Towards Human-Centered Support for Indoor Navigation

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ABSTRACT
This paper presents a new perspective for the design of indoor navigation support. In contrast to technology oriented approaches coming from Context Awareness research, we argue for a wider focus that complements the technical question of providing precise indoor location with the development of more effective navigation practices based on technology available today. Starting from research on indoor navigation conducted with the Paris Fire Brigade, we present two design concepts aimed at supporting firefighters in creating and finding their own paths, together with some of the design strategies that informed the creation of these concepts.

Author Keywords
Indoor Navigation, Ubiquitous Computing, Firefighting

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces (User-centered design).

INTRODUCTION
In the frame of a large research project [11], we worked together with the Paris Fire Brigade in conducting a participatory design process of technology for firefighters working on the first line of intervention. The goal of this work was to explore the navigational practices of firefighters and to look for opportunities for the introduction of ubiquitous computing solutions to support these practices.

NAVIGATION OF UNKNOWN SPACES
Firefighting constitutes a highly complex activity that heavily relies on experience and training. Roles in an intervention change dynamically and decisions respond to highly unpredictable situations, resorting to implicit knowledge constructed through experience. Available information is often incomplete due to the complexities of an intervention, and processing time for this information is limited, as the focus of attention moves rapidly between different tasks during an intervention.

A common practice of firefighters is the performance of reconnaissance missions. Their goal is to help firefighters in building a shared understanding of the situation and to define and organize the tasks to be accomplished during the intervention. These missions are conducted in unknown environments, often under very poor visibility due to smoke or poor illumination conditions. Although firefighters are specifically trained to use advanced cognitive skills and complex physical techniques to navigate under such conditions, performing a reconnaissance mission always represents a source of risk [8]. Currently, little or no information technology comes into play for preventing this kind of accidents. The expert work of firefighters and the complex shift of interaction paradigms conveyed in mobile computing pose a particular challenge for the design of viable systems.

TECHNOLOGY FOR INDOOR NAVIGATION
One consequence of the Ubiquitous Computing vision, articulated by Mark Weiser in 1991 [18], has been a progressive instrumentation of the reality, created by sensors embedded in the environment or attached to objects and garments. Context Awareness, one of the fundamental fields of research motivated by Ubiquitous Computing, has been working with this instrumentation for the last 15 years, looking for answers to the question of how the circumstances in which a user task occurs could be leveraged to provide enriched support [5].

In the tradition of Context Awareness, indoor navigation support has been addressed either by focusing on the technical problem of obtaining precise position information indoors [9, 12], separating it from the contextual nature of navigation; or by postponing the problem of perfect positioning, assuming that it will be solved at some point [1] and working on solutions based on its availability [13, 17]. Both options are not really distinct, but rather two aspects of the same approach—one that equates the question of indoor navigation support with the question of precise position information.

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Centering the problem of navigation on positioning, however, disregards the very nature of navigation as an entanglement of technologies and practices. Navigation, more than just a technical artifact, is an art, constructed around technical possibilities such as orientation or positioning tools, but primarily based on the cognitive and embodied skills used by people engaged in a specific situation requiring navigation [2]. In our case, firefighters doing a reconnaissance mission use a collection of specific tools and signs available around them to find out where they have been, where they are and how to find the way to where they want to be. Hence, beyond the construction of more or less precise positioning systems, the motivating question for Ubicomp supporting indoor navigation of firefighters must lie on how to specifically provide contextual information to firefighters as a useful resource [6] for building more effective practices, overcoming the problems of uncertainty and unreliability of available technology.

DESIGNING TOOLS FOR NAVIGATION SUPPORT

With technology readily available today, it is possible to capture temperature, movement and quite a few other environmental circumstances. Moving from the simple availability of contextual information to a set of useful practices, however, requires the emergence of an appropriation process driven by the interactions between the available technology and the interpretation and practices that users build around these technologies. To spark this process of reflection and appropriation, we follow an approach in which both Participatory Design [7] and Ethnography [14] play a central role.

The design and introduction of technology in our process plays two roles. First, it works as tool to explore practices. Second, it works as a seed of innovation from within practices [16]. This double role of technology is rooted in the work of Crabtree on transferring the ethnomethodological concept of breaching experiment to the study of new technology [3], and the strategies of Gaver for the use of multiple interpretations in the design of technology [15]. Our goal with this double use is to organically grow technological artifacts from inside the work practices and intertwined with them, in a process driven by the design of technology.

