Social Intelligence Design for Knowledge Circulation

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Abstract. Knowledge circulation is indispensable to improving the coverage and quality of knowledge shared in a community. In order for information and communication technologies to be successfully applied to realize knowledge circulation, social aspects need to be considered so that the technologies can be properly embedded into the society. This issue has been addressed in social intelligence design, a field of research aiming at understanding and augmenting social intelligence based on a bilateral definition of social intelligence as an individual's ability to better live in a social context and a group's ability to collectively solve problems and learn from experiences. In this paper, based on an overview of social intelligence design research, I present a generic framework of conversational knowledge circulation in which conversation is used as a primary means for communicating knowledge. I present attentive agents, autonomous interaction learner, situated knowledge management, self-organizing incremental memory, immersive conversation environment, as key technologies in conversational quantization for conversational knowledge circulation.

Keywords: Social Intelligence Design, Conversational Knowledge Circulation, Situated Knowledge Management.

1 Introduction

The advent of the information and communication technologies has significantly increased the amount of information available on the net. Kitsuregawa [1] called it information explosion. Information explosion brings about both negative and positive aspects. On the one hand, we often feel overloaded by the overwhelming amount of information, such as too many incoming e-mail messages including spams and unwanted ads. On the other hand, explosively increased information may also lead to a better support of our daily life. We can access not only public and infrastructure information such as the contact address of public service but also personal twitters and diaries that tell us how other people feel about perceived events.

Still we often run into problems which may be attributed to the lack and incompleteness of information and knowledge. From time to time, we are forced to waste long time to fix simple problems or loose critical moments due to the lack of timely information provision. After all, we are still suffering from unevenly distributed information

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and knowledge. In the industrial domain, uneven distribution of information can be thought of as a potential cause of various flaws in service such as incomplete manuals, ill-designed user interface, excessive functions, or even brittle machineries.

Information and knowledge need to be circulated so that demands for information can be communicated to information holders or providers, and information and knowledge can be communicated to those who need it. In the industrial domain, information and knowledge sharing among specialists in different sectors of service providers is considered to be a gold standard for service provision. In addition to it, communicating the engineers' intention underlying the products may lead the clients to better leverage the services and products; communicating demands of the clients may motivate service providers to design new services; communicating usage reports may force engineers to improve the quality of services and products; not only bug reports or criticisms but also reports on novel usage and proposals of new functions from skilled users might highly encourage new services and products.

In general, information and knowledge circulation is critical to ensure the coverage and quality of knowledge. Knowledge circulation may contribute to bringing about good coverage, by communicating information and knowledge demands among people. Knowledge circulation may help improve the quality of knowledge by collecting flaws, criticisms and proposals for products and services from people.

Although information and communication technologies are powerful, a simple deployment of they will not be enough. Social intelligence design [2, 3] is a field of research aiming at understanding and augmenting social intelligence based on a bilateral definition of social intelligence as an individual's ability to better live in a social context and a group's ability to collectively solve problems and learn from experiences. Issues in embedding information and communication technologies in the human society have been discussed in the context of social intelligence design.

In what follows, I first give an overview of social intelligence design research. Then, I present a generic framework of conversational knowledge circulation in which conversation is used as a primary means for communicating knowledge. Finally, I present attentive agents, autonomous interaction learner, situated knowledge management, self-organizing incremental memory, immersive conversation environment, as key technologies in conversational quantization for conversational knowledge circulation.

2 Social Intelligence Design

The central concern of social intelligence design research is the understanding and augmentation of social intelligence resulting from bilateral definitions of individual intelligence to coordinate her/his behavior with others' in a society and of collective intelligence to specify the discourse for the members to interact with each other. Social intelligence design can be discussed at the different levels of granularity. Social intelligence design on the macroscopic level is about social networking and knowledge circulation in a community. Social intelligence design on the mesoscopic level is about collaboration in a small groups and teams. Social intelligence design at the microscopic level is about fast social interactions in a social discourse.

2.1 The Idea of Social Intelligence Design -- Its Origin and Development

Social intelligence design research is based on bilateral definitions of social intelligence: social intelligence as an individual's ability to manage relationship with other agents and act wisely in a social situation, and social intelligence as an ability of a group of people to manage complexity and learn from experiences as a function of the well-designed social structure [2, 3]. Social intelligence is contrasted with problem solving intelligence / rational intelligence and emotional intelligence.

