REQUIREMENTS ELICITATION METHOD FOR DESIGNING VIRTUAL COLLABORATIVE SYSTEMS WITH COLLABORATIVE SENSEMAKING

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Abstract: Many approaches for requirements elicitation have been proposed to help the design of virtual collaborative systems. The design of virtual collaborative systems with collaborative sensemaking presents a challenge due to the needs of interaction of users with the system in order to process, interpret, and share information collaboratively. However, most of the design approaches fail in capturing the users' needs, because they are not designed to capture precisely the main users' activities interactions during the interplay between 'collaboration' and 'information' with sensemaking. Sensemaking determines the way in which people respond to certain events and allows constructing perceptions taking into account their goals, priorities and problems. This paper describes a requirement elicitation method that captures the interactions of potential users in collaborative environments with collaborative sensemaking activities. The method is based on the simulation of activities it was employed in the design of a virtual collaborative system - a collaborative puzzle – in order to illustrate its usage.

1 INTRODUCTION

Collaboration is an essential aspect of many types of daily activities (Paul and Reddy 2010b). One activity that is central to people's personal and professional lives is information seeking (Paul and Reddy 2010b). An important factor of Collaborative Information Seeking (CIS) practice is to make sense of the information found, i.e., Collaborative Sensemaking (CS) (Feldman and Rafaeli 2002; Weick 1995). CS is the process whereby individuals process information, integrate and interpret it and through social interaction they share their understandings (Feldman and Rafaeli 2002). The objective of process CS is to provide a shared understanding about information, goals, priorities and problems that individuals face in collaborative settings to make decisions and act effectively. Without some shared knowledge base or an effective interaction between team members, severe gaps are likely to occur in the understanding of reality (Ravied et al. 2008). The research area of Collaborative Information Behaviour (CIB) has received increased interest in recent years (Paul and Reddy 2010b). The CIB area concerns about the behaviour exhibited when people work together with information to gain a better understanding of various activities such as CIS, CS and others that happen at the interplay between 'collaboration' and 'information' (Paul and Reddy 2010b). The goal of CIB is to better translate research findings into workable design recommendations and technical solutions.

It is hard to define requirements for an ideal collaborative environment, because they depend on the organization, context, problem, participants and other factors (Baasch 2002). There are some agreements on the characterization of a collaborative environment. Dargan (2001) proposes seven capabilities that a collaborative environment should have. Baasch (2002) adds two more capabilities to the Dargan's list. Among the capabilities there are some that are directly related to the interplay of 'information' and 'collaboration', such as: rapidly find the right people with the right expertise; build, find, and exchange information across organizational boundaries; deliver the right information to the right people as soon as it is

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available, and keep a record of all collaborations for further reference.

A collaborative system is one where multiple users or agents are engaged in a shared activity, usually from remote locations. Comparing with other distributed systems, collaborative systems are distinguished by the fact that the agents are working together towards a common goal and have a critical need to interact closely with each other (Ivan et al. 2008). To achieve this distinction, collaborative systems should have effective mechanisms for communication, coordination, cooperation and awareness. According to Fuks et al. (2008), ***C**ommunication* consists of the exchange of information in negotiations among people; ***C**oordination* is related to the management of people, their activities and resources; and ***C**ooperation* is the production that takes place in the shared workspace. The participants obtain feedback from their actions and feed through from the actions of their companions by means of awareness information related to the interaction among participants. The 3C collaboration model proposed by authors is based on work of Ellis et al. (1991).

Räsänen and Nyce (2006) argue that many systems have failed because developers have neglected the social context where technology is used. Social context is formed by actors and relationships among them. The correct identification of actors and relationships among them may help developers to better understand how software technology should be inserted in such context (Martins 2007). The success of an information system depends on the quality of the definition of requirements (Martins 2007). The quality of the requirements is greatly influenced by techniques employed during requirement elicitation (Hickey and Davis 2002). Requirements elicitation techniques are methods used by analysts to determine the needs of customers and users, so that systems can be built with a high probability of satisfying those needs (Hickey and Davis 2003). However, consensus exists that one elicitation technique cannot work for all situations (Macaulay 1996; Kotonya and Sommerville 1998; Glass 2002; Hickey and Davis 2003). There are lots of requirements elicitation techniques described in literature (Byrd et al. 1992; Davis 1993; Hudlicka 1996; Macaulay 1996; Kotonya and Sommerville 1998; Leffingwell 2000; Glass 2002; Lauesen 2002).

