Supporting Crisis Management Processes by Wirelessly Interconnected Tablet-PCs

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Abstract

When organizations face unforeseen emergency situations its members often resort to unstructured crisis management activities in order to overcome the problems. Researchers have noted that a common activity in these scenarios is the construction of a shared awareness of the situation in order to collaboratively identify the actions required to be carried on and the most suitable people to do them. In this paper we present a collaborative application based on Tablet-PCs to assist these unstructured activities aiming to improve their consistency and effectiveness. Inspired on the Reasons Swiss-Cheese model for accidents, the proposed approach relies on the development of a shared Situation Awareness, constructed from a set of collaboratively constructed Situation Matrixes which expose involved users contributions to the overall solution strategy. Three application scenarios are used as example.

1. Introduction

The most flexible and reliable organizations are used to orchestrate work along a continuum of structured and unstructured activities [1] fostering at the same time productivity and responsiveness. Structured activities are designed a priori based on work plans and models addressing coordination problems, efficiency and consistency. Information Systems (IS) are then usually developed with the purpose to instantiate work models and support the necessary information processing. Unfortunately many unknown variables, both external (e.g., market dynamics, supply chain management) and internal (e.g., deficient requirements analysis, latent problems, emergent work processes or lack of flexibility in work structures), are among the factors that may be the reason behind the lack of existing IS to support unstructured activities occurring when facing unplanned, emergent or highly changing scenarios.

An example of such an unstructured scenario is crisis management. A crisis is an unexpected, unfamiliar chain or combination of events, causing uncertainty of action and time-pressure [2]. In these situations even contingency plans are challenged by particular dynamics. Instead of following contingency plans, people will engage in informal relationships and make use of their tacit knowledge in an opportunistic manner, which quite often reveals as a source of innovation, creativity and flexibility. Markus and Majchrzak [3] highlights several characteristics of emergent processes contradicting the traditional IS approach: no best structure or sequence; typically distributed; dynamically evolving; actor roles unpredictable; and unpredictable contexts. In these scenarios actors engaged in solving problems to overcome the crisis require a high mobility in order to engage in informal communication activities.

A crisis can occur anywhere, at any time, and the people whose job is to respond might be physically dispersed. Flexible and robust mobile communication is paramount for helping ensure that the crisis is handled in the most efficient and effective manner possible. Along with communication, another essential component of a response is the ability to coordinate actions among users. Mobile communication networks must be deployed within an integrated human-system interaction environment that can handle the collaborative aspects of responding to a crisis.

In a crisis scenario the type of major incidents generally involves much information and operational chaos. In such situations, mobile devices, such as Tablet-PCs, which offer both portability and wireless interfacing, may be available for communicating. A Tablet-PC most natural data-entry mode is the stylus (a.k.a. a pen-based or freehand-input-based system), which imitates the mental model of using pen and paper

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thereby enabling users to easily rough out their actions and ideas and/or draw design sketches [4], therefore allowing us a fast interaction, [5]. The state of art on crisis management identifies some recurrent issues: shared awareness of crisis situations; communication and information management; information and knowledge representation and management and usability and interface design [6], [7]. Researchers [7] found that the informational needs in crisis situations emphasized those required for the construction of a shared Situation Awareness (SA) among the members of the crisis management team. SA is understood as a “perception of elements (people, objects, etc.) in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future [8].

Our research aims to study the role of mobile computing for supporting unstructured activities based on the collaborative construction of SA. Since each involved actor may have his/her own perception of the situation, creating a shared understanding of what is going on may be quite difficult. Our approach to support this is capturing the contributions of all involved actors in order to create a unified view of the situation with the help of the so called Situation Matrixes. Concerns about team coordination and decision-making strategies are outside the scope of this work. For the time being we are focusing on the support of unstructured activities in crisis management scenarios and due the mobile collaboration requirement that such scenarios encompasses the presented prototype was developed to Tablet-PCs devices.

