Letting Tools Talk: Interactive Technology for Firefighting

Sebastian Denef
Fraunhofer FIT
Schloss Birlinghoven
53754 Sankt Augustin
Germany
sebastian.denef@fit.fraunhofer.de

Leonardo Ramirez
Fraunhofer FIT
Schloss Birlinghoven
53754 Sankt Augustin
Germany
leonardo.ramirez@fit.fraunhofer.de

Tobias Dyrks
Fraunhofer FIT
Schloss Birlinghoven
53754 Sankt Augustin
Germany
tobias.dyrks@fit.fraunhofer.de

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Abstract
In this work-in-progress report we present the results of a preliminary analysis of a set of fieldwork studies conducted in collaboration with a firefighter school and a firefighter brigade. To inspire the design of ubiquitous computing systems, we provide a description of the equipment used by firefighters, practices built upon them and a set of common properties.

Keywords
Firefighting, Safety-Critical HCI, Ubiquitous Computing, Ethnography

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Fighting fire is a multi-faceted task in a hazardous environment that changes dynamically during an intervention [2]. While it is relatively easy to imagine visions of ubiquitous computing providing support to this work, designing practicable solutions remains an open challenge. The work on the first line of intervention is rather complex and requires a set of very specific skills and tools. It is often conducted in buildings full of smoke, which can only be accessed by

crawling on the floor due to heat distribution while carrying heavy weighted equipment. Design for such a complex domain confronts technology developers with a highly complex set of constraints. The mixture of cognitive and physical load, protective clothing and special equipment leaves very little space for human-computer interaction.

As of today, very little interaction methods are able to cope with this challenging environment. A large part of the research in firefighter domain aim to provide computer support for firefighting mainly for command and coordination emergency response work that takes place in relatively safe and less restrictive environments [4]. Research projects targeting the first line of intervention focus often on specific technological elements but disregard relevant aspects of human computer interaction. Here, firefighting scenarios are used as a motivation or explanation for the need of certain interaction mechanisms but resulting systems are rarely usable in real-world scenarios. Instead, they simply adapt and apply interaction techniques designed for everyday use of mobile technology [3] or optimistically rely on relatively novel interaction techniques such as head-mounted displays [7] without evaluating the implications that they actually have for real-world conditions. The little work that specifically focuses on interaction techniques for firefighting [5] focuses on single aspects of firefighting practices but does not take into account the complete socio-technical system of firefighting work. Successful interaction design of ubiquitous computing for firefighting requires, however, specific methods for firefighters, which take into account the full complexity of the task.

Within the scope of the landmarke project [1], we are working on HCI for firefighters on the first line of intervention. Our ultimate goal is the construction of interactive technologies for this challenging environment from within its specific context, understanding how technology and practices are related with each other in this specific domain. The first step we took for this task was to study the tools already in use, in order to gain an understanding of interaction in firefighting and look for intrinsic qualities that this interaction presents and that can be used to inform and inspire our design.

We present here the result of a preliminary analysis of a corpus of data coming from a set of qualitative studies conducted in collaboration with a firefighter school and a firefighter brigade. We describe the equipment used by firefighters and the practices built around them, and extract a set of properties that can be of interest for the rest of the process. We discuss our findings and provide an outlook to the coming work in our research.

Fieldwork

The corpus of data used to support this paper comes from a set of empirical studies conducted with firefighters over the course of six months. As we cannot have access to real emergency incidents for safety reasons, we used instead professional training and simulation installations as our field of study, and then worked with experienced firefighters to establish a connection between these experiences and real-world incidents. The following studies were the base for our work:

A *Massive Role-Playing Workshop* simulated an entire intervention of a fire in an apartment with a complete brigade comprising 4 trucks and 11 fully equipped teams, each of them composed by one professional firefighters and one researcher. The simulation was conducted in a large-scale, computer-controlled simulation facility, where special lights and sounds as well as a fog machine were used to vividly reproduce an incident scenario.

An *Indoor Tactics Training* focused on the work inside a building filled with smoke. During the exercise researchers and professional firefighters worked fully equipped in teams to find a victim inside and bring her safely outside of the building.

In a *Reconnaissance Mission* teams worked under supervision of a professional firefighter and carried all the equipment and tools to learn about the different roles and responsibilities of each member of a team.

A *Heat Training* in which a team of two researchers had to perform physical tasks in a controlled burning environment with high temperatures and poor visibility conditions, to learn about the stress created by such a situation and the role that isolating clothes play.

A *Breathing Fitness Test* in which a team of researchers had to find their way to a two-story labyrinth by climbing through pipes, opening small doors and using hatches to change floor levels before depleting the air of their breathing apparatuses.

The studies were documented using photography and video recordings and were followed by discussions around the experiences.

