WATCHiT: Towards wearable data collection in crisis management

Simone Mora[*]
simone.mora@idi.ntnu.no

Monica Divitini[*]
monica.divitini@idi.ntnu.no

[*]Department of Computer and Information Science
Norwegian University of Science and Technology
7491 Trondheim, Norway

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Abstract
In this paper we present the work-in-progress on WATCHiT, a wristband computer for data collection during crisis response work. We outline the user-centered research methodology we adopt and we identify four design challenges to be tackled. We report the design of a working prototype that relies on wearable sensors to capture quantitative data and on an eyes-free, token-based interface for tagging sensor data with user-defined text messages. The prototype has been evaluated with emergency workers during a simulated rescue operation.

Author Keywords
Wearable computers; crisis response; sensor data; tangible interface

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. See:

Introduction
Capturing information about the status of the environment and of the workers is critical in crisis response, e.g. in case of earthquake, overcrowding, and flooding. The information to be captured might include for example: location of workers, number of rescued people; and data from the environment

(temperature, noise, air quality). Information is needed: (i) to support cooperation on the field during crisis response [12], (ii) to inform post-crisis debriefings to understand what happened and learn from mistakes [10].

Besides some data is quantitative in nature and can be automatically captured with dedicated sensors, without user intervention; qualitative information (e.g. empirical observation, notes) is also valuable because: (i) workers can provide critical experience-based information that cannot be measured with sensors, for example the perceived level of panic in an area (ii) workers can complement quantitative data by contextualizing raw data points from sensors with personal notes. In fact data from different sources, sensors and humans, might help in building a more complete perspective of a crisis event; and analysis of alignment and discrepancies might promote critical thinking and reflection [1]. Yet capturing qualitative data with technology requires interactions with computer interfaces, whose design space is limited by rescue protocols and the harsh environments where crises usually unfold.

In the current practice qualitative data is captured by means of vocal messages over radio broadcasts that are transcribed and logged by dispatchers in the control room, and turned in immediate action if needed. This is prone to error and demanding for workers. Often collected information gets biased or distorted by factors like attention loss, impossibility to use tools for collecting data or for communicating it while doing a rescue activity (e.g. carrying someone on a stretcher). Those errors affect both the ability to react timely to events (call dispatcher had to ask again to report missing information) and the completeness and correctness of logs to be used during debriefing.

Tangible interaction and wearable computing can improve the capture of both qualitative and quantitative data during crisis response. TUIs have been considered an interesting approach for implementing intuitive interfaces for crisis management, for example for supporting cooperation in control rooms [5], and for field triage [6].

In this paper we report on the process of designing WATCHiT, a tool for situated capture of qualitative and quantitative data in crisis response. In the following we describe our research methodology and the design challenges we identified from user studies conducted with emergency workers. Later we describe how we tackled challenges in the design and implementation of a working prototype that underwent a formative evaluation with emergency workers during a real training exercise. Our prototype relies on wearable sensors to capture quantitative data and it builds on a token-based interaction approach [7] for tagging sensor data with user-defined text messages encoded in NFC (Near Field Communication) tokens.

Research Methodology

WATCHiT has gone through three user-centered design iterations. User studies and prototypes evaluations were conducted during simulations of crisis events organized for training purposes. These simulations are organized to provide a high degree of realism and recreate working conditions that are as close as possible to real life crises. While the first iteration was meant to get familiar with the domain and to identify main design challenges for devices suitable to be used

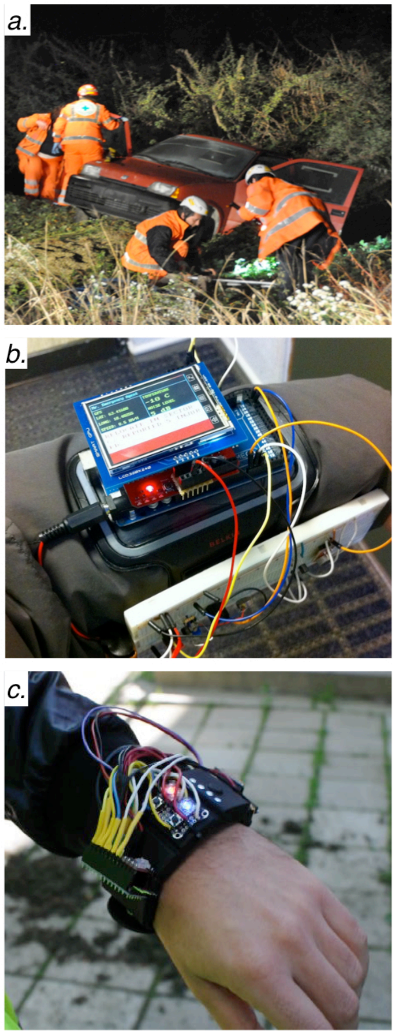

Figure 1: Design iterations and early prototypes

during crises; the following two iterations involved the use of prototypes as *technology probes* [8]. Prototypes were employed to explore the design space, create new scenarios and trigger discussions about technological and usage challenges during focus groups with experts. Data collected during the user studies included video recording of part of the events, notes from one observer, and interviews.

