Improving the Communication of Spatial Information in Crisis Response by Combining Paper Maps and Mobile Devices

Johannes Schöning[1,2], Michael Rohs[2], Antonio Krüger[1], and Christoph Stasch[1]

[1] Institute for Geoinformatics, University of Münster,
Robert-Koch-Str. 26-28, 48149 Münster, Germany
[2] Deutsche Telekom Laboratories, TU Berlin,
Ernst-Reuter-Platz 7, 10587 Berlin, Germany

Abstract. Efficient and effective communication between mobile units and the central emergency operation center is a key factor to respond successfully to the challenges of emergency management. Nowadays, the only ubiquitously available modality is a voice channel through mobile phones or radio transceivers. This makes it often very difficult to convey exact geographic locations and can lead to misconceptions with severe consequences, such as a fire brigade heading to the right street address in the wrong city. In this paper we describe a handheld augmented reality approach to support the communication of spatial information in a crisis response scenario. The approach combines mobile camera devices with paper maps to ensure a quick and reliable exchange of spatial information.

1 Introduction & Motivation

Recently a misconception of a location led a German fire brigade to a wrong place (as noted in the abstract the fire brigade headed to the right street address, but in the wrong city) in this case with terrible consequences [1]. The webpage [2] gives a very similar example of an ambulance that was sent to a wrong address. However, information on locations is not only important when talking about street addresses, but also when mobile units need to enter hazardous areas, such as a flooded area or a forest fire. In such situations graphics and maps are needed in addition to verbal communication between the mobile unit and the control center in order to ensure that the right action is performed in the right location.

Currently paper-based maps are used in conjunction with the voice channel (either through phones or radio transceivers) to achieve agreement on locations between mobile units and the control center. Computer-based displays (as provided in tablet PCs, PDAs and mobile phones) are infrequently used, because they are too small and of too low resolution to handle this task successfully. Larger displays are too heavy or not ruggedized enough to suit the task. Even in the advent of electronic paper [3], one cannot expect robust large-scale electronic maps in the near and midterm future.

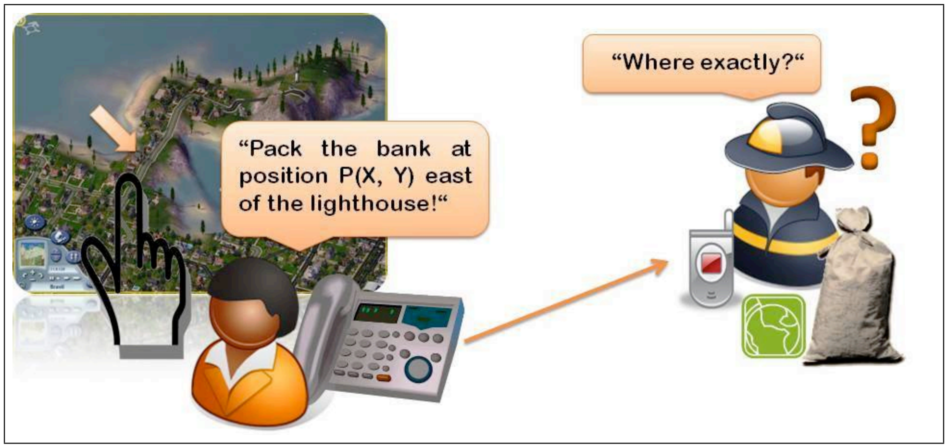

Fig. 1. Problem of exchanging spatial information via the voice channel.

For these reasons we propose an approach where smaller mobile devices (which can easily be ruggedized) are combined with conventional large scale laminated paper maps of the environment. In particular, we argue that if a modern camera-equipped mobile phone is used, information about locations can be easily conveyed by using the available voice channel and a mobile augmented-reality approach. In this approach a mobile device is moved like a *magic lens* [4] over a printed map and location information is superimposed onto the map in real time. Our hypothesis is that with this additional modality communication errors are heavily reduced in comparison to the voice channel alone. Large scale maps can provide an excellent overview of the whole situation, which would not be possible with the device screen alone.

The integrated cameras can also be used to quickly capture up-to-date photographs of the situation on the spot. These documents can then be linked to positions on the map as multimedia annotations created by the mobile units. Relying on our earlier work on mobile camera phone interaction with paper maps [5] we have developed multi-modal interaction concepts suited to the emergency tasks at hand, which are presented in the remainder of the paper.