Social intelligence design research centers on five topics. The first is about theoretical aspects of social intelligence design, involving understanding group dynamics and consensus formation of knowledge creation, theory of common ground in language use, and social learning. The second is about methods of establishing the social context by such means as awareness of connectedness, circulating personal views, or sharing stories. The third is about embodied conversational agents for knowledge exchange, mediating discussions, or learning. The fourth is about collaboration design by integrating the physical space, electronic content and interaction. Multiagent systems might be used to help people in a complex situation. The fifth is about public discourse. Social intelligence design may be concerned with visualization, social awareness support, democratic participation, web mining and social network analysis [2].

Further topics, such as mediated communication and interaction [4], natural interaction [5], collaboration technology and multidisciplinary perspectives [6], evaluation and modeling [7], ambient intelligence [8], designing socially aware interaction [9], and situated and embodied interactions for symbolic and inclusive societies [10], have been added to the scope in subsequent workshops.

Social intelligence design is an interdisciplinary research area. Social intelligence design is discussed from conceptual, scientific and engineering viewpoint. Design is the most important feature to integrate scientific and engineering approach to achieve better social intelligence.

Social intelligence design is studied at three levels. Social intelligence design at the macroscopic level is concerned with networked interactions in community. Social intelligence design at the mesoscopic level focuses on structured social interactions in small groups. Social intelligence design at the microscopic level sheds light on fast interaction loops in the social discourse.

2.2 The Networked Interactions on the Macroscopic Level

Social intelligence design on the macroscopic level is concerned with understanding and supporting communities where knowledge evolves as a result of interaction among members. Major issues include community knowledge management, design and analysis of computer-mediated communication (CMC).

Community knowledge management is concerned with understanding and enabling organizational approach to identify, foster, and leverage insights and experiences shared in a community. It should recognize best practice in a community [11] and enhance the knowledge spiral between formal and tacit knowledge [12]. CMC tools should be amalgamated with organizational structure and process. Tacit knowledge might be better formalized into formal knowledge with CMC tools with face-to-face communication functions, while formal knowledge might be better internalized into tacit knowledge with anonymous communication means [13]. Caire [14] points out that conviviality contributes to promote values such as empathy, reciprocity, social cohesion, inclusiveness, and participation. Katai [15] introduces a framework of social improvisational acts towards communication aiming at creative and humanistic communities.

CMC tools support various phases of the knowledge process in a community. A corporate-wide meeting may not be possible without a powerful CMC tools. FaintPop [16] is designed to provide social awareness. Nakata [17] discusses a tool for raising social awareness through position-oriented discussions. Nijholt [18] discusses the design of virtual reality theater environment for a virtual community. At "WorldJam", the IBM's corporate-wide discussions held for three days and participated by over 53600 employees, a system called "Babble" was deployed which assisted synchronous and asynchronous text communications. Each participant was represented as a colored dot. The position of a dot within a visualization called "social proxy" was designed to allow each participant to grasp who else is present and which topics are being discussed [19, 20]. In the DEMOS project, Survey, Delphi and Mediation methods are combined to connect political representatives and citizens, experts and laymen. They are expected to strengthen the legitimacy and rationality of democratic decision making processes by using CMC tools to inspire and guide large scale political debates [21]. Public Opinion Channel was proposed as a CMC tool for circulating small talks in a community [22]. Kanshin was designed to allow for extracting social concern [23]. In order to cope with digital divide, the culture of the user need to be investigated with the greatest case and sensitivity [24].

CMC tools need to be analyzed in order to understand and bring about better community communication. In general, statistical or social network analysis may be applied to understand the structure and features of community communication [25]. Notsu [26] used the VAT (visual assessment of clustering tendency) to analyze the balance of the network modeling of conceptualization. Miura [27] found that medium-density congestion with a relevant topic might activate communication by experienced participants in online chat, and suggested the cognitive process in the course of communication congestion. Miura [28] suggested that information retrieval behaviors may vary depending on task-related domain specific knowledge in information retrieval. If the retriever has sufficient knowledge, s/he will cleverly limit the scope of retrieval and extract more exact information; otherwise, s/he will spend much efforts on comprehending the task-related domain for efficient retrieval. Matsumura [29] revealed that the dynamic mechanism of a popular online community is driven by two distinct causes: discussion and chitchat. ter Hofte [30] investigated placed-based presence (presence enhanced with concepts from the spatial model of interaction). The lessons learned include: place-based presence applications should be designed as an extension of existing PIM applications so that they may allow people to control the exchange of place-based presence information; place-based presence system should keep the user effort minimum, since the trust in presence status may be lowered otherwise; and wider presence and awareness scopes may be needed to allow people see each other since they will easily lose track of each other otherwise. Morio [31] made a cross-cultural examination online communities in US and Japan, and found that Japanese people would prefer to discuss or display their opinions when there is a lack of identifiability, while US people have a much lower rate of anonymous cowards. Furutani [32] investigated the effects of internet use on self efficacy. The results suggested that a belief of finding people with different social background may positively effect on self-efficacy (the cognition about one's capabilities to produce designated levels of performance), while staying in low-risk communication situation with homogeneous others might undermine self-efficacy. Moriyama [33] studied the relationship between self-efficacy and learning experiences in information education. They suggest that self-efficacy and abilities of information utilization may enhance each other. In addition, creativity and information utilization skills might promote self-efficacy.

