIN v2.0, which includes most of the awareness mechanisms suggested by AIMMA. Users' physical location awareness was improved by including a label with the user names, age and positions. COIN also includes a visual track that allows inferring the users' movements. The buddy list was improved to include awareness information on users' connectivity (present), activities (present and past), relative distance/proximity to other users, and also the availability (present) of other inspectors, including the Chief Inspector. The local user visibility was redefined. Now, when the user decides to be "invisible" he/she remains connected, but the presence is not visible to the other team members.

5.4 Evaluation Results

This version of COIN has been used in a real scenario to support simulated inspections, as a way to evaluate collaboration capabilities that the new features provide to the users [26]. The inspection was done in a large construction project that was at an intermediate stage. The participants in this evaluation process were a Chief Inspector and four regular Inspectors, all of them familiar with the use of COIN v1.5. Three observers were also participating in the process; one of them followed the Chief Inspector during the whole experiment.

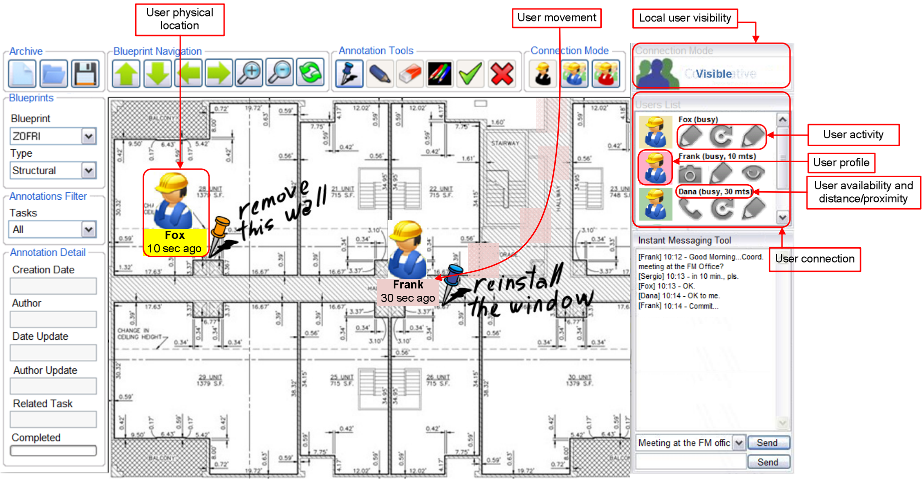

Fig. 8. Main user interface of COIN v2.0

The inspection team reviewed the electrical network of two floors of the building. Fifty post-its were placed in the physical infrastructure to simulate electrical contingency issues. Each post-it included one or more sentences describing the contingency, which were recorded by the inspectors on a digital blueprint using COIN. The Chief Inspector used COIN also to identify the position of the team members and estimate the advance level of the inspection process. The Chief used the users' activity and location awareness to find the inspectors that were delayed with the reviewing process, and thus he helped them to finish the assignment.

When inspectors needed to discuss with a teammate about a particular electrical contingency or when they had to report their inspection results, they used the movement and location awareness to find colleagues or the Chief Inspector.

After the inspection process we conducted a focus group with the participants to try to understand the impact the use of the new system had on both the people interaction process and the activity performance. The participants agreed that the awareness information embedded in the system allowed them to coordinate the tasks and get a more comprehensive view of the process. However they believe it would be even better if some context information is delivered through alarms; e.g. when an inspector finishes the assigned activity. All participants felt highly comfortable using the new version of COIN.

Although the evaluation is still preliminary, the obtained results indicate that the awareness mechanisms embedded in the new version of COIN ease interactions among Inspectors and also between the Inspectors and the Chief Inspector.

6 Conclusions and Future Work

It is well known that designing mobile collaborative applications represents a challenge for software engineers. Particularly, the design of the awareness support embedded in the system will impact the collaboration capability of the users. Moreover, the mobility of these users changes the interaction context between them, therefore the awareness support should be provided according to the interaction context that characterizes the situation that involves the potential collaborators.

This article presented the AIMMA method that helps designers of mobile collaborative applications to identify awareness mechanisms to support nomadic users that perform a particular collaborative activity. This method uses an interaction graph to determine the awareness support that is potentially useful to ease or promote collaboration between the participants, depending on their roles in that activity.

The proposed method was used to determine the awareness support of a mobile application that eases the collaborative work of construction inspection teams. The obtained feedback was then used as an input for the design of a new version of the tool. The results of the new system evaluation indicated that the awareness elements introduced in the application (according to the AIMMA suggestions) were useful and usable for the end-users.

Although these results are still preliminary, they indicate that the suggestions provided by the proposed method can be used to improve the collaboration support of mobile collaborative systems. Clearly, more experimentation is required to determine the real contribution and limitations of this proposal.

As part of the future work we will continue using the AIMMA method to help improve these applications. The other topic deserving of in-depth study is the problem of user privacy: the tradeoffs between providing awareness and granting users privacy is well known. The AIMMA method allows the designer to uncheck an awareness suggestion if the designer believes it to violate a user's privacy, however, this is a complex task and its implications and mechanisms require further study.

The AIMMA method can be adapted to help identify other services that should be required to support mobile users work. Therefore, our research on this method will continue extending it to include the identification of user interaction and data sharing services.

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In-Vivo Therapy Procedures: Design Process of a Geo-Referenced System

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Abstract. This paper presents the design process of a geo-referenced communication system which aims at providing technological support to Cognitive Behavioral Therapy and Social Competences and Skills Training therapeutic procedures. The usage of geo-spatial information while communicating between therapists and patients can be critical, particularly in in-vivo sessions, to identify locations which evoke negative experiences to patients or to encourage the latter to overcome obstacles. We show a high-fidelity prototype multi-iteration design process and complement the discussion with the results from an experimental period which aimed at assessing the system from a usability, user satisfaction and functionality perspectives. Results were positive and led to the revision and ultimately the final design iteration which is reported here. We present the rationale behind these design choices, discuss the advantages over existing similar tools, analyze possible challenges and comment on the fulfillment of providing seamless context to scenarios where such information is paramount.

Keywords: Cognitive Behavioral Therapy, Geo-Referenced Systems, Group Monitoring.

1 Introduction

Exposure to feared, uncomfortable situations is a common and often critical component of success in several forms of therapy, including cognitive-behavioural therapy (CBT) [5] or social competencies and skills training (SCST) [9]. This component, also referred as Exposure Therapy, consists on tentatively taking patients to the entity of distress (e.g. situation, place, person, or object) leading them to deal with situations and thus building their coping mechanisms. Interestingly, many of those entities can be pin-pointed to specific locations (e.g. school, hospital, subway, and the dogs in the neighbours' house).

On a cognitive-behavioural approach patients are usually asked to verbalize or write indicators (e.g., how much fear), thoughts or rationalizations (depending on the therapy stage) towards the situation they were exposed to [17]. This contributes to the patients' cognition restructuring and wellbeing. If possible, these reflexions should be

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expressed at the beginning, during or immediately after the exposing process. This kind of therapy comprehends in-vivo sessions, where the patient works with the therapist, or assignments patients should perform autonomously [18][19]. These in-vivo sessions refer to the activities the patients carry out in determined locations, while being supported by the therapist. Note that geographical co-location may not be required (ensuring face-to-face meetings are not mandatory) since as the therapy process evolves, some of these assignments are carried over as homework, a scenario where the therapist is not physically available. During the sessions, therapists continuously assess the patient status, offering relaxing or encouraging words, as needed. For the off-session assignments, since the therapist is absent, such assessment and support cannot be done. On the other hand, these assignments represent better opportunities to expose the patient to the daily life situations or entities that cause the distress, thus increasing the patient's resilience to these situations.

Solutions for this kind of procedure are scarce. There are various communication systems available, some recurring to geo-referenced cues to provide richer information to individuals monitoring groups, but they are typically too complicated for unspecialized users such as therapists. As such, the research presented in this paper is part of a project – InSiThe – which aims at improving current therapeutic procedures by introducing a set of applications to support the scheduling, and management of in-vivo therapy sessions for therapists and reporting tools for the patients to communicate with the former. The main goal is to create a tool suite capable of supporting therapeutic scenarios by providing therapists and patients alike with seamless contextual data, enriching the knowledge provided to both parties in order to improve the assessment of therapeutic activities. Two teams are actively involved in this project, namely a group of HCI experts from the Faculty of Sciences and a group of clinical therapists and researchers from the Faculty of Psychology, both from the University of Lisbon.

We have developed an application suite comprised by support tools for both therapists and patients which aims at providing technological support to CBT or SCST in-vivo sessions. More particularly, this paper reports the design process of such tools, comprehending three design iterations with appropriate testing and result discussion. We compared the InSiThe application suite to existing and comparable web services based on Google platforms to assess not only the performance of InSiThe's tools, but also if the utilization of an integrated approach would be beneficial to the therapeutic process. We finish our analysis with the discussion of some design aspects we identified to be determinant to the addressed type of systems.

2 Requirements and Related Work

Social competencies and skills training, a sub domain of psychotherapy, promotes in-situ and exposure activities in which they have to complete tasks ranging from talking to someone to being in the vicinity of a specific place. The intrinsic nature of these activities and absence of technological support makes it difficult for therapists to actively monitor and motivate patients along with proactively intervene in special situations, affecting both the therapy process and results.

With the increasing dissemination of mobile devices and enrichment of smartphones with cutting-edge communication and multimodal features one can identify applications that could be used to mitigate some of these issues [6]. Messaging, voice communication, audio and video recording, etc. can certainly be of assistance. Yet, true support could only be provided by an integrated system that adequately addresses the requirements without precluding the therapy process.

The expertise and knowledge of the therapy domain shared with us by the team of psychotherapy researchers' involved was paramount to identify a set of scenarios and assignments in which these integrated technological solutions would be welcome:

- **In-vivo session support**: Therapeutic processes such as those performed in fear therapy or social competences and skills training involve therapists and patients to interact with each other in the fulfilment of tasks related to the pathology (e.g. being confronted with the fear source, developing social skills in public areas, among other). As the therapeutic process evolves, the therapist often steadily dissipates his / her presence in favour of a more autonomous (yet still with proper support) approach by the patient while carrying out his / her assignments. This support may be given either face-to-face in-between assignments or using remote communication channels when physical co-location is not possible.
- **Transition towards homework assignments**: As the patient progresses throughout the therapeutic sessions, typically some of the aforementioned assignments may start being performed fully autonomously as homework between sessions. In these cases, it is paramount for the data collection mechanisms to retrieve as much contextual data as possible in order for the therapist to assess the validity and truthfulness of the patients' records. In this scenario, the therapist's presence is even less frequent, even as a support entity, since both geographical and temporal availability may be in jeopardy.
- **Offline analysis support with context data**: The final scenario pertains to the analysis of patient data after an in-vivo session. Without technological support, therapists are only able to rely on paper registries performed by the patients and which may not be an accurate depiction of the situations they were involved in. Ideally and with technological support, patient context (e.g. location, time of day, etc.) should be automatically retrieved so that therapists are able to re-enact all assignments the patients performed, enabling a thorough more informed discussion with patients.

Transversely, from these scenarios a set of requirements also emerge to ensure that the traditional therapeutic processes are not severely disrupted and that technology becomes an asset, not a liability, for patients and therapists alike:

- Therapists should be able to monitor and facilitate sessions while, if possible, tracking the patients' progress in co-located or geographically distributed in-session settings.

- Therapists should have the ability to communicate with each patient in-session either on a private or broadcast basis giving encouragement and proactively intervening whenever considered necessary.
- Patients should have an application which allows the timely and multimodal registry of their thoughts for on-session settings.
- Support tools should be an asset in aiding stakeholders to achieve their goals, ensuring their presence does not hinder or disrupt established therapeutic protocols.

Based on these pointers, we investigated current and past group communication platforms which covered these aspects either totally or partially. We will now discuss our findings and the adequacy of such solutions to the CBT and SCST problematic.

2.1 On Group Communication Solutions

Communication platforms and, in particular, instant messaging services have progressively evolved over the last few decades. From the introduction of cartoon elements to provide a more vivid and fun experience [7], to the usage of tri-dimensional virtual rooms [4], this type of services has capitalized on the rapid advances in both hardware and software technologies. The recent introduction of location-based services has prompted yet another set of solutions towards new requirements to provide users with enriched information about their context. In light of this progress, we have witnessed the appearance of tools such as MapMail [11] and MapChat [2]. Both offer geo-referenced information to their users: the former uses this information in an integrated email client, while the latter aims at providing users with a way to arrange meetings online while allowing the possibility of having conversations over special landmarks on a map using their mobile devices.

While some of these solutions present interesting solutions, they fail to provide full geo-referenced support to user conversations. These typically rely on previously pointed landmarks, inhibiting the users from chatting over free locations on a shared map. This leads to another challenge: how to share information between users in the same group working towards the same goal? Managing information that is shared between several devices is the usual goal of a system supporting cooperative work in a spatially distributed environment. The Pebbles project [10] was an interesting research aiming at providing groups of co-located users with means to share data and interact between different devices (e.g. PCs and handheld devices). Following similar lines of research, several authors explored how to share data across communal spaces in order to arrange meetings [14] or simply accomplishing tasks together [3]. Still, location-based support is scarce, and some of these solutions use environments which are not suited for mobile devices (e.g. tri-dimensional virtual worlds). If we delve into more specific domains we conclude that both the technological and user-oriented requirements (e.g. freedom to chat over any spot, unique integrated application, simplicity to use) are far from being achieved by the presented related research and ultimately, fail to cope with the requirements of critical domains such as therapy.

3 The Concept and Low-Fi Prototypes

The InSiThe concept encompasses a set of tools to allow supervision and communication between mobile participants, while allowing in-situ data gathering. The first design iteration [4] was rapidly set using low fidelity prototypes, in a close participatory approach with one teams' therapist. The prototypes showcased the envisioned features for the system. Two main tools were designed: one allowing the therapist to follow and communicate with patients; the other allowing patients to gather different media data and send it to the therapists along with their locations and expressions of anxiety, questions and doubts.

Most importantly, the prototypes gave therapists the opportunity to experiment a concrete, even if paper based, system. A Wizard-of-Oz or shadowing based experiment was setup. Therapists were involved in a simulated CBT and SCST scenario. Actual communication was achieved through a mobile phone connection. The team of therapists working in the project was enthusiastic about the envisioned features, with particular emphasis on the ability to easily access patients' location, time spent at specific points and tasks. A new set of ideas and needs were elicited.

4 The Functional Prototype

In the second design iteration our efforts were channelled towards the development of a high-fidelity prototype of the InSiThe applications. The development period lasted for approximately 8 months and included the implementation of the management, monitoring and reporting tools. All design choices documented in the next subsections reflect the valuable feedback obtained in the previous design iteration. We will now discuss each application in detail.

The Management Tool

The Management Tool is a web application whose scope involves patient record management, the scheduling of therapy sessions and the definition of goals within them. Two forms are provided for the creation of new users or new sessions. Both require mandatory information such as real name, in-system user name or email for the user creation process and session name, theme, date or scheduled starting and conclusion hour for the session creation process. Session scheduling itself involves three steps: addition of new or existing users to the session; definition of the session's date; and the definition (if available) of the session's goals. In the latter, therapists are able to define new goals by positioning a pointer in the map, and then provide information such as goal's description, order and patient assignments, among other.

Monitoring Tool

The Monitoring Tool is shown in Figure 1. The therapist is able to operate it to keep track of the patients in the current session, communicate with them and sanction individual goals. The tool comprehends two main areas: the messaging one, on the left, and the map monitoring area, on the right. Each area has its own filters that enable an independent visualization of the conversations and the locations.

The messaging area (left) corresponds to a chat where each message is labeled with the users' name. The therapist's message includes a destination since they are allowed to select one or all patients. The destination of the therapist's messages is also determined by the vertical users' filter bar (left to the chat). If the "All" option is selected the messages are broadcasted to all the users when the "Send" button is pressed. If a particular user is selected then only his / her messages (as sender or destination) are shown and the therapist's messages are only sent to that particular patient. The panel below the send button shows all the received messages.

