Supporting Unstructured Activities in Crisis Management: A Collaboration Model and Prototype to Improve Situation Awareness

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Abstract. In this paper we explore the construction of Situation Awareness using a collection of mobile, collaborative and visual-interactive devices. These devices provide a shared workspace where multiple users may correlate information about the problematic situation at hand and organize the unstructured activities necessary to handle the situation. A PDA prototype of these mobile, collaborative and visual-interactive devices has already been developed with the purpose to evaluate the feasibility of the collaboration model. The paper describes the collaboration model and presents an application scenario in the emergency management area currently being used to evaluate the prototype.

Keywords: Crisis Management, Unstructured Work Activities, Collaboration, Situation Awareness.

1 Introduction

Organizations orchestrate their work along a continuum of structured and unstructured activities [1, 2], trying to balance quite different and sometimes contradictory criteria such as productivity and responsiveness. Structured activities are designed a priori based on work models addressing coordination issues, productivity, efficiency and consistency. Information Systems (IS) have traditionally been developed with the purpose to automate as much as possible such work models, relieving humans from the coordination effort.

Unfortunately many unknown variables, both external (e.g., market dynamics and natural disasters) and internal (e.g., latent problems, emergent work processes or lack

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of flexibility in work structures), are among the factors that may lead to automation failures and lack of support of existing IS to unstructured work activities occurring when facing unplanned, emergent or highly fluid 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 [3]. In these situations, beyond the scope of work models and contingency plans, people engage in informal relationships and make use of their tacit knowledge in an opportunistic manner. [4] highlights several characteristics of these emergent processes: no best structure or sequence; typically distributed; dynamically evolving; actor roles unpredictable; and unpredictable contexts.

The concept of resilience, which may be characterized as a comprehensive endeavor towards increased resistance and flexibility dealing with crisis situations [5-7], should be a concern of IS development. The purpose is to deploy IS capable to preserve work consistency and effectiveness in unpredicted scenarios extending far beyond the predefined work models.

From an analysis of the proceedings of the International Community on Information Systems for Crisis Response and Management conferences (ISCRAM) between 2004 and 2006, some recurrent concerns in dealing with crisis situations were identified: shared awareness of the situation; information and knowledge representation and management; usability and interface design concerns. [8] and [9] also pointed out that communication, information management and the construction of Situation Awareness (SA) are major issues to consider when addressing crises situations.

Our research aims to study the IS support to unstructured activities based on the collaborative construction of SA. In the next section we present some related work that influenced our approach. In Section Three we present our IS approach to support unstructured work activities. That discussion is continued in Section Four with a description of the developed prototype. Then, in Section Five, we discus a possible application scenario: Emergency Management. Finally, in Section Six we draw some conclusions from our research and point future work directions.

2 Related Work

We may find several projects in the research literature addressing the gap from fully structured activities to ad-hoc unstructured activities, e.g., [2, 10, 11]. These works fundamentally studied how to bring the IS back to model guidance after deviations caused by unpredicted events. The problem addressed by our research goes beyond this perspective towards the support of emergent collaborative work structures, where models do not serve as prescriptions but rather as artifacts that may help getting the work done [12, 13].

Our proposal relies in a constructivist approach to SA. The support to 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.

The most popular definition of SA is from [14], which states that: Situation awareness is the perception of elements 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. This perspective over SA regards perception, comprehension and projection as three essential dimensions.

The support to SA has received considerable attention in the Computer Supported Cooperative Work (CSCW) research field [15-18]. However, the vast majority of this research has focused in specific context/domain proposals, and also in a functional-oriented perspective, 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.

Team members should not only be able to monitor and analyze SA, but also anticipate the SA needs of their colleagues. Hence, [19] defines "team SA" as SA plus the mutual adjustment of one and another's minds as they interact as a team in a specific context of action. Rather than considering teams as groups of self-organized people, we should regard them as communities of practice, which encompasses broader issues such as practices, norms and rituals [20].