2.3 The Structured Interactions on the Mesoscopic Level

Social intelligence design at the mesoscopic level is concerned with collaboration support in structured interactions of a group or team. Major issues include design and analysis of global teamwork, collaboration support tools, and meeting support and smart meeting rooms.

Design and analysis of global teamwork is a major concern in many industrial applications. Fruchter [34] proposed to characterize collaboration support systems for global teamwork in terms of bricks (physical spaces), bits (electronic content), and interaction (the way people communicate with each other). Fruchter [35] describes a methodology for analyzing discourse and workspace in distributed computer-mediated interaction. Fruchter [36] formalized the concept of reflection in interaction during communicative events among multiple project steakholders. The observed reflection in interaction is prototyped as TalkingPaper™.

Cornillon [37] investigated the conceptual design of a feedback advisor suggesting the knowledge co-construction aspect of a debate and noted that various aspects of social intelligence are coded in to the dialogue, such as repetitions encoding awareness of connectedness. Cornillon [38] analyzed how people work together at a distance using a collaborative argumentative graph. They found that the number of turning actions (those changing the structure of an argumentative graph) greatly varies between the face-to-face and remote condition, while that of building actions (those contributing new information on the screen) does not.

In the network era, workspaces are enhanced with information and communication technologies. In order to enable people to flexibly interact with one another in a hybrid workplace, communication in the real life workplace need to be analyzed in terms of physical space, communication space, and organizational space [39].

People's behavior in coping with multitasking and interruptions in the workplace has been studied in depth by Mark and her colleagues [40, 41, 42].

Various collaboration support tools have been proposed to facilitate collaboration from different angles. Martin [43] identified story telling as a vehicle for tacit-to-tacit knowledge transfer in architectural practice and proposed the Building Stories methodology. Fruchter [44] proposed RECALL, a multi-modal collaboration technology that supports global team work. Heylighen [45] presents DYNAMO (Dynamic Architectural Memory Online), an interactive platform to share ideas, knowledge and insights in the form of concrete building projects. Stock et al [46] presents a co-located interface for narration reconciliation in a conflict by making tangible the contributions and disagreements of participants and constraints imposed by the system to jointly perform some key actions on the story. Merckel et al [47] presents a framework for situated knowledge management. A low-cost three dimensional pointer is given to allow the user to associate information with arbitrary points on the surface of physical equipments. Analysis is as important as synthesis. Pumareja [48] studied the effects of long-term use of a groupware. The paradigm of social constructivism and the perspective of structuration was proposed as a framework of analysis. The finding from the case study suggests that collaboration technology can serve as a change agent in transforming the culture and structure of social interaction, through the various meanings people construct when interacting with technology and in benefiting from the structural properties of a system. Cavallin [49] investigated how subjective usability evaluation across applications can be affected by the conditions of evaluation and found that scenarios not only affect the task solving level, but also prime the subjective evaluation of an application.

Meeting support and smart meeting rooms have a large potential in application. Suzuki [50] discussed the social relation between the moderator and interviewees. Nijholt [51] describes a research on meeting rooms and its relevance to augmented reality meeting support and virtual reality generation of meeting. Reidsma [52] discussed three uses of Virtual Meeting Room: to improve remote meeting participation, to visualize multimedia data, as an instrument for research into social interaction in meetings. Rienks [53] presents an ambient intelligent system that uses a conflict management meeting assistant. Wizard of Oz experiments were used to determine the detailed specification of the acceptable behaviors of the meeting assistant, and obtain preliminary evaluation of the effect of the meeting assistant. Use of interaction media was studied by Mark [54] and Gill [55].

2.4 The Fast Interaction Loop on the Microscopic Level

Social intelligence design at the microscopic level is concerned with fast social interactions in the face to face interaction environment. Major issues include interactive social assistants, analysis of nonverbal social behaviors, social artifacts and multi agent systems.