The paper is organized as follows. In Section 2 we briefly describe a scenario which underlines the significance of our approach. We discuss related work in Section 3 and introduce the multimodal interaction concepts in Section 4. Section 5 reports the current state of the implementation and a conclusion and summary is provided in Section 6.

2 Scenario

In our hypothetical scenario, floodwaters strike the eastern part of Germany, eventually causing a flood that affects villages and cities, for example the historic downtown of Dresden, along the river Elbe. Evacuation alerts are sent out to the affected populated areas. The Technisches Hilfswerk (THW)[3] constantly inspect all banks and dams to ensure that leaky parts are detected early. On an inspection walkway a THW team gets a call from the Emergency Operation Centre (EOC): A helicopter has reported a leaky spot in the bank on a specific position P with the geographic coordinates (X, Y). The bank is about to break and a THW team has to prevent this by sealing it with sandbags. In this case it is necessary to communicate the exact position P from the EOC to the mobile unit to be sure not to waste valuable time. Of course, this communication channel is not unidirectional. There are situations in which this communication is needed in the other direction as well. Let us assume, for example, that the THW team has detected a leaky spot and needs more sandbags and more manpower to protect the bank. Describing the position verbally or exchanging the coordinates of a position P literally as X and Y via the voice channel is a time consuming and error-prone task [6]. We illustrate this problem in Figure 1.

The way dynamic geo features, such as the approaching floodwater, are visualized on the map obviously has a strong effect on the usefulness and understandability of the presented location information. This can be easily done in the EOC by using large dynamic map displays, but it is challenging task to realize a dynamic map application for THW teams in the field. Tablet PCs still are unhandy and have a short battery runtime. PDAs and smartphones with network connectivity can provide dynamic maps with the desired content by querying an adequate web service, but these maps suffer from the small display size. Because visual context is lacking, it is often hard to identify locations and landmarks on these maps, rendering them rather useless.

3 Related Work

Collaborative visualization and decision-making tools for crisis response have been classical fields of the Digital Cartography, Visualization and GIS communities. In addition, other disciplines, such as the HCI and Ubiquitous Computing communities, have tried to tackle various aspects of this problem. Most of the existing work focuses on large format map applications that support decision-making, for example, in an emergency operation center (EOC). McEachren [7] et al. provide a good overview of these large format map applications that support collaborative visualization and decision-making. The GIS wallboard [8] is a conceptual example of an electronic white board envisioned to support sketch-based gestures to interact with geospatial data. Other systems, designed especially for tablet PCs were implemented by Oviatt [9] and Egenhofer [10]. Sharma

[3] The Technisches Hilfswerk (THW) is the governmental disaster relief organization of the Federal Republic of Germany.

et al. [11] concentrate on multi-modal interaction (speech and gesture) with a large dynamic map display and evaluated that system in a crisis response scenario with real users. All this work concentrates on supporting decision-making and group collaboration in an EOC, but does not concentrate on the problem of the communication between mobile units and the EOC. We provide an easy, intuitive and robust system trying to tackle that problem.

In the HCI community Palen and Liu [12] describe new perspectives on citizen-based activities that arise out of peer-to-peer communications in disaster activities. These activities serves important tactical, community-building, and emotional functions. Since our approach does not require special-purpose hardware it could also be used by the general public to be informed and to provide feedback and take part in the crisis response activities. Yuan et al. [13] propose a concept for an intelligent mobile crisis response system (CRS) that would have facilitated a more effective response in a given scenario. They list six critical tasks of a CRS (Monitoring and Reporting, Identification, Notification, Organization, Operation, Assessment and Investigation) and outline several solutions to improve theses tasks.

In this paper we describe a concrete application of a communication system between mobile units and an EOC trying to support communication of spatial information between them, as well as other critical tasks in a CRS like *Monitoring and Reporting* and *Identification and Notification* [13]. This work differs from the related work in that we apply a combination of two devices typically used by mobile units, namely mobile camera phones and paper maps. Combining both we can provide a robust and intuitive way to easily support the communication of any kind of spatial information.