Designing computational support to the teams' dynamics constitutes a tremendous challenge. We have considered two issues as key design requirements in addressing crisis situations: (1) a minimal work overhead demand; and (2) a rich information visualization schema. [15, 21-23] regard information visualization as a fundamental mean to enhance cognition and information interpretation.

Finally, we should also consider research on context characterization and representation. Research in this area has been polarized around two main perspectives: positivist and phenomenological [24]. The positivist perspective, which is traditionally adopted by the engineering fields, regards context as a stable information entity and separable from action. In our research we adopt the phenomenological perspective, with strong roots in social sciences, which regards context as a relational entity relating all involved actions and objects, and evolving dynamically as actions unfold [25].

3 Proposed Approach

Our proposed approach to assist emergent work activities consists in a collaboration model supported in a set of shared visual-interactive artifacts named Situation Matrixes (SM). The proposed collaboration model is inspired in several resilience engineering principles [7, 26] emphasizing: redundancy regarding existing IS, power deference among the involved actors, situated action and shared situation awareness. In our approach we aim to enhance the individual contributions to the overall situation understanding and handling. By allowing each involved actor to contribute to situation handling, we promote the externalization of knowledge flows [27], and actors' tacit knowledge and experience. The sharing of individual assessments will also facilitate collective sensemaking [28] and situated framing [13, 29].

For the construction of this shared artifact we adopted a situation characterization framework consisting of a set of Situation Dimensions (SD). Samples of situation dimensions may include: involved actors, required actions, needed resources, events, goals, situational attributes, etc. For a given application domain, an initial set of

relevant dimensions may be adopted and later on dynamically redefined, as an unplanned situation unfolds. These dimensions may be completely created and redefined in real time.

The SD are correlated in Situation Matrixes (SM), e.g., Actions versus Actors, Actor versus Allocated Resources, Goals versus Actions, etc. As several SM may be necessary to express complex SD correlations, we were inspired by the Swiss Cheese model of accidents [30], to organize multiple SM as collection of layers for crisis management. The SM may also be defined and organized in layers as the action unfolds.

Our specific implementation of the SM was inspired by the perspective proposed by [31], which uses several types of matrixes to visualize qualitative data, for instance: concept cluster matrixes, empirical matrixes, and temporal or event driven matrixes. In our approach the SD correlations are specified in the SM as circles, using different sizes and/or colors to express the perceived strengths (see Figure 1a). Several alternatives may be considered to express the semantic meaning of such correlations, but in our approach we leave the concrete semantics to the experts of the possible application domains.

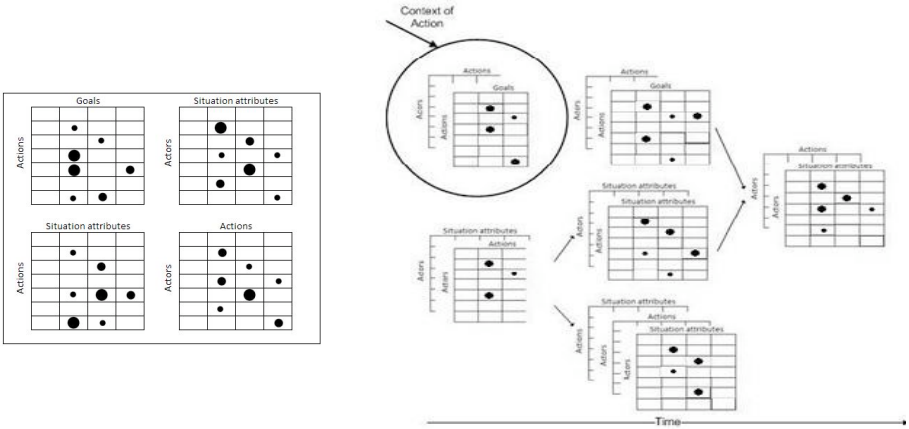

Figure 1. Situation Matrixes (SM): a) Sample of SM; b) SM evolution.