In our survey of the elicitation of requirements, we have not found techniques that take into account the needs of users in collaborative environments considering CS. The understanding of user needs in such contexts is essential to provide mechanisms for an effective cooperation. We believe that a technique that focuses on the understanding of the actors during their activities in a collaborative environment in order to fully take advantage of the synergy among stakeholders to achieve common goals is required.

This paper presents a method for requirements elicitation in collaborative environments with sensemaking. The technique is focused on the observation of actors interacting to perform activities that occur in the interplay between collaboration and information. The method captures the needs of users in collaborative environments whose collaborative activities - which are covered by the activity CS and CS activity itself - are investigated. The technique is based on the simulation of the targeted collaborative system. In the simulation, restrictions and permissions are defined to the participating users in order to provide a close environment of the target system whereby the interactions among them can be monitored. The technique aims to obtain a more effective requirements elicitation to the stakeholders involved.

The remainder of the article is structured as follows. Section 2 presents definitions, concepts about CIB, the difficulty of requirements elicitation, and the related work. Section 3 describes the proposed method for requirements elicitation and its application through simulation. More specifically, we present the experimental environment wherein the simulation carried out, results of experimentation, and analyses of results. In section 4 we analyse the proposed method. Section 5 concludes the article and discusses future work.

2 BACKGROUND

In recent years, researchers from a diverse range of disciplines conducted various studies (Poltrock et al. 2003; Foster 2006; Hertzum 2008; Ravid et al. 2008; Paul and Reddy 2010b) within organizational and non-organizational settings and have provided many key insights about activities that happen at the interplay between ‘collaboration' and 'information' (Karunakaran 2010). To integrate the various terminologies associated with Collaborative Information Behaviour (CIB) in the studies, Karunakaran et al. (2010) define a working definition of CIB as “totality of behaviour exhibited when people work together to identify an information need, retrieve, seek and share information, evaluate, synthesize and make sense of the found information, and then utilize the found information".

Among the activities that comprise the behaviours investigated in CIB, those underlined above, the activity sensemaking is a critical element of collaborative work (Ravid et al. 2008; Paul and Reddy 2010b). Sensemaking is the process through which individuals view and interpret the world and then act accordingly (Ravied et al. 2008). Sensemaking determines the way in which people respond to certain events and construe their perceptions regarding goals, priorities and problems they face (Ravied et al. 2008). Convergent evidence shows that Collaborative Sensemaking (CS) crosscuts the activities within CIB (Paul and Reddy 2010b). CS occurs when multiple actors with possibly different perspectives about the world engage in the process of making sense of 'messy' information (Ntuen et al. 2006; Paul and Morris 2009) to come at shared understandings (Ravied et al. 2008) and then to act accordingly for coming more near their common goal. CS is an important aspect of Collaborative Information Seeking (CIS) (Paul and Reddy 2010b). CIS is defined as "the study of systems and practices that enable individuals to collaborate during the seeking, searching, and retrieval of information" (Foster 2006, p .330). CIS occurs when "a group or team of people undertakes to identify and resolve a shared information need." (Poltrock et al. 2003, p.239). Resolving a shared information need often consists of finding, retrieving, sharing, understanding, and using information together (Paul and Reddy 2010a). Reddy and colleagues in two investigations in healthcare providers environments identify some reasons that lead to the occurrence of CS, such as (Reddy and Jansen 2008; Paul and Reddy 2010b): ambiguity of available information, role-based distribution of information, lack of domain expertise, complexity of information need, and lack of immediately accessible information. CS involves tasks whereby individuals: share information and sense, prioritize relevant information, contextualize awareness information with respect to activities, and create and manipulate shared representations (Paul and Reddy 2010a).

Due to these needs of individuals or users, building collaborative systems that take into account sensemaking is a challenge. The construction of software system requires a software development process that includes the following phases: requirements elicitation, design, implementation, verification and maintenance. We believe that one of main difficulties in the process development is to correctly elicit the requirements due to the needs of individuals in CS.

The goal of the requirements elicitation is to understand the real needs of the users which must be supported by the software to be developed (Sommerville and Ransom 2005). During the requirement elicitation phase, the stakeholders exchange information about the context and the activities that will be supported by the software under development (Laporti et al. 2009). This phase is seldom problem free. Viewpoint, mental model and expectation differences among users and analysts make this task hard and conflicting. In many cases, the clients are not completely sure about their real needs. In other words, the current approaches to address requirements elicitation do not correspond to management expectations (Laporti et al. 2009). Sommerville (2006) points out problems in this phase are responsible for 55% of computer systems' troubles and that 82% of the effort devoted to correcting mistakes is related to this phase. Some techniques that consider social context are proposed to elicit requirements of collaborative systems as shown in (Hickey and Davis 2003; Zoowghi and Coulin 2005; Broll 2007; Machado 2009).