Firefighting Tools

Protection: Firefighters wear protective clothing composed of trousers, a jacket and a set of insulated gloves, which provide isolation from heat. Both trousers and the jacket feature numerous pockets to carry additional equipment. It is important to keep layers of air in between the layers of clothing, as this provides most of the insulation from heat. All other equipment worn on top therefore needs to be relatively loose. At some points during an intervention is necessary to take off the gloves, for example to feel the temperature of a door before opening it as a hot door might signify the danger of a flash-over explosion. While taking off a glove, firemen must prevent hot air from getting inside the glove, in order to avoid burns.

Breathing: To be able to breathe in such a hostile environment, firefighters carry a self-contained breathing apparatus, or SCBA, composed of a breathing mask and a bottle of compressed air. A single bottle holds air for approximately 30 minutes, compressed to around 300 bars of pressure. For special missions, two of these bottles can be combined. The bottle features a pressure control unit, a display of about 5 cm in diameter connected to the breathing apparatus via a tube hanging over the shoulder of the firefighter. Although the background of the display glows in the dark, finding it and putting it close enough to be read is not an easy task in complete darkness, let alone reading it. If the pressure goes below 50 bars, a high-pitched sound alarm triggers. The seats in the trucks provide space for the SCBA, allowing firefighters to wear it during the drive to the incident site. The connection of the bottle to the mask is always made by a teammate to ensure that everything is correctly connected.

Supervising: Before engaging on a mission, firefighters take out of the bottom of the breathing apparatus a small plastic card with their name on it. This card is then put into a mission control board on which the team commander writes down the pressure when the mission started. The board also includes a timer that is set to 10 minutes. After the time has lapsed, the team has to announce the remaining amount of air pressure via radio. After one third of the pressure is gone, teams are advised to return. This way, they ensure to keep enough air for the way back and for any unforeseen problems.

Carrying and using water: Water is an extremely flexible and important tool in firefighting. It is used, among other things, to extinguish fire, to provide protection and to move air and smoke between rooms. The water is distributed using heavy-duty fire hoses, and for streaming water a fire nozzle is used. Hoses used inside buildings are 15 meters of length. Firefighters may need to carry the hoses to higher floor levels. Dedicated cages hold three hoses. For high-rise buildings they carry two hoses tied together with special hose holders that also allow fixing the hose to the handrails so that firefighters doesn't need to carry the whole weight of the hose all the time. The hose pieces are connected together by metal couplings. These couplings can cause problems if they get stuck, especially in doors or around corners. To deal with this, firefighters carry a number of wooden wedges that they put under doors to keep them open. This practice has the downside effect that open doors may allow smoke to enter new places.

The fire nozzle is a heavy, gun-like artifact that provides a steady stream of water with variable flow and aperture. It provides a moving ring to control the width of the water stream and a large handle to control the amount of flowing of water. Water spouts out when this handle is pulled back. This is designed in this way so when an explosion occurs, the movement of the firefighter automatically opens the nozzle, shielding the fireman with water. To prevent such explosions, firefighters use small amounts of water to cool down the hot air at the ceiling before entering rooms. This requires a delicate control of flow and aperture, as firefighters must prevent producing too much steam, which works as an excellent heat conductor and can quickly raise the temperature of the environment.

Navigation: The fire hose serves a variety of purposes besides moving water. When entering a building, it provides a clear retreat path. Ensuring a safe retreat path is an extremely important task in firefighting. Firefighters carry an ax allowing them to open closed doors and windows. The last person in a team carries the ax. While scanning rooms the wooden shaft is used to feel the environment. It allows searching for victims under beds and behind other obstacles. A carried flashlight may also support the search if the room is not fully filled with smoke. When starting the search in a room, firefighters mark the door with a stroke of wax chalk. After completing the room, a second stroke marks the room successfully scanned. Firefighters carry a 30 m rope, the so-called lifeline. This rope can serve as an alternative to the pipe on missions where fire hose are not used, for marking the retreat path. It can also be used when a large room has to be scanned and firefighters cannot find their way using only the walls. The lifeline connects two teammates, one staying in a fixed place and the other scanning the room in circles navigating along the lifeline. In a major incident in

1996 a firefighter lost his life as he was caught up in his lifeline. As a direct result of this incident, firefighters carry a knife to free themselves from the line if necessary.

Communication: Radio communication is also an essential tool for the work of firefighting. While advanced technology such as bone microphones exists, for economical reasons, firefighters use a standard hand controlled device that they carry in a pocket of their jacket. It is quite difficult to control the device while wearing gloves. Firefighters therefore switch on the device long before they reach the incident site and do not interact with it again. Attached to the device is an external speaker and microphone. This device features a push-to-talk button and has a clip that allows it to be attached to the collar of the jacket or to the helmet. Using this device while wearing a breathing mask can be rather challenging, and the structure of the incident site may additionally affect the performance of the radio communication.

