Towards an Indoor Navigation Application for Emergency Evacuations and Persons with Visual Impairments – Experiences from first responders and end users

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Abstract. As natural and human disaster are increasingly affecting people's lives around the globe in a growing and variegated way, the need to be prepared for a variety of conditions is imperative. Notwithstanding the relevance of ICT in assisting in preparedness and the importance of addressing the diversity of the population have been recognized, there are still gaps in understanding *How* to properly apply these principles in emergency management. This study explores how indoor navigation technology can contribute to faster, better and safer evacuations by providing useful information to emergency personnel and affected public at the scene of the evacuation. For this purpose, the ongoing INSIDE project aims to take an existing mobile app that provides universally designed indoor-navigation at Oslo Metropolitan University, the *OsloMet application*, and re-design it to support first responders with situational awareness assistance as well as to assist the public in evacuating efficiently. Contextually, a survey has been conducted among emergency services' representatives, in order to identify what information and functionality could be valuable for their work during emergency evacuations.

Keywords: Universal Design, Accessibility, Disability, Emergency Situations.

1 Introduction

Natural as well as man-made disasters are affecting people's lives around the world in a very disruptive manner. The increasingly felt effects of climate change and human conflicts are contributing to the necessity of being prepared for a variety of emergency situations. There is much research on how ICT can assist in preparedness, mitigation and rescue operations during emergencies, and there is also an increasing awareness of the need of taking into account the diversity of the population [1], as well as the need for ensuring that the relevant ICT tools are accessible by all [2]. UNDRR's Sendai Framework for Disaster Risk Reduction (SFDRR) of 2015 in particular addresses people with disabilities in disaster risk reduction and the need for universal design [3].

However, there are still gaps between these goals and the current reality that need to be bridged:

- Understanding *what/who* vs. understanding *how*:
  - It is well known that we need to pay attention to diversity in disaster situations e.g. during evacuation and make sure that in particular people with disabilities and the elderly are taken care of, but it may be less obvious how to do this in practice [2].
- *Motivation* vs. *implementation*:
  - Even if the requirements are clear, the implementation may fail to consider all aspects the situation and the diversity among users; e.g. to properly cover the needs of people with disabilities [4] and those affected by situational disabilities in disaster situations [5].

Universally designed ICT-assisted indoor navigation is a promising approach to the problem of evacuating a building with a diverse group of people, including employees that may know the building well, but also first-time visitors and people with visual impairments [6]. The ongoing INSIDE project aims to take an existing mobile app that provides universally designed indoor-navigation at Oslo Metropolitan University, the *OsloMet application*, and re-design it to support first responders with situational awareness assistance as well as to assist the public in evacuating efficiently [7]. The original OsloMet application is based on a network of low-energy Bluetooth (BLE) beacons paired with a mobile app to provide a way-finding solution for everyone, including persons with visual disabilities. The approach of using BLE beacons for indoor way-finding has been successfully tested in laboratory and controlled experimental settings [8]. The application is iOS-based and uses the VoiceOver functionality of the operating system to provide voice control.

The main objective of this study is to investigate how indoor navigation technology can contribute to faster, better and safer evacuations by providing useful information to the emergency personnel and the affected public at the scene of the evacuation.

The rest of the article is organized as follows: This introduction is followed by a literature review in Section 2, while Section 3 provides an overview of the methods used in this study. Section 4 presents and analyzes results, and finally discussion followed by conclusions and future work are covered in Sections 5 and 6.

2 Literature Review

2.1 Human Rights and Emergency Situations

The protection of human rights has without doubt improved since the promulgation of the Declaration of Human Rights in 1948 and on a national and international level governments have made numerous steps forward. However, an acceptable standard of conduct by States during internal conflict is far from achieved [9]. Research suggests that public emergencies pose a heightened threat of serious and systematic human rights abuse when States employ extraordinary powers to address threats to public order [10].

