Augmenting and Assisting Model Elicitation Tasks with 3D Virtual World Context Metadata

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Abstract. Accurate process model elicitation continues to be a time consuming task, requiring skill on the part of the interviewer to process information from interviewees. Many errors occur in this stage that would be avoided by better activity recall, more consistent specification and greater engagement by interviewees. Situated cognition theory indicates that 3D representations of real work environments engage and prime viewer cognitive states. In this paper, we augment a previous process elicitation methodology with virtual world context metadata, drawn from a 3D simulation of the workplace. We present a conceptual and formal approach for representing this contextual metadata, integrated into a process similarity measure that provides hints for the business analyst to use in process modelling steps. Finally, we conclude with examples from two use cases to illustrate the potential abilities of this approach.

Keywords: Process Elicitation, Process Context Metadata, Human-centric BPM, Process Modelling, 3D Virtual Worlds.

1 Introduction

Process model elicitation still poses a huge challenge with respect to the quality of the resulting process models, independently of whether the information was gathered from interviews [13], by exploiting existing data sources [6], or by process mining [3].

We will refer to two selected challenges, i.e., *imprecise activity names* and *imprecise time stamps* as described in [3]. Imprecise activity names occur, for example, if interviewees describe their work tasks at different granularity levels. Within a case study from the higher education domain [13], this problem became immediately evident. Also in a case study from the health care domain described in [6], analysis of existing data sources revealed description and storage of activities at different granularity levels. Finally, the analysis presented in

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[3], underpinned the existence of this problem in process logs, e.g., from Business Process Intelligence (BPI) challenges. Imprecise activity names might lead to quality problems with resulting process models, as activities that actually describe the same work task might be identified as different activities and vice versa, leading to overly complex and possibly incorrect process models. Imprecise time specifications occur frequently as well and have a direct impact on the activity sequencing [6]. When interviewing process participants as described in [13], they may not directly talk about the order of their activities and most probably not provide any time stamps. Existing data sources often contain imprecise time stamps due to logging at different granularity levels. A prevalent problem then is that activities might be detected as happening in parallel, e.g., on the same day, despite them having a serial order within the day. Some solutions to tackle such problems have been presented in [6] by enriching the process model knowledge with metadata. This metadata may be derived from the work environment, or it may have to be elicited from process stakeholders in an a posteriori manner[2].

From this thinking, the following three research questions arise:

- R1 – what additional information can be exploited in order to overcome challenges around imprecise activity names and imprecise time stamps?
- R2 – how can we elicit this information?
- R3 – how can we measure the success of eliciting and exploiting additional information?

Addressing R1, in this paper, we analyze the approach presented in [13] for eliciting process model information from interviews. Specifically, [13] provides a list of so called *hints* that were typically mentioned by the interviewees. As a conceptual contribution of this paper, it will be shown how the information from the hint list can be mapped onto virtual world contextual information connected with process activities.

For R2, we posit that an enhanced memory model needs to be used to provide the prompting required during interviewing approaches. What is needed is a methodology to enhance the interview process to provide information necessary to provoke detailed responses from the stakeholder. Such an enhanced memory model can also be justified from a cognitive psychological point of view [10], whereby the presentation of visual stimuli enables the accessing of longer term memory within the brain that provides more information for the stakeholder to use. The argument is that personally situated work representations can increase the loading capability of the short-term memory and arouse prior knowledge in the longer-term memory, consistent with the arguments of Miller [18]. For example, an accurate visualization of a working environment can arouse the prior knowledge of a stakeholder. A personalised visualization of their working environment can provide them with a representation in a "hands-on" manner that simulates real artefacts in real spaces. This enables them to make comments according to their deeper work experiences. Moody concludes that this "hands-on" manner is a form of semantic transparency [19]. People can directly infer information for a conceptual model from the operational representation of the conceptual models in a simulated workplace, in a manner that is consistent with models of situated cognition, that is, that we store work process memories as situated actions, relating our work to physical resources in our workplace [5]. Therefore, we believe it can be argued that an interactive 3D representation of a workplace will provide these stimuli [10]. This is key to the interviewing process that is performed at the commencement of process modelling with stakeholders. Assuming that a work situated, observational version of interviewing is canonical (but not necessarily possible) we suggest that an interactive virtual world will be a major step forward in providing a similar set of stimuli to provoke these memories of a process, thus providing personalised to-do lists that may be merged into a final overall process model for a number of roles.

Finally, we will address R3 by evaluating the approach based on two case studies 1) follows up on previous work by the authors [13] in the context of higher education processes at the University of Vienna and 2) takes logs from the BPI 2011 challenge [16] containing data from the health care domain.

The Vienna case study continues our previous work, applying our new approach to extract the process model of teaching from to-do's of selected process participants at the Faculty of Computer Science, University of Vienna. In face-to-face interviews, selected people working in key positions of the teaching process were asked to list their activities in the process under investigation, similar to a scheduled to-do list. We use examples from this case study to highlight the extra spatial information that can be drawn from the virtual world information that can be used in such circumstances. In particular, we show how to use this information to reinforce the previously mentioned hint process to provide greater insights into the specified activities. For each extracted case, logs previously garnered from interviews were examined for contextual information that could provide hints as to new structures within the final process model.