Machado et al. (2009) proposes a method to support requirements elicitation in organizations where there exists clearly demand by improve in existing systems. Their method combines traditional cognitive and ethnographic methods and focuses on the capture of the actual activities being executed in the context of the workplace, i.e., focused at work. Their approach assumes that there is a difference between information obtained from stakeholders during interviews, and the rich, dynamic and complex reality of workplaces. However, their technique does not take into account the collaborative interactions from the information needs and other activities that support the needs. These activities are main triggers of work in collaborative settings (Poltrock et al. 2003; Reddy and Jansen 2008; Paul and Reddy 2010b). Moreover, ethnography research is very time intensive and it has high costs (Myers 1999).

Simulation is a technique, not a technology, to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner (Gaba 2007). A critical point that has often been missed is that process of using simulators and simulations is a "social practice" (Laucken 2003). A social practice can be defined as a contextual event in space and time, conducted for one or more purposes, in which people interact in a goal-oriented fashion with each other, with technical artefacts (the simulator), and with the environment (including relevant devices). To regard simulation as a social practice puts an appropriate emphasis on the reasons why people take part in it and how they choose to interpret the various simulation endeavours (Dieckmann et al. 2007).

The simulation is chosen due the following advantages: conditions can be varied and outcomes investigated; critical situations can be investigated without risk; it is cost effective; simulations can be speeded up so behaviour can be studied easily over a long period of time, and they can be slowed down to study behaviour more closely. The simulation of the collaborative setting can be used to address types of knowledge, skills, attitudes, or behaviours that people have in specific imposed stimulus, rules or objectives. We believe that these impositions help to show potential problems and deficiencies that users may face in their collaborative environments. Thus, developers can act to solve or mitigate them through computer systems more effective in the environment. In addition, the collaborative environment can be more effective with the participation of users in the simulations because they can recognize difficulties to collaboration in poorly designed organizational processes.

Our proposed approach for requirements elicitation in collaborative settings is focused on the observation of actors interacting to perform activities that occur in the interplay between collaboration and information. The environment wherein the actors interact is simulated. We believe that this approach we provide a more effective elicitation of requirements.

3 PROPOSED METHOD

The proposed method consists of a simulation of the activities that make up CIB. We consider the following CIB activities: identify an information need; search, retrieve and share information; evaluate, synthesize and make sense of information found, and use the information found. The identification of information need is the main factor that drives collaborative activities. In order to design the collaborative environment properly, the proposed method seeks to simulate the virtual setting emphasizing CIB activities that are likely to occur with emphasis on collaborative sensemaking activity. The simulation is made in a co-located environment with restrictions of collaborative systems artificially enforced. The idea is to monitor the users' interactions in a simulated collaborative environment, so that is possible to identify collaborative requirements and build systems. The simulation method consists of four activities:

- **Definition of the System, its Environment, and Restrictions and Permissions of Communication, Coordination, Cooperation, and Awareness (3C+A)**. Define the system and its environment by indicating the characteristics of collaborative setting to be simulated such as the main collaborative activities, potential users, roles of users, and business rules. The activities are defined based on their importance for achieving the common objectives pursued in a collaborative environment. Potential users, their roles and business rules are originated from the definition of key collaborative activities and the objectives to be achieved. The collaborative activities to be investigated in the simulation are mainly those which have intrinsically features of the interplay between collaboration and information. The restrictions and permissions of 3C+A are those that the potential users face when interacting with the actual system. The output of this simulation activity is a document describing the aforementioned items, mainly the restrictions and permissions, of the system and its environment.
- **Planning the Simulation.** Define the procedures, techniques and tools that capture user interactions during collaboration. Define also the procedures, techniques, and tools to analyse the data collected in order to identify both the breaks of restrictions and needs of 3C+A in the interactions. Define monitors (observers) and their role for monitoring the simulation. The output is a list of procedures, techniques and tools to capture and analyse the data related to the users' interactions. The planning output includes the definition of procedures to monitor and control the simulations.
- **Execution, Monitoring, and Control.** Execute, monitor and control the simulation, in accordance with the plan. In this activity, the potential users take part in the simulated activities whereby their interactions with the system and with other users are monitored. The outputs are information and data collected and a set of annotations describing changes accomplished during simulations.