4 Basic Interaction Concept

As described before, the communication between the EOC and the units in the field typically happens via the voice channel today. This modality makes the rapid and accurate communication of spatial information difficult. In our approach the voice channel is augmented by visual information that is presented on the mobile device screen (see Figure 2). Since the device screen is too small to help the user to easily acquire overview knowledge for a spatially extended area, we combine the handheld display with a medium to large size laminated paper map (A5 to A2 size). The paper map provides the static long-term information of the area, which is not affected by the crisis event, such as landscape features or street names. The paper map can still be updated regularly. Since (even laminated) paper is cheap, a new map could be handed out once a day, which includes recent changes induced by the crisis (see Figure 3). The paper map is easily transportable, robust, does not require any power supply, and in effect constitutes a high-resolution display.

The mobile device with an integrated camera is used as a *magic lens* [4] for the paper map. It analyzes the part of the paper map that is visible in the camera view and determines the current focus position on the map. The device shows dynamic overlay graphics and textual information that reflect the most up-to-date state of the crisis. As the situation changes or as new requirements and tasks are communicated by the EOC, the map is updated in real time. During a phone conversation, virtual annotations of map areas can be created in the EOC and the result becomes immediately visible on the display of the first responder (or vice versa). This concept achieves maximum transfer of spatial information at minimum reliance on special-purpose technology and is therefore expected to be quite robust. The camera phone as well as the paper (or cardboard) map can easily be ruggedized. By combining the voice channel and the visual channel, tasks and needs can effectively and unambiguously be communicated.

4.1 1:1 communication between the control center and the first responder

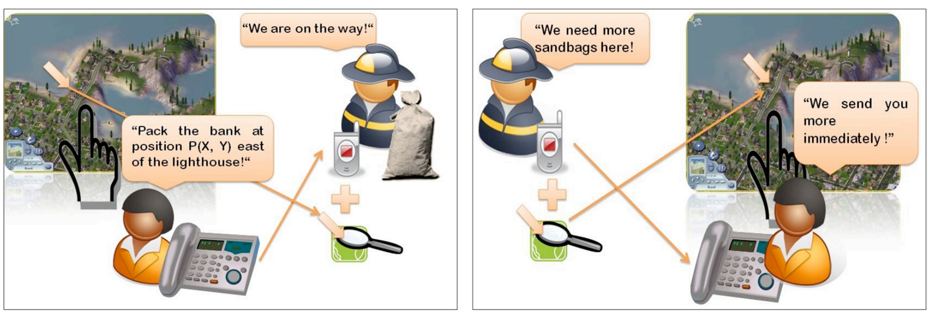

Fig. 2. Supporting the exchange of spatial information by combining the voice channel and the visualization on the mobile device.

Figure 2 illustrates one-to-one communication between the control center and the team member. Figure 2, left, is an example of communication from the EOC to the THW team. The EOC issues a command to the leader of a THW team that involves a spatial target to operate on—in this case a bank that needs to be protected. Figure 2 (right) shows, how a specific requirement, again involving a spatial component, is communicated from the first responder to the EOC. In both cases the involved location can be accurately determined by the first responder, when using the *magic lens* approach.

4.2 1:n communication between the control center and the first responder

Normally, a single task is collaboratively performed by a large number of THW teams in the field. The EOC has to issue out the task to the group as quickly as possible. Again, the *magic lens* approach enables the team members to individually receive voice commands and review the graphical annotations of the map using their personal displays. Even a single large paper map can be collaboratively shared by multiple THW team members by using multiple camera phones.

This one-to-many communication is not limited to the EOC. One team member might need to quickly send information about a spatial object to the others nearby. In this case he or she would create a graphical annotation or select an icon from a library of icons, place it at the intended location, and attach a textual or voice annotation to this icon. This annotation would then be visible to the other first responders in the vicinity.

Fig. 3. 1:n Communication between the control center and the first responder (left). Showing an augmented (or alternative) view of the printed map (right).

5 State of Implementation & Usability Test

Figure 4 shows the prototype architecture. The mobile device is tracked over the map using the algorithm described in [14], which relies on a tiny dot grid that is printed on the paper map. This dot grid allows pixel precise augmentation of the paper map on the mobile device screen in a robust way (see Figure 3 left). Given the different test maps with about 500 patches, the current implementation (with 12×12 samples per patch) processes 8 to 12 frames per second on a Nokia N95, depending on the number of patches found in the camera frame. The map can be rumbled to a certain degree without severely affecting the recognition rate. The spotlight integrated next to the camera lens on many camera phones can be used to illuminate the map in low light conditions.