To round out the content of the case studies, we have included from a separate study two examples from the Business Process Intelligence (BPI) 2011 challenge [16]. The BPI challenge is an annual process mining competition, used to test, compare and improve process log analysis techniques. The logs are raw data drawn from the Academisch Medisch Centrum (AMC) hospital, a teaching hospital in Amsterdam, the Netherlands. Diagnostic and treatment activities recorded in the logs were examined from a group of 627 gynaecological oncology patients treated in 2005 and 2006.

In each case there are issues with ambiguity and lack of precision in the specification of log activities. In both cases, we aim to show that the original processes, without using the virtual world and exploiting hints, can be enhanced in quality by using the virtual world metadata. In addition, the two case studies support our argument that the new approach is easy to apply to widely differing process modelling domains, such as education and health.

The structure and contributions of the paper are as follows. Section 2 is a theoretical mapping of key contextual information to hints for use by the process modeller. We then show how these hints relate to key challenges in process log quality used in process mining. Section 3 describes the design and implementation of a novel virtual world interview tool to help elicit process activities.

From this initial analysis and development, a formal set of operators has been developed to apply to the resulting contextual data in Section 4. Next, an initial theoretical analysis in Section 5 is applied to an admixture of real and synthetic use case data, illustrating the ability of the hint in guiding modelling decisions. The paper concludes with a listing of relevant work in the field and discusses future work.

2 BPMEVW: Virtual World Extended BPME

In this paper, we present a 3D virtual world process model elicitation approach for the purpose of assisting with process elicitation by supporting better personal activity recall and by providing hints for later analysis tasks being performed. The Business Process Model Extraction (BPME) method as presented in [13] can be extended by using a virtual world as the first stage in the individual view elicitation. The newly modified methodology – called Virtual World Extended BPME (BPMEVW) – is depicted in Figure 1, with a new stage involving the use of a 3D virtual world tool in the process elicitation phase.

We should note that we have chosen for a number of reasons to use the BPME method, extended with a virtual world into the BPMEVW. The BPME hint structure conceptually aligns with the contextual priming provided by the virtual world representations. In addition, virtual world context metadata can be applied to stages in the process of creating process models in the BPMEVW, allowing a context information model to support further process modelling steps, see the *World Context* document in Figure 1. The BPMEVW method also supports a transparent and comprehensible way of developing process models. Typical methods that aim at the elicitation of process information are, for example, the scanning of textual process descriptions, if available, by the business analyst, interviews performed with persons acting in specific process-relevant roles in the enterprise and workshops in which processes are described and modelled in groups. Although all these elicitation methods have their abilities, often there might arise a kind of black box between the process elicitation and the final model. The virtual world helps us to elicit process information from the user, and at the same time, automatically document the information in terms of a process elicitation log. In later steps, the process elicitation log is prepared and used automatically for process mining to obtain the final model, thus offering a fully documented, comprehensible and repeatable process of process modelling.

From such an approach, we propose that the augmented virtual world method will provide the following hints to the BMPEVW approach. Each of these may be articulated with extra context information that provides insight into process activity equivalence. In order to provide answers to R1 (see Introduction), we analyse each in turn for insight into the ability of the context information to refine this process.

Hint 1 - data transfer - (datainput and dataoutput) or events (e.g., eMail, Mail, and PhoneCall) between two or more process participants (connection). For example, to-do of the AdministrativeCooperator: “Mail lecturing contract to

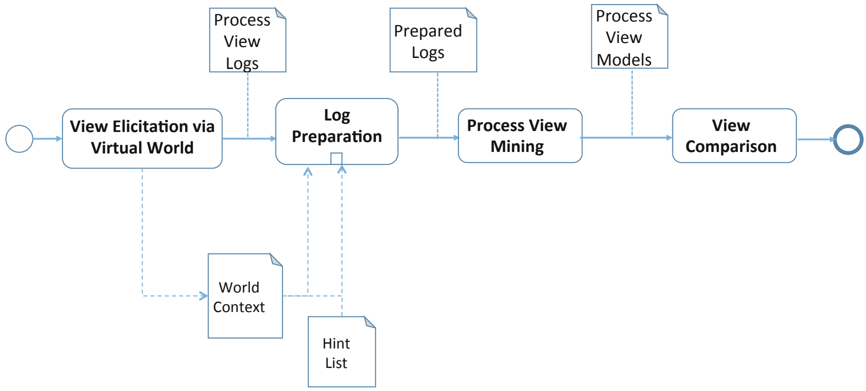

Fig. 1. BPMEVW method, augmented with virtual world-based process elicitation activities and associated metadata to assist with merging and alignment activities.

lecturer," and to-do of a Lecturer: "Receipt of the lecturing contract in my post office box." In the virtual world, human resources can be represented visually, thus direct interactions with people can be recorded automatically in the world, providing an explicit mechanism to record human to human data interactions.