FIELDWORK TO INFORM DESIGN

The starting point for our work was an approach to the work of firefighters working on the first line of an intervention. We conducted two qualitative studies in Paris in which we observed firefighters in a usual work situation, in order to get an insight of navigation practices and to look for opportunities for supportive technology. From the analysis of the videos, images, field notes and transcripts of the fieldwork, a set of core issues or patterns emerged, which captured some of the essence of what we learned. A detailed account of the studies can be found in [4]. Four of these issues are relevant for the design concepts presented in this paper:

Cooperative navigation

Teamwork is a central element in firefighting and defines and highly affects every detail of the practices. There is a strong bond of responsibility between firefighters that provides the basis for collaboration. Navigation is a task that involves a whole team. Firefighters always engage in reconnaissance missions in teams of two, actively share information about actions performed and link this information to places.

Improvisation as a strategy

Firefighting requires lots of improvisation and instinctive reactions. Existing hierarchical structures of command define action patterns and provide a common reference frame that supports very fast intuitive decisions. Some of the improvised practices emerge later, in debriefing sessions and then evolve slowly to standard practices.

Shared ad-hoc reference systems

Firefighters resort to a complex set of practices to overcome the absence of supporting navigation infrastructure. They combine their common sense with the use of available supporting structures like walls, doors or stairs; and build collections of reference systems that support them in their reflections on space. Over the course of an incident these reference systems change, adjusting dynamically to new conditions.

Appropriation as the creative (re-)action to changes

We were able to observe the dynamical emergence of new practices as a response to the introduction of supportive technology. Current practices present a very complex behavior when confronted with the introduction of new technical elements, and the effects observed were rather unexpected.

TWO CONCEPTS FOR HUMAN CENTERED NAVIGATION SUPPORT

Following our studies in Paris, we worked on the creation of design concepts conceived in a way that makes them realizable by using existing or emerging technologies. We specifically aimed at centering their potential on the relevance that contextual information could have for navigation instead of focusing on the availability of any particular positioning technology. The core guideline that we chose for our design is that, beyond telling firefighters where to go, we wanted to help them in creating their own paths, providing tools to support their spatial cognition and navigation practices rather than blindly guiding them through predefined paths based on more or less precise location information.

To define a space where to look for design ideas, we worked specifically on our observation of the way in which firefighters collaboratively use reference points to build shared navigational models both while navigating and

while debriefing after a reconnaissance mission. Inspired by this observation, we created a central design theme around the creation of ad-hoc reference systems, that is, systems detached from the explored infrastructure, deployed in-situ by firefighters as a way to establish a relatively stable semiotic connection with an unknown environment. Such a system should offer a collection of building blocks without any strong associated semantics, to support the construction of a mental model that can serve as a basis for the communication of ideas around space. By supporting this construction, we can compensate for deficiencies and shortcomings of location systems and other technologies by leveraging the highly trained cognitive skills that firefighters use when navigating in unknown environments.

In the following, as an example of the shift of focus that we are arguing for, we present two concepts created around the described design theme.

Augmented Lifeline

Following a standard procedure, teams entering a building use a so-called 'lifeline', a rope latched on one end to the belt of the exploring firefighters and held on the other end by a team leader who is in charge of pulling out the lifeline when requested by the exploring team, to guide them outside the building. The first concept, which we called Augmented Lifeline [Figure 1], is inspired by the way firefighters make use of this lifeline as a reference system for finding a retreat path, and explores the extension of existing artifacts using small modifications that build upon existing interpretations of technology. It envisions the construction of a one-dimensional reference system on top of the existing lifeline by embedding sensors at fixed intervals along the rope. These sensors can read information from the environment, including every time that a firefighter passes by, and can also store pieces of information coming from the firefighters in specific portions of the line.