To reduce this risk, the United Nation adopted the International Covenant on Civil and Political Rights (ICCPR) in 1966, which requires the States to notify the international community hastily when a suspension of their human rights obligations is required due to national crises (art. 41). The derogation of human rights obligations is possible thanks to two criteria expressed by the ICCPR: the presence of a public emergency threatening the life of the State, and the necessity to adopt emergency measures due to the exigencies of the situation [9]. Nonetheless, states of emergency have been declared by governments around the world to face a vast assortment of crises, including political unrest, general civil unrest, criminal or terrorist violence, labor strikes, economic emergencies, the collapse of public institutions, the spread of infectious diseases, and natural disasters (U.N. Treaty Collection Database). These initiatives are actually in contrast with the "Lawless" criteria for declaring a state of emergency, which affirms that the threat must be present or imminent, exceptional, and a "threat to the organized life of the community". As a consequence, even the threat posed by terrorist groups such as Al Qaeda seldom justify a declaration of emergency [11]. To overcome the ambiguity of these parameters, the academic world has suggested four non-derogable human rights: 1) the right to life; 2) prohibition of torture; 3) prohibition of slavery; 4) prohibition of retroactive penalties for crimes [9]. The said four points are to be added to the three non-derogable human rights already highlighted by the ICCPR: the prohibition of imprisonment for breach of contract, the right to recognition as a person before the law and the right to freedom of thought, conscience and religion. Not considering the theoretical aspect, there is no evidence of a universal acceptance of any of these [9]. It is also unclear whether and to what extent obligations for accessibility constitute a non-derogable right for persons with disabilities.

2.2 Universal Design

According to the U.S. Census Bureau, disadvantaged populations include persons with disabilities, elderly, indigent and illiterate, and cover more than 50% of the U.S. population. In view of the above, it is clear that keeping on using the term "special needs" does a disservice to the groups included in the definition and reduces the chances of planning interventions for specific needs and, consequently, providing an efficient, inclusive response [12]. It is also important to notice that disasters, terrorism and other emergency situations tend to instantly increase the number of people with disabilities and functional limitations, temporarily or permanently, both as a physical or psychological consequence of the traumatic event and due to the environment's conditions [13].

Eliminating the use of a "special needs" category could improve disaster preparation and emergency response processes, procedures and systems introducing the consideration of humanity as a totality of different individualities into the fabric and culture of emergency management and disaster planning. If disability and other socially disadvantaged groups keep being considered as unique or special isolated entities the system's existing inefficiencies and inefficacies will continue [12]. To achieve this necessary upgrade the universal design perspective needs to be adopted, in order to address the needs of a variegated population that deserves consideration.

3 Methods and Research Design

The data collection has been conducted in two parts. First, a quantitative research study was conducted amongst emergency service personnel in order to understand their needs and interest for implementing an indoor navigation application in their work with evacuations. Second, a framework for user testing was developed with an aim of determining improvement areas in the indoor navigation application.

The survey consists of a combination of open-ended and closed questions: Open-ended questions were used to address specific concerns that demanded qualitative feedback, whereas closed questions were used to collect quantitative data for statistical purposes. The main target group for the survey was emergency response personnel from the Norwegian fire-and-rescue department, police and paramedics. Some factors that differentiates them from the rest of the respondents are:

1. their location when the emergency occurs (outside of the evacuation site). Emergency response personnel cover large areas and move in to assist where they are needed. This implies less local knowledge about the specific buildings they are called out to and a longer response time than personnel stationed on-site.

2. Higher level of responsibility. This group carries the main responsibility for the evacuation and public safety once arrived at the scene.

Based on these factors, one can assume an indoor navigation solution could be very valuable for this group. Nevertheless, the personnel working on-site with evacuations cannot be omitted since most evacuations take place before the emergency response personnel arrive at the scene. One major group within this segment is security officers. Other relevant groups are personnel that work with emergency preparedness, Environment Health Safety, as floor or chief wardens. Great care was taken in choosing whom the survey was distributed to since the survey responses were anonymous, which would make any link between the response and a specific person impossible to determine. Thereby, the answers were provided only by the qualified personnel. Each response was also thoroughly checked during the translation- and data analysis- process to verify whether had occurred any invalid or duplicated responses. Three of the responses were removed before data analysis, two of which derived from the pre-test of the survey from persons that had never taken part in an evacuation before, which made them not entitled to answer. Personal identifiable information about the personnel the project team corresponded with directly has also been anonymized due to confidentiality rights. The correspondence was conducted via e-mail and personal Facebook messages between the personnel and the project group.

A survey has been conducted with emergency services' representatives with the intention to identify what information and functionality could be valuable for their work during emergency evacuations. Personnel from the fire-and-rescue services, paramedics, police and security offices took part in the questionnaire. The questions were formulated to provide crucial information considering their roles, experiences and outlooks on emergency situations procedures. The amount of the obtained survey responses was equal to one hundred and twenty-two (122).

The survey consisted of three parts. The objective of the first part was to collect necessary data about the respondents' background and their experience with emergency

evacuations. The second segment aimed to obtain information considering those situations they had assisted in. Finally, the third part intended to investigate the utility of the OsloMet application's implemented and planned features.