Interactive social assistants help the user make social activities. S-Conart [56] supports conception and decision making of the user while online shopping. PLASIU [57] is designed to support job-hunter's decision making based on the observations from their actual job-hunting process. StoryTable [58] is a co-located cooperation enforcing interface, designed to facilitate collaboration and positive social interaction for children with autistic spectrum disorder.

Analysis of nonverbal social behaviors will provide insights needed to implement collaboration support systems or social artifacts. Yin [59] shows a method of extracting information from I-dialogue that captures knowledge generated during informal communicative events through dialogue, sketching and gestures in the form of unstructured digital design knowledge corpus. Biswas [60] presents a method for exploiting gestures as a knowledge indexing and retrieval tool for unstructured digital video data. Ohmoto [61] presents a method for measuring gaze direction and facial features to detect hidden intention.

Social artifacts aim at embodying social intelligence to interact with people or other social agents. Xu [62] presents a two-layered approach to enhance the robot's capability of involvement and engagement. Xu [63] describes a WOZ experiment setting that allows for observing and understanding the mutual adaptation procedure between humans. Mohammad [64] presents NaturalDraw that uses interactive perception to attenuate noise and unintended behaviors components of the sensor signals by creating a form of mutual alignment between the human and the robot. Mohammad [65] discusses combining autonomy and interactivity for social robots. Yamashita [66] evaluates how much a conversational form of presentation aids comprehension, for long sentences and when user had little knowledge about the topic, in particular. Poel [67] reports design and evaluation of iCat's gaze behavior. Nomura [68] studied negative attitudes towards robots.

Multi agent systems fully automate a computational theory of social agents. Roest [69] shows an interaction oriented agent architecture and language that makes use of an interaction pattern, such as escape/intervention. Rehm [70] integrates social group dynamics in the behavior modeling of multi agent systems. Mao [71] studied social judgment in multi agent systems. Pan [72] presents a multi-agent based framework for simulating human and social behavior during emergency evacuation. Cardon [73] argues that the emerging structure or the morphological agent organization reflects the meaning of the communications between the users.

2.5 Knowledge Circulation in the Context of Social Intelligence Design

Discussions in social intelligence design research may be applied to bring about better knowledge circulation.

At the macroscopic level, organizational design of knowledge circulation should be needed to make sure that a community knowledge process properly functions. A model of knowledge evolution need to be explicitly formulated which may specify when and how knowledge is created, how it is refined, how it is applied and evaluated, how it is archived, and how it is generalized for transfer. It is critical to identify contributors and consumers. The structure of participation need to be well-designed so that many people with different background and motivation can be motivated, participate in and contribute to knowledge circulation. Most importantly, it is critical to identify the structure of affordance and incentive of contribution. Consumers need to be provided enough affordance in order to apply knowledge. The social structure should be well-designed so that creators can find values in contribution in addition to affordance in order to create knowledge. Furthermore, trust and value of information and knowledge need to be addressed.

CMC tools for knowledge circulation should be designed so that they can enhance the affordance and incentive structure by reducing the overhead of knowledge circulation. They should be able to provide the user with cues for evaluating trust and dealing with a large amount of information. A method of evaluating CMC tools for knowledge circulation need to be established.

At the mesoscopic level, the central issue is to support the teamwork of steakholders who play a critical role in knowledge circulation. On the one hand, awareness need to be supported so that they can coordinate their behaviors with colleagues. Knowledge provision should be coordinated with team activities such as schedule maintenance. On the other hand, the complexity of the structure of workplace and multitask complexities must be considered, for knowledge workers are working simultaneously on multiple tasks by moving around multiple workplaces. The relationship among awareness, shared information, and privacies should be carefully analyzed by taking the structure and dynamics of participation into consideration. Collaboration support tools will augment a distributed team of steakholders. Smart meeting rooms will help co-located collaborative activities. Measurement and analysis of activities and the communication tools will be helpful in improving collaborations.

At the microscopic level, quick interaction loops using the combination of verbal and nonverbal behaviors need to be understood and supported. It should be noted that nonverbal behaviors not only control the discourse of communication, but also give additional meaning to verbal information. Understanding and leveraging quick interaction loops will help identify tacit information underlying the communication activities. Although it is challenging, developing social artifacts that can create and sustain interaction loops with people will significantly accelerate and improve the quality of knowledge circulation. Multi agent systems techniques might be used not only to control distributed systems but also to understand social systems as an accumulation of microscopic interactions among participating agents.