The map monitoring area shows the paths of each selected user and his / her goals, shown as pins. The filter (above) the map enables the selection of specific goals by current status goals with a given status (e.g. approved, waiting approval, and in progress) or by patient. Patients' tracks are shown in colors corresponding to the legend on the top right corner of the map. A route checkbox enables or disables the track lines. The map is updated periodically requesting the repository for the new messages since the last update. Objective pins [17] have balloons that provide detailed information about the goals and their status. The pins change color to reflect the status of accomplishment: a red pin corresponds to a rejected accomplishment attempt or a not yet accomplished task, while a green pin relates to an accomplished task.

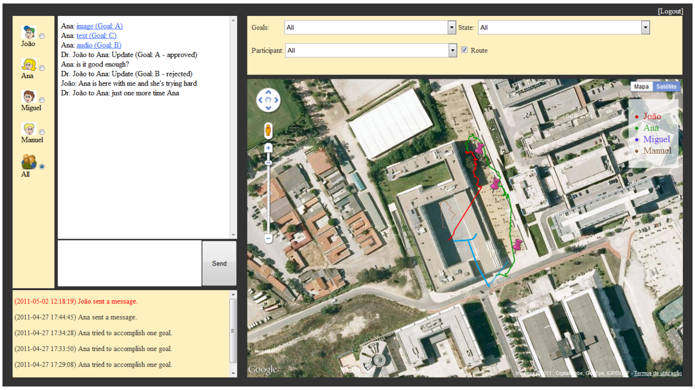

Fig. 1. InSiThe Monitoring Tool

The therapist can also receive multimodal messages (e.g. photographs, audio records). To access it, the therapist must click on the corresponding message in the message area or on a specific area of the balloons that pop over the pins.

Reporting Tool

The Reporting Tool comprises three main panels: map, messages and goals. The bottom bar on all three allows the direct navigation through each panel. Figure 2 (left) shows the vicinity of the patient's current location, along with the goals that he / she has been assigned to accomplish. Goals are depicted as a cup. The balloon that pops on top of the cup (the top one, in the figure) provides some details on the objective and direct access to requesting the approval of that task. Touching the balloon shows the requesting panel represented Figure 2 (right) which enables the patient to send a text message, an audio recorded message or a photograph. This request is sent to the therapist who will then reject it or accept it. Back on the maps panel on Figure 2 (left), the red and green checks over the cup relate to these states. If rejected the cup goes back to the unchecked state. A similar interface to Figure 2 (right) can be used to send multimodal messages to the therapist whenever the patient needs to communicate with him/her. By performing a swipe gesture on this screen, the user can access the message log and read the entire conversation with the group's members.

Implementation Details

The web services and the managing and monitoring tools were built using web technologies; the reporting tool was implemented in Java for an Android platform; the repository was implemented in MySQL. The option for web technologies is due to portability and the rapid and easy access to communication and remote access protocols. Although several adjustments were done, the tools currently execute adequately in Chrome and Firefox. It has been tested in desktops and laptops, and in two tablets: an IPad 1 and an LG running Windows 7. The choice for the mobile platform was also straightforward. At the beginning of the development is was the best available platform free of charge and providing easy access to the underlying smartphones features. The reporting tool has been tested in a HTC Desire, a Nexus One and a Samsung 550, running Android 2.2 and 2.1. The adoption of a web approach for the mobile platform was considered, yet, at that time the mobile web development technologies were still short of access to some of the smartphone features. The access to maps is done through the Goggle Maps API.

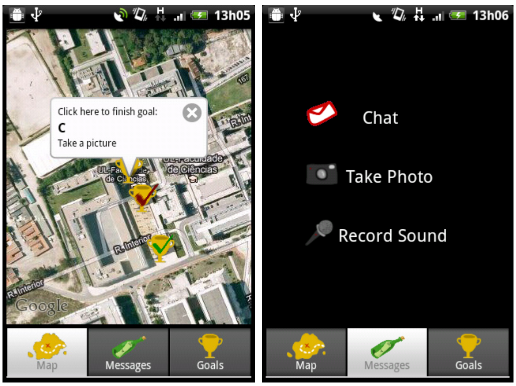

Fig. 2. InSiThe Reporting Tool: map screen (left); messages screen (right)

4.1 Evaluation

We conducted a set of experimental sessions to assess the first design iteration of InSiThe's tool suit from a usability and user satisfaction point-of-view. Since clinical deployments typically require a final version of the applications and testing with individuals undertaking therapy procedures is often not recommended, we opted to perform a role play experimental period [20], while including individuals from the area to carry out specific roles. We took special care in the recruitment of participants, since we preferred them to have knowledge of therapeutic procedures and tools in order to obtain valuable feedback from individuals from the domain.

Testing took place at our university campus, spanning through the course of two weeks. Four groups composed of three people each participated in the test sessions. Each session lasted for approximately 45 minutes. For each session, one group element would take on the role of a therapist while the remaining subjects would perform the role of a patient.

Goals

The goal of this experimental period was to perform a thorough usability and user satisfaction analysis of the InSiThe toolset. Aspects such as perceived difficulty in taking certain actions, speed to accomplish determined actions or how the user feels while interacting with the tool suite are taken into account in this study. In particular we intend on comparing InSiThe with a set of tools capable of delivering comparable services, namely Google Maps in conjugation with Gmail and Google Talk. The main justification for picking the Google toolset pertains to the applications therapists were mostly used to work with for comparable tasks.

Metrics

The only quantitative metric assessed in this experimental period was the number of messages exchanged by role. We expect InSiThe to present a lower number of messages exchanged – the integration of geo-spatial cues in all applications is expected to make some information users typically send in their messages redundant, thus reducing the amount of data sent to each other. In the context of CBT, the enrichment of information regarding user location is welcomed by therapists, since it allows the patients to focus on the task at hand, instead of the description of their surroundings. In addition to it, we distributed a brief questionnaire to retrieve qualitative responses to features related to each tool and in common between the InSiThe and the Google suite. A Likert-type scale (1 to 5) was used to scale the answers. The therapist questionnaire can be observed in Table 1.

Table 1. Therapist's questionnaire

Tag	Question	Scale
MQ1	Perceived ease of use.	1 – Very Difficult; 5 – Very Easy.
MQ2	Perceived sense of quickness to perform task status management.	1 – Very Slow; 5 – Very Fast.
MQ3	Perceived user satisfaction.	1 – Low Satisfaction; 5 – High Satisfaction.
MQ4	Perceived difficulty during message sending.	1 – Very Difficult; 5 – Very Easy.
MQ5	Perceived difficulty in chat user management.	1 – Very Difficult; 5 – Very Easy.
MQ6	(InSiThe only) Perceived usefulness of the link between goals and map in completing tasks.	1 – Not Useful; 5 – Very Useful.

The patient questionnaire can be consulted in Table 2.

Table 2. Patient's questionnaire

Tag	Question	Scale
Q1	Perceived ease of use.	1 – Very Difficult; 5 – Very Easy.
Q2	Perceived sense of quickness to perform a task completion action.	1 – Very Slow; 5 – Very Fast.
Q3	Perceived user satisfaction.	1 – Low Satisfaction; 5 – High Satisfaction.
Q4	Perceived difficulty in text message sending.	1 – Very Difficult; 5 – Very Easy.
Q5	Perceived difficulty in picture message sending.	1 – Very Difficult; 5 – Very Easy.
Q6	Perceived difficulty in audio message sending.	1 – Very Difficult; 5 – Very Easy.
Q7	(InSiThe only) Perceived usefulness of the link between goals and map in completing tasks.	1 – Not Useful; 5 – Very Useful.

Participants

12 participants (aged 21-35; 8 male, 4 female) volunteered to participate in the experiment, forming 4 groups composed by 3 elements each – one therapist and 2 patients per group. All participants were students of a Psychology course at our university – we picked MSc students to undertake the role of a therapist (since they already undertake on therapist roles during their master's courses), while undergraduate students took the role of patients. None of them were undertaking any therapeutic procedure. They were all familiar with the campus layout and proficient with modern smart phones. Although aware of the existence of tools like the ones they would be using, none of them had previous experience with any kind of monitoring or reporting application for their devices. Individuals in each group did not know each other prior to this test.

Tools & Equipment

Participants undertaking the role of the therapist were handed a tablet (LG XNote c1) previously loaded with InSiThe's Monitoring Tool. Subjects assigned to the patient role were handed Android devices with a 3G connection, namely an HTC Legend and a Google Nexus One, both loaded with InSiThe's Reporting Tool application. The tools used for this test were as follows:

- **InSiThe toolset –** the InSiThe toolset comprised the applications presented in this paper – the monitoring tool and the reporting tool.
- **Google Suite –** the Google Suite was defined as a set of services (e.g. email services, IM services, map services, etc.) available through an Internet connection which could offer the same functionalities present in InSiThe. The proposed services included using Gmail, Google Talk and Google Maps, since all these can be accessed from a tablet or a smartphone, free of charge.

Procedure

Each experimental session consisted of two tests – one with the Google Suite and the other with the InSiThe's toolset. The order was randomly assigned at the beginning of each session. After the first step, subjects carrying out the patient role were assigned to complete a small set of tasks across the university campus. These tasks were recommended by our therapist team as being representative of the type of assignments typically given to patients in clinical settings (e.g. enter a crowded area, go near a specific location which typically causes fear, etc.). The following list contains an elucidative subset of the tasks available to complete:

– **Task 1 –** write the middle name imprinted in the statue at the front of the campus.
– **Task 2 –** take a photo of the chemical element "Silver" in the Periodic Table on the atrium of the C8 building.
– **Task 3 –** record an audio file nearby the main entrance of the C1 building.
– **Task 4 –** write the name of the street sign near the C8 building.
– **Task 5 –** in the same street as in the previous task, take a photo of the building with door number 7.
– **Task 6 –** go to the bar in the C5 building and record the surrounding sound.

Other tasks consisted in variations of the ones presented (e.g. changing location or the type of content used). For each test within a session, users were randomly assigned 6 tasks, meaning they would not repeat the same ones using the different tool suites.

Results

Results for the experiments can be consulted in Figure 3 and 4. In Figure 3 we can observe the number of messages exchanged between therapists and patients. While the majority of subjects carrying out the therapist role were more active in exchanging messages, the same trend was not witnessed in the patients' case. Overall, there was a substantial decrease in the number of sent messages for participants taking on the patient role. Figure 4 depicts the qualitative results for our experiment (refer to Table 1 and Table 2 for the questions asked). Regarding the Monitoring Tool, subjects perceived it as being generally easy to use, provided quick processes to accomplish their tasks and provided a good sense of satisfaction during their usage experience.

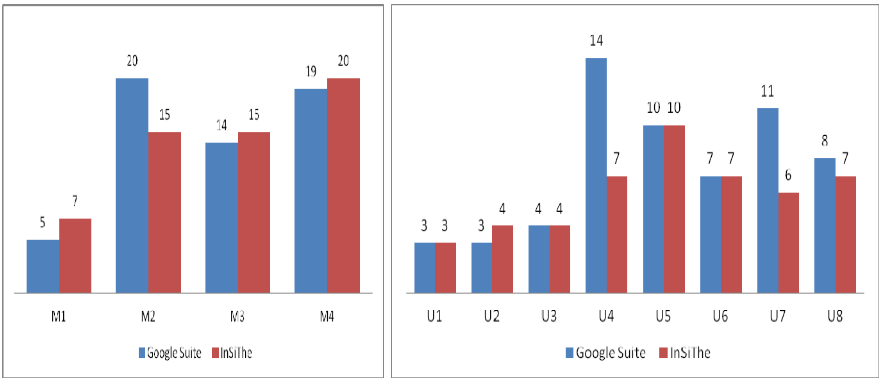

Fig. 3. Number of messages sent from users engaged in the therapist role (left) and in the patient role (right)

As for the chat functionality, users scored the message sending interface as mildly adequate, but the user management features were not positively received. Nevertheless, participants indicated that the coupling between goals and the displayed map was paramount to the task completion assignment they had to carry out.

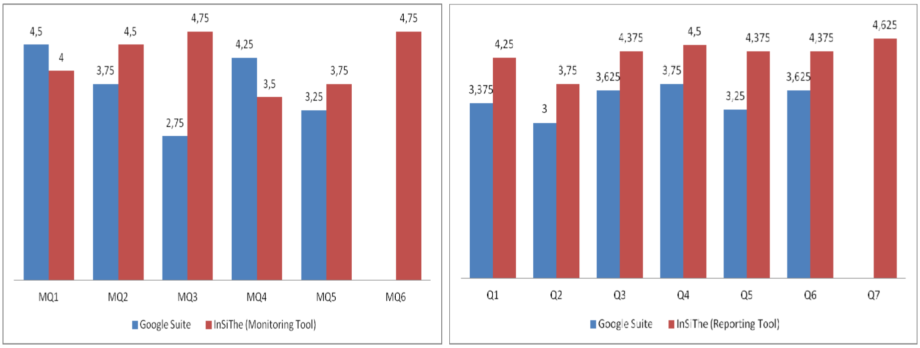

Fig. 4. Qualitative Monitoring (left) and Reporting (right) Tool assessment

Despite InSiThe performing well according to both our quantitative and qualitative metrics, there are a few features, namely user chat management on the monitoring tool and goals screen on the reporting tool, which need further analysis to understand what are the current issues and challenges and how to overcome them.

5 The InSITHE System Revision

Based on the previous results we performed some adjustments to the InSiThe system. Despite an overall positive reception, some issues were raised during that evaluation period. Difficult chat management and poor integration between chat and map visualization areas were the main concerns raised by participants and therapists alike. As such, we proceeded to the idealization and design of a solution which could circumvent the aforementioned issues. After discussing multiple approaches, we agreed that the elimination of the dedicated chat area in favor of design integrated into the map surface would allow all users, but especially therapists, to maintain awareness of the whereabouts of the patients as well as the zones which generated more discussion between them, without the need to divide attention between map and the conversations being kept.

Monitoring Tool – Enriched User Routes

The redesign of the Monitoring Tool capitalizes on a feature already present in the previous iteration to provide a unified area that allows the therapist to track and chat with his / her patients. In this solution, the chat interface is eliminated, allowing the main focus of the tool - the map area - to be maximized to the browser's window. The chat is then integrated into the map itself, in a similar way to that present in MapChat [2] but with a few modifications and a small focus change. In MapChat, conversations are attached to points-of-interest (e.g. restaurants, museums, etc.) preventing users from freely opening new chat windows. In InSiThe, we intend on marking chat bubbles over user routes so that both they and their peers have spatial knowledge where the messages are sent from and where conversations are taking place.

Figure 5 presents the high fidelity prototype for this solution. As observed, the enriched user routes approach builds on the features already present on InSiThe's Monitoring Tool. Chat bubbles appear over user routes and special filters allow therapists to show / hide messages from determined patients.

The change in the application's main focus to encompass the visualization of a single map, prompted us to rethink the target devices of InSiThe's suite as well as the need for a Reporting Tool. According to the interaction distribution results, users were primarily interacting with the map and chat screens, thus making these two the most important features in the tool. As such, we are keen in testing a new form factor which supports the enriched user routes solution for tablets and to assess user acceptance. However, response from the therapist team was mildly negative. Since CBT and SCST procedures' target demographic may encompass children from 6 years old, the usage of tablets would not be beneficial: size and weight are an impacting factor on their recommendation; such novel device can also prompt socially awkward situations if seen at the hands of children, harnessing unwanted attention and possibly affecting the therapeutic process.