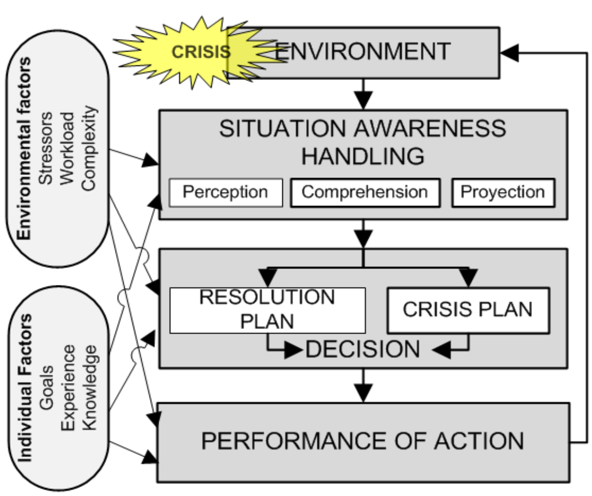

Figure 1. Situation Awareness model modified [8]

2. Situation Awareness Model

We may find in the research literature several projects addressing the gap from fully structured activities to ad-hoc unstructured activities, e.g., Freeflow [9], [10]. These works studied how to bring IS back to model guidance after deviations caused by unpredicted events. The problem addressed by this paper goes beyond this perspective towards the support of new emergent and collaborative work structures, where models do not serve as prescriptions but rather as artifacts that may help getting the work done [11].

Our approach to support unstructured activities is grounded in the collaborative construction of SA, relying upon the IS to maintain up to date and shared information about the situation. One adaptation of the most established models in SA research [8] which we related with a crisis management model [2] is showed in Figure 1. This model regards perception, comprehension and projection as three essential dimensions in SA. In [8], authors organize these dimensions in three levels: a) Perception, which provide awareness of the multiple situational elements (objects, events, people, systems, environmental factors) and their current states (locations, conditions, modes, actions). b) Comprehension, an understanding of the overall meaning of the perceived elements - how they fit together as a whole, what kind of situation they fit, what they mean in terms of mission goals; and c) Projection, awareness of the likely evolution of the situation and possible/probable future states and events. It is tempting to see this three-level model of SA as a sequential model but clearly it is not. Despite presenting a hierarchical model, Endsley defends that SA alternates between data-driven (bottom-up) and goal-driven (top-down) processes.

The support to SA has received considerable attention in Computer Supported Cooperative Work (CSCW) research [12]. However, the vast majority of research has focused in specific context/domain proposals and a product perspective, or in a specific physical location (disaster zones, [13]) while in our research we emphasize a process perspective, considering the resources and activities necessary to obtain, manage and use SA information in crisis scenarios.

According to the CSCW perspective, team members should be able to monitor, analyze and anticipate the SA needs of their colleagues while adjusting their own actions accordingly. Hence, [14] defines team SA as not just the sum of shared SA but also the mutual adjustment of one and another’s minds as they interact as a team in a specific context of action.

3. Proposed research

In our approach we aim to facilitate the exposure of user's tacit knowledge to the team, enhancing the individual contributions to the overall understanding of the situation. As referred in [15]., the main processes for sharing tacit knowledge include socialization and internalization. We assume that the collaborative construction of a shared computational artifact will definitely influence the "perspective making" and "perspective taking" [16]. By sharing individual assessments, we also facilitate collective sensemaking [17] and situated framing [11].

We adopted the well-known Swiss-Cheese accidents model [18] to organize SA (actors, resources, actions, events, goals, etc.). The Swiss-Cheese model posits that for an accident to occur, an alignment of holes in different dimensions must occur. We defend that in order to construct SA, the involved actors should be able to align and correlate different situational dimensions in a way very similar to the proposed by the Swiss-Cheese model. Regarding the visualizations issues, we adopted a perspective proposed by [19] which uses several types of matrixes to visualize qualitative data: concept cluster matrixes, empirical matrixes, and temporal or event driven matrixes. We therefore defend two complementary ways to organize and visualize SA: (1) using Situation Matrixes (SMs) to visualize two dimensions of the situation and corresponding correlations (such as goals/actions and actions/actors, see Figure 2; note that the circles marking the correlations are directly related with how strongly they are perceived); and (2) aligning a set of related SM as in the Swiss-Cheese model, thus affording structuring SA according to multiple dimensions.

