A Situation-Aware Mobile System to Support Fire Brigades in Emergency Situations

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Abstract. In a firefighter emergency mission it is essential for the members of a fire brigade to get an intelligent and reliable overview of the complete situation, presented according to the role of each member. In this paper we report on the design and development of a system to support a fire brigade on site with a set of mobile services that offers a role-based focus+context user interface. It provides the required overview over the emergency situation according to the user task and context, while life-saving information is emphasized. The implementation of a context-rule-based decision module enhances the visualization of required information. Interaction with the user interface is designed for use in the wild; which in this case comes down to providing a "fat finger" interface that allows firemen to interact with the user interface on site with his gloves on.

1 Introduction

Though mobile crisis management systems have been researched for some time now [1,2], their usage is not very common among intervention teams. We started from the requirements of an actual fire brigade to design and develop a situation-aware mobile system that supports the different members of the brigade and their particular roles. Contextual information plays an important role in the design of the system. Certain parts of the user interface can be emphasized because they contain critical information according to the context (situation).

We had some interviews with firemen of a firebrigade involved in the project that revealed a set of requirements we needed to fulfill to produce a mobile system that could be used during a firefighter emergency mission. Immediate access to site specific information in combination with team communication facilities is highly rated: currently most firebrigades use reliable walkie-talkies to communicate with each other and the site-specific information comes from paper plans

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that show the floorplan of a building annotated with the places where toxic gases can occur, where the hydrants are located, where the emergency exits are located etc. The system should also provide a quick overview of the situation of the environment (e.g. direction the wind blows) and of the team (e.g. whether there is a team member that has a very low heartrate). This is contextual data that can influence the user interfaces and presentation of data. Furthermore, it should support the coordination of a fire brigade team while they are on the site, and take into account the outfit a firefighter needs to wear during a emergency mission such as thick gloves.

For the design of the user interfaces we used a task-based approach [8]. Task specifications for the different types of users were created and presented to a fire brigade team member. After this iteration mockups of the interface were created: for each task specification a mockup covered the tasks embedded in the specification. The mockups were presented to the firefighters, their feedback was collected and the designs were adapted accordingly. Next, the concrete interfaces were implemented and tested with the users. With this user-centered approach we aimed at creating a complete and usable system first, that fullfilled the complex requirements typical for a mobile crisis management system. Furthermore, the chances for acceptance by the end-users were increased, an important goal for the design of this type of application that deals with critical situations.

The part of the user interface that is created this way has a static structure and navigation: a fireman does not have time to interpret possible changes in the interface because of a change in context. However, a context-aware interface helps to emphasize critical situations and data related with these situations. Jiang et al. already showed the importance of context-sensitive user interfaces for firefighters in the Siren project [5]. The system we present in this paper has many similarities to the work presented in the aforementioned project. The challenge is to add context-awareness without changing the structure or navigation of the user interface, but merely parts of the presentation. This is an important issue; although a context-aware user interface can help in making a quicker assessment of the situation, the interface needs to be predicatable and reliable at all times. Our approach differs from Siren that mainly focuses on context-aware messaging; we integrate different types of information sources in a single user interface that are used during an intervention.

2 Dynamic Mobile Networking Infrastructure

To satisfy the need for real-time information, we implement an advanced mesh networking technology to dynamically build up a network in the disaster area [10]. This mesh network will be connected to an infrastuctured network (wireless or wired), providing permanent access to various sources of information, relevant during the crisis intervention. It is necessary to provide a self-configurable, dynamically adaptable and self-healing mesh network, because one cannot trust the existing infrastructure, in order to maintain communication at each step of the ongoing intervention. Besides transporting different media streams such as voice data and video streams, the mesh network is also responsible for the exchange of context data with other team members and the commanding officer. The former has the highest priority; context data is sent over the network with a lower priority and must not effect the voice communication. An *On The Go-Coverage* service is provided by the mesh network to measure the quality of the network connection for each member of the team. According to the physical location of the firemen, there will be differences in signal strenght and thus bandwidth.