The above discussions may lead to a layered model of community knowledge process [74]. The first layer from the bottom is about context sharing. It accumulates the background information that serves as a common ground for a community. Thus layer remains often tacit in the sense that it is not explicitly and represented as a well-described static documents. Rather it is a dynamic collection of ongoing conversations among members or tacitly shared perception of the common ground. The second layer is information and knowledge explicitly shared in the community. The third layer is collaboration. Special interest groups are often formed to act to achieve a goal for a community. The fourth layer is discussion. Conflicting propositions are identified and discussed from various angles. The topmost layer is decision making. Resolutions to conflicting goals are determined at this level and disseminated to the community members. Knowledge circulation is indispensable to make knowledge process function effectively at each level.

3 Conversational Knowledge Circulation

Conversation is the most natural communication means for people. People are fluent in expressing ideas by combining verbal and nonverbal behaviors. People are skillful in interpreting communicative behaviors of other participants. People make nonverbal behaviors, iconic gestures for instance, not only to control the discourse but also to modulate the proposition conveyed by verbal utterances. Conversation is a heuristic process of knowledge creation by a group of people. Although it is pretty hard to express half-baked ideas, those filled with indeterminacies and inconsistencies, in a written language, vague thoughts often turn into clear ideas as a result of conversation on the spot by incorporating knowledge from participants and gaining better grounding on the subject. The discourse of conversation often allows participants to critically examine the subject from multiple angles, which may motivate further contributions from the participants. Conversational knowledge circulation centers on conversation, aiming at circulating knowledge in a conversational fashion by capturing information arising in conversations, organizing it into knowledge and applying knowledge to conversational situations. It focuses on communicating intuitive and subjective aspects of knowledge representation in a situated fashion.

3.1 Computational Framework of Conversational Knowledge Circulation

Conversational knowledge circulation depends on a method of capturing and presenting information at conversational situations. The result of conversation capture need to be packed into a some form of conversational content from which conversation will be reproduced. Design of the data structure of conversational content is critical to the design of conversational knowledge circulation. In general, the more sophisticated data structure is employed, the more flexible and reusable becomes conversational content, but the more complex algorithms may be required in implementation. Typically, conversational content may be implemented as an annotated audio-video segment. Although it is more useful if transcript of utterances or even semantic information is given as annotation, it will be more expensive and challenging to (semi-)automatically create high-quality annotated video clips. Basic elements of conversational knowledge circulation are the augmented conversational environment equipped with sensors and actuators, the conversational agent, and the conversational content server.

The augmented conversational environment is used for generating and presenting conversational content in the real world. Not only participants' conversational behaviors but also the objects and events referred to in conversation need to be captured. Although motion capture systems or eye trackers are useful devices for achieving the quality of data (such as accuracy or frequency), they may constrain the quality of interaction by compelling the participants to attach measurement devices or markers which may seriously distract natural conversations from time to time. The conversation capture may be enhanced by introducing conversational robots that may move around the environment to capture information at appropriate viewpoints or even to interview the participants to actively elicit knowledge. The key algorithms in smart environment and situated social artifacts are recognition of conversational environment and automated segmentation and annotation for captured conversation.

Conversational agents are used to interactively present conversational content. A conversational agent may be an embodied conversational agent that lives in a virtual world simulating the subject world. Alternatively, it may be a conversational robot that cohabits with people in a physical space. Although it is still a big challenge to build a conversational robot that can exhibit a proper conversational behaviors, conversational robots may embody strong presence as an independent agent in conversation once they are realized. In contrast, embodied conversational agents are portable over the net and versatile in expressing ideas without incurring by physical constraints, while their presence is often weaker than physical robots and their communicative expressions are usually bound to the two-dimensional display. The key algorithms for conversational agents are generating proper conversational behaviors and presentation of conversational content according to the conversation status.

Conversational content servers accumulate conversational content for distribution. Ideally, they may be equipped with a self-organization mechanism so that new conversation content may be automatically associated with a existing collection of conversational content and the entire collection of conversational content may be organized systematically. A less ambitious goal is to provide an visualizer and editor that may allow the user to browse the collection of conversational content, organize them into topic clusters, and create new conversational content from existing collection.

In addition to the basic elements mentioned above, high-level functions may be introduced to allow the users to utilize the collection of conversation content in collaboration, discussion, and decision making.

Figure 1 shows a simplified view of how the conversational knowledge circulation might be applied to the industrial environment where communication among customers and engineers are critical. Emphasis is placed on enhancing the lower layers of community knowledge process. It illustrates how conversations at the design, presentation and deployment stages might be supported by conversational knowledge circulation.