During the first design iteration we performed observation and shadowing of emergency workers during a three-days simulation of massive emergency response held in Italy, in October 2011 (Figure 1-a). Different crisis scenarios were simulated both during daytime and nighttime, including flooding, earthquake and a massive car crash. The simulation involved different units (ER units, civil protection, police, dog units, …), and people with different roles (disaster managers, team coordinators, volunteers, "simulated" victims, …). The simulation was conducted in a physical environment that resembled as much as possible a real emergency (e.g. broken trees, debris, broken cars). Rescue operations involved, in sequence cooperation among: police forces, to handle traffic and fence the operational area, firefighters to explore and secure undisclosed areas, dog handlers to search for survivors and teams of paramedics to activate triage. To communicate data all the party relied on handheld transceivers (also known as walkie-talkies). Call dispatchers in a coordination room were in charge of logging radio communication and of updating a digital map with the location of units.

Building on our first user study, we developed an initial arduino-based prototype of wearable device for capturing and displaying sensor data (noise and temperature) (Figure 1-b) [2] and we tested it against technology acceptance. Results were encouraging and pushed us towards improving wearability and deepening our understanding of which types of information are relevant to be captured and which are not. Building on the evaluation results, we designed a second version of the prototype adopting a watch-like form factor (Figure 1-c). Furthermore in April 2012 we ran a second focus group with 10 emergency workers, with different roles and levels of field experience, to evaluate the prototype and to investigate requirements for new interaction techniques, and to refine scenarios of use.

Design Challenges

Analyzing the data gathered during three user studies we were able to define the following challenges to drive the design of new prototypes.

DC1. Mobility of work and sensing - Due to the nature of crises, sensing information with static sensors embedded in the environment is not always a viable solution. While urban environments are nowadays populated with many sensors, there are large areas of the world that are not instrumented, or not instrumented with the right type of sensors. Since the location where a crisis unfolds is often unforeseeable, it is important to complement data from static sensors with mobile ones. The degree of mobility is also important. While rescue vehicles can be equipped with sensors, the highest degree of mobility is achieved with sensors worn by workers.

DC2. Different crises, different relevant data – Being each crisis almost unique, it is difficult to define which data might be relevant based on generic

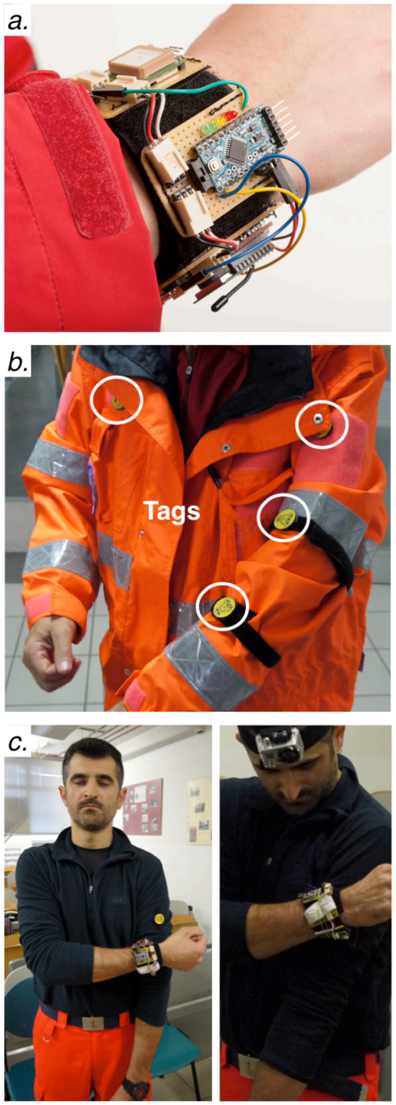

Figure 2: WATCHiT Prototype

typologies of crises. For example gas and radioactive exhalation might be relevant information for a nuclear plant accident but not for a flooding. For these reasons workers have to carry or wear a set of capturing tools for the specific emergency, the set of sensors can be decided only minutes from an emergency. Moreover data is also depending on the role of the worker.

DC3. Different classes of data - Three classes of information have emerged from our studies: (i) information for assessment of worker's safety and well being (e.g. stress levels), (ii) information for mapping the territory (e.g. temperature, noise, air quality), (iii) information for logging the work (e.g. location of operations, number of persons rescued).

DC4. Intuitive, hands-free interaction - Experts drew attention on the need for simple and intuitive user interaction approaches that leaves hands free for the work. The focus of the workers must be as much as possible on the rescue operation and not on data capturing and logging, they say. Most of the tasks a field worker is engaged in require both hands to be free; for example to carry someone on a stretcher, to break into a building or to set up a field hospital as quick as possible. (*"Forearms and hands are needed to be free for movements and to raise weights"* experts say). It is also considered unfeasible to use consumer technology like smartphones because it's nearly impossible to use touchscreens with gloves and the use of a smartphones at work could be misinterpreted in some cultural settings. Because of the harsh working environment audio and visual feedbacks could be problematic but also haptic feedbacks could not be a proper choice because the thick jacket worn by the workers would soften the vibration feedback, unless the device is worn underneath the uniform.