The new interface can be observed in Figure 5. The map area occupies the entire browser window, with additional options being accessed from clicking over the appropriate elements: user routes, user avatar, and user list or message icons over the routes. We can also see two chat bubbles representing conversations between one therapist and two different patients. The user routes contain envelope icons representing the approximate location where a message was sent. By clicking it, the therapist can read the conversation until that point. On the rightmost area of the screen the therapist has access to the list of patients he / she is currently monitoring. By right clicking each one, it is possible to set filters such as toggling user routes on / off or toggling the messages over routes on / off.

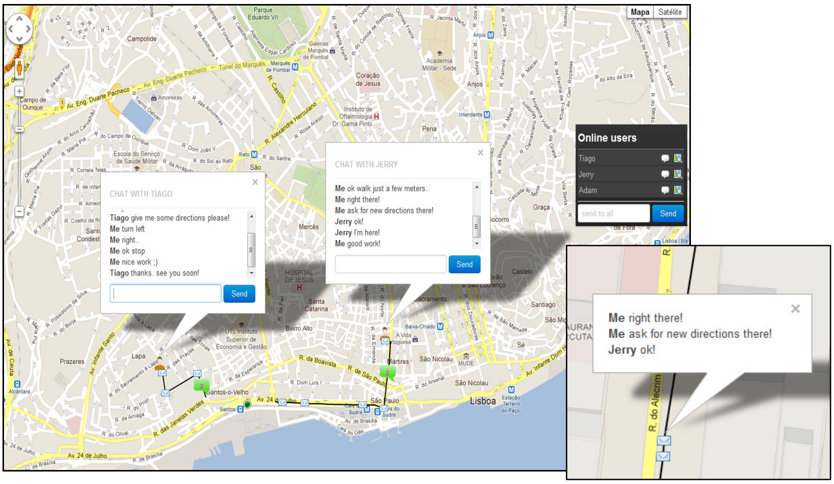

Fig. 5. Enriched User Routes high-fidelity prototype

Reporting Tool
Due to the positive results and comments obtained during the second design iteration experimentation period, no significant changes were envisioned or deployed to the Reporting Tool. The tool, however, will reflect the modifications made to how chat is visualized in the map area, to provide a similar design to therapists and patients alike. Finally, various types of feedback (namely audio and vibratory) were integrated to cater to the patients' preferences and to cope with any situational impairments which might come to fruition given specific therapy scenarios or patient contexts (e.g. crowded areas, etc.).

5.1 Evaluation

We conducted an evaluation period to assess InSiThe's third iteration design. The experimental procedure was in its entirety similar to the one detailed in section 4.1 for the evaluation of previous prototypes. In sum, we carried out 4 trials comprising 3 subjects each (2 patients and 1 therapist). Again, testing took place in our campus. The goal was to perform a usability and satisfaction analysis and, in particular, compare how the latest design iteration fared against the previous ones.

Results. In light of InSiThe's main goals, questionnaire results pointed towards a significant improvement in the message management and exchange processes, whether they involve text, image or sound for the third design iteration. Participants' perception on how quick they were able to accomplish each task also noticeably increased in the mobile application. User satisfaction remained high, leading us to assume that the primary changes performed to the system had no impact in it. Again, the connection between the displayed map and the user goals was determinant for the latter's fulfilment. The goal management mechanism was praised by the subjects. However we do have to mention that this process was significantly altered from the previous version, as this management is now done in run-time settings. We also witnessed a substantial increase in the number of exchanged messages, pointing to the importance of the system changes we carried out on the latest iteration.

6 Discussion

We will now discuss the main findings stemming from InSiThe's design iterations and the main results found in the experimental periods we carried out.

Quantitative Results
The introduction of InSiThe was determinant for a reduction in the amount of messages exchanged. From the comparison between the Google suite to each of the system's versions, we witnessed a steady decrease in message traffic. This was more evident for the participants undertaking the patient role, as the results for the therapist role were not entirely conclusive on this matter. One can discuss these results from two perspectives: on the one hand we could assume this particular group of users had less difficulty accomplishing the tasks. Since task difficulty was significantly low and

we assume it could not influence as much the number of messages exchanged we discard this possibility. On the other hand, we could analyze the messages' content to assess the type of information exchanged. This analysis made us conclude individuals using the Google suite often sent short messages in bursts, with the first one pertaining to the issue they want to discuss, while the subsequent one(s) would provide a description of the situation.

Qualitative Results

Our qualitative analysis discussion will contemplate both the Monitoring Tool's and the Reporting Tool's results. Overall, the response to the Monitoring Tool was positive across all assessed features and user satisfaction was moderately higher when compared with the Google suite (MQ3). Subjects considered the link between goals and the map to provide invaluable help in managing and monitoring their group's members' activities (MQ6). InSiThe's Monitoring Tool second design iteration failed to provide a proper management mechanism for the chat functionality (MQ5). This was solved in the third design iteration with a substantial increase in user satisfaction.

The Reporting Tool was praised for the quick task conclusion process and in overall user satisfaction (Q2 and Q3, respectively). However, it failed to appease to subjects on the ease of use (Q1) and difficulty to send / receive various types of messages (Q4, Q5 and Q6). One of the reasons behind these results is linked to message reception feedback. Google Talk, when running on a smart phone, issues a short vibration when a new message is received, allowing users to carry the device in their pocket and reach it whenever they are notified. This behavior was not present in InSiThe's Reporting Tool's second iteration, forcing users to keep visual contact to check for new messages. This issue was completely addressed in the third iteration, prompting a more positive response from the experiment's subjects.

The Importance of Context

The performed trials were important for the identification of a set of interface design directives for this project and which could easily be generalized for other similar tools as well. Among these directives, we must emphasize the importance of context. Since our initial prototype, our stakeholders have always stated how they wanted the ability to monitor the whereabouts of each patient during a session. This requirement was fulfilled with the addition of patient path tracking via GPS. The trials for the second design iteration presented positive responses from our subjects, praising the ability to see where each patient was going in order for the therapist to proactively intervene if appropriate. Still, subjects pointed it was difficult to which point in the path certain messages pertained (for instance, if they were sent far from an objective pin). This issue was addressed in the third design iteration via the addition of chat bubbles which summarize the exchanged messages within the vicinity of a certain location. As evidenced by the quantitative data, such design choice was responsible for a decrease in the number of exchanged messages. The enrichment of the context in which messages were sent eliminates the necessity of adding redundant information to each message describing the whereabouts of each user. In sum, we achieved our goal of adding seamless contextual information to scenarios in which such data is critical, removing the onus of transmitting such information from the end-users.

Conversation Evolution

Albeit related to context, the ability to track the way conversations evolve during time was another determinant modification employed in InSiThe's latest design. As depicted in Figure 5, the therapist is able to observe conversations in two ways. The first spreads conversation fragments throughout each patient's path. In each location the therapist is able to read the messages exchanged in its vicinity (messages are typically grouped up according to a configurable distance threshold). The second approach pertains to the aggregation of the whole conversation on the patient's current location. This way the therapist is provided with a broader view of the content exchanged with a particular patient without disregarding his / her location's context. During the third design iteration trials, subjects praised both approaches, stating they complement each other well and they provide the therapist with a complete view of the session's and each participant's progress.

7 Conclusion

This paper presented the design process and respective evaluation of a tool-suite which aims at providing therapists and patients with adequate tools for in-vivo therapy sessions. InSiThe is a web-based tool suite which comprehends a therapist's application (Monitoring Tool optimized for laptops and tablets) to monitor patients, registering their conversations, their routes and special markers which contain task assignments, and the Reporting Tool (for smart phones) which users can operate to keep track of their objectives, route and conversation with the therapist.

We presented a three iteration design process, encompassing low to high fidelity prototypes of InSiThe's application set. We complemented the design presentation with the discussion of an evaluation period's results in which we assessed the tool suite from a usability and user satisfaction perspective. We also compared InSiThe to an existing and comparable application suite which reinforced our findings. Results have shown a strong reception from users, based on their opinions. Testing also provided evidence on the importance of geo-spatial cues during conversations, namely awareness of each other's locations. Based on the gathered results, namely user performance and the comments provided by both users and therapists alike, we proceeded to the revision of particular applications within InSiThe, with emphasis on the Monitoring Tool and how therapists are able to keep awareness of a group of users in a session. The solution proposed capitalizes on InSiThe's design to provide a fully integrated geo-referenced chat over user routes on a map. This approach allows the therapist to focus on a single functionality while maintaining awareness of each patient's locations as well as keeping track of their conversation and from where messages were sent. Finally, we presented the early and current prototypes of the third version of this toolset, whose evaluation is currently being finished.

In the near future we will finish the evaluation and respective results analysis for the second design iteration of InSiThe's tool suite. We intend on comparing the new design from a quantitative and qualitative perspective to the suited reported in this paper. We also expect the tool suite to be deployed in real CBT and SCST pilot studies with therapists and patients engaged in in-vivo sessions with these tools.

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Extending the Dependency Taxonomy of Agile Software Development

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Abstract. Systems and software development is a collaborative activity and agile software development epitomises collaboration by formalising how teams and their customers work together to develop a software product. Collaboration is achieved, in part, using mechanisms for coordinating interdependent work. Coordination is defined as the managing of dependencies and this study explores the nature of dependencies in software development projects. Firstly, this study extends an existing taxonomy of dependencies based on evidence from agile projects by showing that three agile and one non-agile project show the same pattern of dependencies. Secondly, this study finds that knowledge dependencies are the most frequently occurring dependencies in these small co-located software projects. The key contribution of this research is a better understanding of the dependencies in software development projects. Understanding dependencies can lead to more informed selection of coordination mechanisms, and ultimately more effective collaboration.

Keywords: Agile software development, coordination mechanisms, dependency analysis, knowledge dependencies.

1 Introduction

Systems and software development is a collaborative activity [1] and agile software development epitomises collaboration by formalising how teams and their customers work together to develop a software product [2, 3]. A software development team cannot collaborate effectively without mechanisms for organising and coordinating their interdependent work, therefore coordination can be considered a supporting pillar of effective collaboration [2, 4]. Coordination is the managing of dependencies in a situation [5], and the central concern of this paper is to advance understanding of the dependencies that occur in software development projects.

A dependency occurs when the progress of one action relies upon the timely output of a previous action or the presence of a specific thing. When dependencies occur in a development project, they can be well-managed with appropriate coordination mechanisms that support the smooth flow of collaborative interdependent work, or poorly managed constraining progress and leading to delays as people wait for resources, for the activities of others to be completed, or for necessary information.

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Building on an earlier study that identified knowledge, task, and resource dependencies in agile software development projects [6], this study provides additional insight into these dependencies. Currently, it is not clear if the dependencies identified in [6] are unique to agile projects or if they are also relevant in non-agile projects, because [6] focused exclusively on agile projects. We propose that both agile and non-agile software development projects might experience some of the same dependencies because they are carried out under similar environmental constraints such as unclear or changing requirements, team member's lack of domain or technical knowledge, or lack of resources. Dependencies in agile and non-agile projects might be similar; it is the coordination mechanisms used to manage them that differ.

Another gap in our understanding involves the relative frequency of knowledge, task, and resource dependencies in agile software development projects. Adopting an agile method often involves selecting specific practices from a method or amalgamating practices from two or more agile methods [7, 8]. A better understanding of the predominant dependencies in agile projects would help a project team to select appropriate coordination mechanisms (i.e. agile or non-agile practices) for managing those dependencies, thus supporting a smooth project workflow. This paper, therefore, poses two research questions:

1. How do dependencies in agile software development projects differ from those of non-agile projects?
2. In agile software development projects which dependencies are most commonly encountered?

Evidence from three case studies of agile software development and a single case of non-agile software development is drawn on to address these questions.

The paper is organised as follows. Agile software development is described followed by a brief review of literature on dependencies as they are addressed in organisation theory, information systems development, software engineering, coordination theory, and agile software development. The multi-case study research method is described, and findings are presented based on an analysis of dependencies in the four projects. A discussion of the implications and limitations of the findings is presented, and the paper concludes by summarising key findings, and reflecting on future work.

2 Agile Software Development

Agile methods emerged in the 1990s in reaction against existing "heavyweight" systems development methodologies that were often unsatisfactory in practice [9]. Agile methods were designed to support flexible, rapid, and effective development under conditions of change, uncertainty, and time pressure [10]. There are at least 12 agile methods, the most popular are Extreme Programming (XP) and Scrum [11]. Each agile method consists of a cohesive set of practices and each method has a distinct purpose. For example, Scrum is focused on project management, whereas XP provides techniques for rapidly producing quality software.

Agile methods each conform to a published set of values and principles for conducting systems development [12]. This unifying philosophy is based on commonalities in the methods identified by early agile method authors [3]. This philosophy emphasises the importance of individuals and their interactions, teamwork, production of early working software, collaboration with customers, and responding effectively to change. This is in contrast to the traditional software development focus on process, tools, documentation, contract negotiation, and following plans. Each agile method loosely conforms to this philosophy [13]. To describe the use of any agile method or combination of agile methods, the catch-all term "agile software development" is used. Agile software development, although widely accepted, challenges accepted best practices in software development and project management [14-16], and consequently has become a focus for research.

3 Dependency Research

Research into dependencies occurs in various domains relevant to software development. In organisation studies, pooled, sequential, reciprocal, and team dependencies describe the workflow arrangements in organisational units [17]. In IS project management, dependencies between tasks are identified as part of project planning [18]. In software engineering it is recognised that "*developers must manage a cadre of dependencies simultaneously if they are to build any working systems at all*" [19, p. 50]. Spanning these domains is an interdisciplinary theory of coordination developed by Malone and Crowston [5]. Their coordination theory focuses on dependency as a fundamental element in coordination and is based on the tenet that "*coordination is the managing of dependencies between activities*" [5, p. 90]. Furthermore, Malone et al. [20] have proposed that there are only three fundamental types of dependency: fit, flow, or sharing. In that conceptualisation, resources and activities interact to form dependencies. A fit dependency occurs when multiple activities produce a single resource. A flow dependency occurs when one activity produces a resource used by another activity, and a sharing dependency occurs when two or more activities use a single resource.

Each of these research domains acknowledges the importance of dependencies in work arrangements, but each views dependency from a different perspective. Dependency categories from organisation theory focus on routine work, as opposed to non-routine time-bounded project work. IS project management focuses on instances of tasks rather than generic dependencies occurring in projects, and therefore offers no means of exploring or explaining dependencies in agile software development projects. In software engineering the focus is on large and distributed projects [21], but dependencies in these contexts are likely to be of a different nature to those of small and co-located projects, which is the environment where agile methods were designed to be effective. Coordination theory is a general analytical framework and does not discuss dependencies in any particular domain.

Coordination is a focus of research in software development projects generally [22-25] and has also emerged in agile software development research. For example, Sharp and Robinson identify communication, collaboration, and coordination as three functions of agile practices [2]. Pries-Heje and Pries-Heje [26] found that Scrum works because it supports communication and social integration, and provides effective mechanisms for project control and coordination. Strode, Huff, Hope and Link (2012) made coordination a central focus in their study of agile software development [4]. In related work exploring the dependencies underlying the need for coordination, Strode and Huff [6] presented a taxonomy of dependencies in agile software development projects. Their taxonomy is reproduced in figure 1. The research in this paper extends that work.

Taxonomy of Agile Software Project Dependencies

A dependency is created when the progress of one action relies upon the timely output of a previous action, or the presence of some specific thing. Dependencies lead to potential or actual constraints on projects. Potential constraints are those that are currently organised or managed well, causing no problems in the progression of a project. Actual constraints are bottlenecks or points in a project that stakeholders are aware of, but have no immediate means to circumvent.