The collection of SM constitutes a shared workspace accomplishing several goals: provide a situation representation shared by the team; support collective and individual action; serve as a monitor/feedback mechanism; and also deliver information in a flexible and manageable way.

As the situation evolves, the SM may include more SD items (e.g., more actors involved, more actions, more situation attributes), with different correlations, and new SM may also be added to the pool (see Figure 1b).

4 Prototype

In this section we present the current status of the prototype development. The prototype supports managing the SM described in the previous section, allowing the collaborative creation, sharing and organization of SD correlations. Since mobility may constitute a key requirement to support emergent work activities, the prototype operates seamlessly with Tablet PC and PDA. Keeping in mind that a minimal overhead is a necessary requirement, the manipulation of SM was designed to be as fast and simple as possible, without limiting the potential to describe and share the different views of the emergent situation that people may have.

The prototype does not support different roles in order to stay as simple and flexible as possible. The prototype operates in a full peer-to-peer model, using the Wi-Fi communication channels available in Tablet PC and PDA. This means that every user has exactly the same application and seamlessly interacts with every other user running the application in the vicinity.

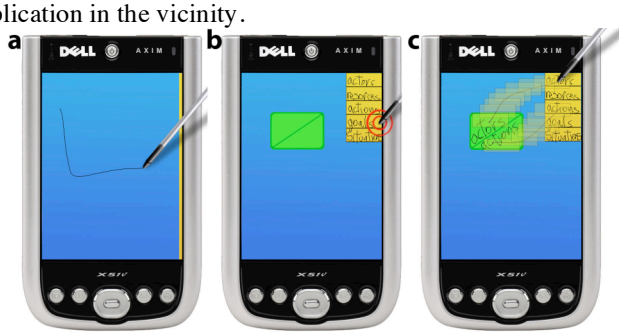

Figure 2: PDA prototype: a) SM creation; b) SD selection; c) SM composition.

The prototype was developed on top of a pen-based application framework developed at the University of Chile. Besides handling all communication and collaboration issues, this framework provides a very rich collection of predefined pen-based gestures supporting the creation and manipulation of visual objects [32].

Concerning the way users interact with the prototype, a new SM is defined by drawing half a rectangle (see Figure 2a). The user assigns the respective SD to each side of the rectangle (Figure 2b-c). Double-clicking a SM it will open the matrix and by double-clicking the sides of the matrix affords creating rows and columns (Figures 3a-c). Handwritten text is used to specify both SD and rows and columns headers, although there is also the possibility to select predefined ones from a menu. Finally, the correlations in the matrix are defined with double-clicking gestures (Figure 3d).

When the size of the rectangle becomes larger, it may be navigated with left-right and up-down gestures. There are also available zoom-in and zoom-out gestures to navigate within the rectangle.

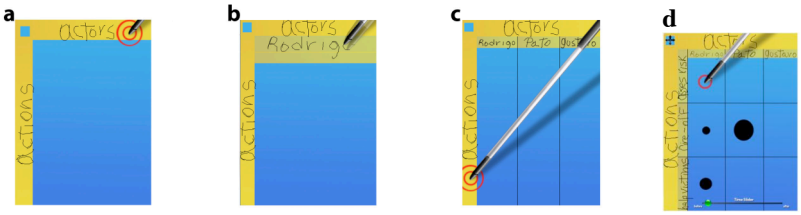

Figure 3: Managing the SM: a) b) column insertion; c) row insertion; d) specifying correlations

Currently, the navigation between several SM must be accomplished by selecting the small rectangle at the top-left corner, which leads the user to a workspace displaying all available SM. Please note that although the SM are shared, the users individually interact with the workspace, i.e. there are no tightly coupling.

A final note regarding the prototype, to refer that when a connection is not possible users may update their SM when in the proximity of other user and exchange SM between them by an Ir link. A compability mode is available to deal with the differences.