- **Analyses and Identification of Requirements**: Analyses the data collected previously according to the chosen techniques and defined procedures. The purpose of the analysis is both to validate the proposed restrictions of communication, coordination, cooperation and awareness and identify new needs (requisites) related to restrictions and permissions of communication, coordination, cooperation, and awareness. The identification of the requisites is a result of the restrictions that were suitably proposed and proposals of new restrictions in the collaborative interactions that occurred in the simulations.

4 EXPERIMENT, RESULTS AND ANALYSIS

In order to illustrate the usage and evaluate the proposed method, we conducted an experiment in a simulated collaborative workplace. The aim of the method is to find the appropriate requirements of communication, coordination, cooperation and awareness (3C+A) for the system or subsystem to be developed for the targeted collaborative environment. The (actual) collaborative environment is a Web environment whereby participants can work together to solve a puzzle challenge. A puzzle is a problem or enigma that tests the ingenuity of the solver. In a basic puzzle, one is intended to put together pieces in a logical way in order to come up with the desired solution. Puzzles are often contrived as a form of entertainment, but they can also stem from serious mathematical or logistical problems. The type of puzzle that inspired us to create a collaborative environment for study is Tiling Puzzles. Tiling puzzles are two-dimensional packing problems in which a number of flat shapes have to be assembled into a larger given shape without overlaps (and often without gaps) (Puzzle 2010). Unlike tiling puzzles, the collaborative puzzle defined is not guided by the construction of a known image, but by a single contiguous area containing blocks of the same cor. In our collaborative puzzle, a piece is an arrangement of rectangle blocks of defined shapes and the goal is to set the highest number of pieces (or blocks) which must have cohesion. The cohesion is characterized by absence of gaps and pieces of the same color. The change of colors in a contiguous is a measure of the team´s performance. Below we apply the method proposed to collaborative environment target.

4.1 Definition of the System, Its Environment, and Restrictions and Permissions of Communication, Coordination, Cooperation and Awareness (3C+A)

As a result of the first step we have the following scope for the simulation. The collaborative challenge must be resolved by four participants co-located. The common goal of participants in the challenge is to place the pieces on the table so that they form one cohesive contiguous area (puzzle) with a minimum of empty areas (gaps) inside. The pieces have different shapes and each piece is made up of different amount of blocks of the same color. Fourteen or more contiguous blocks of the same color that form a contiguous area is enough to score. Therefore, the eleven yellow contiguous blocks showed in Figure 1 is not considered a contiguous area. The team earns points according to the cohesive contiguous area formed. For achieving the maximum degree of cohesion, it is necessary that the area formed by the pieces covers the available space with all blocks of the same color without any gap.

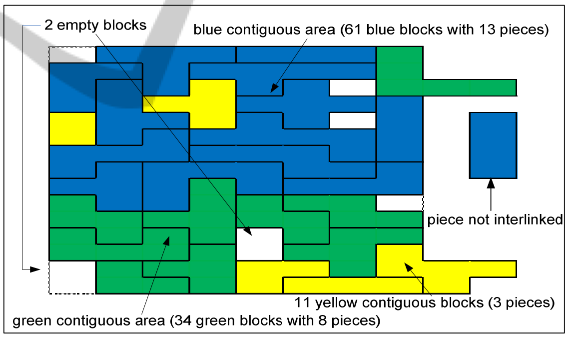

Figure 1: Sample of single contiguous area formed with three minor contiguous areas.

The simulated collaborative setting has the following characteristics: (C1) each participant has a number of particular pieces initially and they can be presented to other participants when placed on the table; (C2) the amount of private pieces is not necessarily the same for all participants; (C3) Each participant has a placeholder (box) wherein his/her *private* pieces are; (C4) on a public area (table) some pieces are present from the beginning of the challenge and they are called *public* pieces, and any participant can access them; (C5) particular pieces presented on the table become public regardless of whether they are placed in the puzzle or not; (C6) all pieces, private or public, are made of colourful blocks, and (C7) the pieces have different shapes and sizes and each piece is unicolor.

Private pieces are a tentative to represent the individual tacit information whereas public pieces try to represent information that is shared by the group of people. The placeholder is a simulated space that its owner has access (knowledge). The owner is restricted in its ability to show his pieces by time and amount. We discuss the restrictions below.