At the design stage, the product is designed and possible usage scenarios are developed by discussions among engineers and sales managers. The discussions contain valuable pieces of knowledge, such as intended usage or tips, that may also be useful to the users. Conversational content about the product and service can be composed as a result of the design phase. Conversational content may also used as an additional information source at the fabrication phase to help developers understand the intention of the design.

At the presentation stage, the product and service are displayed to the potential customers in an interactive fashion. In order to make the interactive presentation widely available on the net, embodied conversational agents may be used as a virtual presenter. Embodied conversational agents will be able to cope with frequently asked questions using a collection of conversational content prepared in advance. When questions cannot be answered based on the prepared conversational content, the

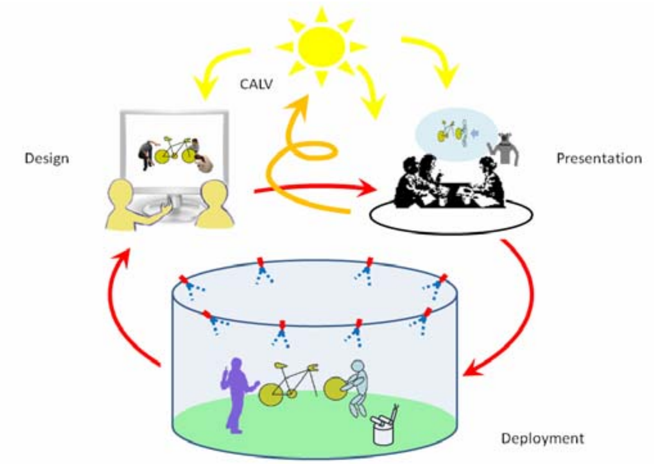

Fig. 1. Conversational knowledge circulation applied to industrial environment

engineer may control the presenter agent as an avatar to create a proper reply. Such communication logs can be saved so that the service division may extend the "FAQ" conversational content for future questions. Embodied conversational agents may be used as a surrogate of the customer to ensure the anonymous communication from the user. The presentation stage can also be employed to train novices when the product and service is introduced to the user.

At the deployment stage, conversations may contain various pieces of knowledge sources, such as the real usage scenario, evaluation from the user, complaints about the current service, demands for new services, etc. The conversation between the user and system engineer may be captured by an intelligent sensing devices. Service robots may be deployed to help the user as well as collect usage data. The collected conversational content may be fed back to the design phase for improvement and further product and service development.

It should be noted that the collection of (potential) customers, salespersons, and engineers forms a community that shares a common product and service. CALV (Community-maintained Artifacts of Lasting Value) [75] is expected to be created as a result of the conversational knowledge circulation. The more information and knowledge is circulated, the richer CALV may be obtained.

3.2 Conversation Quantization

Conversation quantization is a computational framework of circulating conversation quanta that encapsulates discourse units into annotated audio-visual video segments. Conversation quantization is based on the idea of approximating a continuous flow of conversation by a series of minimally coherent segments of discourse called conversation quanta [76].

Augmented conversational environment can be implemented as a smart meeting room or augmented environment that can provide conversation quanta with the participants according to the conversational state and produce conversation quanta by sensing conversational interaction among the participants. The role of the conversation quanta capture is to (semi-)automatically produce a sequence of conversation quanta for a given conversation session. Fully automated conversation quanta capture is considered to be out of the scope of the current technology, for significant knowledge and technological development is required to segment conversations into small pieces and produce semantic annotation for conversational situations. Saito et al [77] discussed human-assisted production of conversation quanta. Vickey [78] is an augmented conversational environment for a driving simulator. It can ground the conversation on the events observed through the simulated window of the vehicle, by analyzing pointing gestures of the participants. IMADE (the realworld Interaction Measurement, Analysis and Design Environment) [79] allows one to capture conversational behavior of a group of people with an optical motion capture device, wearable eye mark recorders, etc. A tool called iCorpusStudio was developed for browsing, analyzing, or annotating an interaction corpus consisting of multimedia data streams obtained from sensing conversation sessions.

Conversational agents have been implemented which will use conversation quanta to make speech acts in conversations. Conversational agents may be virtual or physical. Speech acts contain a full spectrum ranging from linguistic, paralinguistic, and nonlinguistic. EgoChat agents [80], SPOC and IPOC agents [81, 82]. GECA [83] provides a platform on which virtual agents are developed on an open platform using a markup language. We have also developed listener and presenter robots [84, 85], though they still exhibit only basic nonverbal behaviors.