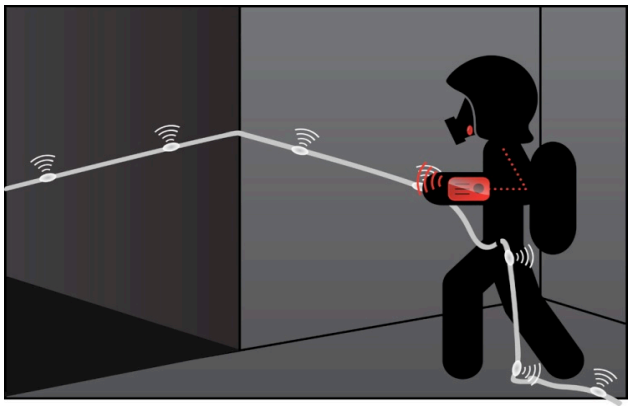

Figure 1: Augmented Lifeline

The augmentation of the line creates a finer-grained spatial reference on top of the essential reference offered by the rope itself, providing the foundation for a vocabulary to speak about places and trajectories. It becomes a live record that can talk about the use of the line in relation to space. It can answer questions like how far a firefighter walked along the line, or where in the line a firefighter was last seen, questions that can play a very relevant role for orientation in the environment and for the rescue of injured firefighters, without being specifically dependant on precise location information

Augmented Landmarks

In the Augmented Landmarks concept, we play with the idea of physical markings in the space to provide an additional layer of spatial information to support and enrich navigation practices. This idea is connected to the use made by firefighters of features of the environment to navigate, as well as to the strong improvisational character of their work. Based on the idea of sensor networks, the concept is envisioned as an ad-hoc reference system based on a mesh of small deployable tokens, which can store a certain amount of information and communicate to each other in order to share information about their whereabouts.

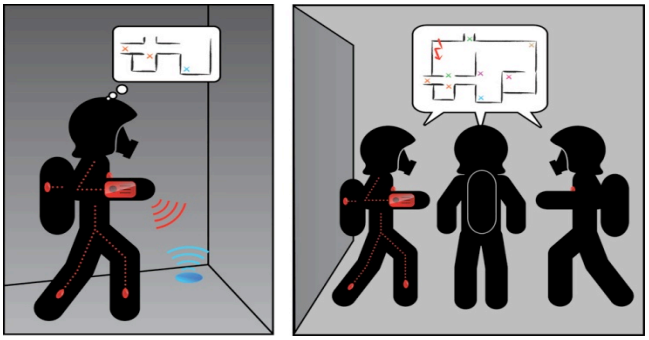

Figure 2: Augmented Landmarks

During a mission, firefighters deploy tokens to annotate the space with small units of information that form an ad-hoc reference system to be used as a guide for finding navigation paths and that can also support the whole team in building a shared mental model. Once dropped, an augmented landmark works as a probe that senses around for ambient information such as firefighters passing by, noises, temperature, etc; and that stores this information for further encounters with firefighters, creating a rich layer of information. Firefighters can read or write new information in a token as soon as they enter the range of reach of the device. This limitation of reach in the devices allows each Landmark to define a place, a locality that works as a reference for orientation in the environment [Figure 2]. Firefighters can build upon this localities to talk about space and communicate ideas such as path descriptions ("walk to landmark 3 and turn left") or events related to a place ("I was here before", "I turned left here on my entry way"). Again, this communication does not depend on precise positioning, but on the interpretation practices created around the tokens.

FUTURE WORK

The concepts described here became the base for a new project involving a fire brigade, a firefighting school and partners from industry and academia. In this frame, the concepts are currently being further discussed and extended in participatory design sessions, in which firefighters and technical partners evaluate the potential of the new concepts and provide ideas for their practical implementation using technologies such as RFID and relative positioning [10]. To further develop our ideas, we are working on prototypical implementations for both of the concepts presented here. The main goal for these prototypes is to stimulate further steps in the design process. They should get embedded into the co-evolution cycle of technology and interpretation practices in firefighting, bringing new ideas and solutions into our design process, and at the same time, expanding our understanding of navigation practices.

CONCLUSIONS

In this paper we argued for a new perspective on the design of Ubicomp technology for supporting indoor navigation in poor-visibility conditions. A central concern of this work, and probably its main innovation, was to avoid answering the technical question of positioning. Our argument was that the main question for indoor navigation supports should not lie in finding technological solutions for precise indoor positioning, but in finding ways for bringing available digitally-mediated information into the specific navigation practices that we intend to support. To find these ways, we should give artifacts the chance of playing a richer set of roles in relation to context. Design can provide this chance if we find the right methodological tools for using it and listen very carefully to what the process of appropriation has to say.

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