Knowledge dependency

A knowledge dependency occurs when a form of information is required in order for a project to progress. There are four forms of knowledge dependency:
Requirement - a situation where domain knowledge or a requirement is not known and must be located or identified and this affects project progress
Expertise - a situation where technical or task information is known only by a particular person or group and this affects project progress
Task allocation - a situation where who is doing what, and when, is not known and this affects project progress
Historical - a situation where knowledge about past decisions is needed and this affects project

Task dependency

A task dependency occurs when a task must be completed before another task can proceed and this affects project progress. There are two forms of task dependency:
Activity - a situation where an activity cannot proceed until another activity is complete and this affects project progress
Business process - a situation where an existing business process causes activities to be carried out in a certain order and this affects project progress

Resource dependency

A resource dependency occurs when an object is required for a project to progress. There are two forms of resource dependency:
Entity - a situation where a resource (person, place or thing) is not available and this affects project progress
Technical - a situation where a technical aspect of development affects progress, such as when one software component must interact with another software component, and its presence or absence affects project progress

Fig. 1. A taxonomy of dependencies in agile software development projects from Strode and Huff (2012) [6]

4 Research Design

A positivist multi-case study was used to explore the concept of dependency in agile software projects. This approach is a well-accepted way to investigate phenomena in information system development contexts where events cannot be controlled and where it is important to capture detail in a situation [27-29]. The guidance of Dubé and Paré [30] on achieving rigor, and addressing validity and reliability in positivist case study research in information systems was followed. This study met each of their 34 quality criteria relevant to single researcher, multi-case study research.

Case Selection

Case selection followed a replication logic strategy, a tactic recommended in case study design [27-29, 31]. This involves selecting cases that are similar and therefore likely to provide similar results (literal replications), or selecting dissimilar cases that are likely to provide contrasting results for predictable reasons (theoretical replications). The literal replications were three agile software development projects, whereas the single theoretical replication was a project not using an agile method. This number of cases was deemed large enough to identify patterns of dependencies across cases, while providing detail rich enough to ensure dependencies could be thoroughly explored within a case. Each case was a 'typical' project selected because it was expected to show normal or average characteristics [28]. Projects met pre-specified selection criteria regarding the development method (i.e. Scrum, Extreme Programming, a combination of the two, or not using an agile method), team size (2 to 10 people), and co-location (team members co-located rather than distributed). Each project was carried out in a different organisation located in New Zealand. Those projects using agile methods were code-named Land, Storm, and Silver. The non-agile project was named Rock. Table 1 describes the cases.

Data Collection

In each project, up to five people taking different roles, such as project leader, developer, and tester were interviewed for up to 1½ hours. Source data included interview transcripts, field notes taken during observation of work sites and when attending meetings, project documents, photographs of the work sites, and questionnaire data. Questionnaires developed by [32] were used to efficiently gather data on the organisation, project, and the agile method practices used in the project. Summary information about the interviews is provided in Table 1.

Data Analysis

The first step in data analysis was to prepare a full description of each case using a common framework as recommended by Eisenhardt [27]. This description included details of the organisation, the project, the technologies, the team, the development method, and any problems in the project that emerged during the interviews. The description was sent to one project participant for verification, and any factual errors found in the description were corrected.

Table 1. Case and data collection information

	Projects			
	Land	**Storm**	**Silver**	**Rock**
Organisation type	Government	Commercial service provider	Commercial software development firm	Retail bank
Organisation size	2000 in NZ	200 in Australasia, Asia and Europe	20 in NZ	5000+
Project purpose	To improve the organisations interactions with the public by fully automating a semi-manual system	To migrate a critical legacy system to a modern technology platform	To provide a replacement reporting system for an external client	To provide customers with a registration and statement viewing process by enhancing an existing system
Contractual basis	In-house development	Independent contractors working on the client site	Development for external client	In-house development
Development methodology	Scrum	Scrum and XP	Scrum	Waterfall with a Kanban wallboard
Project team size	6	10	5	7 (rising to 15 in the final phase)
Interviews	2	5	4	4
Roles of interviewees	Project manager Software developer	Project manager Software developers (2) Tester Domain expert	Development manager Scrum coach Software developers (2)	Business analyst Analyst programmer Test analyst Technical designer

The second step in data analysis was within-case analysis. Interviews were transcribed and entered into the qualitative data analysis tool NVivo™ for ease of qualitative coding. A general inductive coding approach was followed [31, 33] guided by heuristics developed by Crowston and Osborne [34] for analysing dependencies and coordination mechanisms. Their two-part procedure includes [34, p. 352]:

Dependency-Focused Analysis - identify dependencies, and then search for coordination mechanisms. In other words, look for dependencies and then ask which activities manage those dependencies. Failure to find such activities might suggest potentially problematic unmanaged dependencies.

Activity-Focused Analysis - identify coordination mechanisms, and then search for dependencies. In other words, identify activities in the process that appear to be coordination activities, and then ask what dependencies those activities manage. This approach asks directly whether all observed coordination activities are necessary.

Each case was analysed independently using dependency-focused and activity-focused analysis. This produced analytical codes describing instances of coordination and dependency identified in the transcripts and other data sources. Codes identified in the first case were used as starter codes for the second case, and codes from the second case acted as starter codes for the third case, and so on. New codes were added as they emerged from each case during the analysis.

5 Findings

To visualise dependencies and coordination mechanisms in each case, the findings were arranged in 2x2 data display tables as Miles and Huberman [31] recommend for the analysis of qualitative data. Figure 1 and 2 provide examples of these data displays. Figure 1 also includes quotes from the transcripts to illustrate typical evidence of dependencies and coordination mechanisms (codes such as [BP01] uniquely identify the source of a quote). Coloured cells in the tables represent one or more quotes or other evidence (e.g. a photograph or note taken during an observation) identified as a coordination mechanism-dependency pair. Figure 2 shows findings for case Rock, the non-agile project, which was analysed in the same manner as the agile projects.

Although project Rock was not using an agile method, there were similarities between this project and the agile projects. Rock had fewer than 10 team members and used a Kanban board (similar to a Scrum board) and the team held a daily stand-up meeting beside their board to discuss progress. This team size, the use of a display board for tasks in progress, and daily stand-up meetings were also used by the agile project teams because they are recognised agile practices. Rock was not agile in other respects. The team described themselves as using a "waterfall on the wall" process, they maintained strict role differentiation, team size varied during the project, the project requirements were collected prior to the project starting and recorded as use cases, and testing was carried out after the bulk of the code was developed. These activities are typical of a waterfall process rather than an agile process [14, 15, 35].

The 2x2 tables illustrate how coordination mechanisms were categorised by their common purpose. For example, figure 2 shows iteration zero planning session, weekly iteration, iteration planning session, and progress tracking with user stories, story point prioritising, daily team session, and software release were all named synchronisation activities. A synchronisation activity is defined by [4] as an activity involving all team members that brings them together at the same time and place for some prearranged purpose. Coordination mechanisms, however, are not the focus of this paper therefore they are not discussed any further. They are shown in the tables because they illustrate how dependencies identified in data analysis are addressed by coordination mechanisms.

Dependencies found in the four projects included requirement, expertise, task allocation, historical, activity, business process, entity, and technical dependencies. In a similar manner to the categorisation of coordination mechanisms, these dependencies were grouped into categories based on their common qualities, that is, knowledge, task, and resource dependencies (see figure 1, 2, and 3). Requirement, expertise, task allocation, and historical dependencies were categorised as knowledge dependencies; activity and business process dependencies were categorised as task dependencies; entity and technical dependencies were categorised as resource dependencies.

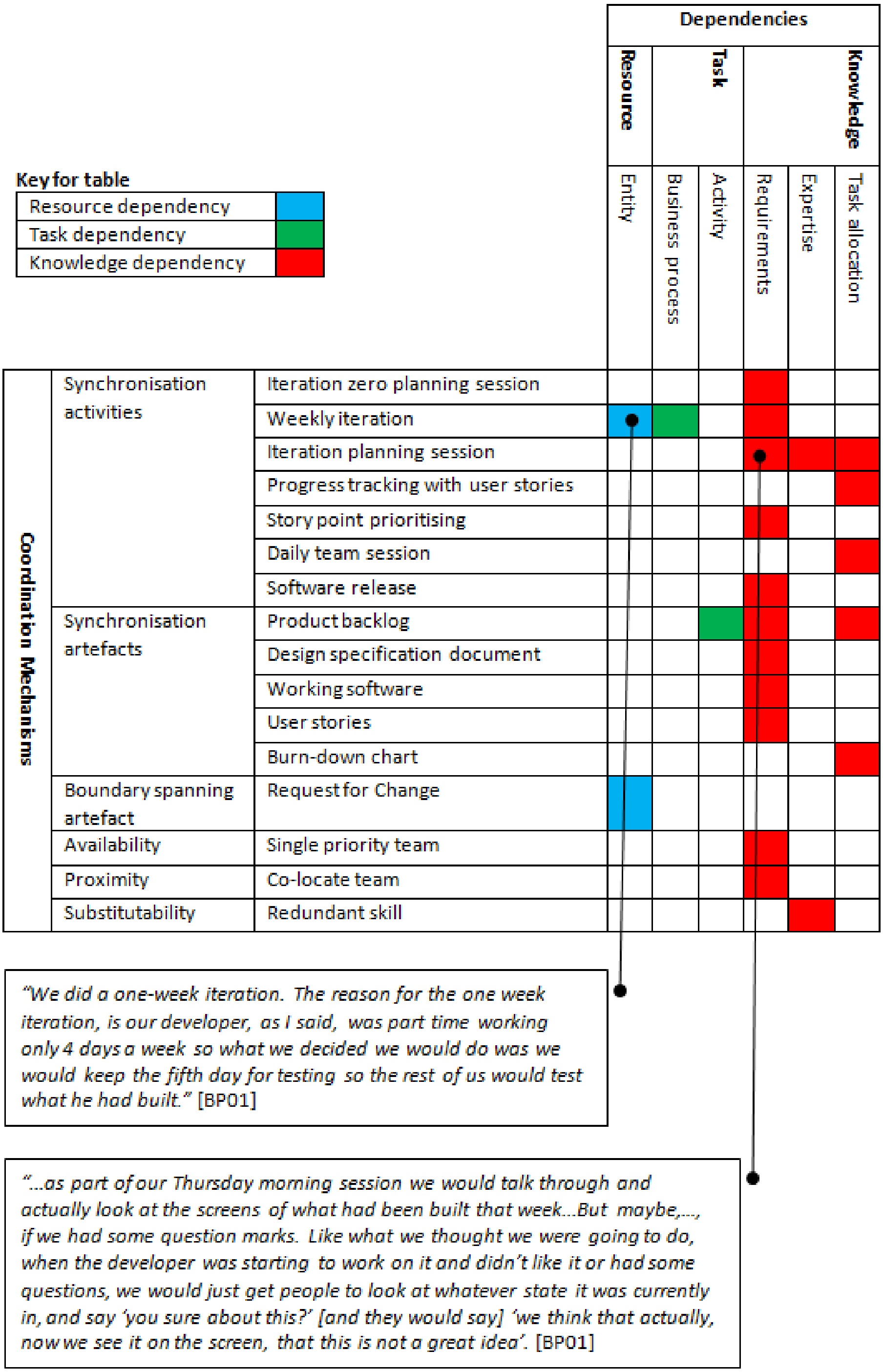

Fig. 2. Land dependencies and coordination mechanisms

Key for table

Resource dependency	[blue]
Task dependency	[green]
Knowledge dependency	[red]

			Dependencies							
			Knowledge				Task		Resource	
			Expertise	Requirements	Task allocation	Historical	Activity	Business process	Entity	Technical
Coordination Mechanisms	Synchronisation activities	Initial meeting	[red]							
		Daily stand up		[red]	[red]					
		Software release to production								[blue]
		Informal chat using SMS	[red]							
		Impromptu planning session		[red]						
		Informal negotiation (f2f)	[red]	[red]	[red]		[green]			[blue]
		Use case breakdown session		[red]						
		Conference call with stakeholders				[red]				
		Continuous integration and test								[blue]
		Technical specialist on team	[red]							
	Synchronisation artefacts	Kanban wall			[red]		[green]			
		Work item			[red]					
		Avatar on work item			[red]					
		Work in progress limit					[green]			
		JIRA™	[red]							
		Architecture					[green]			
		Source code control					[green]			
	Impersonal artefact	Use case specification		[red]						
		System design specification		[red]						
		Unit test document				[red]				
		Defect document								[blue]
	BS activity	Informal negotiation (f2f)		[red]						
	BS artefact	Test data spreadsheet					[green]	[green]		
	Proximity	Team member co-location	[red]							
	Availability	Full-time team	[red]							
	Substitutability	Redundant skill/specialisation	[red]	[red]			[green]		[blue]	
	Coordinator role	Project manager	[red]							
		Business analyst		[red]						
		Technical designer	[red]							
		Tester	[red]				[green]	[green]		

Fig. 3. Rock coordination mechanisms and dependencies

To calculate the relative frequency of occurrence of dependencies in each project, the coloured cells in the 2x2 tables were counted and converted to percentages. The resulting summary of dependency data is shown in table 2. The data displayed in table 2 led to the following observations.

Agile and non-agile projects can experience the same dependencies. That is, the non-agile project Rock experienced each dependency identified in the three agile projects.

Table 2. Comparison of dependencies

Dependency (aggregated)	Dependency	Land	Storm	Silver	Rock
Knowledge	Requirement	50	40	18	26
	Expertise	9	15	23	21
	Task allocation	23	11	14	12
	Historical	-	4	20	5
Task	Activity	4.5	19	16	19
	Business process	4.5	-	-	5
Resource	Entity	9	2	2	2
	Technical	-	9	7	10

Key
All values are percentages indicating the number of coordination mechanism-dependency pairs identified in a project. For example, in project Land the 50% requirement dependency means that there were 11 dependency-coordination mechanism pairs from a total of 22 coordination mechanism-dependency pairs identified in that project overall.

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Requirement dependencies were encountered in all projects when domain knowledge or a requirement was not known and had to be located or identified. Requirements are a critical input to most software projects, and in agile projects they were elicited as the projects progressed in regular story creation sessions [2, 14, 15]. In an agile project, when requirements fail to emerge in a timely manner this can cause the project to falter unless the project team takes some action to cope with the situation. This occurred in Silver when their client did not provide timely information to the team on story prioritisation or design details on some user stories. To cope with this, the team chose to de-prioritise these blocked user stories and address lower priority stories to maintain workflow and keep to their iteration schedule. These dependencies also occurred in Rock due to the extensive consultation with external organisations needed to acquire requirements as the project progressed, even though use cases were used to capture requirements before the development work officially began.

Expertise dependencies were encountered on all projects involving the need for technical or task information. In Storm and Rock, this could be attributed to the type of system under construction. Each of these projects involved replacement of an existing complex system that had been in use in the organisation for many years. The project team would consult experts in the details of these systems so they could better understand their internal structure. This was to ensure they understood enough about the existing system to design the new system so it would integrate appropriately with existing infrastructure. Silver was somewhat different. In that project, expertise was unevenly distributed among the project team members when the project began.

Expertise therefore needed to be shared, and this situation led to a high number of expertise dependencies within the project.

Task allocation dependencies were encountered on all projects and involved project team members knowing who is doing what and when. These dependencies were higher in Land than in the other projects because the team was not fully co-located; some sat at adjacent desks while others were on another floor of the building. This meant the team relied on regular weekly meetings to identify who was doing what and when.

Historical dependencies were encountered in three of the projects. This involved knowledge of past decisions made prior to the current project. In Storm, Rock, and Silver this occurred because knowledge about decisions made in the construction of the existing system needed to be understood by the project team so they could decide if they needed to recreate certain functionality in the new system. Land had no historical dependencies because that project involved automating an existing manual system rather than replacing an existing system or parts of an existing system.

Activity dependencies were encountered on all projects. These dependencies occurred when an activity could not proceed until another activity was complete. This response from a Silver team member describes an activity dependency: "*We started off trying to work on the second story and then found out 'hold on, I can't complete this because it requires something that you are working on*'."

Business process dependencies were only encountered in Land and Rock, and caused activities to be carried out in a certain order. These two projects needed to integrate the data processing of their new systems with existing automated business processes.