The On The Go-Coverage Indicator (OTG-CI) is a user interface element that is shown at the Personal Digital Assistant (PDA) device of the team member and provides an overview of the quality of the mesh network. The OTG-CI will help to decide when and where to deploy a new wireless node inside the building, in order to maintain a wireless connection with the fire truck. As the team explores the building, the OTG-CI indicates when the wireless signal between the node, that is carried by the first team member, and the nearest node becomes too weak or will die. At that point, a new node, carried by another reconnaissance team member, is deployed in order to extend the mesh network. Since the nodes are battery powered, they can be easily installed by e.g. putting it on a window bench. The new node will automatically register itself within the current mesh network, and new routes are calculated. The integration of a new node is seamless. The OTG-CI will also make an estimation of the end-to-end bandwidth from the reconnaissance team to the fire truck. Whenever a node goes down, the mesh network will automatically try to recover itself, within a minimum amount of time. Thus, it is important that there is a certain redundancy when deploying the nodes. A dynamic channel selection algorithm is implemented to optimize throughput.

3 A Focus+Context Interface

During an intervention, each member of the fire brigade has a specific role. The commanding officer (CO) will coordinate the team, but will not take part in the exploration. It is essential that he has an overview over the situation and knows the status of the different team members of the fire brigade. The other members of the fire brigade have to follow his orders and trust on his insights. The exploratory team members are the first to enter a building to get a detailed overview of the situation. One fireman of the exploratory team carries a camera that transmits a video stream to the fire truck where it is stored and can further be distributed. The fire truck contains a server that allows access to this video stream and secures communication. Finally, there are some stakeholders (e.g. the local governor) who mainly observe the actions of the fire brigade and can decide to send backup.

Focus+context [6] is a central concept used during the design of the user interface. Context is often used to determine the way information is presented (or focused) in a mobile guide: e.g. TIP [4] and GUIDE [3] are both context-aware mobile guides. Context changes in mobile guides are mainly location- and time-based (e.g. when approaching, more information about a hospital appears), whereas in crisis management systems, the interface is influenced by events during the intervention (e.g. the heartrate of a firefigher suddenly drops).

Depending on the role of the person he/she will be equipped with a mobile device. We use two classes of devices: PDAs and Tablet computers. Figures 1 and 2 show the ruggedized devices that are used in the *GeoBIPS* project. On each of these devices, a user interface is implemented that meets the demands of the user depending on its role, as well as the current circumstances. As a tablet PC provides a larger screen space than a PDA, multiple information resources can be visualized simultaneously on the Tablet PC while a PDA interface requires the display of a single information item, to provide a clear and simple overview of the ongoing intervention. Each firefighter is provided with a ruggedized PDA as shown in figure 1. The CO has a ruggedized tablet PC as shown in figure 2.

Fig. 1. The ruggedized PDA shows the floorplan and shows the status of the exploration

An easy to understand interface is important in these types of situations. We used a standard icon set as part of the visualizations: currently we are using the ANSI-DIN icons, but these could be easily replaced by the Homeland security set[1]. This makes communication between different team members more effective because of the common understanding of these representations [9].

4 Role-Driven Mobile Crisis Interfaces

4.1 The Commanding Officer

It is of great importance that the CO is provided with information concerning both the crisis location and the environment. Decisions made during the intervention often depend on the amount of information available at the current

[1] http://www.fgdc.gov/HSWG/index.html

Fig. 2. The ruggedized tablet computer is used by the commanding officer and gives an overview of the situation including the status of the different team members of the fire brigade at the intervention site

time. The mobile crisis management system relies on four fundamental information sources: relevant Geographical Information Systems (GIS) information, intervention plans, team overview and realtime on-site video streams. Important relations between these information sources, or within one information source, can be predefined to allow easy access while operating the user interface. Figure 2 shows the tablet interface. Basic operations such as panning, zooming and selecting information items are supported by all the four parts of the user interface (the video stream itself does not allow panning). Information items are presented as dynamic icons on the GIS map and intervention plan. A semantic zoom is supported by our system: e.g. information items on the map can change presentation according to the zoom level, thus give an adapted view according to the level of interest in a certain region.

To provide a general overview of the environment, the interface of the CO's Tablet PC implements the presentation of GIS information. The dynamic mobile networking infrastructure provides access to a web service that delivers an environment map with different layers of information. This web service interprets the requests according to the user role requirements and renders a result bitmap accompanied by the user defined information layers. These layers present interactive information items that are important for the specific user. Relations between items presented on the map provide more background information: this allows the user to easily filter out information that is necessary depending on the situation. The semantics of these relations can be visualized, e.g. selecting one information item in a layer on the map can result in highlighting other information items from other layers on the map.