Hint 2 - group tasks and activities (participation) - for example, to-do of the Lecturers and the TeachingCoordinators: "Participation in coordination meeting." This can be determined by extracted world location information. If activities occur within a particular location, then an analysis of the 3D space with different subjects will indicate a potential group activity.

Hint 3 - decisions - for example, to-do of a Lecturer: "Either I contact the AdministrativeCoordinator if I want to book the lecture hall X or I contact the Secretary if I want to book the lab." While explicit choices cannot be shown in the world we have implemented, there is definitely the ability to record the *if* as a choice or decision by recording two instances of an activity with an embedded if in the text.

Hint 4 - delegation - it can be assumed that the to-do's are performed by the process member who listed the to-do's. Otherwise, a hint to another person is given. For example, to-do of a ModuleCoordinator: "A lecturer of our lecturer team books a lecture hall for all of us". If the activity has another human resource involved, then this is a strong hint of a delegation being performed.

Hint 5 - tools - it might be the case that process participants would rather mention the particular tool name (e.g. Fronter) than the general term (e.g. learning platform). For example, to-do of a Lecturer: "Then I enter the grades of the students into ISWI[1]." The interviewee may interact with a mobile phone to define an activity, either as: phone person to book room, or send email to person to book room. Indeed, we conjecture that specifying the object used to perform the task will provide a priming prompt to divulge the tools used.

[1] Online platform at the Faculty of Computer Science, University of Vienna

Hint 6 - reoccurring activities - for example, to-do of a Lecturer: "Reoccurring task: conduction of the units". The virtual world accommodates the definition of repetitious activities via providing extra information to correlate with the activity label, for example, the location and resources used in the task will provide further hints that these repeating activities are indeed the same task being repeated.

Hint 7 - time notes - we assume that the to-do list already reflects a sequential order of the to-do's. The first to-do mentioned in the list is the first to-do that is performed by the person in the process under investigation. Explicitly mentioned time notes may be vague but support the designer to sequentially order summarised tasks and activities. For example, to-do of a Lecturer: "At the day of the unit I print the attendance list.", or "Before the semester starts I plan the course". Such a hint addresses issues raised by [3], instead of the interviewee relying on their memory, the priming of the world will push the user towards a temporally aligned specification of the to-do list.

Hint 8 - activity merge - in addition to the seven hints listed by [13], we add an activity merging hint, drawn from the context metadata provided within the virtual world. In essence, along with simple activity string similarity measures, similarity measures can process extra virtual world context metadata, for example, resources (human and non-human) and locations.

3 Virtual World Representation

We use 3D virtual world technology to provide the interactive environment to support process elicitation tasks. Virtual worlds are immersive 3D environments which contain 3D artefacts and avatars that have real-time interaction capabilities [4]. Such technology is ubiquitous, due to the rise of advanced graphics technology, enabling virtual world systems to run on standard desktops. The focus of the representation component is thus not the virtual world technology, but the actual capabilities and realism required for the visual representation to be used. Major open source components of the implementation include a world server (OpenSim[2]) a viewing client (Firestorm [3]), a mySQL database backend (WAMP[4]) and some small PHP applications to generate .xes format process logs.

Using a floor plan and imported artefacts, the general layout of key areas can be quickly modeled for use in an interview scenario. For our two use cases, we analysed typical workspaces to find out what are the key objects in the rooms (e.g., chairs, tables and phones) in order to select corresponding virtual world artefacts. A key research question is the level of detail required for the visualization of the workplace. A complete model is out of the scope of this paper, however, it should be noted that the visual fidelity of the environment is modulated by the interaction needs of the space [15]. A designer will provide

[2] Opensimulator: `www.opensimulator.org`, accessed: June, 2014
[3] Firestorm: `www.firestormviewer.org`, accessed: June, 2014
[4] WAMP: `www.wampserver.com`, accessed: June, 2014

artefacts in the environment to support the extraction of relevant events for process mining. Detail is focused upon the items that are specifically used in processes. The more superfluous items, with regards to this simulation, are the walls and roofs of the buildings, as they do not play as strong a part in the process of priming people [10]. We argue logically that the objects of most relevant affordance should be presented at the highest level of detail as they have the most influence on the cognition of the user with respect to their process activities. We argue that the rest of the scene may be left in lower levels of detail, with a lowered effect on the tasks being elicited. As a corollary, we have adopted a common visualization approach of presenting our examples with floor plans and uploaded meshes from free sources (3D Sketchup Warehouse[5]). Examples of the environment have been developed for our case studies and are shown below in Figure 2. We used office artefacts gained from the Google 3D SketchUp service, thus no real modelling was required for the office example. In the hospital version, the objects in the scene have been constructed by hand, but similarly, representational hospital objects can be found in the online Sketchup database. We emphasise that, in these use cases, low amounts of modelling were required in order to generate a useful virtual world.