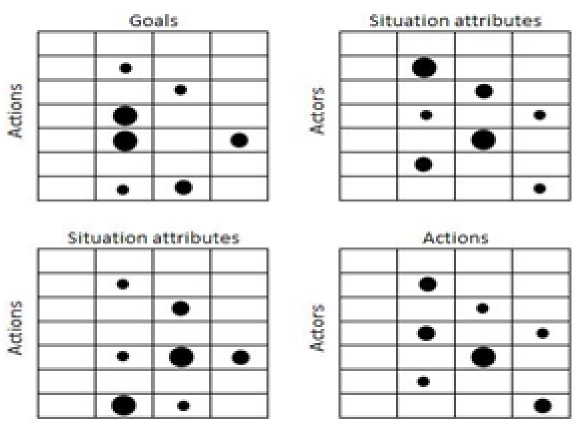

Figure 2. Situation Matrixes

This approach also provides a continuous situation feedback mechanism necessary to maintain complex SA. As situations evolve, information is renewed in the SMs (e.g., more actors involved, more actions proposed, more situation attributes considered as relevant) and different SMs may be aligned.

4. Prototype

The computer application supporting the creation and manipulation of Situation Matrixes during the management of a crisis should necessarily also support a mobile collaboration, since it should be possible to create, share, analyze and modify collaboratively those matrixes in emergency situations, when two or more people responsible for dealing with the situation and find solutions may meet. For the same reasons, the manipulation of these matrixes should be as fast and simple as possible, without limiting their potential to describe and share the different views of the situation people may have. The system does not support different roles in order to stay as flexible as possible (in emergency situations roles may change dynamically). We assume that the members of a crisis managing team will operate the system according to the attributes of the role they have inside the organization. The system is a full peer-to-peer application. This means, every user has exactly the same application and they communicate in order to share data using the ad-hoc network that emerges when two or more Tablet-PCs are set together. Using multicast messages, the application finds automatically other partners and established a reliable wirelessly ad-hoc link with them for transmitting data.

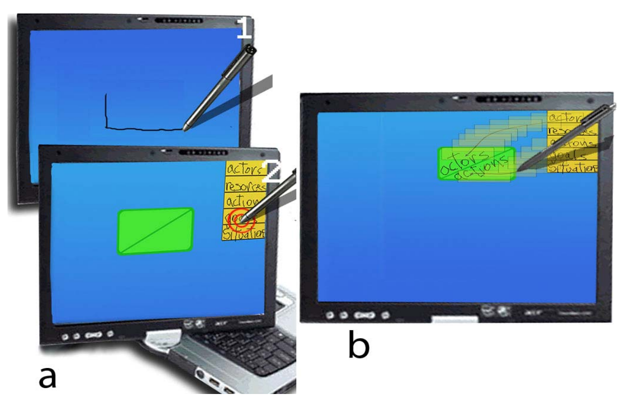

Figure 3. Screenshot of the MC-CM application (Mobile Collaborative Crisis Management) showing. a) matrix creation without defined dimensions, and c) defining the matrix dimensions

4.1. Matrix Creation

A matrix is created by one person and distributed to the rest. This is necessary in order to avoid chaos by having different representations of the same matrix. This can be done during the collaborative session or previously, as seen on Figure 3. A new matrix is defined by drawing a "half rectangle" (screen 1 in Figure 3a). This gesture will be recognized by the system and a rectangle representing an empty matrix will be created on the working area (screen 2 in Figure 3a). In order to specify the dimensions represented by rows and columns a menu is displayed after a double click gesture at the right hand vertical border of the screen. The different options for row and column dimensions can be dragged from the list to the rectangle identifying the newly created matrix in order to define the vertical and horizontal "dimensions" of the matrix (see Figure 3b), like action vs. actors, actions vs. goals, etc.

