Mobile Usability Testing: Gathering Evidence for Designing User Interfaces for Emergency Disaster Management Systems

Ajay Bandi, Abdelaziz Fellah, Harish Bondalapati, and Mark Corson*
School of Computer Science and Information Systems
Department of Humanities and Social Sciences*
Northwest Missouri State University
Maryville, MO, 64468, USA
{ajay, afellah, s530741, corson}@nwmissouri.edu

Abstract

Though the innovations of technology have increased, human life is still vulnerable to hazards. One such example is natural disasters. Mobile apps and its user interfaces play an important role in rescuing people during those situations. The goal of this paper is to explore the design issues of disaster management systems using mobile usability testing. We followed a systematic approach of conducting usability testing on mobile devices using usability measures (speed of performance, the rate of errors, time to learn, and subjective satisfaction). Our findings show that high speed of performance and low rate of errors are important in designing the mobile interfaces. We also provide the general guidelines for developing mobile user interfaces using the appropriate GUI components to overcome the design issues.

keywords: usability testing, mobile devices, measures, emergency disaster management, design issues, user interfaces, user experience design

1 Introduction

Web development becomes predominant for several businesses such as marketing, e-commerce, banking, education, and social media. Mobile sites and applications have also emerged due to the demand for using a wide variety of mobile devices by users [2, 11]. There are several commonalities and differences in designing and developing websites, mobile sites & apps. User interfaces for mobile devices play an essential role in improving user experience and eventually achieving a successful business expansion. Usability testing is a technique to explore the usability issues of a software product using prototypes [8, 9]. Usability testing helps identify the major design issues before implementing the actual system. The functionality of the system is not required to conduct the usability testing. Performing usability testing on any software applications is essential to address the design issues, and it also reduces the development time and the associated costs [6]. The traditional usability testing techniques of software development are suitable for desktop applications such as standalone and web applications but not ideal for mobile sites and apps. The challenges associated with the mobile context are performance or loading time of the app and fat-finger syndrome [14].

Performing usability testing while designing the user interfaces on various types of emergency systems would help identify design issues. These systems can range from simple to complex GUIs such as life-critical, home & entertainment applications, industry & commercial systems, sociotechnical systems, exploratory, collaborative, and creative interfaces for several desktop applications. Researchers identified the importance of usability testing for mobile devices and termed as mobile usability. In this paper, we primarily focus on the mobile usability of the life-critical systems category especially for the Community Emergency Response Team (CERT) and propose guidelines to design user interfaces for the generalized CERT applications. The rationale for choosing this emerging interdisciplinary area, as the rescue team members, who use these systems vary from one disaster to another. Even though appropriate training was provided to the team, there is a need to review the design principles of the disaster management systems when the rescuers use the mobile apps at the disaster location. While using the CERT application, there is a possibility of communications within and among the teams involved in the rescue operations. This requires that the interfaces should support ranging from novice users up to well-experienced ones. A research challenge is to establish the usability guidelines or principles in particular for designing designing Emergency Disaster Management Systems (EDMS) interfaces.

The rest of the paper is organized as follows. Section 2 describes the background work on the EDMS and

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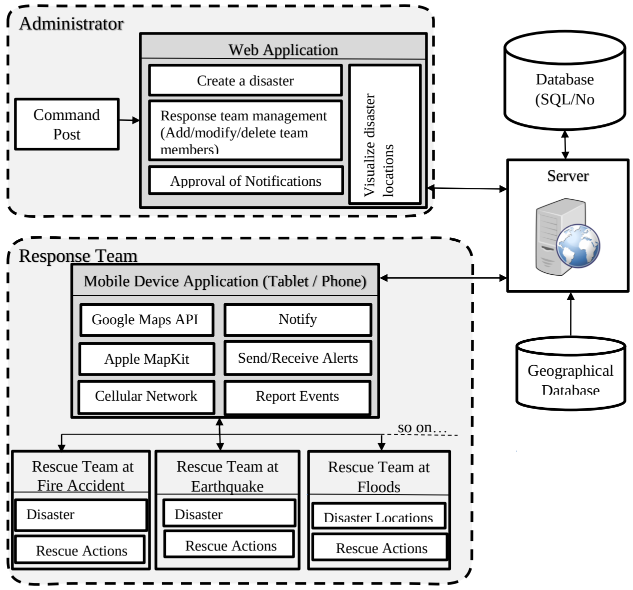

Figure 1: Architecture of the proposed EDMS

CERT system with a high level architecture diagram. Section 3 explains the case study of the mobile usability testing. Section 4 presents the results in a comprehensive tabular format and discusses the findings and observations. Section 5 presents the conclusion of our research.