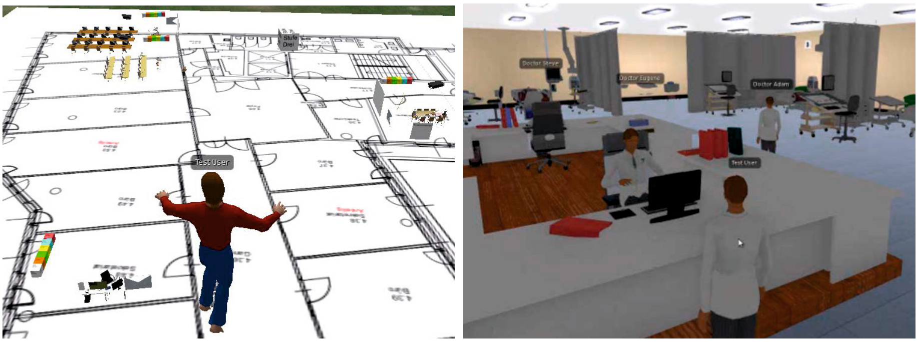

Fig. 2. Images from virtual worlds developed for the Vienna Computer Science (left image) and Dutch hospital (right image) case studies.

3.1 Interaction Approach

As this project is, at its essence, a process elicitation project, we have sought to integrate methods for process activity definition in a manner similar to free form interview answers. We seek to provide a solution for R2 (see Introduction) by designing an elicitation method that intuitively incorporates a 3D virtual world view. The 3D view is from a worker perspective, being an avatar-based third person view [4]. This world view provides a setting that is cognitively subjective, facilitating a personal viewpoint when eliciting to-do lists from interviewees. An

[5] 3D Sketchup Warehouse: `3dwarehouse.sketchup.com`, accessed: June, 2014

interaction approach was chosen in order to configure the virtual world client and server for optimal use by interviewees. Therefore, the basis for interaction is a free form specification of text describing executed activities. This is motivated by a number of factors. Firstly, when being interviewed by a business analyst, the responses of the interviewee are free form text as speech or questionnaire responses [13]. In principle, we provide an interaction mechanism that is as close to the data capturing done by an interviewer as possible, see Figure 3.

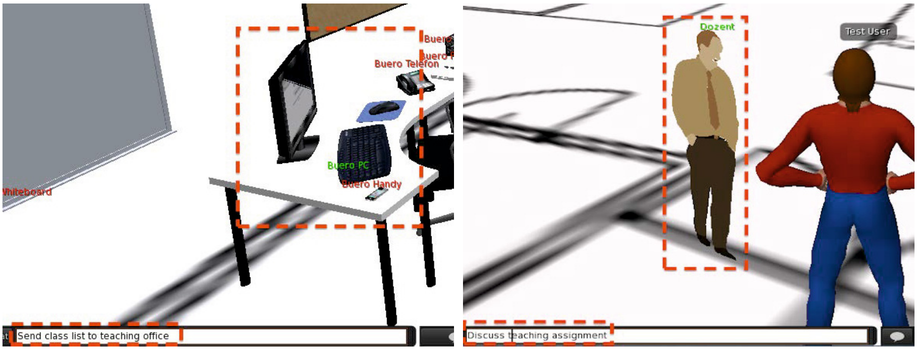

Fig. 3. Example image of text being entered after interacting with a resource within the virtual world. In the left image, an office PC has been clicked (dashed rectangle), and the user is now recording the actions they perform with that PC (dashed rectangle at bottom left). In a similar manner in the right image, a lecturer has been clicked.

Despite this free form entry method, the text input is constrained via interactions with relevant human or non-human resources. The direct manipulation interface provides a natural, mnemonic approach to interact directly with the objects having most affordance for the activity [7,24]. A further benefit of the usage of direct manipulation interfaces – also called WYSIWYG interface (what you see is what you get) – is that the objects are visible and hence the interviewees do not need to remember complex syntax [24,12]. This way, novices can also learn the functionalities quickly. For virtual worlds, the direct manipulation principles are very helpful in providing the feeling of direct involvement with the simulation [24,23,12]. Such involvement, we believe, will result in a more consistently defined set of activities, due to the priming interaction with a visually familiar representation of resources.

The interaction approach is implemented as a single script, programmed in the Open Simulator scripting language. It is able to invoke PHP service calls within a WAMP system. In each case the information recorded is drawn from the virtual world data for the object. A single script is used for each object, which packages the name and read text from the user, saving it on the WAMP server, resulting in an easy interaction configuration of the world. An object to be used, for example the PC shown in Figure 3, has this single script attached to it via a menu interface. From then on, it is able to provide process elicitation information as text descriptions typed in by the user. This can be done for every resource in the world that is relevant to the process being elicited.

It should be noted here, for clarity, that the virtual world does not contain animated functionality, it simply represents the visual state of the world, with mostly static artefacts. None of the interactions change the state of the world, they are simply user interface functions for drawing out process activity information from the interviewees, and so only represent the world in an as-is state. Furthermore, the intention is that the interactions in this prototype are to be used in an interviewing scenario where the person is being interviewed to describe the process from their perspective. While human and software services have representations within the virtual world, no human resources are animated. Thus agent simulation and modelling capabilities regarding to-be components are out of the scope of this present research and have been left for future work by the researchers.