4.2. Specifying rows and columns content

In order to specify the content for the matrix it should be "expanded" by a double clicking on the rectangle. The empty matrix will be shown with the previously defined labels for the vertical and horizontal dimensions (Figure 4). In order to create a new column the user has to double click on the label of the columns (Figure 4a). After this, the user has to enter the header text for the column as shown in the Figure 4b. After this, the new column with the given header text is created at the right hand side of the last created column. Figure 4c shows the user has created already 3 columns and is starting the creation of a new row. The width of the columns will be uniformly distributed, depending on the number of columns. If the number of columns exceeds the possibility to show them all on the screen, the columns to the left will be hidden and a scrolling mechanism will be activated. If the order of the columns should be altered, the user has to point to the header of that column until it changes the color and then drag it to the new position.

The creation of the rows is done in a similar way. The text for the columns and rows which has been entered by free-hand writing will be scaled in order to fit the width or height the columns and row have at any time.

4.3. Traversing the matrix

The left-right and up-down scrolling functionality combined with a zoom-in and zoom-out functionality enables an easy and swift traversing of whole matrix. First the user has to click on the icon located at the upper-left corner of the screen. After that an up-down or left-right scrolling is possible by moving the stick in the respective direction. A zoom-in or zoom-out of the whole matrix can be done by moving the stick diagonally. In this way the user can define the portion and the size of the matrix area she/he wants to work with.

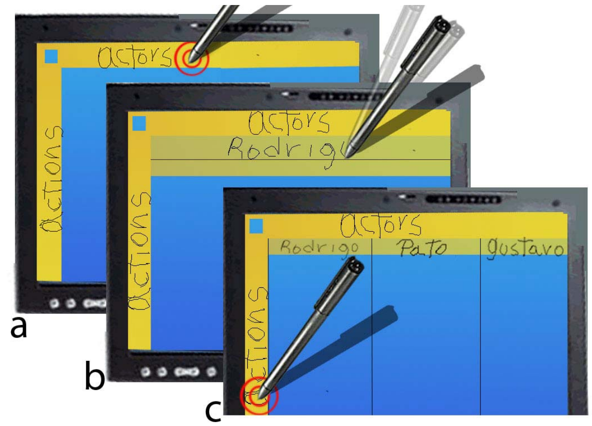

Figure 4. Creation of rows and columns of the matrix is shown in three steps.

4.4. Inputting information into the cells

As explained in section 3, the matrix helps the users to describe and share their situation and context awareness by stating with the help of a situation matrix, how important is the relationship between a certain element of the column with a certain element of the row with a dot of a certain dimension, with bigger dots meaning tighter relationship (more important). For example, a user can record that actor x has a big importance in dealing with the action y by inputting a big circle in the cell corresponding to the intersection of the column and the row identifying them, while another can put a smaller or no circle at all. In order to facilitate the input of a dot and (even more important) the comparison between dots assigned by different users, the system will allow four previously defined "importance values": a) no importance is specified with an empty cell; b) small importance with a small dot; c) relative importance with a mean circle; d) big importance with the biggest circle as shown in Figure 5a. The initial state of a cell is of course empty, a new value can be input by clicking on the cell. This will cause a pop-up menu to be displayed with the four "importance values" options. The user can select one, after which the pop-up menu disappears. It is also possible for the user to attach an annotation to the cell, which may be used for instance to justify the selected relation strength. The sliding bar in the bottom part of the screen represents the "time-line" of the matrix (Figure 5c). Each change on the cell values will be recorded by system as a new event in the life of the matrix. By moving this sliding bar the different stages of the cell values will be shown, in addition to the time and date the change was made.