The intervention plans enhance the CO's overview of the current crisis site. Intervention plans provide an overview of the building, together with emergency exits, surrounding hydrants, the locations of dangerous materials (e.g. toxic gases) etc. As elements on the intervention plan are updated, e.g. when a hydrant outside the building appears to be damaged, these updates are automatically updated in the user interface of the CO. These dynamic updates are necessary to maintain a clear and concise overview of the crisis situation. Updates in the user interface should increase the CO's awareness of the situation keep him/her up to date. For example, if the status of one of the members of the exploratory team changes indicates the condition is critical, the ongoing task of the CO should be interrupted by a user interface update that shows this information.

When selecting an information item on a GIS map or intervention plan, detailed information is shown to the user. For example, when clicking on a hospital near a crisis site, other hospitals in the environment could also be highlighted if this relation is emphasized in the configuration. This linking speeds up information querying by the user, and creates an easier way to have a general overview and interpretation of the environment. For each zoom level, the interface will decide if distinct layer elements are separately visualized, or whether an aggregation of different elements within that layer will be shown. Understanding information of a particular layer element is done by exploring and filtering the aggregate representations.

4.2 The Exploratory Team

Each fireman taking part in the site exploration wears a ruggedized PDA that provides an overview of the intervention plan, current team status and the OTG-CI. The PDA interface is shown in figure 1. It is designed in such a way that it supports touch-based interaction with gloves on. We implemented a "fat-finger" interface library: a set of controls for mobile devices that allows an interface designer to add large dynamic widgets to an existing interface. Example widgets that are available are different types of custom buttons, trackbars, selectors, combo-boxes and image-enabled combo-boxes. Informal preliminary tests with firemen have shown the added value of such a widget set. Furthermore, the fact that no other tools are required to interact with the touch sensitive screen increases acceptance by the firemen.

The intervention plan can be panned by moving a finger over the screen. The PDA interface provides two large buttons that can be easily activated by the gloves. A detailed view of the OTG-CI and the intervention plan can be accessed by one of these buttons. The other button is an alarm button that notifies the CO when a life-threatening situation occurs. Activating this alarm triggers an alert in the Tablet PC interface of the CO.

Because the PDA interface is used during an exploration of the site, the amount of information should be limited. The firemen might well be in the middle of a burning house when he needs to access the information. The visualization of information is adjusted to this context. The interface for the PDA allows the firemen to focus on exploring the building and deploying new wireless access points when necessary, and provides the necessary information to ensure a secure intervention.

5 Situation-Awareness

A detailed description of the different user roles taking part in the exploratory intervention was created as part of the design process. They clarify which interaction tasks and visualization features can or must be implemented for each role. We defined the roles of a CO, firemen surrounding the CO, firefighters and the team member carrying the camera who are part of an exploratory team and created a task specification for each role. Next to these roles and tasks there are other team members, like the firemen who monitor the ongoing situation while seated in the fire truck, that we did not take into account here. However, since we are creating a mobile system that needs to support a team of firemen, indirect and direct communication between team members is integrated in the interface. Examples include real-time video streams from the exploratory team to the tablet PC of the CO, the status feedback to the firemen who participate in the team and an overview of each member's situation on the CO's tablet PC. We take advantage of the wireless mesh networking infrastructure that is set up.

The following types of direct style communication are supported:

Verbal communication: A RTP[2]-based VoIP implementation is used. Each firefighter and the CO can be equipped with a Bluetooth earpad connected to their *GeoBIPS* mobile device (e.g. a PDA).

Streaming video: The camera man from the exploratory team permanently films the situation and streams the output via the wireless mesh network towards the video server that is deployed on the fire truck. This video server forwards the video stream towards the mobile device of the CO.

The following types of indirect communication are supported:

Team member context: Each fireman's PDA permanently aggregates incoming data of different personal sensors. These sensors can describe the fireman's blood pressure and heartrate for example. This aggregation of data is pushed towards the CO's interface via the wireless mesh network, allowing for the interface to interpret and visualize the sensor information in a status view of the firefighter.

Team member connectivity status: Because of the particular situation it is important to know the degree of connectivity (using the wireless mesh network) of each team member. This can influence the reliability of data retrieved from the team member device, and can also indicate a problem when the team member goes further out of range of the wireless network.

The implementation of zoomable user interface elements, combined with focus+context visualization techniques [6], provides a detailed view of firemen in trouble, while maintaining a concise overview of the other firefighter in the exploratory team. To enable indirect communication, it is possible for the CO to interact with the team management view. For example, when a fireman has an exceptionally low heartrate, the CO is alerted and can alert the other firemen to

[2] `http://www.ietf.org/html.charters/avt-charter.html`

join the troubled firefighter. The CO can alert the team of firemen through verbal communication, and can appoint a team member to help the troubled fireman. Complementary, this notification is sent towards the PDA of that team member. Verbal communication is always preferred, other communication is complementary but nevertheless also important.