Continuing on, each activity is specified in turn by interacting with (clicking on) the resources and typing to them the description of the activity. This activity description (predicate), along with the resource description, is stored in a database. Each table entry will encode the action taken with the resource, and any business objects used in the process for an initial data perspective. In addition, the stored text string provides a simple sentence structure which can be utilised later in natural language processing algorithms, as shown below.

<Subject>, <Object>, <Predicate>

The subject is the user of the system (automatically recorded), the object is the human, non-human resource utilised in the interaction (automatically recorded), leaving a free form predicate string to describe what the subject is doing with the object in question. A detailed description of the string, as placed in the database, is given later in Section 3.2. An example from our case study is:

<Jan>, <Office PC>, <Send application for PC software installation>,
<Doc:"IT Services Software Installation Form">

As mentioned previously, one of the major challenges in process elicitation is the garnering of consistent data [13,3]. The need for consistent nomenclature is assisted here by the selection of named resources in the environment and automatic recording of the subject's name; any activity is constrained to be related to modelled human and non-human resources within the organisation. However, this approach is balanced by a need for free form expression, so that interviewees are able to provide a subjective view of their to-do list that may be outside of a specified action, or may contain other useful contextual metadata.

3.2 World Context Information Data Modelling

Once these strings have been captured, they must be stored in a manner that will facilitate future merging and processing. This stored information, gathered from traversing the virtual world, provides further information to the analyst regarding the context of the activities, in particular, their equivalence and temporal ordering. The intention is to allow multiple people to use the environment, record their traces and then use these results to generate process models. While context information has been modelled before, from the perspective of activity equivalence determination [21], we extend this model to include world context information that will enhance the identification of similar activities for merging. Each of the to-do activities recorded will contain the following information:

- **Subject**: the name of person carrying out the elicitation activity, drawn automatically from configuring the avatar representation in the environment.
- **Object**: the name of the resource being interacted with in the environment; for example, printer, table, x-ray machine, reception desk, and so on.
- **Predicate**: a free form string used to describe the activity performed with the object in the activity, for example, print class attendance sheet.
- **Data Object**: the business object used, representing a data perspective within the activity, for example, enrolment application form.

In addition to the information listed above for the to-do strings, the following is stored in the database:

- **Position**: the x,y,z coordinate of the event recorded by the subject in the virtual world, measured in metres.
- **Timestamp**: time and date of the recorded event during the interview, providing a relative temporal order to activities.

These elements have been implemented in WAMP as an SQL database table. Note that the Data Object component is assumed to be within the predicate string in this implementation. The table can be written out as an .xes format event log if required.

4 World Context and Similarity Measures

Once the world has been modelled and used within the interview sessions, the data extracted needs to then be processed effectively to provide useful log data for later analysis. Previous work has defined equivalence as a context analysis with respect to the semantics of the underlying services being executed by an activity [21]. We take a similar approach to answer R3 (see Introduction), but formalise the context operators from the perspective of the extra world context information previously listed. This comparison process is supported in part by the nature of the interface to the virtual world, as it constrains the specification of activities to key resources and locations, making the process of analysis for determining merge points a lot easier. The interface, as a by product, also assists with the challenges of precision and reproducible log data, by constraining the user somewhat, to a more regular expression of key activities within the process, in itself facilitating the equivalence formalism.

Definition 1 (World context). *Let $\mathcal{A}$ be the set of all activities executable within a world domain of activities. An activity $A \in \mathcal{A}$ is defined as tuple $A := (S, O, P, D, dT, W, T)$, drawn from the information typed by users of the virtual world during an interview session, where:*

- *S - subject, name of agent carrying out the elicitation activity.*
- *O - object, the name of the resource being interacted with in the environment to execute the activity.*
- *P - predicate, a verb used to describe the activity performed with the object in the activity.*
- *D - set of data objects, representing a data perspective within the activity (set of input/output data related to activities).*
- *$dt : D \mapsto \{input, output\}$ - function dT maps each data object in D onto its type, i.e., input or output data*
- *$W \subseteq \mathbb{Z} \times \mathbb{Z} \times \mathbb{Z}$ - world position, three-dimensional coordinates of the activity recorded.*
- *T - timestamp of the activity.*

For this paper we focus on similarity as a measure, due to the need to specify, as best as possible, inexact comparison capabilities for the context metadata, in particular, locations in space, and references to labeled objects; we therefore use a small set of measures directly from [26].

Definition 2 (Label similarity). *For activity A tuple elements S, P, D - O and W are defined uniquely below in Definitions 4 and 5. We use a modified version of the string edit measure definition, from [26], where l_1, l_2 are two labels, and let $|l|$ represent the number of characters in the label l. The string edit distance of the labels is denoted $ed(l_1, l_2)$ and is the minimal number of atomic string operations needed to transform l_1 into l_2 or vice versa. The atomic string operations are: inserting a character, deleting a character or substituting a character for another. The label feature similarity of l_1 and l_2, denoted $lsim(l_1, l_2)$ is:*

$$lsim(l_1, l_2) = 1 - \frac{ed(l_1, l_2)}{max(|l_1|, |l_2|)}$$

As the context data provided in a virtual world is spatial in nature, there is a need for a similarity operator that takes into account the locations of activities and resources within the environments, so a positional similarity measure must be developed to assess the relative locations of entities within the virtual world.