WATCHiT Prototype

In the current design iteration we prototyped a wristband computer named WATCHiT equipped with GPS and noise sensors, ZigBee[1] connectivity and a NFC reader (Figure 2-a). The system has been built leveraging the Arduino platform[2]. The design is modular allowing extra sensor modules to be connected to the arduino board. Data captured (including an identifier of the transmitter) is broadcasted to ZigBee-compatible receivers, enabling data logging and integration with existing information and decision-support systems.

A set of NFC tags encodes qualitative information, text messages, that might be useful to be captured on action. For example texts to contextualize data from the GPS sensor with information about the activity "Here I rescued someone" or for self-assessment of own stress levels during the work e.g. "I'm disappointed", "I'm safe and confident". Tags are labeled with icons. Texts encoded in tags can be customized by the user, before going on duty, using NFC-enabled smartphones (and desktop readers). Tags are sized about a dime and have a Velcro-covered side to allow attaching them to clothes and objects (Figure 2-b).

We addressed the challenge related to hands-free interaction exploiting a token-based interaction with information. In Holmquist et al. [7] terminology the NFC tags we use are *tokens* that physically resemble

[1] Zigebee alliance – http://zigbee.org

[2] Arduino platform – http://arduino.cc

digital information, while the WATCHiT wristband is a *tool* to access and manipulate the digital information contained in the token.

The tool interacts with tokens in the following way. Once WATCHiT is hovered on a token the enclosed text is used to tag location and noise data captured by the wristband computer, the dataset is then broadcasted to receivers. Haptic feedbacks provide eyes-free guidance during the interaction with tokens.

By reading a token hovering the wrist the user performs a body gesture bounded by the token's location, and the wrist where WATCHiT is worn; for example crossing arms when a token is located on the forearm (Figure 2-c). In this way the user can define multiple types of gestures to interact with the system by appending different badges in different body areas. This helps defining gestures that comply with the precise role the worker is engaged on the rescue field, or with symbolic meanings (for example a badge for tagging heart rate data could be worn on the user's chest).

Evaluation

We evaluated our prototype with two emergency workers during simulated rescue operations in a city park setting. Workers were presented with the device and asked to self-assess their stress levels in different location using the token-based interaction. We used a semi-structured interview to gather their feedbacks about the prototype; we video recorded the exercise for further analysis. The goal was to evaluate the technology acceptance of the device and user interaction approach.

Initial results show that the token-based interaction technique was well accepted. The workers could easily fit WATCHiT underneath the heavy work uniform and they appreciated the hands-free interaction and the freedom of movement. We validated that body gestures (e.g. shaking or crossing arms), which leave hands free, are a suitable approach for the interaction with the device during simulated operations, to tag the capture of a particular data without interrupting the work. Tokens can be worn on the work uniform using bands and Velcro (work uniforms observed in action already used Velcro bands for attaching labels like the name and field role). Workers also reported to have clearly perceived all the tactile feedback generated by the wristband computer.

On the other side the WATCHiT prototype was too fragile to be used during a simulation and consequently during a real emergency. The perceived fragility of the devices made the worker keep focus on protecting the device from shocks and contributed to distract them from their tasks. Indeed one of the two WATCHiT got damaged during the experiment.

Related works

Several works investigated the use of “Body-centric interactions” [3] in order to exploit body movements for triggering digital operations. In [11] Pasquero et al. investigate exploiting eyes-free tactile interactions on a wristband prototype for acquiring information from a companion mobile device. The wrist is used as an anchor point to perform hand gestures like cover-and-hold, shake and swipe. Similar to this work, the “Gesture watch” [9] investigates contact-free hand gestures over a watch-like device to control media players. While the above-mentioned projects use the wrist or a surface as anchor points for gestures recognition, Cho et al. [4] exploit the capture of forearm gestures in the air using accelerometers embedded in a armband.

Conclusions and future work

Through a user centered iterative process we defined design challenges for computer-augmented qualitative and quantitative data capture in crisis management. The work has informed the design of the WATCHiT prototype that partially addresses the highlighted challenges. Initial results from user evaluation show that the designed interaction approach was well accepted but the prototype need to be more robust before undergoing more evaluations.

Further work is needed to address all the challenges we drafted. For example the challenge of capturing relevant information no matter the type of emergency (DC2) still need to be addressed. Moreover evaluating prototypes in even just simulated emergencies requires a degree of physical resilience of prototypes beyond what is usually required with testing with the general public. Additional studies about the impact of user interfaces on rescue work need to be performed in order to assess if such tool could be safely used in a real emergency or should be only employed during training.

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