Different users may be interested in viewing different parts of the matrix according to their context of action. Therefore, the system allows hiding rows or columns by clicking on the label of the row or column the user wants to hide (see Figure 5b, 5c). The hidden row or column will be represented by a thicker line. In order to show again a hidden column or row the user has to double click on the thick line.

4.5. Information sharing and collaboration

Sharing the information is of course one of the important features of this application. In the first place, the author of a certain matrix has to share it with the other users. After that, they should be able to work synchronously over the matrix in order to exchange their views about the situation and converge to an unified assessment of the situation represented by the Situation Matrix. An ad-hoc wireless network created by the Tamblet-PCs is used to exchange information between two users. However, in order to detect there is another team member physically close with whom the user wants to share information the IRDA device of the Tablet-PCs is used. When two users approach their Tablet-PCs they activate an “exchange zone” which appear in the upper part of the screen (see Figure 6). A matrix can be shared by dragging its corresponding icon to the exchange zone. The other user will receive it and has to drag it to his/her working area. A shared matrix is automatically synchronized additively. This means, when user A shares a matrix with user B, if B did not had a corresponding matrix before, it will be created with the same content. If B had already a corresponding matrix, all corresponding cells of the matrix of B without information (no circle) will be filled with the information of the matrix of A and vice-versa. Also all new rows and columns will be added on both sides. In the case there are incompatibilities of the information in corresponding cells of the shared matrix, these are highlighted and the users have to agree on a unified representation.

5. Application Scenario: Emergency Management

Most of the works appeared so far in the literature describing mobile computer applications to support people in crisis situations aim to improve the awareness of the rescue team of the physical conditions of the area where the crisis emerged and provide communication among the members [13], [20]. As we already mentioned, our application aims at helping people to create a shared assessment of the situation in order to come out with an action plan. Therefore, the addressed emergency scenarios may be a firefighter team in a burning or destroyed building, a crisis in a working facility, like in a factory which has to deliver a certain production but the supply line has been disrupted (for example, the fuel to perform certain production processes in a refinery), or during a conference organization in which the proposed venue of the conference has to be changed in the last week. All these situations have in common that they are more or less unexpected and a solution plan has to be developed and applied in a short period of time. Berrouard and Cziner [21] showed that several emergency scenarios share common crisis management characteristics, such as: teams’ organization, information paths, communication across different teams and/or organizations and information needs. For the case of firefighters, [22] identified the major requirements to collaboration: accountability, assessment, awareness, and communication.

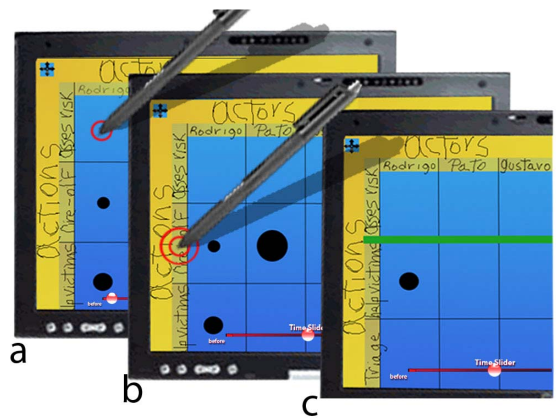

Figure 5. a) changing the cell content b) hiding a row, c) a hidden row can be made visible again by clicking over the green thick line

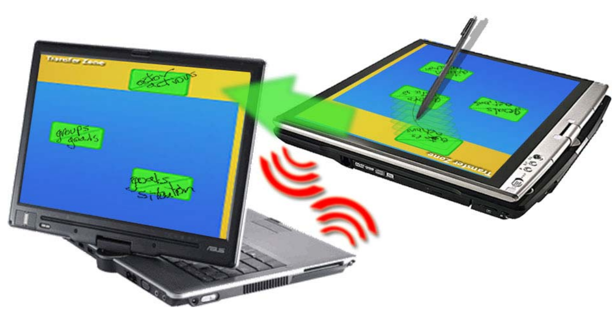

Figure 6. Two Tablet-PCs activate an “exchange zone” when they approach each other