5 Application Scenario

When facing an emergency situation two main behaviors will coexist: rule-based behavior and knowledge-based behavior. Rule based behavior relies on existing contingency plans originated from simulations and training. On the other hand, knowledge-based behavior relies on contextual information, tacit knowledge and expertise to address contingencial factors. The developed approach addresses the support of team collaboration aiming to improve actions consistency when dealing with such unplanned factors.

[33] showed that several emergency scenarios (e.g., fires, floods) share common crisis management characteristics, such as: teams organization, information paths, cross teams communication and information needs. For instance, a common firefighter's organization is based on the Incident Commander (IC), as an organizer and decision-maker. Depending on the size of the situation, the operations are conducted in the field by several companies, each one constituted by a Captain and a small group of firefighters.

The major requirements to collaboration between the IC and the Captains were identified by [34]:

- Accountability: Accountability of resources and personnel
- Assessment: Assessment of the situation through multiple sources
- Awareness: Promoting a shared awareness of the situation
- Communication: Communication support should add reliability and/or redundancy to existing channels

Actually IC and Captains maintain situation awareness by communicating through radio and/or meeting face-to-face at regular intervals. However, this type of collaboration lacks information persistency. With the proposed approach beside the support of information persistency, by allowing involved actors to monitor and

participate in a shared workspace, the system will also provide a valuable feedback mechanism of operational status. As the emergency situation unfolds, the situational dimensions (involved actors, needed resources, proposed actions, etc.) may also evolve. The correlations between these dimensions will be continuously updated, according to different perspectives coming from the field.

This approach can be extended to the support of cross-organizational collaborations, e.g., between Police, Civil Protection and Firefighters, which often face communication barriers. For instance, the different forces in Portugal use non-compatible radio communications devices and sometimes the IC has to listen to three radios plus a cellular phone. The shared workspace affords bringing together scattered information. It is however expected that some training and discipline be necessary to develop social protocols and to devise the best ways to organize this information coming from several people in the field. The prototype purposefully does not control who is allowed to modify the SD and SM, thus allowing the level of flexibility envisaged by the notion of resilience.

Next, we present a description of the proposed model and prototype usage by firefighters in an emergency situation. Since IC usually stays at a safe distance of the incident (but close enough to be aware) he/she could be equipped with a tablet PC (Figure 4) which due the dimension and interface may promote a better overall situation state awareness and application usability, and deliver to company captains PDAs which will assist them in the management of relevant awareness information to their context of action and also in their contributions to the solution strategy.

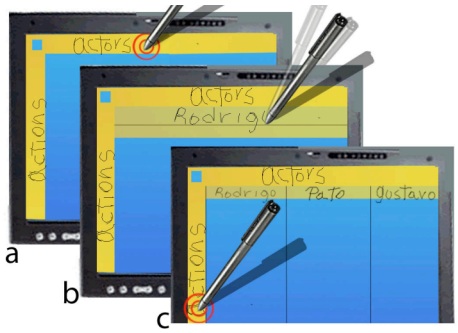

Figure 4: Managing the SM – Tablet PC: a) b) column insertion; c) row insertion.

5.1 Prototype usage description

After an alarm is received, depending on the perceived scale of the accident, a predetermined number of emergency response resources are dispatched. On the way to the incident location teams receive by radio additional information regarding the type of incident they will face (e.g. a urban fire), such as weather conditions, existence of victims, existence of dangerous materials in the neighborhood, …

Once identified the type of incident a set of initial (pre-determined) SM can be selected containing typical dimensions necessary to address the kind of situation (in this example they could be for instance Situational Attributes versus Actions, Situational Attributes versus Actors and Actors versus Actions). The situational attributes presented above (weather conditions, existence of victims, existence of

dangerous materials) could be registered in a Situation Attributes dimension and related with other dimensions such as Actions to take (e.g. to deal with the presence of dangerous materials), and/or involved Actors (e.g. with specific expertise for dealing with dangerous materials). All the situation dimensions, could initially contain typical items, for instance, the Actions dimension could enumerate typical actions under the type of faced scenario: crowd control, traffic control, obtain fire hydrants locations, etc. Also recommended correlations (e.g. expert actor to specific action) could already exist in the SM cells.