Entity dependencies were encountered on all projects when a resource was not available and this affected project progress. Entity dependencies typically involved acquiring servers from external business units such as the IT support team (Storm, Silver, and Land all reported this problem), or acquiring multiple additional developers for the project to complete work according to the planned schedule (Rock).

Technical dependencies were encountered in three of the projects when a technical aspect of development affected progress, such as when one software component interacted with another component, and its presence or absence affected project progress. Land was the only project with no identifiable technical dependencies. This was a small straightforward project with a single software developer which might explain this lack of reported technical dependencies.

The next step in data analysis was to aggregate the data in table 2 to show only the knowledge, task, and resource dependencies, as shown in table 3. This involved summing all knowledge dependencies (i.e., requirements, expertise, task allocation, and historical dependencies), summing task dependencies (activity and business process dependencies), and summing resource dependencies (entity and technical dependencies). This highlights the predominance of knowledge dependencies; averaging 73% of all dependencies across the four projects. Task dependencies were the next most frequently occurring dependency at 17%, and 10% of dependencies were resource dependencies.

Table 3. Summary of dependencies

Cases						
Dependency	**Land**	**Storm**	**Silver**	**Rock**	**Average – agile projects**	**Average - all projects**
Knowledge	82	70	75	64	76	73
Task	9	19	16	24	15	17
Resource	9	11	9	12	10	10
Key All values are percentages indicating the relative number of coordination mechanism-dependency pairs identified in the project. For example, in project Land 82% of all dependencies were identified as knowledge dependencies						

These findings indicate that lack of information affected project progress more than any other form of dependency. Consider the three dependencies that focus on information acquisition: requirements, expertise, and historical dependency. Summing the percentages of these dependencies provides the following: Land 59%, Storm 59%, Silver 61%, and Rock 52%. This indicates that in each project at least half of the dependencies are related to obtaining information about requirements, information on the structure and function of existing systems, or acquiring other people's expertise.

6 Discussion

Agile software development is fundamentally different from other approaches to software development. Yet, an agile project can be carried out within an organisational environment with similar characteristics and constraints as that of a non-agile project. Therefore the dependencies occurring in agile and non-agile projects might also be similar. This research has explored dependencies in software development projects by analysing dependencies in three agile projects and one non-agile project to find out if dependencies are similar in these different projects.

The first research question asked if dependencies occurring in agile software development projects differ from non-agile projects. The findings show that dependencies identified by [6] in agile software development projects can also be found in a non-agile project. That is, dependencies in these co-located software projects with less than 10 developers, agile or non-agile, include knowledge, task, and resource dependencies. As in the agile projects, the non-agile project had knowledge dependencies including requirements, expertise, task allocation, and historical dependences; task dependencies including activity and business process dependencies; and resource dependencies including entity and technical dependencies. This study found no evidence suggesting that dependencies in agile software development projects are different to those in non-agile projects. This finding has implications for the applicability of the taxonomy of dependencies in agile software development projects proposed by [6]. That taxonomy can now be tentatively extended to encompass non-agile projects because this paper provides empirical evidence that the taxonomy is relevant for both agile and non-agile collocated projects of fewer than 10 developers.

The second research question asked which dependencies are most commonly encountered in agile software development projects. The findings show that knowledge dependencies consisting of expertise, requirements, task allocation, and historical knowledge are the most commonly occurring dependencies in the four cases in this study and averaged 73% of dependencies. The agile projects had an average value of 76% (see table 3). Dependencies involving information acquisition (i.e., requirements, expertise, and historical dependencies) accounted for 58% of dependencies on each of the four projects and 60% for the three agile projects. Therefore, in the context of these four projects, it is the knowledge dependency that is the most frequently occurring dependency. Task dependencies in the four projects accounted for 17% of the dependencies, and 15% in the agile projects. Resource dependencies accounted for 10% of dependencies in the four projects and also in the agile projects.

These findings have practical implications for the selection of coordination mechanisms to address dependencies. In other words, for the selection of appropriate practices to ensure knowledge, task, and resource dependencies are effectively addressed in software development projects. Two findings are not new in software project literature: tasks must be organised so that they can be worked on simultaneously with smooth integration of outputs, or sequentially with efficient handover of outputs. In addition, resources must be made available as and when needed. How to manage or coordinate knowledge dependencies, however, is seldom addressed in the extant literature on project management or software development, and this study shows that practices for managing knowledge dependencies need to be seriously considered in work arrangements. The two most commonly encountered knowledge dependencies in this study were requirements and expertise, indicating the necessity to select coordination mechanisms for arranging people and their work so that requirements and expertise are available as and when needed. In agile projects the requirements dependency is addressed with the "customer on site" practice [3, 14, 15]. Martin et al. [36] have shown that this practice can be difficult to achieve. If "customer on site" cannot be achieved in a project, then alternative coordination mechanisms must be adopted such as developers regularly visiting customer sites, using proxy customers on site, or other arrangements. Expertise must also be acquired by the project team. This might involve practices such as inviting experts into the team, sending out team members to visit sites where knowledge can be gained, or other more traditional ways to garner expertise such as training and education.

The limitations of this study include those common to case study research and those peculiar to this study. Case study research is limited in its ability to generalize beyond the specific cases studied [29], and we make no claim that the findings of this study are applicable in all agile software development contexts or all software development projects, but only to those identified in this study. Further cases would strengthen the validity of the findings, and we argue for further research to verify these findings. Limitations particular to this study include the selection of cases. Different cases in different contexts might have led us to find different dependencies. Furthermore, we might not have captured all dependency types in the projects in the study because interviews might not draw out all dependencies when participants recall not only recent events, but events occurring many months prior to the interview.

7 Conclusion

The key contribution of this research is a better understanding of the dependencies in software development. This understanding can lead to more informed selection of coordination mechanisms from agile methods, or other methods, and ultimately lead to more effective collaboration within software development projects.

This paper has built on prior work on dependencies in agile software development projects [6] by presenting evidence from three cases of agile software development and one non-agile project showing that agile and non-agile projects exhibit the same pattern of dependencies. All projects in this study showed evidence of knowledge, task, and resource dependencies providing evidence that the dependency taxonomy developed by [6] might be relevant to other small co-located software projects, not just agile projects.

This paper has presented evidence for the primacy of knowledge dependencies in agile software development projects and non-agile projects, and the lower frequency of task and resource dependencies. This means that knowledge in the form of requirements, expertise, knowing who is doing what and when, and information about historical decisions, require effective coordination mechanisms, so these dependencies do not constrain the smooth flow of collaborative work.

Future work to verify the applicability of the dependency taxonomy in different contexts would be valuable. Some dependencies might be more critical in certain types of project, or at certain times during a project. In particular, distributed software projects, large software projects, and globally distributed projects might provide evidence for extensions to the taxonomy provided by [6]. This would contribute to a better understanding of the types of dependency in software projects, providing a sound basis for selecting effective mechanisms for managing them and thus better supporting this form of collaborative work.

Another area for future work is to improve the understanding of what and how agile practices address particular dependencies in a situation. There is a problem for practitioners in knowing what practices to select from an agile method, or how to effectively blend agile methods [7]. Selecting practices based on an understanding of project dependencies might help address this problem. The findings presented in this paper are a starting point for research into this aspect of agile software development.

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Building a Domain Model for Mobile Collaborative Systems: Towards a Software Product Line

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Abstract. Software Product Lines are a recent approach to the software reuse problem: they allow implementing a set of applications that share common features. The mass use and increased availability of mobile computing devices has allowed for people to use their devices to work while on the move, including emergency response workers. Several initiatives propose software reuse for collaborative systems, e.g. components, architectures, toolkits and frameworks. We propose building a software product line for mobile collaboration in the emergency management domain, as there is a need for different products depending on user types, fire company needs, and evolving requirements. This paper proposes a domain model as the first step towards building a software product line. The domain model summarizes findings in related work and several years of experience working in the emergency management domain. It was evaluated in interviews with firefighters, who said it was a useful summary of their needs in emergency management.

Keywords: Emergency management, Domain Model, Software Product Line.

1 Introduction

In mobile computer-supported cooperative work (CSCW), people work together from several locations, and the locations move during work [1]. *Action teams* work in challenging environments, resolving situations that require quick, improvised responses [2]. Emergency management workers, such as firefighters, form action teams that perform mobile CSCW that shares many elements with loosely-coupled collaboration: they work autonomously but require awareness of others' work, collaborate in a discretionary way only when they find it valuable to do so, and require a shared space to implicitly share information [3]. The opportunity to support mobile collaborative work through mobile computing devices is driven by the fast adoption of mobile devices of considerable computing power: in several countries, over 95% of people own a mobile device, and it is expected that during 2013, over a billion smartphones will be sold worldwide [4].

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The needs of each actor involved in emergency management are different, and to achieve their goals efficiently, each would need an application tailored to their requirements. For example, the Incident Commander is a decision-maker who needs aggregated information about firefighters' activities, while a firefighter at the emergency site may need information about nearby resources. Other fire companies may have different needs - e.g., a unit specialized in hazardous materials is especially interested in data such as weather, winds, and chemicals involved in an emergency. These different stakeholders therefore need different functionalities and views of the data, which may also evolve as their requirements change. Therefore, there is a need to create applications that are high quality, customized to the particular stakeholder's need, reusing parts of previous products, and able to be deployed quickly, to keep up with new and changing needs. A recent approach to the software reuse problem is to implement a Software Product Line (SPL), a set of software-intensive systems that share a common, managed set of features satisfying the specific needs of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way [5]. To do so, the first phase is understanding common and variable features of a particular domain, and proposing a model that summarizes the possible configuration of features an application might have. This work focuses on building a domain model for the collaborative aspects of mobile applications designed to support firefighter work, as part of the work of developing a SPL for this domain.

This paper is organized as follows. First, we present previous work, describing software for emergency management, software reuse for collaborative systems, and methodologies for SPL development. Then, we introduce the domain model process. Section 5 applies this process and section 6 presents conclusions and future work.

2 Related Work

The aim of this work is to traverse the first steps towards building a software product line for mobile collaborative software for emergency response. Therefore, this section discusses software for collaborative emergency management, the situation of software reuse for mobile collaborative systems, and what a SPL is and how it could help build a family of related applications for emergency response.

2.1 Software for Emergency Management

Several researchers have studied emergency management done by firefighters and other emergency responders. Way [6] recognizes the importance of mobile communication and collaboration in crisis response and identifies 15 criteria that are important to consider when choosing technology to support an emergency response process. Several experimental and commercial solutions for emergency management have been presented. One approach is Siren [7], a context-aware messaging application that uses sensors to detect dangers, and supports spontaneous and opportunistic interaction. Luyten, Winters, Coninx, Naudts and Moerman [8] present a mobile system that shows users an overview of the emergency situation, adjusting the interface according to each user's role. Another example system is MobileMap [9], a low-cost solution used to share locations and resources between several firefighting teams, which was a starting point for the current work.

2.2 Software Reuse for Mobile Collaboration

Several researchers have recognized the difficulties in developing collaborative systems, and have proposed to use different kinds of software reuse methods to ease this process. In the late '90s, several groupware development toolkits were proposed, e.g. Prospero, a toolkit that allows users to develop a wide range of applications [10]. Another approach was a component-based approach requires users to abstract their system in four levels: enterprise, system, component and object [11]. Recently, Lukosch and Schümmer [12] identified several problems with frameworks and toolkits used to implement group support applications, such as having to use a specific programming language, the supported architecture, and how the development process becomes technology-driven instead of user-oriented. Therefore, they propose design reuse, through a pattern language in development process involving end-users.

Most previous efforts focus on collaborative systems or groupware in general. However, a new kind of collaboration began to emerge with the widespread availability of mobile devices: mobile CSCW. Few efforts at software reuse have targeted this particular type of application. Several architectures have been proposed for this type of system, some focusing particularly on important aspects of mobility such as context-awareness [13], others to support mobile collaboration in general [14]. One recent proposal presents a reusable architecture for mobile collaborative systems, used to develop a first version of MobileMap [15]. Another approach proposed a product line for emergency plans [16].

2.3 Software Product Line (SPL)

A SPL is a set of software-intensive systems that share a set of characteristics, satisfy the needs of a particular market segment or mission, and are developed using a set of common core assets in a pre-established fashion [5]. A high initial investment is required, but the break-even point at which SPL is less expensive than single system development is generally understood to occur at only 3 developed systems [17, 18]

In a SPL, two main technical phases can be identified [19-21]: *domain engineering*, where reusable core assets are developed and maintained, and *application engineering*, where particular products are built by combining the assets already developed. Understanding and identifying both common and variable aspects plays a central role during the domain engineering stage. Commonalities are requirements that must hold for all products in the SPL, while variabilities are requirements that may or may not be present in a particular product, and, as such, define how SPL products may vary [22]. Although domain engineering and application engineering may have different substages, most authors agree on the importance of the first stages. In particular, the most important stage is the *domain analysis* stage, as it is where the stakeholders define the limits of the SPL and establish its commonalities and variabilities.

Domain analysis is the process by which information used to develop software systems is identified, captured, and organized, with the purpose of making it reusable for creating new systems [23]. The input to the domain analysis stage is generically represented by the domain knowledge, which in turn has diverse sources such as existing systems, domain experts, manuals, systems, prototypes, customers, known requirements of future systems, among others. The output is a domain model, which is "*an explicit representation of the common and the variable properties of the system in a domain, the semantics of the properties and the domain concepts, and the dependencies between the variable properties*" [20].

The domain model consists of two artifacts: a *domain lexicon* and a *feature model* [24]. A *feature* is a distinguishable characteristic of a concept that is relevant to some stakeholders [20]. The feature model is a tree-like structure that represents a series of constraints about the included features. The domain lexicon or domain dictionary [24] represents the identification and definition of terms used in the domain model, allowing the stakeholders a shared understanding of the domain.

2.4 Domain Model Methodologies

The sequence of steps to be followed to build the domain model, and the artifacts composed by it, varies [20, 21, 24-26]. The PuLSE methodology [27] is an important exception, as it provides a thorough description of the domain model building through a complete series of process diagrams. The activities for domain model creation depend on the artifacts identified as belonging to the model. For example, [25] and [26] define the feature model as the only domain model artifact. Others propose that the artifacts are the feature model, the goals of the SPL, and the scenarios that present the behavior of the different products [28].

3 The Domain Model Process

The domain model process we propose is an improvement of one developed for the meshing tool domain introduced in [29]. *Processes* are defined by identifying roles, artifacts and activities. The *artifacts* are those work products that need to be generated in order to complete the domain model. *Activities* are those that are carried out by the stakeholders to build the artifacts. The *roles* summarize what the stakeholders can do. The process proposed here has three fundamental differences from the previous work, driven by the fact that it is applied to a different domain. These differences are as follows:

- The business goal is now considered as part of the domain model, which allows us to establish an explicit relationship with the particular goals.

- The abstractions that were used in the previous work are the same in this proposal (data storage, parameters, functionalities and user interactions), but mobile collaboration features were added.
- This proposal considers an initial business goal and the explicit identification of the stakeholders.

This section describes each of these elements, identifies both the relevant stakeholders and their respective roles, and includes an activity diagram to depict the complete process for producing the domain model.

3.1 Stakeholders

A stakeholder is a person who has an interest in a given domain [20], e.g. manager, marketing person, end-user. SPL stakeholders must validate the requirements, providing feedback about whether or not their interests have been correctly represented. Building a domain and scope model for a complex domain is difficult, so people involved should have a clear idea about the role they should play. In any SPL, stakeholders can be classified in three groups [30]: business, domain, and product stakeholders. The first one refers to customers and system users, the second one to domain experts, and the third one to developers and technical specialist.

3.2 Artifacts

This work defines a domain model based on goals, scenarios and features, similar to the work of [28], and adds a lexicon for describing the concepts within the domain and a business goal for contextualize and delimited the SPL. Fig. 1, adapted from [29], summarizes the elements of the domain model mentioned above and their relationships. These elements and the relationships allow explicitly preserving the rationale for building the domain model.