The role of the conversational content server is to circulate conversation quanta in a team/group/community/society. It should be able to deliver conversation quanta to situations on demand or proactively. POC (Public Opinion Channel) [86, 22] implements part of the idea. The role of the conversation quanta manager is to accumulate a collection of conversation quanta. SKG (Sustainable Knowledge Globe) [87] allows the user to visually accumulate a large amount of conversational content on the CG sphere surface so that s/he can establish and maintain a sustainable external memory coevolving with the internal memory. A media converter may be used to translate conversation quanta from/to other information media such as videos or documents. Kurohashi et al [88] developed a method for automatically creating a spoken-language script from a knowledge card consisting of a short text and a reference image.

3.3 Technical Challenges

There are many technical challenges to overcome to put conversation quantization in effect for conversational knowledge circulation.

Challenges on the conversational environment are semantic and contextual processing. Although it is highly desirable to annotate data with semantic information, difficulties may arise from the size and complexity of the semantic domain. The dynamic nature of semantic information need to be addressed. Meaning cannot be predefined, for it arises dynamically in the interaction. Contextual information should be handled properly. When the discourse is well-shared, contextual information should be kept to the minimal, while maximal contextual information should be added when conversation quanta are transported to communities with different background. Thus, contextual information should be properly added or removed depending on the conversational situation.

Challenges on the conversational agents are concerned with the naturalness of interaction and presence of the agent. In order to conduct natural interactions with the user, subtle nonverbal cues in interaction should be captured and reflected on the reactive behaviors of agent. Large varieties of behaviors should be generated efficiently. Situatedness appears to be a key to naturalness. Agents should be situated in the sense that they can allow the human to share information about objects and events in the environment. The agents should at least partly share the way the humans may perceive the world. When the agent lives in the virtual environment, the entire system should permit the user to feel the environment as if s/he is involved. When the agent lives in the physical environment, the system should be able to recognize the objects/event the user is referring to and share the perception. Social awareness must be supported by capturing and forwarding member's status without violating privacy of the sender or disturbing the recipient.

Furthermore, agents should be able to attract and sustain the attention of the user during the conversation session, by recognizing the user's conversational status and managing the utterances based on the user's status. This requirement becomes more evident when the agent is interacting with more than one user. The ultimate goal is to realize empathetic interaction between the human users and the agent. Affective computing need to be introduced to have conversational agents behave naturally based on internal emotion model. Although the agent must be able to recognize the user's subtle change in emotional state, the emotional state of the user must be sensed without distracting her/him.

Challenges on the conversational content server include a self-organizational incremental memory and high-level social functions. Incoming conversation quanta should be able to structurally organized into a collection of conversational content into coherent stories. Automated digesting or summary is needed to navigate the user to a potentially large collection of conversation quanta. The dynamic nature of the memory should be considered since conversation quanta may continuously come in. Automatic visualization might be needed to have the user intuitively grasp the accumulated information. The landscape of the collection of conversation quanta should be transformed gradually so that the users can track the change of the collection. High-level functions might be introduced to account for social awareness and wellness. Social mechanisms such as trust, incentive, reciprocity, fairness, or atmosphere should be properly designed and assessed.

In general, it is challenging to make sure that social intelligence is in fact incorporated in the design of community support system. Green pointed out five challenges for this [89], namely supporting user-centered design for social intelligence; evaluating social intelligence; understanding the effect of social characteristics; ethical considerations for social intelligence; and establishing & maintaining social intelligence.

4 Towards the Breakthrough

In this section, I overview five projects aiming at overcoming the technical challenges in conversational knowledge circulation.

4.1 Attentive Agents

The goal of the attentive agent project is to build a conversational agent that can behave attentively to the dynamics of the interaction with multiple concurrent participants [90]. An agent can be said attentive if it can properly control its conversational behaviors according to the status and behaviors of other participants. For example, the agent should keep quiet when other participants are discussing with each other for a while, whilst it can urge them to come back to the conversation if they have been off the discourse for a long while. In case of talking with multiple concurrent participants, the agent need also to speak to a person who is considered to be a proper addressee. In order to have the conversational agent behave according to such attentive utterance policies, a couple of indices have been introduced: AT (interaction activity) that indicates whether the users are active in their interactions or not, and CLP (conversation leading person) that denotes the participant who is the most likely leading the group during a certain period of the conversation session. In order to overcome the limitation of two-dimensional agent coming from so-called the Mona Lisa Effect, three-dimensional physical pointer have been introduced to point to an intended addressee. The ideas have been implemented into a quiz game agent that can host a quiz session with multiple users and evaluated.