2 Background

Though the humankind has tremendously advanced, it has been proven that they are always vulnerable to hazards. To reduce the impact of hazards and to cope with disasters, several Emergency Disaster Management Systems (EDMS) have been proposed [1, 12, 15]. It is not only important to develop a highly reliable and rapid EDMS application, but also equally important to design their user interfaces with utmost usability. The major challenge with EDMS is that disasters occur rarely, thus users of these applications are not well used to them. To overcome this problem, EDMS need to be designed in such a way that errors are minimized; learning efforts are minimized; accountability of actions and tailoring of user roles are provided. The other challenges that EDMS often come across are the reduction of complexity; priority of primary task; heterogeneity of involved actors; heterogeneity of information technology; security and privacy [12, 15]

The user interface should project the incident/disaster in a compact form such that an operational picture can be effectively communicated to the involved users. There is a possibility of heterogeneity among the involved users, which requires that the interfaces should support ranging from novice users up to well-experienced ones. User interfaces are expected to be adaptive in displaying diversified information structures [4, 5]. Providing advanced communication capabilities so that relevant information can be supplied to all involved parties to improve control and command could be a "must" feature in EDMS. Since the major part is users' involvement in the field directly, a focus on audio or touch-based interaction could be a better choice in a few scenarios. Visual information plays an important role to convey information and priority of the tasks more clearly [4, 5].

There exist systems to manage emergency or disaster situations [7, 10]. However, these systems lack quick communication and the ability to predict and visualize the locations of several response teams in different areas simultaneously. We proposed an approach to identify and view the rescue teams and to manage those teams using the web application and mobile applications for both Android and iOS devices simultaneously. Also, our system has other enhanced features, including the communication between groups and administrator using an external server as shown in Figure 1.

3 Case Study

Our goal is to investigate the design issues to form the guidelines for designing the user interfaces of emergency disaster management systems for mobile devices. To achieve this, we conducted the mobile usability testing with the following research goals.

RQ1. Can the users understand the information and perform the task on the mobile devices? RQ2. What are the appropriate Graphical User Interfaces (GUI) components to enter data?

The selection criteria of our case studies are limited to the proprietary EDMS software, which is developed by the graduate students at Northwest Missouri State University as part of their capstone course. For the EDMS architecture shown in Figure 1, the electronic prototypes are developed using Adobe XD and Mockups software. Later, the admin module is implemented in the MEAN stack (MongoDB, Express.js, Angular.js, and Node.js) technologies and the functional modules of the rescue or response team is developed in two major mobile-based platforms (Android and iOS).

The selection criteria of the users who participate in usability testing are the graduate students of computer science and undergraduate students of emergency disaster management. The graduate students finished the user experience design course and are knowledgeable of

Table 1: Tasks Description

Task Item	Description
T1	**'Accept' or 'Decline' a notification to report a disaster**
Start	A notification is sent to all the relevant responders about a disaster.
End	Accepting or declining to report.
Frequency	Whenever a new disaster occurs.
Difficulty	Any other responders who accepted the notification and their location.
Steps	
1.	Open and view the notification about the disaster.
2.	Check the details on the disaster.
3.	Accept/Decline the notification to be a responder.
T2	**Report a disaster with images**
Start	Accept a notification about a disaster.
End	Submit a report on the disaster from the disaster location.
Frequency	Whenever a new disaster notification is accepted.
Difficulty	Searching the disaster from the dashboard containing several items.
Steps	
1.	Select a disaster to report from dashboard.
2.	Open Map option to view/navigate to disaster location from your current location.
3.	On arriving the location of disaster, choose 'Upload file' option in the report form
4.	Click on camera option to take/select a photo for the report.
5.	Provide brief description between 40 – 50 words for report.
6.	Submit the report to admin.
T3	**Share images of Tornado disasters**
Start	Open images.
End	Share required images.
Frequency	Whenever particular data is requested.
Difficulty	Selecting a set of required images from complete library.
Steps	
1.	Open photos using option in side menu.
2.	Select photos of tornado disasters from this library.
3.	Select share option and submit.
T4	**Share images of Recent disasters**
Start	Open images.
End	Share required images.
Frequency	Whenever particular data is requested.
Difficulty	
Steps	
1.	Open photos using option in side menu.
2.	Select recent photos (as default ordering is by time) from photo library.
3.	Select share option and submit.

designing user interfaces. The undergraduate students majored in the emergency disaster management could be the future employees working as rescue team members.