Definition 3 (Euclidean distance feature similarity). *Let W_{a1}, W_{a2} be the world positions of two activities $a1$, $a2 \in \mathcal{A}$. Then the distance edist between W_{a1}, W_{a2} can be determined by*

$$edist(W_{a1}, W_{a2}) = |W_{a1} - W_{a2}|$$

where $|W_{a1} - W_{a2}|$ represents the euclidean distance between the two 3D points.

When world object similarities are to be considered, there is the need to combine label and spatial similarity estimates in order to have an accurate estimation of the similarity of two objects in the virtual world. The strong assumption is that objects, with the same label and same location, are the same object. Objects with similar labels, but in a different location, are different objects, being used for a similar activity. These two similarity estimates are combined into a ratio, as shown in the following, allowing the distance between the log entries, measured as *edist*, to suppress any label similarity effect.

Definition 4 (Object feature similarity). *Let O_{a1}, O_{a2} be the objects associated with two activities $a1$, $a2 \in \mathcal{A}$ and W_{a1}, W_{a2} be the associated world positions. Then object similarity osim between $a1, a2$ can be defined as follows:*

$$osim(a1, a2) = \frac{lsim(label(O_{a1}), label(O_{a2}))}{edist(W_{a1}, W_{a2}) + 1}$$

where label(O) returns the label of object O.

The interpretation of *osim* is that if the object labels and world positions are similar, then *osim* returns a high similarity. However, if the object labels are similar, but the world positions are not, then object similarity is decreased. This reflects, for example, a case of similar devices being on different floors. In case that *lsim* of two object labels is 1 and the distance between their world positions is 0, *osim* yields a similarity of 1. In case the label similarity is 0, *osim* becomes 0. For $lsim = 0.5$ and $edist = 0.5$, $osim = 0.33$.

5 Formalization and Analysis of Hints within the Logs

We now initially validate the technical method via examples and descriptions of functionality [11] as an initial presentation of the capabilities of the new BPMEVW approach. A number of detailed examples of using the virtual world are used to generate augmented to-do lists for later merging into process models. For this initial research, we have a two fold validation process. Firstly, we map the hints listed in Section 2 to a list linking the metadata features with related similarity operations. This forms an initial set of comparison operators that can be applied to the metadata to generate hints. Secondly, we provide examples of these hints being generated for activity specifications drawn from the two example use cases. Analysis of examples for the Vienna use case [13] are drawn from a codebook generated to fully define process activities. The codebook contains key terms processed by the interviewer, in order to provide a basis for activity merging and alignment. Raw logs provided by the BPI2011 challenge, as previously mentioned, were used as a source of activity specifications and resource information for the Dutch healthcare case study. Log examples have been selected from this health example, to best highlight issues around the *tools* and *reoccurring activity* hints.

The following sections detail the hints, showing the similarity operator developed and their application to data from either use cases. In each case, the examples refer to unary or binary operations performed on two activities $a1$ and

$a2$ from the set of $\mathcal{A}$. The examples have each been labeled CS for Vienna Computer Science and DAH for Dutch Academic Hospital respectively. The bolded example data for CS or DAH are the extra context metadata extracted from the virtual world, over and above any interview information that would be gained using a normal BPME approach.

5.1 Data Transfer Operator

Let $a1, a2 \in \mathcal{A}$ be two activities, S_{a1}, S_{a2} be the subjects carrying out $a1, a2$, and D_{a1}, D_{a2} the data objects of $a1, a2$ (cf. Definition 1). Then a data transfer between $a1$ and $a2$ can be detected from the log based on Equation (1) using label similarity metrics $lsim$ defined in Definition 2 and threshold *lcutoff*:

$$lsim(D_{a1}, D_{a2}) > lcutoff \wedge S_{a1} \neq S_{a2} \tag{1}$$

CS Example : P_{a1} = "Mail lecturing contract to lecturer," P_{a2} = "Receipt of the lecturing contract in my post office box" **$\mathbf{S}_{a1}$ = "AdministrativeCoordinator," $\mathbf{S}_{a2}$ = "Lecturer," $\mathbf{D}_{a1}$ and $\mathbf{D}_{a2}$ = "lecturing contract"**

Obviously, the two subjects are different and the label similarity between the data elements D_{a1} and D_{a2} is 100%. This indicates that a data perspective element D has been shared between two different subjects. In addition, the use of the interactive virtual world interface (see Figure 3) ensures the subjects chosen are predefined, and indeed different, providing a clearer indication of such data transfer events upon log analysis.