Ohmoto et al [91] addressed visual measurement of involvement of participants. Social atmosphere or extrinsic involvement attributed to the state of the group of participants as a whole is distinguished from intrinsic involvement attributed to that of an individual. Although physiological indices can be used to identify the weak involvement of a person affected by extrinsic involvement, participants of conversation are often reluctant to attach physiological sensing devices. Ohmoto et al investigated the correlation between the physiological indices and visual indices measuring the moving distances and the speed of user's motions, and have found that both intrinsic and extrinsic states of involvement can be detected with the accuracy of around 70% by changing the threshold level.

4.2 From Observation to Interaction

The goal of the autonomous interaction learner project is to build a robot that can autonomously develop natural behavior at three stages [92]. On the discovery stage, the robot attempts to discover the action and command space by watching the interaction. On the association stage, the robot attempts to associate discovered actions with commands. The result of association will be represented as a probabilistic model that can be used both for behavior understanding and generation. On the controller generation phase, the robot converts the behavioral model into an action controller so that it can act in similar situations. A number of novel algorithms have been developed. RSST (Robust Singular Spectrum Transform) is an algorithm that calculates likelihood of change of dynamics in continuous time series without prior knowledge. DGCMD (Distance-Graph Constrained Motif Discovery) uses the result of RSST to discover motifs (recurring temporal patterns) from the given time series. The association algorithm estimates the natural delay between commands and actions so that it can properly associate commands (cause) with subsequent actions (effect).

4.3 Situated Knowledge Management

The goal of the situated knowledge management project is to develop a suite of algorithms so that the system can recognize how knowledge is associated with real world objects and events. The key algorithms are the real-time, light-weight object pose recognition algorithm that takes the CAD model (Piecewise Linear Complex) and the camera-image of the target object to estimate the pose of the object with respect to the camera [93, 94]; the interface for correcting the estimated pose; and a low-overhead three-dimensional items drawing engine [95]. The suite works both in the augmented reality and augmented virtuality environments. In the augmented reality environment, it enables to overlay annotations on the camera-image of the target object. In the augmented virtuality environment, it allows for creating three-dimensional virtualized target object by automatically pasting surface texture. The three-dimensional items drawing engine consists of a hand-held Augmented Reality (AR) system. It allows the user to directly draw free three-dimensional lines in the context of the subject instruments.

4.4 Self-Organizing Incremental Memory

The goal of the incremental self-organizational memory project is to develop a self-organizing incremental neural network that can make incremental unsupervised clustering of given segments of time series. We have developed HB-SOINN (HMM-Based Self Organizing Incremental Neural Network) that uses HMM (Hidden Markov Model) as a preprocessor of SOINN so that the resulting system can handle the variable length patterns into fixed length patterns [96]. The role of HMM is to reduce dimensions of sequence data and to map variable length sequences into vectors of fixed dimension. HMM contributes to robust feature extraction from sequence patterns, which allows for similar statistical features to be extracted from sequence patterns of the same category. As a result of empirical experiments, it has turned out that HB-SOINN can generate a fewer number of clusters than a few competitive batch clustering algorithms.

4.5 Immersive Conversation Environment

The goal of the immersive conversation environment is to build an ambient environment that can provide the human operator with a feeling as if s/he stayed “inside” a conversation robot or embodied conversational agent to receive incoming visual and auditory signals and to create conversational behaviors in a natural fashion [97]. The immersive conversation environment will be used to pursue Wizard of Oz experiments with the embodiment of a conversational robot or an embodied conversational agent. A 360-degree visual display can reproduce an immersive view around a conversational agent. The current display system uses eight 64-inch display panels arranged in a circle with about 2.5 meters diameter. Eight surround speakers are used to reproduce the acoustic environment. It is designed to collect detailed information about how the operator behaves in varying conversational scenes.

5 Conclusion

Knowledge circulation not only decreases uneven distribution of knowledge in a community but also improves the coverage and quality of the shared knowledge. In this paper, I shed light on social aspects of knowledge circulation. First, I have overviewed social intelligence design and discussed how the insights obtained so far might be applied to the design, implementation and evaluation of knowledge circulation. Then, I have presented a generic framework of conversational knowledge circulation in which conversation is used as a primary means for communicating knowledge. Finally, I have presented recent results in conversational quantization for conversational knowledge circulation.

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