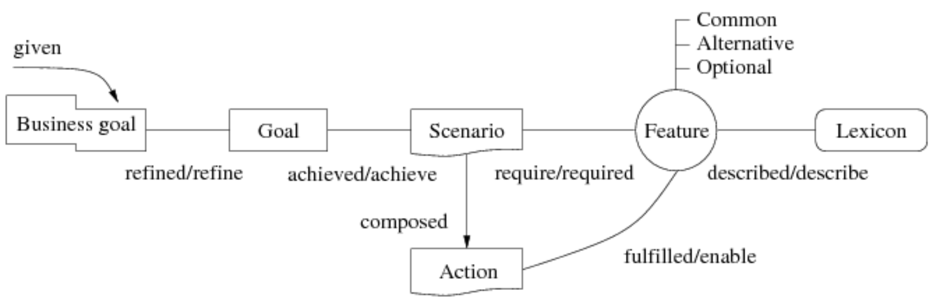

Fig. 1. Domain Model Artifacts

The business goal states the purpose for developing products as part of a SPL and thus gives context to the domain model artifacts. There may also be several particular goals that must fulfill the purpose of the business goal as a whole. Both business goal and particular goals are stated in natural language, as they are provided by the domain expert in her/his own terms.

Scenarios can be typically divided into *development scenarios*, which are those followed whenever a product of the SPL is being built, and *use scenarios*, which are followed by particular products while they are being executed. This work considers only use scenarios, and uses structured natural language to establish scenarios as a sequence of atomic actions, similarly to Kim et al. [31]. The use of this kind of scenarios is due to the ease of discovering sequences of actions by execution of the developed applications.

In this particular domain, those data storage, parameters, functionalities or user interactions identified for the potential products in the SPL are considered *features*, such as in [29], but we must consider some other kind of features, that we call *mobile collaboration features* [32], such as communication, interoperability, and awareness. The features may either be common for all products in the SPL (mandatory), optional or alternative. Features are usually identified from already developed components and existing products as well as from concepts of the application domain. As is usual practice in SPL development, we document software features using a feature model which includes a tree-like structure as well as a series of constraints among the included features [20, 33].

Finally, the lexicon is, by definition, a natural language explanation of the concepts involved in the domain. We propose that all identified features should be described in the lexicon.

3.3 Activities

Although the existing literature is rich in proposals for domain model specification, it is sorely lacking in the description of the actual steps to be performed in order to build the domain model. In contrast, this work proposes a rigorous process, depicted in Fig. 2, to guide the activities that need to be carried out in order to build this model.

The business goal definition is the first activity in the process of building the domain model. This activity takes into account the knowledge about the domain and the software products to be developed. Then, a second activity, stakeholder identification, is done considering the defined business goal. Both activities are fulfilled by the domain analyst. With a tentative business goal and a stakeholder list, the domain experts and the domain analysts interact in order to identify completely the stakeholder list and build a representative domain model. Both activities use a variety of sources of information that complement the domain experts' knowledge, e.g. available components, external information (e.g. emerging technologies, market information) and if available, systems information (e.g. system documentation).

Once the first set of goals, scenarios, actions, features, lexicon and business goal is available, the domain analyst establishes the relationships among these elements. The most important relationships are between goals and business goal, between goals and scenarios, between actions and features, and among features themselves (Fig. 3).

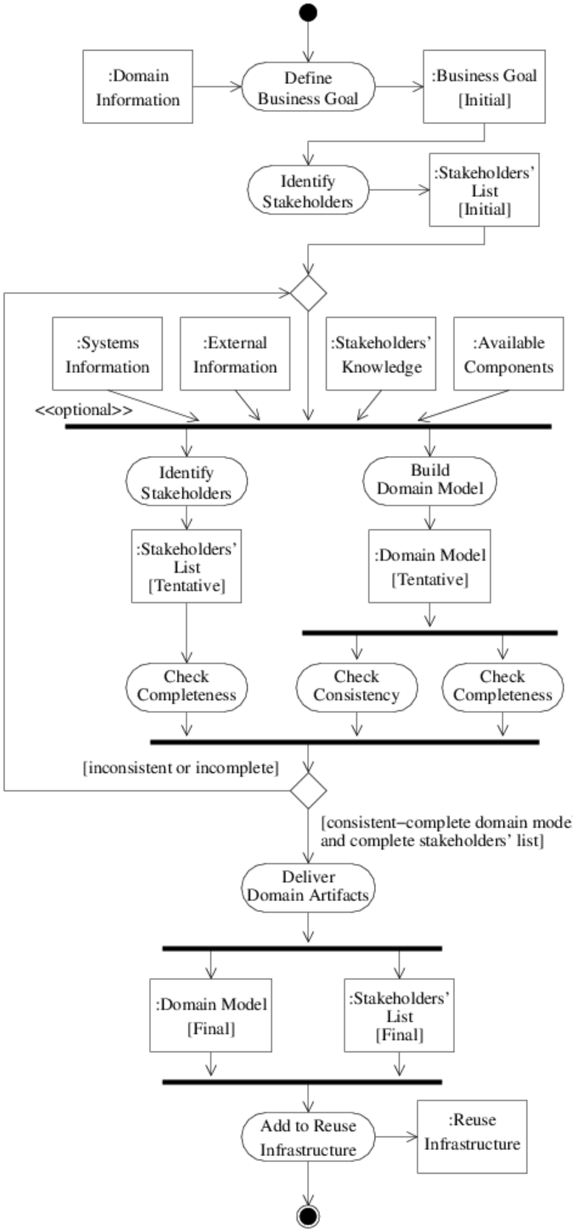

Fig. 2. Domain Model process

Once these activities are done, the domain expert checks for completeness by analyzing if the captured model elements are enough for building all the expected products, and if the stakeholders' list considers all people involved in the SPL development. Meanwhile, the domain analyst checks for consistency by verifying that the domain model satisfies all the consistency conditions given by the relationships among model elements. If any of these conditions does not hold, then the process should iterate. Otherwise the domain model and the stakeholder list can be considered to be ready and we can proceed to the next step in the SPL development.

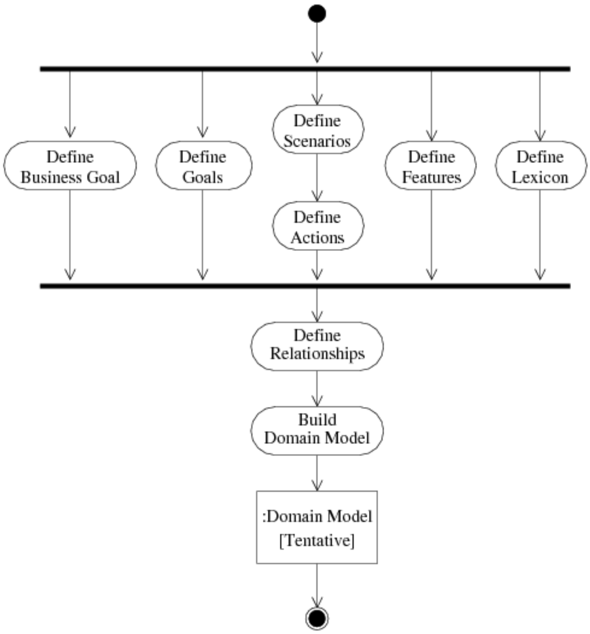

Fig. 3. Build Domain Main subprocess

4 Applying the Domain Model Method to Emergency Response Domain

To build a domain model for emergency management, we followed the process described in Section 3. Therefore, the first step was defining an initial business goal. It was done by conducting a small literature review [34], [35]. Then, it was possible to identify some stakeholders, mainly the ones who are closely related to the domain (firefighters, incident commander, among others) and the software development stakeholders such as domain analysts, product architects and product developers.

The next step consisted of joining information from various sources and reviewing it to produce the domain model and complete the list of stakeholders. The feature model was built initially considering the features in an isolated way. The features, goals, and stakeholders were identified from two sources: a corpus of papers about firefighters' emergency response work [7, 8, 36-39] and from three one-hour focus groups with groups of approximately 5 firefighters each. The transcripts from the focus groups were then coded to extract repeated requirements from the firefighters.

With this information, 9 goals were established, and changing the initial business goal was necessary because it did not reflect the stakeholders' needs. The domain analyst and stakeholders iterated five times to create the proposed feature model.

4.1 Domain Description

An emergency is a critical situation that requires taking action quickly to reduce adverse consequences [36]. There are several types of emergencies, e.g. earthquakes, fires, explosions. Fires are particularly challenging due to the high number of incidents and the need of firefighters make decisions without complete information [7]. Among the available information we can consider: dangers, affected resources, location, status of the response process, resource location, site-specific information, and environmental situation [8, 34]. Furthermore, the type of people involved in the emergency is varied [7], e.g. firefighters, incident commander, and battalion leaders.

4.2 Stakeholders

The stakeholders in the emergency response domain may be characterized as follows:

- Business Stakeholders: Customers, end users.
- Domain Stakeholders (domain experts): firefighter, incident commander, truck driver, truck driver companion, off-duty firefighter, team leader.
- Product Stakeholders: Domain analysts, product managers, family architects, product architects, component designers, component developers, component integrators, product developers, product maintainers.

For the process of building a domain model in the emergency management domain, the most relevant stakeholders are the domain experts, who provide the domain knowledge, and the domain analysts, who put together all the knowledge in a structured and organized way.

4.3 Emergency Management Domain Model

The domain model of this domain is composed of several parts: a business goal, particular goals, some scenarios and their actions, a feature model, and a lexicon.

Business Goal. We have identified the business goal for this domain as follows.

"*Develop mobile software tools for different roles present in a medium or small size emergency attended by a Fire company*".

This business goal emphasizes building mobile software tools, considering different stakeholders that can use the products (applications), and establishing the target of those applications by size dimensioning of the kind of emergencies.

Goals. Goals define what stakeholders want to achieve through the SPL. We have identified particular goals for this domain. Table 1 presents nine goals that describe both the context and the attributes of the SPL that we would like to develop.

Table 1. Description of goals in the emergency management domain

Goal	Description
G1	Ensuring that the resources arrive to the emergency site as soon as possible.
G2	Provide contextual information about the emergency for interested firefighters outside the emergency site.
G3	Support the communication of spatial information at the emergency site.
G4	Support the decision-making process by providing access to appropriate, accurate, timely information.
G5	Allow participation of off-duty firefighters in active emergencies.
G6	Improve first responders' situational awareness at the emergency site.
G7	Improve communication between the alarms center and firefighters.
G8	Improve dissemination of assessment information.
G9	Improve storage and availability of relevant assessment information.

Scenarios and Actions. We determined a list of scenarios that help achieve each of the presented goals, as well as a sequence of corresponding actions for each scenario. Furthermore, we have identified the features that are present in each action by underlining each one of them. Because of space constraints, we exemplify this process through two scenarios, S1 and S2. S1 is related to goals G4 and G8, while S2 is related to goals G1, G2, G3 and G5. Both scenarios are presented in Table 2.

Table 2. Description of two scenarios in the emergency management domain

Scenario	Sc. Description	Goals	Action	Ac. Description
S1	Arrival of incident commander to emergency site	G4, G8	A1	The <u>incident commander</u> opens the <u>map</u>.
			A2	On the <u>map</u>, the <u>incident commander</u> sees the <u>location</u> of the <u>fire trucks</u>.
			A3	On the <u>map</u>, the <u>incident commander</u> <u>sketches</u> the closure of the <u>street</u>.
			A4	The <u>incident commander</u> opens the <u>list of inhabitant</u> of a building from the <u>digital resources</u>.
			A5	The <u>incident commander</u> takes a snapshot of the <u>escape route</u> of the building.
			A6	The <u>incident commander</u> <u>shares to everybody</u> the <u>escape route</u> of the building.

Table 3. (*Continued*)

Scenario	Sc. Description	Goals	Action	Ac. Description
S2	Off-duty firefighter receives emergency notification	G1, G2, G3, G5	A7	A firefighter receives a notification message from the incident commander about a close emergency site.
			A8	The firefighter visualizes a summary that contains the basic information about the emergency site.
			A9	The firefighter responds if he will assist or not to the emergency site by a message shared with everybody.
			A10	If the firefighter will attend the emergency, he receives a map with the route to the emergency site.

Feature Model. The feature model has been divided into two figures for issues of space and clarity. Fig. 4 establishes that every application in this domain manages resources, has information about the emergency site and its context, and allows communication among applications. Fig. 5 presents context information, with two child features. Basic information is a mandatory feature, while detailed information, is

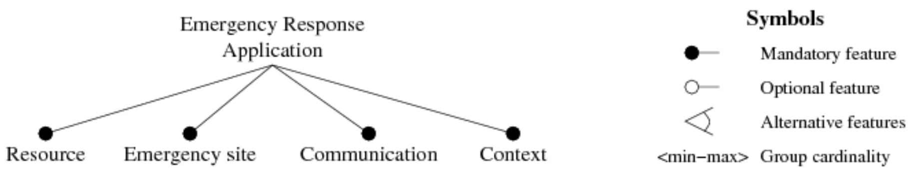

Fig. 4. Feature model, part 1

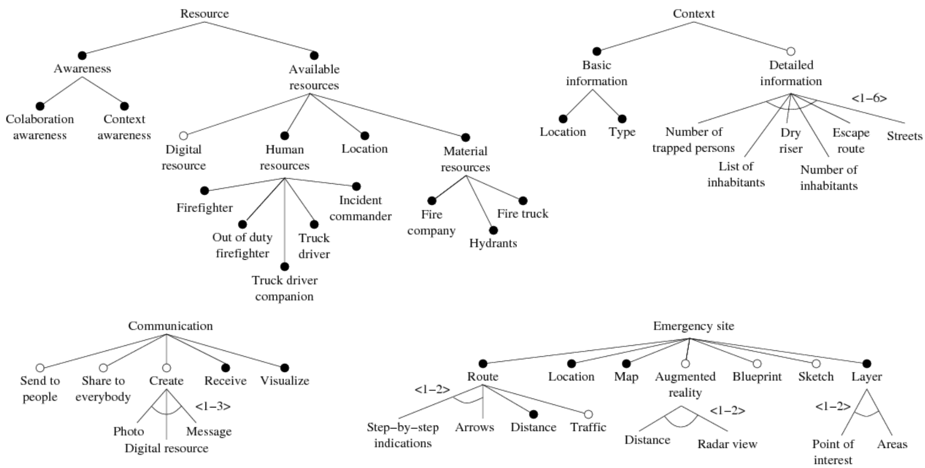

Fig. 5. Feature model, part 2

optional. Furthermore, if this feature is present in the application, then at least one of its sub-features and at most six of them must be present in the application.

Lexicon. The lexicon includes the definition of the terms that are identified as essential in the application domain. These definitions allow the stakeholders to understand the concepts of the domain and establish a common language.

In this section we describe a few of the terms used in the emergency management domain. Even though it is non-exhaustive, it makes it easier to understand the domain.

- *Incident Commander*: person in charge of the all aspects of an emergency. Among his main responsibilities are: assigning resources, evaluating risks and making decisions, following up the progress of actions, among others [36].
- *Truck driver:* person who drives the fire truck in which the firefighters go to the emergency site.
- *Firefighter*: person trained in firefighting. Some firefighters have further specialization, e.g. hazardous materials, ventilation, etc.
- *Digital resource*: any kind of resource information that can be used in the emergency and that is in digital format, e.g. digital maps and digital blueprints.
- *Location*: a position in the world, e.g. latitude and longitude.
- *Map*: figure that contains information such as streets, addresses, locations, places of interest, among others.
- *Share with everybody*: functionality that permits digital resource sharing and messaging with all the people involved in the emergency.
- *Visualize*: feature that allows visualizing digital resources.

Relationships. Several relationships were established between the different artifacts of the domain model. Maybe the most obvious are between business goal and particular goals, because it is necessary to refine the business goal through the goals. However, the other relationships must be established explicitly.