Usually the highest rank of the first team that arrives to incident location will assume the IC role. This team will make a quick in place size-up of the situation considering an initial assessment of: hazards, safety procedures, incident scope, etc. and develop an attack plan. Again, regarding the situation assessment a set of SM can be selected (or created) to accommodate information gathered. If the situation demands, more resources are requested and the IC role may be passed to a higher rank that arrives later on, providing a quick status report. Since information is persisted in a set of SM, they may help this role transition in a very important issue: perceive overall situation status.

As situation evolves, a problematic concern for IC is to track resources allocation, "who or what is where and doing what?" (accountability and awareness above presented requirements [34]). Usually, IC has a number of threads going on and information comes from multiple sources. To overcome this problem the set of SM: Resources versus Actors, Actors versus Locations, Resources versus Actions and Resources versus Locations could be used. Figure 5 shows SM relating resources with respective responsible actors, being operated in a PDA.

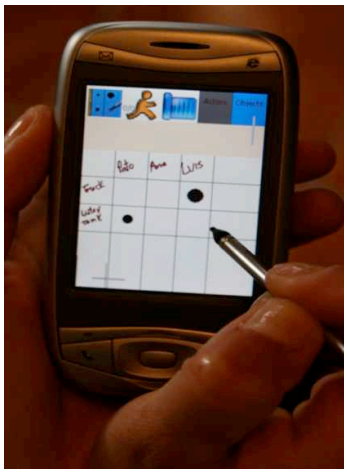

Figure 5: PDA Prototype

A *locations* dimension may be important if an incident is large enough, because in such cases, companies will be organized into divisions which operate within a specific geographic region (e.g. north, third floor). Divisions may also be organized in groups which perform specific functions (e.g. rescue, medical care).

Since, with this approach, a lot of incident's related information is registered, the proposed prototype has an additional utility: it will allow a posteriori analysis of the

course of action to promote further improvement in procedures, as well as new situation dimensions (and respective dimension items) and/or SMs to be initially available for future occurrences.

6 Discussion and Future Work

In this paper we describe a collaboration model and prototype aiming to support the unstructured activities that emerge in emergency scenarios due to contingential factors. The adoption of our prototype assumes that agents involved in these scenarios are professionals with expertise in emergency management and have specific training. In this way the information shared through the prototype will have a clear semantic meaning to the involved actors.

We should note that similar collaborative approaches exist and are already used in some other domains. For instance, flight operators and firefighters adopted several variations/generations of the Crew Resource Management (CRM) training, which has its foundations concerning not so much the technical knowledge and required skills but rather the interpersonal skills used for gaining and maintaining situation awareness, solving problems and making decisions [35, 36]. The CRM approaches fosters a climate and a culture where the freedom to respectfully question authority is encouraged, aiming to increase resilience while reducing the discrepancy between what is happening and what should be happening.

Keeping the IS up to date in these scenarios, without adding unacceptable overheads, presents major challenges to IS developers. For instance, status reports and situation assessments are hard to track due to dependencies on the explicit user interactions and information volatility.

We have been studying a pulling strategy to IS support in this context: as information becomes old, the users may be prompted to report on their validity, in combination with a visualization schema to express the degradation of the quality of the available information. For now we are considering two ways to implement such concept: 1- when users input information, a deadline is also introduced (e.g. valid for the next 15 min); 2- if no deadline is introduced that correlation will incrementally became more transparent as time goes by. Once we refine the prototype, a field evaluation should be made. The preliminary step of our evaluation methodology will be to conduct a workshop with domain experts and discuss the proposed approach in a scenario based evaluation.

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