Lastly, a framework for user testing was developed with an aim to determine possible improvement areas in the OsloMet application. For this purpose, the users were asked to fill in two surveys and fulfill the requirements adding to the user test. The first questionnaire was a System Usability Scale (SUS) followed by a user test of the application, where the participants had to find a location in the building. Notes and comments were made by both users and conductors.

4 Results and Analysis

In the first part of the analysis, the results from the survey with emergency service personnel will be presented. Then the second part of the analysis will present the results of the indoor navigation usability tests.

4.1 Results from Emergency Service Survey

The emergency service personnel came from a variety of backgrounds. Nearly half of the respondents came from fire-and-rescue service providers. Other respondents included police officers (28%), paramedics (13%), security officers (7%) and others (7%). 78% of respondents had a leadership role in their organization, and the remaining had non-leadership roles. All respondents had assisted in emergency evacuations with 53% having assisted in 15 or more evacuations, 7% in 10 to 14, 17% in five to nine, and 23% in less than four. The most common types of emergency evacuation with which the respondents were involved included fire (n=113), followed by terrorism and life-threatening violence (n=31), gas leakage (n=52), natural disaster (n=31). Less common were accidents (n=5), other emergency situations (n=9).

Respondents also provided useful results on their experiences during emergency evacuations. During emergencies, their primary source of information came from callers and call centers (33%). In addition, respondents also cited their leaders (16%), people on the scene (16%), radio communication (13%), local guides (12%) and their own experiences or training (10%) as their primary source of information. However, these results differ based on whether the respondent had a leadership or non-leadership role in their organization. For respondents in a leadership role, they primarily turned to callers and call centers (41%), local guides (33%), other leaders (23%), radio communication (14%), people on the scene (14%), and their own experience or training (9%). The differing results suggest that persons in leadership positions in emergency situations rely to a greater extent on callers and call centers, other leaders, and local guides than persons in non-leadership positions. The results also suggest minor differences between leaders and non-leaders when it comes to primarily receiving information from people on the scene, radio communication, and personal experience and training.

Table 1. Primary Sources of Information During an Emergency Evacuation.

Information Source	Overall	Leaders
Callers and call centers	33%	41%
Leaders	16%	23%
People on the scene	16%	14%
Radio communication	13%	14%
Local guides	12%	33%
Personal experience and training	10%	9%

The respondents were also asked about the kinds of devices that they use during emergency evacuations. The majority of the respondents used a radio (n=106), with a smaller minority using a smartphone (n=37), tablet (n=25), other device (n=16), or computer (n=15). Only one respondent reported using pen and paper.

Finally, the respondents were asked a set of questions that focused on the functional requirements of an indoor navigation emergency evacuation application. The majority of the respondents (n=89) considered an application that provided an overview of the users located inside the building as very useful (the best of 5 ratings). Similarly, the majority of the respondents (n=84) considered an alarm for users with injuries as very useful. An even larger majority (n=88) considered an alarm for users in need of evacuation assistance as very useful. A smaller majority (n=77) rated sensor data from motion detectors, gas alarms, and temperature as very useful. An even smaller majority (n=64) believed that an automatic alarm from immobilized users or a message service to contact users who triggered an alarm would be very useful. A larger majority of respondents (n=72) consider an indoor navigation system as very useful.

Table 2. Functional Requirements of an Emergency Evacuation Application.

Requirement	Very Useful	Useful or Not Useful
Overview of users inside building	73% (n=89)	27% (n=33)
Alarm from injured users	69% (n=84)	31% (n=38)
Alarm from users needing assistance	72% (n=88)	28% (n=34)
Building sensor data	57% (n=70)	43% (n=52)
Automatic alarm for immobilized users	52% (n=64)	48% (n=58)
Message service for users triggering alarm	52% (n=64)	48% (n=58)
Indoor navigation system	59% (n=72)	41% (n=50)

4.2 Results from Usability Testing of Indoor Navigation System

The results from the usability tests of the indoor navigation system showed that respondents generally considered the system unusable (see Fig. 1). This finding contrasts with existing studies of similar indoor navigation systems, which showed high levels of usability among persons with visual impairments [1]. Unlike prior research, this article targeted persons without disabilities. The respondents varied in age from 19 to 43 years old, with an average age of 24. All respondents identified as either women (n=18) or men (n=10). Nearly all respondents (n=22) reported having problems with using the system. These problems may explain the lower levels of reported usability. The system usability score, based on the SUS, ranged from 40 to 60 with an average of 50 (n=28). Research shows that usability scores above 68 are considered usable [2]. The difference in average scores between men (50, n=10) and women (51, n=18) and users that spoke Norwegian (52, n=10) and those that did not (50, n=18) were negligible. The only area where respondents reported slightly different average system usability scores were between users who experienced problems during the test (51, n=22) and those that did not (48, n=6). This discrepancy contradicts the expectation that users who experienced problems using the system would report lower average usability scores. However, due to the low number of respondents (n=6) of the users who did not experience a problem, the results are inconclusive.