The activities identified in the collaborative environment are: (A1) *present one particular piece on the table*; (A2) *present one particular piece and place together it with other pieces on the table*; (A3) *arrange public piece(s) that are on the table*; (A4) *disconnect piece(s) of puzzle*; (A5) *compute the performance of the group according to the pieces placed together*; (A6) *come to the consensus*; (A7) *evaluate information collectively*; (A8) *share information*; (A9) *identify information need*, and (A10) *make sense collaboratively*. The activities A1 - A5 were identified by the characteristics of collaborative environment of the challenge and by the common goal that has to be achieved. The activities A6 - A10 come from the interactions of participants in the challenge as actions or operations that support the activities A1 - A5. As described, we consider the particular pieces like information and knowledge to each participant in the challenge. The pieces already presented on the table are information known to (shared by) the group of participants. Each one can simply present his/her information on the table (activity A1), without giving meaning to them. On the other hand, a participant may connect his/her information with others (activity A2) or just connect the information that is already on the table (activity A3), thus giving the information a particular meaning in the context. The various possibilities for links of information are due to different interpretations of them. The interpretations may be the products of both activities, make sense (activity A10) and evaluate information (activity A7), both executed collectively. The interpretations may also occur during the activity disconnect pieces (activity A4). Sharing information (activity A8) on the table by each participant is encouraged due to information needs that arise as the resolution of the challenge goes on. Identifying these needs (activity A9) depends on the interpretation and evaluation of information available to all participants, for example, the information from the computation of group performance (activity A5).

Possible actions/behaviours of the participants on some activities identified have been defined. Group members must meet the following rules (R):

(R1) Only one group member at a time has access to the puzzle to carry out his/her activities.

(R2) The next member to access the table to play is chosen by the group members themselves.

(R3) Each member to perform activities A1 - A4 must justify the reason for his/her act.

Each group member, during his/her participation, can act as follows:

(R4) Execute the activity A1 or A2 at most once.

(R5) If the results of activities A2 - A5 performed by a member, are not considered by the group, it is the responsibility of the member to undo the work.

(R6) The pieces that are placed on the table must remain on it regardless they are interlinked or not to the other pieces in the puzzle.

(R7) The solution presented by the group members as the final solution is just one single strongly connected area, i.e., there exists a path from each block to every other block.

Group members may use the following permissions (P):

(P1) Perform activities A3 and A4 as many times as necessary in each participation and the member can be assisted by other group members during these activities.

(P2) The group can measure their performance, activity A5, during the challenge at any time.

Participants are not limited to actions/behaviours defined. In other words, they may take other actions/behaviours, but without violating the aforementioned restrictions.

4.2 Planning the Simulation

We propose to divide the planning into three stages: pre-experiment, experiment and post-experiment. In the pre-experiment stage, four participants are informed of the details of the challenge, such as the characteristics, rules and how the group is evaluated. The form of evaluation of the group, in particular, is thoroughly explained with the help of illustrations of possible solutions. Doubts of participants should be answered before proceeding to the next stage. Only after the participants understand the challenge, the challenge can be initiated.

During the challenge the participants can ask questions to the monitors of the simulations. However, the participants are aware that the time spent with questions is considered as play time. The end of the challenge occurs when the group presents its final solution or when the challenge reaches its limit of 30 minutes. The second stage begins at the signal of the monitor. The monitor, turn on the video camera to record the behaviours and actions of group members. In other words, the stage comprises the running of simulation to collect data from users' interactions of interest. Before going to the last stage, the solution presented by the group is evaluated by the monitors and the result announced to the group. After all members know their performance in group, each member receives a questionnaire to answer it. It is the final stage.

We analyse the data of questionnaires using the method content analysis (Stemler 2001). Our objective is to capture the perceptions of each member about the rules imposed and collaborative activities that they perform. With their answers, we can know what rules, permissions and collaborative activities are most problematic, difficult, awkward, and challenging. With this information, we can look for reasons for these problems. This can be achieved through the analysis of the recorded videos of the challenges made. The use of videos is suitable to analyse the interactions of the actors when they perform their activities. According to (Ruhleder and Jordan 1997), there are several advantages of using video for interaction analysis, and the main reason is that video is permanent information that can be recurrently analysed. It provides the opportunity to several researchers to perform their own interpretations and a collaborative multidisciplinary analysis can create an unbiased view of the events. Video-based Interaction Analysis (VbIA) also avoids the say/do problem, i.e., what people say they do and what they really do may not necessarily be the same. VbIA exposes mechanisms and antecedents due to the fact that the video provides process data rather than snapshot data. Since video records the phenomenon of interest in context, it is possible to ask about antecedents, varieties of solutions produced on different occasions, and questions of what led up to any particular state. The third source of information is the notes of the monitors. These notes highlight the perceptions they had of episodes that attracted their attention during the simulations.