These requirements can also be applied to the emergency situations this application has been designed to support since they are aligned with the main concerns of our model and prototype. After an emergency situation is perceived, once identified the type of incident a set of initial (pre-defined or created on the spot if no existing matches the needs) SM can be selected containing typical dimensions necessary to address the kind of situation. In the example of the firefighters, they could be for instance Situational Attributes versus Actions may represent which “environment variables” are necessary consider in order to take actions, for example, if it is raining, if there are victims or presence of dangerous material. After that, an Actions vs. Actors matrix can be used to decide which are the most suitable people for taking the most important actions, given the expertise of each person. For the scenario of the producing facility, the first matrix could be a Goals vs. Actions one, in order to established which are the goals the enterprise is seeking (delivery on time, maintain the quality of the output, not disrupting the production chain) and which actions are required to achieve the goals. This will help the team to visualize the most important actions they have to carry on. Then, a second matrix Action vs. Actors can be created in order to choose the people who will take care of the actions. For the conference organization, where the venue must be changed in the last minute, a matrix Situation Attributes vs. Actions will help team members to consider the different alternatives. Here the requirements of the conference could be registered for example, number of people, number of parallel sessions, banquet alternatives, coffee break, etc. Then a Goals vs. Actions matrix can be created in order to find out which actions should be taken in order to select an alternative for the conference venue. Finally, the Action vs. Actors matrix will help them assign responsibilities to the different members of the organizing team. An interesting “side product” of this process is that an organizational memory [23] can be built because this application will register the alternatives that were considered and their importance. This information can be used in future occasions where the organization may face similar challenges.

6. Discussion and Future Work

This paper proposes a collaboration model and prototype application aiming to support unstructured organizational activities. Although there are a number of scenarios with similar requirements for IS support to unstructured activities, there are also some specific characteristics that may influence the type of support required, e.g., the existence (or not) of: a support organization, adequate training, clearly defined hierarchical structures and chains of command, group support and decision support tools, cross-organization cultures regarding coordination and collaboration, geographic dispersion, and time criticality. The approach proposed in this paper assumes an existing organization with trained professionals responsible for and focused on crisis management.

Based on the Swiss-Cheese model for accidents [18], we propose the construction of situation awareness, capturing what involved actors perceive, know and expect about a situation into a series of aligned Situation Matrixes (SM), each one allowing visualizing and correlating qualitative data about the situation according to situation’s dimensions. Furthermore, as situation awareness is tightly coupled with action, we also propose filtering situation awareness according to the specific actors’ needs, using a visualization mechanism. The combination of the Situation Matrixes and Situation Awareness provides a rich and flexible, yet manageable, mechanism to visualize situation awareness.

Keeping the IS up to date in these unstructured situations, without adding unacceptable overhead, presents major challenges. For instance, status reports and situation assessments are hard to track due to their dependencies on the explicit user interactions with the IS. To address this problem, we aim to: (1) focus on immediate gains, which may overcome the losses associated to the required interaction with the IS, for instance offering persistency; and (2) further develop the quality control of information available in the IS, mostly addressing information filtering according to context. We will also address prototype usability concerns, e.g. minimize interactions and explicit user’s information declaration by for instance, using a pulling strategy: as information becomes old, respective users may be prompted to report their validity, in combination with a visualization schema to express the degradation of the quality of the available information. Another feature that we intend to further develop is to auto fills some dimensions relations inferred by the other existing related dimensions relations. For instance, based on fulfilled correlations in some SMs (e.g. Goals versus Actions and Actions versus Actors) some dependent relations (e.g. Goals versus Actors) can be inferred by the systems. With this mechanism we can also detect correlations conflicts.

Currently, we have a prototype allowing us to study the feasibility of the proposed collaborative model. Once we refine the prototype, a real life evaluation will be made.

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