In the case of goals and scenarios, scenario 1 is related to goals 4 and 8; scenario 2 to goals 1, 2, 3 and 5. In the case of scenarios and features, they were related considering an underlining in each action belongs to each scenario (see Table 2).

4.4 Evaluation

Two semi-structured interviews were conducted with firefighters for preliminary evaluation. The interviewees were aged 33 and 41, had on average 6 years of experience as firefighters, and had not participated previously in any aspect of this research. Each interview lasted 20 minutes and was recorded. The interviews were done as follows: one researcher explained the research project and presented a printed version of the domain model, which the interviewees discussed.

Both firefighters agreed that the model made sense. For example, one commented "*It seems that the model includes many of the elements one deals with as a firefighter, although I could add more resources, the ones I see are the most common you would encounter. Also, the detailed information would be useful in a real emergency*".

The interviewees commented on the different roles needing different parts of information, which is part of the SPL goal. "*One application that considers all of these elements will be useful for firefighters in general, but I think that you need to have different roles managing different information in the application. Certain information is useful for the incident commander, other for the firefighter, and other for the truck driver companion*". They also had some comments that reflect on some weaknesses of the feature model representation, e.g. "*I am confused about the 'Emergency site' and 'Context' features. If I had not seen the children of each feature I would have thought they were the same and therefore they are redundant*". The comments of the firefighters suggest that the feature model captures relevant information about the domain, and that the model has potential to be improved using the process described in Section 3. Naturally, further validation is needed, but as a starting point, the positive opinions of unrelated firefighters, and the model being grounded in the literature and focus groups suggests that the SPL could effectively create useful applications in the emergency domain.

5 Conclusions and Future Work

Performing domain analysis is not an easy task, since it involves the participation of several stakeholders, who may have different visions about the domain and about the features that would be useful in an application for it. This paper presents the domain modeling process, adapted for the emergency management domain. We identified the valid abstractions in this domain and adapted a process that is able to incorporate them. The process is iterative, which allows the model to be built incrementally.

Since there are clearly defined relationships between the domain model artifacts, and each artifact and relation are explicitly established, it is possible to have evidence as to why each element was included in the model. Even though the model presented in Section 4 is not exhaustive and user requirements may change, it is possible to use it while improving and augmenting it according to stakeholders' needs. According to the Fig. 3, the process does not enforce starting by one specific artifact (business goal, goal, scenario, action, feature and lexicon), so it is possible to advance in completion in any of them, and iterate as many times we need until to achieve a complete and consistent domain model.

As future work towards the development of the SPL, we will work on several simultaneous steps, which are the following ones:

- Domain model formalization: The process proposed in [29] had formalized relationships between the artifacts, which allowed establishing clear conditions to achieve model completeness. Since the process was adapted, it is necessary to redefine this formalization.
- Domain scope definition: Define the specific products the SPL may generate.
- Product Line architecture: Define the structure and behavior of applications.
- Software component development: Develop components that may be assembled to create applications through, e.g. code generators.

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Supporting Requirements Elicitation Practices

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Abstract. In this paper, we examine the practices in requirements elicitation activities from the perspective of a developer of software projects. By doing so, we want to contribute to a better understanding of how the main activities between stakeholders can be supported by IT, particularly social software. We have interviewed six key persons from five different software projects and identified the potential roles of social software to improve in five main activities of requirements elicitation. We present these critical points in the context of the cases and discuss them across the cases.

Keywords: Requirements elicitation, practices, social software.

1 Introduction

Requirements elicitation can be broadly seen as the "*process of identifying needs and bridging the disparities among the involved communities for the purpose of defining and distilling requirements to meet the constraints of these communities*" [1, p. 26]. It is one of the most critical and complex collaborative tasks in software development. It involves stakeholders who benefit from or develop the system, such as end users, developers, legislators, and decision makers [2]. The activities include understanding the application domain, analyzing the stakeholders, choosing appropriate approaches and techniques, and eliciting requirements from identified sources [3]. Conventional methods for identifying requirements include interviews, surveys, focus groups, document analysis, and prototyping. Studies show that collaboration in requirements elicitation is often challenged by the difficulties of establishing a common understanding, implementing effective communication, cultural and business differences, getting the relevant stakeholders on board, ineffective knowledge management, and ineffective conflict management [4, 5, 6, 7, 8]. In recent years, a set of new tools has been developed that seems appropriate to support requirements elicitation activities technically [9]. These new tools, such as blogs, wikis, and social networking platforms—in general termed social software—are said to be capable of facilitating complex task management in collaborative software development [10]. However, there is a lack of studies that focus on how the tools actually support requirements elicitation.

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More specifically, a lack of "*understanding of actual work practices led to problematic perspectives of how highly distributed work should be set up in the software industry*" [11, p. 1]. Thus, a careful investigation of the domain characteristics is highly recommended.

With this empirical study, we want to achieve a better understanding of how different stakeholders collaborate in the requirements elicitation process. In the same vein, we would like to examine how this process is currently supported by information technology. We are particularly interested in how existing collaboration practices can be supported by social software and how this support can be extended. Therefore, we have interviewed six key persons from five different software projects. From the knowledge derived in the study, we contribute to a better understanding of how social software can improve collaboration in requirements elicitation. Our research questions are:

1. How do requirements analysts and other stakeholders collaborate in requirements elicitation activities?
2. How can social software support the establishment of a common understanding in requirements elicitation activities?

The remainder of this paper is organized as follows: In the next section, we describe our research methodology. In Section 3, we present the state of the art of stakeholders, main activities, handling elicitation, existing problems, and social software in requirements elicitation from related works. The results from the empirical study are summarized in Section 4. We discuss the results across the cases in Section 5 and present our conclusion and future work in Section 6.

2 Methodology

2.1 Review of Related Studies

We conducted a review of related studies to provide conceptual understandings of the subject matter with respect to the practices of requirements elicitation. We followed the guidelines of [12] for reviewing literature, which consist of five main phases: (1) definition of scope, (2) conceptualization of the topic, (3) a literature search, (4) a literature analysis and synthesis, and (5) the research agenda.

In defining the scope (1), the guidelines follow the work of [13]. We set the focus to observe research outcomes from other studies related to activities in requirements elicitation, the actors of the activities, and problems that exist in the activities. We aim to integrate the outcomes found in the review and organize them conceptually from a neutral perspective. The review is written for general scholars, and it covers only significant sources concerning the topic. In drawing a broad conception (2), we define key terms such as requirements elicitation, stakeholder, problems, and social software. In searching for the relevant literature, some of the keywords used to search (3) were "requirements elicitation," "requirements elicitation collaboration/collaboration tools," "requirements elicitation practices/techniques/methodologies," "problems/issues/challenges in requirements elicitation," and "stakeholders in requirements elicitation." The online databases used include IEEE Xplore, the ACM Digital Library, Springerlink, emeraldinsight, EBSCOhost, SAGE, JSTOR, and Google Scholar. We also did a backward search by referring to literature cited by certain articles, and we received article recommendations from experts in the field (4). Finally, we synthesized the literature and developed insightful questions to construct the agenda for this research study (5).

2.2 Empirical Data Collection and Analysis

The second step was conducting semi-structured interviews. We did six interviews with key informants from five different software projects. We named the sample projects Project A to Project E for confidentiality reasons. Four of the selected projects are from Germany, and one is from Malaysia (Project E). Each project in Germany is represented by a key informant, while two informants from the Malaysian software project participated. The key informants are called I1 (Informant 1), I2, and so on. Semi-structured interview is suitable for understanding subjective theories for everyday knowledge [14]. To ensure that the researcher would address the point of interest, we prepared an interview guide consisting of twenty nine open-ended questions. However, additional questions could be addressed during the sessions to understand related subjects of interest better [14]. Most of the interviews were conducted in English except for one (Project E), which was conducted in both English and Malay. Three interviews were conducted face to face, and five were conducted via Skype Internet telephony. Each interview was recorded and transcribed. The interview transcripts were then sent to the key informants for validation.

We did an interview analysis of the collected data. Codification was performed to support the connotations of the data. We coded the collaboration practices of stakeholders in requirements elicitation based on the transcribed interviews. We used the Atlas.ti version 7 software to assist in managing the empirical data, including transcription, codification and categorization. After the analysis of the transcript, five small case studies were conducted to provide a better picture of the practices from each project in requirements elicitation.

3 Related Studies

In this section, we define and explain the stakeholders and practices involved in requirements elicitation. Next, we focus on the handling of collaboration and problems in requirements elicitation.

3.1 Stakeholders in Requirements Elicitation

In software engineering, stakeholders are "*people or organisations who will be affected by the system and who have a direct or indirect influence on the system* *requirements*" [15]. The term "stakeholder" does not refer to a specific person but indicates the role [2]. The roles of stakeholders in the requirements engineering process can be divided into four main groups: users, developers, legislators, and decision makers. Users can include the employees, managers, suppliers, and customers who will mainly use the system. Developers are responsible for setting requirements definitions and for software development as a whole. Some examples of developers are programmers, designers, requirements analysts, and testers. Legislators produce guidelines or standards that the socio-technical system must comply with and may include certified bodies, public agencies, councils, legal advisories, and security executives [2]. The final group of stakeholders is decision makers, who make decisions about system requirements. Decision makers can come from both the user and developer sides, such as managers, directors, and financial controllers. The identification of stakeholders can be done by considering internal and external parties in the organization [28]. Every stakeholder may have different needs for information systems due to their different roles and work practices.

3.2 Practices in Requirements Elicitation

As the basis to examine the practices in requirements elicitation, we use five main activities as suggested by [3]: understanding the application domain; identifying the source of requirements; analyzing stakeholders; choosing techniques, approaches, and tools to use; and eliciting requirements from stakeholders and other sources. These five main activities are appropriate for our research aims, as it provides a clear indication of the work that requirements analysts and other stakeholders normally conduct in the requirements elicitation process.

Understanding the Application Domain

"*Requirements elicitation is about learning and understanding the needs of users and project sponsors with the ultimate aim of communicating these needs to the system developers*" [3]. To support requirements elicitation activities, it is necessary to understand the application domain. An in-depth investigation of the domain characteristics, including political, organizational, and social elements, as well as constraints on the system, is critical in determining the appropriateness of software projects [16]. Analyzing human and technical factors are critical in strategizing how they can be supported by technology [11]. The information system should be able to support diverse work activities, the types of information associated with those activities, and human-computer interactions. These concerns are in line with the Multiview methodology of [17] because the methodology highlights the importance of including five critical views to be analyzed in software development: (1) analysis of human activity, (2) analysis of information, (3) analysis and design of socio-technical aspects, (4) design of human-computer interfaces, and (5) design of technical aspects. These views are necessary and appropriate in analyzing and designing software systems, as they fulfill both human and technical needs.

Identifying the Source of Requirements

Identifying the source of requirements is an important task in collecting information about the organization and its environment. Besides stakeholders as the primary source of requirements, other reliable sources, such as current systems and processes and documentation (e.g. manuals, forms, and reports), can help analysts to identify the requirements [3]. The information available from these sources enables analysts to understand the current work practices, system process, and problems.

Analyzing Stakeholders

Analyzing stakeholders is critical to determine the right requirements sources. The identification of key users and domain experts is always included in analyzing stakeholders [3]. Relevant stakeholders can be internal and external to an organization. There are four steps in eliciting basic requirements from the identification of stakeholders [18]: stakeholders need to be identified and prioritized according to their roles and levels of influence; each stakeholder's profile will be collected to allow further understanding of the stakeholder; the prediction of requirements will be done based on learned profiles; and the requirements must be prioritized.

Selecting Techniques, Approaches, and Tools

Techniques such as interviews, observation, task analysis, workshops, and prototyping are among the common techniques used by software practitioners [16, 3]. Depending on the project type, some may tend to use more than one technique. According to [3], interviews, domain analysis, and group work are the most appropriate in determining the major practices in requirements elicitation. Additional approaches such as those based on goals, scenarios, viewpoints, and domain knowledge are also employed in some projects, though interview and group work are still the most popular techniques.

Eliciting Requirements from Stakeholders and Other Sources

After the application domain is well understood, sources of requirements are identified, relevant stakeholders are analyzed, and techniques or approaches have been selected, the elicitation of software requirements will begin [3]. At this stage, the scope of the system will be defined and a detailed extraction of users' needs will be performed [19]. Effective communication between analysts and other stakeholders is critical in this stage. The information gathered will be used in the next stage of requirements engineering, which is requirements specification, where the functionalities will be finalized.

3.3 Handling Requirements Elicitation

In handling collaborative work during requirements elicitation, the objectives of the collaboration should be clearly stated and well structured. For instance, [3] proposes three phases of collaboration in requirements workshops: (1) the scoping phase, (2) the high-level phase, and (3) the detail phase. Scoping is the process by which appropriate stakeholders are identified, problems are described, and the mission and vision are agreed upon. In the high-level phase, using the results of the scoping phase, relevant documentation will be reviewed and related work practices and system operation will be observed to give the analyst a basic understanding of the work domain, the software requirements, and the software project direction. In detailed workshops, analysts refine the results from earlier phases and validate them with the stakeholders. Each determined work practice is decomposed into individual process using use case analysis, for example. "*Documentation using natural language with graphical description should iteratively improve and incrementally develop during all phases*" [20]. This practice is important so that the document can be validated and agreed upon by all stakeholders to reach a common understanding. Furthermore, the final document can be a useful reference in the next stage, requirements specification, where functional requirements are determined.

3.4 Problems in Requirements Elicitation

Problems and challenges can affect the quality of requirements. The most common problems identified in previous work are problems of scope [5], communication and common understanding, e.g. [4], domain knowledge [16, 15, 21], and stakeholders [3]. The final software requirements are the results of collaboration among stakeholders, which is challenged by conflicts and contradictions among them [22].

The process of requirements elicitation is not only associated with technical issues but also involves social and communication issues among the stakeholders of the project, who play a significant role in the requirements elicitation process [5, 23]. Several studies have highlighted the importance of maintaining effective communication between stakeholders and the development team in generating quality requirements, e.g. [21]. Further, communication skills and the relationships between stakeholders determine the quality of the requirements [16] because the requirements will be documented and further addressed in the subsequent phases of development. Effective communication is the answer to the need to establish a common understanding of requirements elicitation. Without a common understanding, various conflicts can arise among stakeholders and may result in fluctuation in the requirements due to different interpretations of them. It has also been found that the main point of communication during the software requirements phase is to discuss changes in requirements [6]. In distributed software development, this problem is even more challenging, as the participants are not in the same location or time zone and do not have the same language skills and culture.

The barriers to effective communication in requirements elicitation include the effectiveness of existing means of interaction, terminology (e.g. software jargon), team size (e.g. too few or too many stakeholders), lack of awareness, limited knowledge flow, and social and organizational issues [8]. Further, [8] suggests that documentation (e.g. specification documents) is a poor communication channel and that relying too much on it will only widen the gap between the analysts and other stakeholders. As mentioned earlier, geographical distance also can affect the quality of communication among stakeholders, especially in distributed teams [7]. However, the effective implementation of collaborative tools can assist in addressing the communication quality. Finally, informal communication can bridge the gap between software developers and other stakeholders in defining requirements [8].

3.5 Social Software in Requirements Elicitation Collaboration

Effective and quality communication tools are essential to ensure successful software development collaboration [24]. It is claimed that informal communication and asynchronous communication can strengthen the relationship between the developer and other stakeholders [6]. At present, a growing number of studies (e.g. [9, 25, 18, 24, 26]) are observing the use of a new type of application called social software such as Facebook, Twitter, wikis, and blogs, to mediate collaboration in software development. This new form of Web applications, which has remarkably changed people's informal communication [31, 32], is becoming more significant in software development processes. For example, [24] attempts to develop new social networking platforms to facilitate requirements engineering collaboration for distributed teams. Meanwhile, in [18], a social networking platform is developed to improve the stakeholder identification process, predict possible requirements, and prioritize them. Both [24] and [18] claim that their platform has been tested in several projects and received promising feedback from users. Notwithstanding these first insights, further research must be done to establish the real potential of social software in this field. We need to understand better how they support the requirements elicitation process so that we can improve collaboration.