The voice channel is established via a normal phone call (see Figure 4, green arrow, labeled *voice channel*). Spatial information displayed on the large map display, like the actual flood water level, in the EOC can be easily transferred via a specific XML protocol using GSM or, if available, via UMTS. (see Figure 4, red arrows, labeled *position data*).

The question of the relative benefit of this interaction technique compared to two other navigation techniques that only use the mobile device display for map visualization was already presented in [15]. In a formal user study the performance of three methods for map navigation with mobile devices was compared. These methods were joystick navigation, the dynamic peephole method without visual context, and the magic lens paradigm, as described in this paper, using external visual context like paper maps. We measured user performance and motion patterns and collected subjective preference via questionnaires. The results demonstrate the advantage of dynamic peephole and magic lens interaction over joystick interaction in terms of search time and degree of exploration of the search space.

Additionally we casually observed different visual exploration strategies. Some subjects constantly focused on the mobile display to find the next target, others switched their gaze to the background map to identify a target region, moved their mobile to that area and finally fixated the display again.

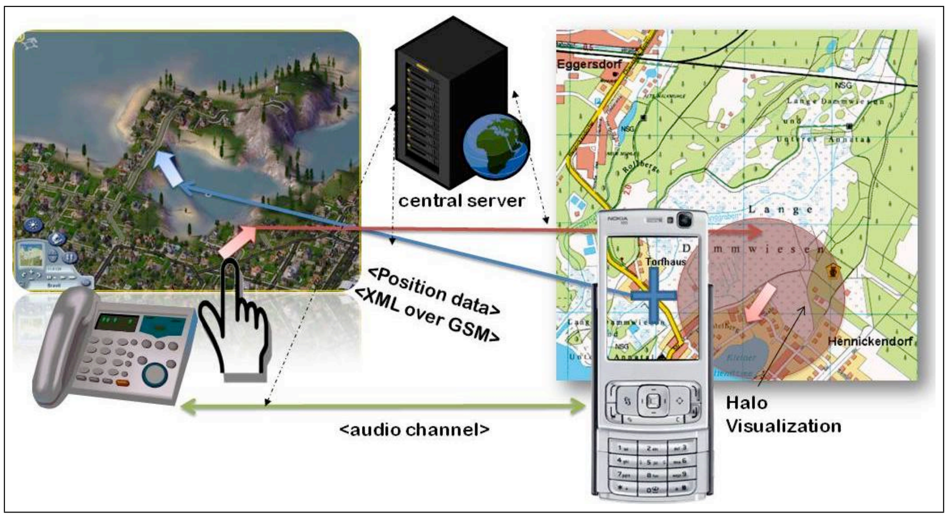

Fig. 4. System architecture of the application.

Off-screen information can be visualized with the *Halo* technique [16] or the *Wedge* technique [17]. The former draws a ring around off-screen objects that reaches into the border of the device display. From the position and curvature of the ring segment the user can infer the approximate direction and distance of the off-screen object. The Wedge technique increases scalability by drawing “pie Wedges” instead of circles and lays them out such that overlap is avoided if possible. In user studies it was found that both techniques provided equally good cues about the distance of the off-screen object. To illustrate the basic principle of operation, a video of a mobile magic lens for paper maps is available under http://www.youtube.com/watch?v=5Z_D5JNcfuQ. It shows the Wikeye [18] application, in which geo-referenced Wikipedia content is made accessible by moving a camera phone over the map. The live camera image of the map is enhanced by graphical overlays of the hyperlinked objects and snippets of Wikipedia content.

6 Conclusion & Future Work

We described a method to support the communication of spatial information in crisis response situations. The method combines standard mobile camera devices with printed maps to ensure a quick and reliable exchange of spatial information. We use a robust mobile augmented reality tracking approach to generate overlay graphics at interactive rates. The tracking technique has been successfully deployed in a number of applications [5], [18], [19], [20] and [21] . However, this work is at an early stage and we mainly presented concepts and ideas that have to be verified in usability tests and in training exercises in the field. The infrastructure that allows for communication between the EOC and the team is under development. Nonetheless, we are convinced of the applicability and practical value of the proposed concepts and look forward to take this work further. In terms of usability tests we particularly want to focus on users under stress with little time and little attention available for mobile map interaction. As a next step we plan to conduct a structured interview with a manager of the EOC of the Berlin fire brigade to give a first impression of the feasibility and acceptability of such an application.

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