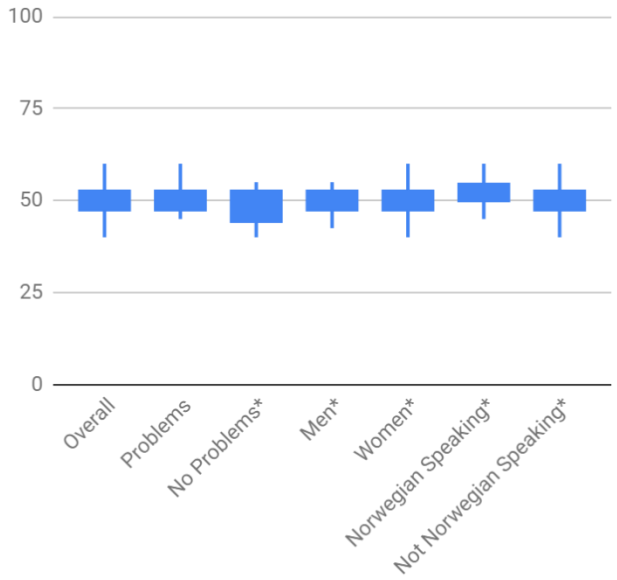

Fig. 1. Boxplot diagrams showing the average SUS scores overall and broken down by the category of users. *SUS has been validated for samples n>20, asterisk indicates where n<20

Research using the SUS typically uses short qualitative responses as a means to explain and calibrate the scores. Due to an error in the data collection procedure, this

information was not systematically recorded. However, the respondents did provide some comments regarding the problems that they experienced. Respondents who did not speak Norwegian commented that the app was only available in Norwegian and used commands spoken only in Norwegian. As a result, they commented that they could not use some of the app's functionalities. Norwegian speakers commented on spelling mistakes. The respondents also commented that the blue dot, which identifies where the user is located, moved occasionally when the user was standing still and did not change floors automatically during navigation.

5 Discussion

There are a couple of methodological weaknesses in the data collection that have to be mentioned. First, the results in Table 2 were based on a five-item Likert scale. The Likert scale ranged from 1 "Not useful at all" to 5 "Very useful". Typically Likert scales are balanced in the sense that items 1 and 5 and items 2 and 4 reflect similarly positioned responses – e.g., 1 "Very Unuseful" and 5 "Very Useful, with 2 "Unuseful" and 4 "Useful". However, due to the skewed distribution of the data showing a majority of respondents considering the functional requirements as "Very Useful", it is unlikely that the unbalanced Likert scale has biased the results.

Concerning the user evaluation of the app, there was a weakness in the SUS data collection procedure as the researchers did not consistently collect short qualitative responses to explain and calibrate the scores. While this is the generally accepted practice in using the SUS instrument, the data nonetheless provide a useful point of reference to consider the usability of indoor navigation systems, particularly as it contrasts with previous research on the usability of indoor navigation systems for persons with visual impairments. While the qualitative responses would provide a more detailed explanation of the scores, the results nonetheless have merit on their own.

Despite these weaknesses, the results are valuable in pointing out weaknesses and bugs as well as missing features in the current implementation of the OsloMet application, and for providing insights on which features to prioritize for the next version, from the first responders' point of view.

6 Conclusions and Next Steps

It is clear that the current implementation of the OsloMet app has several weaknesses and shortcomings when it comes to usability, as uncovered by the user testing, but most of these issues are bugs rather than inherent problems and can be fixed with relative ease. In addition, the input from first responders also points to a potential for significant usefulness. During the survey the respondents highlighted a few important implementation on the OsloMet app that would improve the efficiency of the rescue operations, such as an overview of the users located inside the building and alarms for users with injuries and in need of evacuation assistance. Sensor data from motion detectors, gas alarms and temperature was also considered useful information to be added to the app in order to give rescuers a more complete look to the emergency. A smaller majority of

the respondent finally individuated an important upgrade in the implementation of an automatic alarm from immobilized users and a message service to contact alarm-triggering users. It is also notable that a vast majority of the respondents indicated an indoor navigation system as very useful during emergency situation, confirming the direction to follow in order to improve the emergency management. The most important next step in our project is now to implement the revised app based on the input gathered in this study, followed by extensive field-testing with users, security officers and first responders during evacuation training exercises for validating its usefulness in practice.

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