Other tools: Firefighters carry additionally a number of varying, small items. The selection of these items is a personal decision of firefighters, and represents a strong statement of things that a firefighter might need during his work in an intervention. Standard keys allow removing pillars and access to gates as well as opening restroom doors and doors where the doorknob has been damaged by fire. A firefighter carried a seatbelt to tie things together or pull things out. Others also brought small saws, screwdrivers and multi-function tools. Some more special tools such as pH meter paper that is usually only stored on the trucks could also be found as personal equipment.

Properties

In the study and when reflecting on field data, we were looking for surprising facts and repeating patterns to collect a set of properties of the tools that we observed. These properties go beyond purely physical properties such as robustness, heat or water resistance. Although such physical qualities are also relevant for our design work, they have been extensively captured in the literature. What we were looking for was the way in which the equipment is entangled with the practices of firefighters, and the affordances that it provides in the frame of the work. A preliminary collection of these properties follows.

Assigned tools are role-based: Each firefighter carries a set of tools specific for the role he has been assigned to. This role is pre-defined in the work schedule and defines a set of responsibilities, tasks and even the seat he takes in the truck. Based on this division of work, a pre-defined set of tools is assigned to each firefighter.

Tools are personal: Firefighters carry different stuff in different places. Here, they resort to their experience in relation to their assigned roles and there are no standards for this equipment. Some prefer carrying redundant equipment that is usually to be found only in the truck. Some of these tools are also built ad hoc by firefighters in the warehouse on the fire based on their experience and specific needs.

Tools reflect experience and status: In describing their tools, we found firefighters to use them as a way to capture and express experience. A firefighter told us that he always carries a piece of safety belt with him and that in case somebody forgot e.g. the pipe holders, he is prepared for the situation and can assist his less

experienced teammate. Being prepared, being able to handle any situation is a life-saving qualification reflected in the tools people carry.

Tools are simple and multi-purpose: Firefighting relies on high levels of improvisation practices [2]. When looking at how tools are used, we found that firefighters consciously prepare for improvising. Every tool was simple to explain but used in more than one way and firefighters actively looked for new ways of using tools. The safety belt piece, for instance, could also be used to drag a person. Firefighters stressed that they continuously have to improvise and need to prepare for the unforeseen.

Discussion & Future Work

In this work-in-progress report we provided a preliminary analysis of the tools used by firefighters working on the first line of intervention. They are based on a set of field studies conducted in close collaboration with firefighters. Ubicomp for firefighters has largely neglected the complex nature of firefighting, focusing on transferring technology for other areas of research and adapting them to firefighting. Contrasting with that, we are focusing on creating technology reaching from the contextual nature of firefighting towards ubicomp, and not the other way around.

There is an intrinsic complexity in ubicomp systems that cannot be denied and the properties we derived from our studies are not easy to be materialized within this context. Yet, we think that they capture a fundamental character of the tools used in firefighting, and could be helpful in inspiring and informing interactive tools for firefighters on the first line of an intervention.

In our future work we hope to reify the identified qualities and produce a ground for a solid set of interaction mechanisms as part of a system providing support in indoor navigation [6] for firefighters working on the first line of intervention.

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Citations

[1] *landmarke project*. 2008 [cited 2008 12/12]; Available from: http://landmarke-projekt.de.
[2] Denef, S., L. Ramirez, T. Dyrks, and G. Stevens, *Handy navigation in ever-changings Spaces: an ethnographic study of firefighting practices*. DIS 2008, ACM: Cape Town, South Africa. p. 184-192.
[3] Jiang, X., N.Y. Chen, J.I. Hong, K. Wang, L. Takayama, and J.A. Landay, *Siren: Context-aware Computing for Firefighting*, in *Pervasive Computing*. 2004, Springer: Berlin. p. 87 - 105.
[4] Landgren, J. and U. Nulden, *A study of emergency response work: patterns of mobile phone interaction*. CHI 2007, ACM: San Jose, California, USA. p. 1323 - 1332
[5] Naghsh, A.M. and C.R. Roast, *Designing user interaction with robots swarms in emergency settings*. NordiCHI 2008, ACM: Lund, Sweden. p. 519 - 522.
[6] Ramirez, L., S. Denef, and T. Dyrks, *Towards Human-Centered Support for Indoor Navigation*. CHI 2009, ACM: Boston, USA. p. Forthcoming.
[7] Wilson, J., V. Bhargava, A. Redfern, and P. Wright. *A Wireless Sensor Network and Incident Command Interface for Urban Firefighting*. in *Mobile and Ubiquitous Systems: Networking & Services, 2007. MobiQuitous 2007.*