4 Summary of the Cases

Five software projects are involved in the empirical study. Projects A, B, C, and D are funded innovative projects in Germany, while Project E is a commercial project in Malaysia. All of the informants interviewed are key persons in the software projects, such as project managers, technical coordinators, business analysts, and technical leaders, who are directly involved in requirements elicitation processes.

The main objective of Project A was to build a community platform within a large-scale corporation. It was carried out by three universities and two leading companies in Germany. The universities' stakeholders consist of researchers, including professors, post-doctoral researchers, and doctoral researchers from three disciplines: psychology, information science, and information systems. The participants from the two partner companies include the members of the board of directors, various operation and management executives, and selected employees.

Project B is a software project to develop a social networking platform for military medical officers and trainee officers at a university. The administration of the medical branch appointed a research institute at a university to steer and develop a social networking platform to address the issue. The institute is represented by researchers who will manage and develop the platform. They require strong support from medical officers and trainee officers to gather requirements.

Project C is the development of a mashup solution that collects data from social media services such as Facebook and Twitter with certain filters. The data generated by the mashup can be used by other software applications, such as tablet computer or smartphone applications. The interface between the mashup and software applications is also among the elements that the project must address. At the moment, there are three applications of other projects that use the mashup service. This is a service-oriented architecture project.

The mission of Project D was to develop a solution to support elderly people's daily life after demographic developments. The objective is to lower the barrier of access to the benefits of social software for elderly people with a specially designed tablet computer based on the Android operating system. The stakeholders of the project consist of developers of different aspects (e.g. the hardware design, the human-computer-interaction, and the operating system) from ten partners of four different countries (Germany, Spain, Italy, and Austria). Also involved is a partner who wrote the business plan, a partner who conducted project coordination, and elderly people from Spain and Germany.

Project E is the enhancement of a retail collection module in a banking information system for a Malaysian bank that was affected after the restructuring of the Retail Collection Center. The module is used by more than 200 employees who make collection calls and conduct recovery processes and legal actions nationwide. It is also used by managers for managerial and reporting purposes. Recently, the bank's management decided to centralize the whole nation's retail collection in one center. The restructuring directly affected the existing information systems, including the module to be implemented. Table 1 below summarizes all the studied projects; however, we do not discuss their actual elicited requirements.

5 Discussion across the Cases

In this section, we compare the results across the cases to reveal insights concerning practices by stakeholders in the requirements elicitation process. We analyze the cases based on the five activities summarized by [3]. We will propose potential roles that can be played by social software, and we further address the concept for a prototype in Section 6.

5.1 Understanding the Application Domain

There are different motivations in understanding the application domain among software projects. For instance, in innovative projects such as Projects A, C, and D, the process of understanding the application domain was initiated by researchers after a certain period of analysis inspired by research areas of interest and before executing a project. The application domains were studied in detail, supported with certain theories and reviews of related work.

Table 1. Summary of the Cases

	Project A	Project B	Project C	Project D	Project E
Project Goal	Development of community platform	Development of social networking platform	Development of mashup services	Development of special tablet computer	Enhancement of a module in a banking information system
Application Domain	IT experts within large organization	Social interaction of medical officers and trainees at military university	Collection, process, and distribution of data for community platforms	Elderly people and their needs in tablet computer	New structure and system of Collection Management Department of a bank
Source of Requirements	Employees, management, market research, prototyping, workshops	Administration, medical officers, medical trainees, prototyping, rules and regulations	Research, technical leaders of other projects	Research, elderly people	Business requirements document, bank management, employees, standard operating procedure
Stakeholders Involved	Researchers, multidisciplinary experts, management of partner companies, employees	Researchers, administration of medical branches, medical officers, trainee officers	Researchers, technical leaders of other projects	Researchers, sponsor (EU), developers from different partners, selected elderly people	Business analyst, technical leader, project manager, programmers, software quality and tester, high bank management, departmental managers, IT executives, employees
Elicitation Techniques, Approaches, and Tools	Market research, formal meetings, interviews, workshops, prototyping	Formal meetings, group interview, individual interviews, prototyping	State-of-the art analysis, informal group discussion	State-of-the-art analysis, interviews, observations, prototyping	Formal meetings, document analyses, user acceptance tests

The business and user needs must be carefully defined before the requirements elicitation for their software takes place. However, this type of project requires adequate support from their partners to establish an equal understanding of the project proposed to benefit them. In Project A, the developer team conducted market research to identify the status quo, including understanding which solutions are well accepted by people. Meanwhile, Project C requires more technical knowledge; the application domain is around the mashup itself and the people who needed its services. Therefore, besides a theoretical understanding, Project C involves a lot of collaborative programming work among the team to understand how the solution will work. In Project D, the project team used interviews and observation of tablet usage by elderly people. They learned about the elderly people's perceptions toward and needs in a tablet computer.

> "*First of all, we did market research… What kind of communities are up there? What kind functions do they support? So we can have a market overview of what is out there and what is used and what users really accept. Because sometimes you cannot say from scratch which kind of functions users will accept. It's really hard to tell...*" —I2

Project B was initiated by the administration of the medical branches at a military university, who perceived that the passive social interaction among the medical staff members and trainees need to be resolved. The appointed software institute is developing a solution with a social networking platform. The team learned about the application domain through individual and group interviews with medical officers and trainees introduced by the administration office. Similarly, in Project E, a commercial project, the process of understanding the application domain was motivated by a request from the client or user side (bank) through a document called "business requirements" to the software vendor. The business analyst (or requirements analyst) from the vendor side is the champion for the application domain knowledge. In general, the understanding of the application domain in a software project can be initiated on the developer side or the client side. The developer has to possess the most accurate understanding of the application domain, as the knowledge derived will be used as a foundation for the next steps. However, the rest of the stakeholders can also contribute. In relation to that, we find that knowledge obtained in this stage should be easily accessible by all stakeholders to minimize conflicts and stimulate a common understanding [16, 21, 6]. The knowledge derived from fieldwork such as interviews and meetings or from state-of-the-art analysis such as extensive readings and reviews can be stored in a platform like a wiki. The other stakeholders who are not collecting the information can obtain knowledge from the wiki. Such a platform is actually exists in Projects A, B, C, and D. However, the platform is only actively used in Projects B and C, and they find that the platform is very useful in promoting shared understanding among stakeholders.

5.2 Identifying Source of Requirements

In identifying the sources of requirements, we discovered in some projects that this activity was conducted in parallel with the understanding of the application domain. Besides state-of-the-art analysis (for innovative projects), the sources of requirements can be identified through discussion with the decision makers during early-stage meetings. For example, Projects A, B, and E received lists of who would be participating in the projects. Detailed profiles of the different types and backgrounds of users and documentation also can be obtained. For Project D, the main source of requirements is elderly people from Spain and Germany, whom the project team observes and interviews to gather requirements. In the case of Project C, we learned that the source of requirements depended on other software projects that use the mashup services to provide new requirements from time to time. In Project E, as mentioned in section 5.1, the software vendor received a business requirements document from the top management of the bank. From this source, the development team can predict other potential sources of requirements, such as the managers at the Credit Management Department, the end users, and affected software module (collection).

> *"We used the contacts at the administration of the medical branch. They were able to tell us the key persons we should ask, and then we did a bit of background research and asked them about the product contacts"* —I2

For this activity, we observe that the potential role of social software is to gather the sources in one space and communicate them. All stakeholders of the project should know where requirements come from, as they can contribute by proposing other potential sources to be taken into account, such as additional contacts (e.g. end users and managers) and documentation (e.g. business requirements, reports, forms, standard procedures, guidelines, and manuals), as highlighted by [3].

5.3 Analyzing Stakeholders

In analyzing stakeholders, most developers, except for those of Projects C and D, collaborate with their partner or client to identify relevant stakeholders, especially the actual users. In the beginning, lists of users or employees are provided by the management, but the developer can examine the list and then request more relevant stakeholders when necessary.

> *"…we also got detailed profiles of certain user types; for example, many of our medical officers are not used to using Internet technology… we select the most suitable users…"* —I2

For Project C, the user stakeholders and the main source of requirements are the project managers or technical coordinators of software projects that are using Project C's solution (mashup). Thus, it is very easy for this project to identify and analyze the relevant stakeholders. Meanwhile, Project D has to determine suitable elderly people as the users. They finally selected about 20 people from Spain and about 20 from Germany to participate in the tablet computer testing. Identifying partner developers is a challenging task, especially in selecting an interactive designer for the tablet. As shown in [3], the stakeholders can be internal or external to the organization, which shows that stakeholders may come from outside or have indirect involvement. Generally, each surveyed project has all the stakeholders defined by [2]. However, we did not clearly identify the legislative stakeholders, especially for Projects A, C, and D. However, according to the work, a legislative stakeholder may also be in the form of documents, such as operation and quality manuals. For example, Project C has to ensure data privacy under military rules, and Project D has to follow new Central Bank guidelines.

"There are new guidelines from the Central Bank that we were told by them (bank's management) to follow, for example, about check management. A copy of a check received by a customer must be sent to them in a data file..." —I5

Based on the practices involved in analyzing stakeholders, we believe that the list of relevant stakeholders with their details should be available in a space that other stakeholders of the project can see. Knowing who is participating will help in coordinating the collaboration, especially for projects that involve external stakeholders and stakeholders in different locations, as in Projects A and D [6]. It can also helps in predicting requirements based on their profiles [18]. Legislative stakeholders of non-human form, such as policies or regulations, should be accessible by the project stakeholders in the space. Here is where social software can play a role. We will address this issue further in Section 6.

5.4 Selecting Techniques, Approaches, and Tools

All of the software projects except for Project E decided to use interviews along with other techniques, such as observations, workshops, formal meetings, group discussion, and prototyping, to elicit requirements. Several prototype versions were created, distributed, and tested among user stakeholders in Projects A and D. Project A began with a workshop to provide an overview of the project. Meanwhile, Project E mainly used a series of formal meetings with the management and the IT department of the bank to gather the requirements. Apart from that, documents such as the new standard operating procedure for the new structure of the Credit Management Department will be analyzed in detail. Test cases were prepared for software testing and quality assurance purposes.

"We did a lot of interviews, and we didn't follow a clear top-down communication; we were communicating at different levels. We have one guy at XY who was an employee doing the IT management systems before, and he has explained his experience with the previous system." —I1

In terms of collaboration tools, all software projects except for Project E have a wiki platform, but as we mentioned before, only Projects B and C are actively utilizing the platform especially for progress update. Informants from Projects B and C claimed that a wiki is very useful in allowing stakeholders to keep up with the latest updates on work in progress from the side of the developer and the other stakeholders. In relation to that, informants from all the projects spoke about the use of email as the main asynchronous communication tool and stated that Skype is the most frequently used synchronous tool in discussion.

In this activity, we proposed that the selected techniques, approaches, and tools to elicit requirements should also be mentioned to all stakeholders because the objectives of any selected techniques, approaches, and tools should be clearly stated and well-structured to achieve the goals [3]. The information can be included in a wiki by describing, for example, why a certain workshop format was selected, how the workshop would be conducted, who would be participating in the workshop, and what is expected from the workshop.

> *"… you have to have the overall goal that everyone has to understand. Otherwise, you do some minor or very detailed changes or you try to develop some requirements at a very detailed level, and later they don't matter because they don't understand; they don't fit the overall idea. So what we did at first was really to get the overall idea so that everyone understood this basic idea in the kickoff event and workshops."* —I1

5.5 Eliciting Requirements from Stakeholders and Other Source

In this activity, active interaction between the developer and the identified sources of requirements will begin to determine the actual and accurate needs. In Project D, for example, the developer conducted a direct observation of elderly people in the use of conventional tablet computer, followed by open interviews at a convenient location like a restaurant. The information gathered will be analyzed and translated into requirements. When a prototype of the tablet computer has been developed, it will be tested by elderly people to obtain feedback or new requirements. This iterative process will continue until the users are happy with the special tablet computer. The process in Project A is nearly identical, as different levels of prototypes for the community platform were distributed to gather the requirements from selected employees at partner companies. Project B elicited requirements through interviews and extraction of the problems that can be solved using the social networking platform.

In Project E, the elicitation of requirements from formal meetings is done in collaboration among a business analyst, a technical leader, and a project manager. After analyzing the business requirements, the business analyst will consult with the technical leader and the project manager to decide whether the request is feasible to implement. To verify and validate the requirements, several meetings were held with the bank side and included the sponsors, managers from the credit management department, and people from the IT department. Later, a technical team (e.g. programmers, systems analysts, and quality analysts) will be formed to finalize the requirements until they are signed off on.

However, some issues were reported during the elicitation process. In Project B, it is reported that the idea of open communication on a social networking platform is in conflict with the military rules. Thus, some modifications have to be made to follow the rules. In the case of Project E, the problem is inconsistency in explaining certain requirements by different representatives. A series of meetings was arranged during the requirements elicitation, but managers who are participating in the project sometimes failed to attend due to other commitments and sent someone else. However, I5 sometimes found that there were conflicts between requirements provided earlier and the most recent versions. Moreover, verifying requirements via email with the original manager who provided the requirements sometimes takes a long time to get a response. This issue can cause delays in the development work. The involvement of people from the management can sometimes ease the confirmation of requirements but can also slow down the process. Other than the domain knowledge issue, communication breakdown also contributes to this problem [16]. After looking at the practices and issues from the case, we proposed that elicited requirements should be published in one space so that all the stakeholders can read them and respond to them. Communication issues and inconsistency in requirements can be reduced when every stakeholder has the same access to the elicited requirements. If other information, such as a list of stakeholders and sources of requirements, is also available in the space, it can minimize conflicts between requirements and other variables.

> *"…we have a problem in finalizing requirements; the managers sometimes have other commitments, and they are unable to attend the meetings. Although they have representatives, the information sometimes is not consistent and confuses us [….] we can reconfirm and get clarification, but this takes some time.*" —I5

In summary, we propose that the outcomes from all five activities in requirements elicitation, which are mainly performed by the developer, are useful to extend to other stakeholders. The shared outcomes from requirements elicitation activities among stakeholders can stimulate a common understanding among them. As a result, collaborative issues in the requirements elicitation process and the later stages can be reduced. This is where the potential role of social software lies in establishing a common understanding among different stakeholders in requirements elicitation. In the final section, we will briefly address our future work to develop a wiki prototype to extend the outcomes of this research.

6 Conclusion and Future Work

In this paper, we examine the practices of requirements elicitation activities. Five software projects were studied to gain insights from the main activities identified by [3]. Conducting these activities is the role that requirements analysts or business analysts play. However, we propose that the outcomes from the activities should be shared among other stakeholders to establish a common understanding of the requirements and that social software has the potential to support this. It was reported that most of the projects have their own IT in supporting their entire project management; however, the manipulation of the technology for requirements elicitation is limited. In addition, some projects did not fully utilize their social software platform. To extend the results of this research, we will develop a wiki prototype for requirements elicitation in our future work.

The wiki should collect and communicate the outcomes from the five main activities in [3], making them accessible to all project stakeholders. For instance (recap from 5.1 to 5.5), in understanding application domain, the activity will generate knowledge like work environment, processes, standard procedures, routines, issues and challenges within the application domain. In addition to that, the current or final list of elicited requirements with descriptions will produced after requirements elicitation process. We propose that, these outcomes from five main activities should be shared through a wiki platform so that it can assist in establishing common understanding among stakeholders.

In this research study, we have a limited number of interventions. For example, we have only one sample of a commercial project and only one informant interviewed for each software project except for Project E, which has two informants. We will ensure more samples in future data collection for our future work.

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