5.2 Group Tasks

Let P_{a1}, P_{a2} be two activity predicates written into the log of interest. Let further S_{a1}, S_{a2} be the subjects and W_{a1}, W_{a2} be the world positions associated with $a1, a2$ (cf. Definition 1). Then it can be detected from the log that (similar) activities $a1$ and $a2$ belong to a group task based on Equation (2) using Euclidean distance feature similarity metrics $edist$ defined in Definition 3 and thresholds *lcutoff*, *ecutoff*:

$$lsim(P_{a1}, P_{a2}) > lcutoff \wedge edist(W_{a1}, W_{a2}) < ecutoff \wedge S_{a1} \neq S_{a2} \tag{2}$$

CS Example : P_{a1} = "Participation in coordination meeting," P_{a2} = "Coordination meeting" **$\mathbf{S}_{a1}$ = "TeachingCoordinator," $\mathbf{S}_{a2}$ = "Lecturer" $\mathbf{W}_{a1}$ $= <134, 131, 23>$, $\mathbf{W}_{a2}$ $= <134, 131, 23>$**.

The distance between the predicates P of $a1$ and $a2$ turns out as 0.48 (i.e., 1 - 18/37). The spatial distance between W_{a1}, W_{a2} is 0. The multiple different subjects in a shared 3D location for a similar activity hints at a group activity. As a consequence, activities $a1$ and $a2$ might be aggregated in the resulting model.

5.3 Delegation

Let P_a be an activity predicate contained in the log of interest and O_a be the object associated with a. Then a hint to a delegation can be found based on the following Rule (4):

$$label(O_a) \in H_{Role} \vee label(O_a) \in H_{ID} \tag{3}$$

where, H_{Role} is the set of human resource roles allocated to the running case (e.g., "Lecturer"), H_{ID} is the system ID of a human resource (e.g., "Lect2314") and $label(O)$ returns the label of object O as a string.

CS Example : P_{a1} = "A lecturer of our lecturer team books a lecture hall for all of us" **O_{a1} = "Lecturer"**.

As the object O in the interaction event recorded is a human role found in H_{Role}, then this is a strong hint of a delegation. In addition, we note the use of the virtual world tends to constrain the interviewee to identified roles.

5.4 Tools

Let P_{a1}, P_{a2} be two activity predicates written into the log of interest. Further, let O_{a1}, O_{a2} be the objects associated with $a1, a2$. Then it can be detected that the two activities $a1$, $a2$ use the same tools based on the following Equation (4) using label similarity and object similarity with thresholds *lcutoff* and *ocutoff*:

$$lsim(P_{a1}, P_{a2}) > lcutoff \wedge osim(O_{a1}, O_{a2}) > ocutoff \tag{4}$$

DAH Example : **P_{a1} = "ultrasound scan abdomen," P_{a2} = "ultrasound hip," O_{a1} = "UltrasoundMachine," O_{a1} = "UltrasoundMachine." W_{a1} = <120, 131, 10>, W_{a2} = <120, 131, 10>**.

The similarities for the above example turn out as follows: $lsim = 0.26$ (ie. 1.0 - 17/23), $osim = 1$ (i.e.. identical in name and location). Resource alignment in an interactive virtual world hospital will be better defined and aligned with activities due to direct interactions with precisely named resources.

5.5 Reoccurring Activities

Let P_{a1}, P_{a2} be two activity predicates written into the log of interest. Further, let S_{a1}, S_{a2} be the subject, O_{a1}, O_{a2} be the objects, and D_{a1}, D_{a2} be the data objects associated to $a1, a2$. Then it can be detected that P_{a1}, P_{a2} belong to a reoccurring activity based on the following Equation (5) using label similarity and object similarity with thresholds *lcutoff1*, *lcutoff2*, and *ocutoff*:

$$\begin{aligned} &lsim(P_{a1}, P_{a2}) > lcutoff1 \wedge S_{a1} = S_{a2} \\ &\quad \wedge osim(O_{a1}, O_{a2}) > scutoff \wedge lsim(label(D_{a1}), label(D_{a2})) > lcutoff2 \end{aligned} \tag{5}$$

where label(D) yields the label of data object D.

This definition corresponds to the attribute equivalence proposed in [22], and is detailed for logs in this approach.

DAH Example : P_{a1} = "Administrative Fee," P_{a2} = "Administrative Fee," **$\mathbf{O}_{a1}$ = "Reception," $\mathbf{O}_{a2}$ = "Reception," $\mathbf{S}_{a1}$ = "Patient," $\mathbf{S}_{a2}$ = "Patient," $\mathbf{D}_{a1}$ = "Receipt." $\mathbf{D}_{a2}$ = "Receipt." $\mathbf{W}_{a1}$ = <113, 131, 0>, $\mathbf{W}_{a2}$ = <113, 131, 0>**.

Label similarity between the predicates of the activities and the labels of the associated data elements turns out as 1. The same holds for the object similarity, as it is the reception desk at the same location. The associated subjects are the same. Hence, it can be concluded that the activity predicates in the log really belong to the same activity that has been executed in a repetitive way.

The equivalent context information in this administrative fee charging medical case (subjects, resources and data objects) may highlight loops due to contextual similarities.

5.6 Time Notes

The hint "Time Notes" is illustrated based on the following example.