6 Context-Processing Rule System

To further support efficient decision making in crisis management systems, we integrated a rule-based system for context information. Partially based in the idea of event webs introduced by Chandy et al. [7], that considers routes events over a web of connections to the subscribed clients. Clients on the network are represented by knowledge agents that are deployed on mobile devices and communicate over the wireless network. The agents continuously share new or changed context information and interpret incoming context. Each knowledge agent is configured with a predefined set of decision rules which are loaded when the system is prepared for usage. A decision rule might be “If heartrate lower than 75 then send an alert to all other team members and fire truck”. This rule can be triggered when context information originating from sensors enters the mobile device of the user. The information is distributed to other devices according to the rule. Each client device can have its own specific set of rules; according to the tasks and role of the user it can be useful to specify additional rules.

Usually, the Tablet PC of the CO is the mobile device which first obtains all time critical information, since he/she makes all strategic decisions during the intervention. Since different predefined sets of rules can be deployed on different devices, rules can also be shared with others when they are triggered on the source device. This automation ensures the context information is spread over the context web, together with the rules that are responsible for this, so an agent can easily deduct the reasoning that was used to send the information. This can be useful if the systems of different intervention teams need to be integrated on the fly, and cooperation between members of different teams is desired. Our interface has fixed parts because of the critical information that must be accessible at all time, the exchange of processing rules will not lead to missing data in the interface. It could lead to confusing information being displayed in the non-fixed parts though: this is an open issue that needs attention. The result of a rule being triggered, does not immediately affect the intervention. Information visualization techniques alter the provision of data, corresponding to the rule, and alert the user of ongoing happenings. This approach allows the user to control the situation, being assisted by tips or notifications which might facilitate the decision making.

Decisions made by the context processing agent result in user interface events that notify the user. As the crisis situation progresses, dynamic updates in overall available information based on changing context like environmental parameters can influence the behavior of the exploratory team. For example, when the direction of wind conditions changes, toxic gases can endanger team members inside a building on fire. The reflection of changing conditions or context in team specific information further emphasizes the importance of this integration. Similarly, team specific information can influence overall information. For example, when a team member collapses because of a critical shortage of oxygen, his location can be interactively visualized on the intervention plan accompanied with a sound and a flashing animation on the map. This feature allows the CO to respond and order other team members to relocate to the firefighter.

7 Future Work

The system described in this paper is not yet tested in a real intervention. However, we used a user-centered approach and informal acceptance tests to validate our approach. An initial demo in realistic settings was done before the public[3], and the pariticipants in the demo were all firemen. This is still different from a real intervention, so additional tests are necessary to have a complete assessment of the system. Software systems that need to handle complex and context-dependent data and that are life-critical systems are probably the hardest to get completely right: there is no room for error. We provide a clean separation between the fixed interface part, and the context-dependent interface parts, since no interference can happen between both.

Currently, there is no integration with a body-sensor network that captures the context data. Although the software system embeds processing rules to handle context and adapt the interface presentation accordingly, we still simulate the contextual data with custom servers that are deployed on the network. In addition, a vocabulary for describing and exchaning contextual data will be created. The different types of components integrated in the system like GIS data, body-network sensors, messaging,... should be able to make use of this vocabulary to exchange information easily and indicate that this information is delivered to the devices invoked by a context-change and not a direct human action.

8 Conclusions

Within the *GeoBIPS* project we present a mobile crisis management system. Our solution allows the user to focus at the task at hand without losing the overview of the situation. Different types of information sources are combined and presented to the user according to the user role, tasks and situation of context. GIS data, intervention plans, streaming video, team status and also different types of communication are integrated into one single system.

Current user tests and practical use indicate that the interface for the mobile devices is intuitive and easy to use. It assists the firefighters with the required information and supports the decision making process by providing a smooth integration with contextual information. The Tablet PC data visualization allows

[3] See https://projects.ibbt.be/geobips/index.php?id=183

the CO to consult all necessary intervention and crisis data, while maintaining a clear overview over the current situation. A team status visualization supports monitoring the status of the exploratory firefighters. The interface can emphasize data according to the user context, which is based on different sensors that can be integrated in the environment. However, more realistic testing is required to ensure usability of the entire system in a real-life situation.

The GeoBIPS project web site can be found on `http://geobips.ibbt.be/`.

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