Twelve persons are invited to participate in the challenge. They are chosen among the students enrolled in the undergraduate course of engineering at the Technological Institute of Aeronautics (ITA). Students are both informed about the objectives of the experiment and asked to participate. The twelve students faced the same challenge but in three groups of four. The three groups are established according to the students' choice. Two monitors monitor and control the three simulations to be performed. The degree of their participation is restricted to answer questions of participants, take notes of the simulation, check the capture of images by the camera and apply the questionnaire to participants. Four sets of particular pieces were chosen and offered to members of each group. The pieces in these sets were chosen randomly by the monitors, meeting the characteristics C1 and C2. For each group, the pieces are placed in four boxes of different colors. Before starting each experiment, the boxes are chosen by members. Thus, each member does not know its contents in advance and also uses the boxes during the challenge as a placeholder. Each member is unaware of the contents of the boxes of the other members during the challenge, respecting the characteristics C3 and C5. Before each experiment, nine public pieces are already available on the table, satisfying C4. These pieces are also chosen randomly. Before starting each challenge, a camera is adjusted and turned on to capture the actions and behaviours of the group members. The camera is placed on the table inside the room where the simulations takes place. The monitors observe the three groups and take notes of events that call their attention, as shown in Figure 2.

Figure 2: Group members collaborating in a puzzle observed by a monitor.

4.3 Executing Simulation

The simulation of three collaborative challenges generated the following data: video recordings of the simulations, notes of the interactions that called attention, the performance of groups that was calculated according to the final solution presented to the monitors, and the solutions that were photographed,. All groups took the period of 30 minutes to build their solutions. The performances of the groups were then calculated. The first, second and third group achieved the degree of cohesion of 83.4%, 65% and 56% respectively. We stress that the same pieces were used in three simulations, both public and private ones.

4.4 Analysing and Identifying Requirements

As the last step of the method we analyse the collected data to identify requirements for building the collaborative challenge on the Web. The analysis was conducted as planned in the second stage. Data collected in questionnaires responded by participants were copied into electronic form before being analysed. Stretches of audio-visual recorded also were copied into electronic form. First, we classify the data collected from the open questions of the questionnaires in the following units of content: *(Q1) How do you evaluate the rule R1 as to the group's performance? Justify your evaluation. (Q2) How do you evaluate the rule R2 as to the group's performance? Justify your evaluation. (Q3) How do you evaluate the rule R3 as to the group's performance? Justify your evaluation. (Q4) How do you evaluate the rule R4 and permission P1 as to the group's performance? Justify your evaluation. (Q5) How do you evaluate the rule R5 as to the group's performance? Justify your evaluation. (Q6) How do you evaluate the rule R6 as to the group's performance? Justify your evaluation. (Q7) During the evaluation of pieces connected and disconnected the participants had any problem? If so, describe them. (Q8) Making sense in a group, i.e., participants with different perspectives and goals engage in making sense together of how to arrange the pieces available and interpret them, and understand what information (pieces) are needed and where. Did you have any problems during this activity? If so, describe them. (Q9) There were problems to arrive at consensus on actions taken by the participants? If so, describe them.*

After sorting the data collected from questionnaires we analyse the data collected. The analysis consisted of the comparisons of the participants' perceptions with the monitors' perceptions, i.e., notes and analysis of the videos.

In short, the group that has the best performance was the one with better coordination, cooperation and awareness. G1 began to address the challenge by defining a strategy. The strategy was based mainly on two steps: understanding (in group) what degree of cohesion of a contiguous area is, and how to obtain the area with the highest possible degree of cohesion. All members of the group at the beginning of the challenge sought to make sense of all information presented to them. The result of this search yielded a unique understanding of the problem leading to better group performance. This was not seen in the activities of the other two groups. We note the difficulties of G2 and G3 to coordinate their activities because the different perceptions of members of these groups on how to achieve the goal of the collaborative challenge. The cooperation of members of these groups was not that productive due to the lack of a shared understanding among them. Shared understanding was reached by the G1 only after making sense of the information together. The G2 and G3 did not explicitly define a suitable strategy as the G1, but by analysing the video and other data sources we realize that they had strategies, but divergent. At the start of their challenge, each member of groups G2 and G3 seemed to be worried for creating large contiguous sub-areas of a specific color by himself. At some point of the challenge, the member wanted to join his area to build a single contiguous area, satisfying the rule R7. Of course, there were some conflicts and time wasting. As result of the strategy, G2 handed in a puzzle with 40 pieces and G3 a puzzle with 49 pieces. As previously reported, the degrees of cohesion of their solutions were, respectively 65% and 56%. The G1 needed only 24 pieces for reaching 83.4%.