CS Example : P_{a1} = "inquiry for technical requirements," P_{a2} = "apply for licenses" **$\mathbf{T}_{a1}$ = "28/03/2014 5:20 pm," $\mathbf{T}_{a2}$ = "28/03/2014 5:22 pm."**

Our conjecture, to be confirmed by empirical experimentation, is that due to the visual priming effect of an interactive virtual world, and automatic time stamps, $a1$ should be correctly positioned before $a2$, reducing previously mentioned issues with temporal ordering.

5.7 Activity Merge

Let P_{a1}, P_{a2} be two activity predicates written into the log of interest. Further, let O_{a1}, O_{a2} be the objects, and W_{a1}, W_{a2} be the world positions associated with $a1, a2$. Then it can be detected that $a1, a2$ might be candidates for an activity merge based on the following Equation (6) using label and object similarity as well as Euclidean distance with thresholds *lcutoff*, *ocutoff*, and *ecutoff*:

$$\begin{aligned} lsim(P_{a1}, P_{a2}) > \mathit{lcutoff} \wedge osim(O_{a1}, O_{a2}) > \mathit{ocutoff} \\ \wedge\, edist(W_{a1}, W_{a2}) < \mathit{ecutoff} \end{aligned} \tag{6}$$

Note that the distance between the world positions is implicitly considered in $osim$. However, as illustrated by the following example, it is important to emphasize that the work associated with the activities was performed in the same location.

CS Example : P_{a1} = "course design," P_{a2} = "describe course" **$\mathbf{O}_{a1}$ = "Home PC," $\mathbf{O}_{a2}$ = "Tablet PC" $\mathbf{W}_{a1}$ = <90, 200, 23>, $\mathbf{W}_{a2}$ = <90, 200, 23>**.

The similarities for the above example turn out as follows: $lsim = 0.4$ (ie. 1.0 - 9/15), $osim = 0.4$ (ie. (1.0 - 6/10)(0.0 + 1.0)). If the subjects are found to be doing this work in the same location, with similarly labelled services or resources, then this is a hint that the activities may be the same.

6 Related Work

Process model elicitation is an important stage in the BPM-life cycle, and its contribution to successful modelling exercises cannot be underestimated. However, we note that not many software tools have been developed beyond descriptive methodologies to elicit this information [13], with even experiential papers as guidelines [1]. There has been some work to use forms of simulation and recommendation to extract information from users [17], but by and large, elicitation methods are usually implemented as workshops with stakeholders, or interviews, one-on-one [13].

From an HCI perspective, some tools have been developed to engage users in process elicitation, including collaborative tables and tangible modelling approaches. A stakeholder driven collaborative modelling table approach to process elicitation, that seeks to allow stakeholders to model their processes using a subjective form of grammar, has been developed [25]. The table seeks to facilitate discussion via tangible blocks mounted on an interactive light table, that assists in specifying processes from a subjective point of view. In related research, tangible modelling approaches have been developed by Luebbe and Weske [14], whereby plastic tiles marked with pens are used as modelling artefacts. While these tangible techniques have been found to engage users, they do not progress past variations on standard modelling grammars, and do not incorporate any novel 3D interfaces beyond those based on graph like process grammar representations.

Previous work has been carried out by the authors into using virtual worlds for various aspects of process modelling, including modelling and remote collaboration [20], and simulation [9] but they have not explored the priming aspects of virtual worlds in process elicitation, except in a high level theoretical manner [10]. The research described in this paper is a first attempt at operationalising such an approach with a formalism and case study examples to illustrate the potential of such an approach.

7 Conclusion/Future Work

We have motivated in this paper the need for better approaches to expert knowledge elicitation, as it stands with process modelling tasks. Addressing R1, we have theoretically shown the potential efficacy of virtual worlds as tools for tacit knowledge elicitation as modelling hints. This tacit knowledge extraction is expected to improve via the immersion of the stakeholder into a view that promotes recall of subtle information in their world, viz. a virtual world of their work. Addressing R2, from our analysis of challenges in log processing, we have developed an approach to using a virtual world model of a workplace to elicit more consistent and accurate information from an interviewee. This approach has been encoded as a formalism for processing via virtual world context metadata, which was then mapped to explicit hint mechanisms for use by business analysts in their process model merging and alignment tasks. Addressing R3, examples were drawn from CS and DAH logs, showing the potential for this approach to be integrated into an automated software system to advise analysts.

Potential limitations to the validity of this preliminary work arise from a lack of testing with a cohort of users to determine the effects of such a virtual world approach on process elicitation, including issues around usability and a detectable improvement in models elicited. Therefore, validation with a user cohort will be the next major aim of this work, in particular, to gauge the ability of this approach to improve process activity recall, and to improve issues with activity specification ambiguities, temporal granularity and accuracy in activity ordering. Furthermore, future work involving the integration of online lexicons (eg. RadLex - radlex.org) for user input text validation, may prove effective in assisting with quality control of resource and activity specifications. We expect that a future implementation may apply this context data to a process mining algorithm (such as the fuzzy miner [8]) to provide merge possibilities from mined logs.

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