By cross-analysing the data collected we realize that some restrictions were not beneficial to the resolution of the collaborative puzzle. The definition of who must access the table was based on consensus by the group members, rule R2. However, some participants suggested another option to determine who should access the table. They suggested that it would be better to determine in advance the turn of access to the table. The rule R4 was also identified as an obstacle by several participants. The suggestion is to change R4 for the following: the group member who is accessing the table may display and place various pieces in the puzzle during his/her access. The rule R5 was also suggested to be changed: any member who is accessing the table, can undo previously actions if the member asks permission and justifies his/her changes. The rule R6 that does not allow group members to withdraw non used pieces from the table (that are not interconnected to the puzzle) brought problems. This restriction overloaded the group with pieces and resulted into difficulties to the group to make sense and decisions. The overload was reported by the participants and was identified by monitors. Many participants complained that the pieces were hard to be linked, thus polluting the public are and making the resolution of the challenge harder.

Based on cross-analysis of data collected, we define the following requisites of communication, coordination, cooperation and awareness to build the collaborative challenge for the Web:

- **Communication:** (a) Use synchronous communication through speech and handwriting. The characteristics C1 and C3 oblige a restricted communication as the video, e.g., use a tool as video-conference. Thus, to support coordination, cooperation and awareness among group members they must have a similar tool to chat, but without the video conferencing feature. (b) Communication must be flexible, i.e., unicast and broadcast. This requirement is due to the need for each group member having to report and seek information with others in a particular and broadcast way. For example, when you want to know who has pieces of a similar format and specific color, or request to a specific member to rearrange pieces.
- **Coordination:** (a) Allow access to the virtual table of only one group member at a time. (b) The next group member to access the virtual table is determined by vote and the decision will be by consensus (to be established through the synchronous communication as occurred in the simulations). Another option is to define the order of access of all members in advance. The group can change the form of selection of the next member. The first option is defined because three participants reported that they lost time with the rule R2 and that it should be possible to determine the order of their moves earlier. (c) The access to the table will have a maximum time pre-determined by the group members. The member who is supposed to access the table can yield the access to the next member. If the maximum time is reached the member loses his/her access and the table will be available for the next group member. The time spent in accessing the table in the simulations by the group members varied widely. So to avoid that a member locks the access to the table each member will have a time limit of access.
- **Cooperation:** (a) Allow that more than one particular piece be presented in the table by a group member at a time. Several participants complained and we also observe in the videos that the rule R4 was not helpful for the group performance. Because of this the group members decided to simply "circumvent" this rule. As they could not place more than one piece or arrange pieces on the table, the members asked several consecutive accesses to the table to perform the activities. (b) Pieces that the group believes that are not useful, should not remain on the table and should be returned to the members who presented the pieces. Thus, the computation of the degree of cohesion of the solution becomes simpler. (c) The calculation of the degree of cohesion of contiguous areas can be made automatically if a member requests. Although we believe that the calculation is not difficult, in the simulations we found that two groups have not coordinated their activities. (d) Undo interconnections and disconnections reverting to the previous play can be executed by any group member, but it should only be performed by one group member. In practice the participants will not recognize the rule R5.
- **Awareness:** (a) Allow group members to chain messages exchanged based on a specific event and its sequences. This requirement aims to bring understanding to group members on decisions and their consequences. (b) Each piece on the table must indicate to whom it belonged. Public pieces do not have this identification. Thus, a piece at a specific time can be removed from table by member who placed it. (c) The following information must be visible to all members of the group: who is accessing the table at a given time and how long he/she is taking. This information can help coordination and cooperation of the group. (d) Each member must be notified when the table is available to him.

5 ANALYSIS OF THE PROPOSED METHOD

The proposed method is based on simulation of collaborative activities that are important to achieve the objectives of stakeholders. The method allowed us to find unexpected behaviours. The simulation study was defined it according to the objective, constraints, and permissions for the users. The restrictions were validated by performing experiments with potential users of the collaborative environment. The result was the identification of requirements for communication, coordination, cooperation and awareness (3C+A) for the development of the collaborative puzzle on Web.

The effort spent in the simulation of the collaborative puzzle can be considered low when we compare with other existing methods, for instance, ethnographic investigations. This is due to the fact that the collaborative environment simulated is less complex, i.e., has a small number of actors involved and the resources employed in the simulation are of low cost. However, we consider the puzzle a collaborative challenge which allows analysing the behaviours and interactions in a collaborative environment based on the concepts of CIB, in particular the concept of collaborative sensemaking. We believe that the simulation method can be employed for more complex collaborative environments where there are several roles and artefacts. In these environments the method can be used in the key scenarios of environments that need research due to a poor knowledge of the interactions of the actors.

In this method, the perspective of monitors and developers are captured through notes during the simulations, and the perspective of users by means of questionnaires. The two perspectives aim to identify common findings and discrepancies. The discrepancies can be further investigated with the help of the video-based analysis.

If the elicitation of requirements for 3C+A is not made in a satisfactory manner, the collaborative environment simulation can be performed again on specific scenarios that presented problems.

We are aware that there are various techniques for gathering and analysing information, but the utilization of the questionnaire, notes of observations and video, and content analysis and video-based interactive analysis showed to be adequate in the collaborative puzzle simulation. The techniques were chosen because of the following characteristics of the collaborative challenge: number of users collaborating is low, number of activities performed by users is not high, and the common goal is not complex to understand. The choice of collection and analysis techniques of information to be used must consider the characteristics of the environment to be studied - for example the context and situation - as pointed out in (Hickey and Davis 2003; Zoowghi and Coulin 2005; Davis 2006).

Some problems reported by participants such as: the difficulty to physically place the pieces in the collaborative puzzle and the complexity of computing the performance of collaborative groups can be readily removed when the challenge occurs in the Web. The virtual environment to be developed can place the pieces with a drag of mouse and make the computation of the team's performance automatically on each piece insertion or removal.

The method, however, is unable to capture some requirements, for instance, those related to log and presentation of the history of usage by the participants. The history might be useful to roll back (undo moves) to past configurations.

Another restriction is physical limitation of the usage of the co-located simulation. For the collaborative puzzle, the simulation is not adequate if the number of users is high. If the number of users is high, coordination requirements should be investigated deeply and elicited.

Other limitation has to do with the synchronism of the collaboration. Our proposed method was effectively employed for a synchronous collaborative puzzle. We envision that the method can be employed to other synchronous collaborative applications; however, it may not result in the same success if it is applied to asynchronous collaborative applications.

In summary, our proposed method presents the following advantages: it allows the identification of requirements of 3C+A in an efficient manner in terms of time and resources; it is suitable to be used in synchronous collaborative environments, and it allows capturing perceptions of major actors involved in the development of the collaborative system. On the other hand, the method has the following disadvantages: it does not capture/save the history of the interactions of the users involved in collaborative activities; and it may not allow investigating satisfactorily collaborative environment that has many actors, roles and resources involved – i.e. it is physically limited to be employed.

6 CONCLUSIONS

In this research work, we propose a method of requirements elicitation in collaborative environments considering activities CIB, especially the collaborative sensemaking activity. The method utilizes the simulation of the target environment to capture requirements of the following aspects of collaboration: communication, coordination, cooperation and awareness (3C+A). The simulation environment is defined by restrictions and permissions of the collaborative aspects. The method was illustrated on an environment of collaborative puzzle. It allowed finding requirements for all collaborative aspects considered in simulation through verifications and inconsistency identifications of the restrictions and permissions assigned to the environment under study.

Some difficulties encountered in the co-located simulations of collaborative environments can be mitigated simply because these environments come to be supported by computer systems. For instance, in the collaborative puzzle two difficulties arose: handle pieces of the puzzle and calculate the group performance during the challenge. The difficulties can be solved easily in a virtual version of the challenge on the Web, as described in the previous session. On the other hand, the support of computer systems can bring new problems that are not necessarily perceived during the simulation of collaborative environments, for instance the feedback from actors can be inefficient because the computer system may have restrictions on capturing and presenting interaction information – e.g. gestures, expressions, tone of voice, etc., and the actors may not have confidence or may not have the knowledge to effectively use the system interfaces, especially in critical collaborative environments, as in air traffic control (Merlin and Hirata 2010).

As the next steps this research work, we are developing the virtual collaborative puzzle and soon after its development we will perform experiments on it to evaluate the gains and the difficulties. In addition, we are planning to expand the use of the method in other collaborative environments, for example in health care settings.

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