We followed the systematic procedure [3] to conduct the mobile usability testing and collect the data related to usability metrics and design issues. The four different roles in the usability study are a user, facilitator, log keeper and mobile device. A user is a person who performs a given task using prototype and mobile device. A facilitator is a person who provides the task and explains it to the user. Log keeper is a person who records the number of taps on the mobile device, keystrokes, start time & end time of a task performed by the user. Mobile device (iPad, Nexus tablet, iPhone and an Android phone) is used to view the prototypes. In our study three users used iPhone 6, two users used Galaxy S5, two users used the iPad mini, one user used iPad Air, and two users used Nexus 9. It is the user's choice to select their device. All of our users used their own devices.

We conducted our case studies in the computer laboratory setting. We explained the functionality of the system to the users for approximately half an hour before they perform the usability testing. The facilitator provided one task at a time to the user. The tasks and its description are given is Table 1. We asked users to think-aloud when they work on the tasks. We used "observations" data collection method to collect data [13, 16]. The rationale of using observations data collection method is because of the deep understanding of the user's performance in the study. Users are aware of collecting the data while performing their tasks and interacting with the facilitator. Our log keeper records the number of taps on the device screen, keystrokes, start time & end time of a task performed by the user. We also recorded issues encountered by the user. The log keeper used the stopwatch, and an Excel workbook to record the data. At the end of testing, we asked the users feedback on the ease of accessing the system using prototypes on a Likert scale of 1 to 5 (1 being the lowest and five being the highest) to the subject's satisfaction. After data collection, we computed the speed of performance by the difference between the start time and end time of the task. The rate of errors is calculated by the logging the number of errors encountered while performing a particular task.

4 Results and Discussion

To provide the overview of the data of different metrics collected during the usability testing, we presented comprehensive tabular formats to report the results.

Table 2: Time Taken by the Users to Finish Tasks (in seconds)

Tasks	Users										Mean
	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	
T1	37	42	40	37	33	40	37	39	35	39	37.9
T2	132	145	129	140	124	117	120	138	123	125	129.3
T3	28	25	31	25	29	22	25	20	23	22	25.0
T4	15	20	18	21	14	18	17	14	20	15	17.2

Table 3: Design Issues

P ID	Task ID	Description
P1	T1	There is no information available to the rescue team member about how many other respondents have accepted to report before he/she decides whether to accept or not.
P2	T1	There is no option to see second disaster notification until first one is Accepted/Declined in case of multiple disasters.
P3	T1	There is no option to access the directions of the disaster location until the notification is accepted. The user may not know the distance of disaster location and may not be able to make a decision.
P4	T1	There is no option to share the disaster information to others.
P5	T1	The notification is not saved/archived if user declined it.
P6	T1	There is no option to modify the response in case of accidental clicks.
P7	T2	There is no option to visualize other responders on map.
P8	T2	Map features such as auto center and auto zoom are missing while visualizing.
P9	T2	There is no option to upload multiple files.
P10	T3	No filter option for images/videos based on a disaster type.
P11	T3	No sorting option (other than natural sorting in descending order of date) for images/videos.

Table 2 represents the time taken to finish the tasks by the users. The time taken to complete the task is measured in seconds and computed as the difference between the task finish time and the task initiative time. The last column in Table 2 gives the average time taken to complete the corresponding task by all the ten users. On an average, the second task (T2) carried the highest time, and the fourth task (T4) took the shortest time. The descriptions of the tasks are provided in Table 1. User (U2) took more time to finish the task (T1) when compared to other users. However, the extra five seconds took by the user is a considerable amount of time in the emergency situation.

The log keeper notes the design issues encountered by the users in the think-aloud process during the usability testing. A total of 11 different design issues were faced by the users in the first three tasks and are given in Table 4. The rest of this section explains each problem that users have encountered and our observations from the mobile usability testing. The problems P1 through P6 occurred while performing the task (T1). While performing this task, users do not have any information regarding how many other respondents have accepted to be in the rescue team. Six out of 10 users faced this issue. In case of multiple disaster notifications, two users would like to review all the announcements before making their decision whether to accept the notification or not. Two users faced a design issue with accessing directions to the disaster location before accepting the notification.

Three users did not find an option to share the disaster information to other people. The design was restricted not to share information because of security issues. Announcing the information for awareness to other people is out of the scope of our application. Even though users declined the notification, they want to see the disaster‘s announcement in the app for later purposes. In case of a user, U2 who accidentally refused the notification, unable to go back and view the disaster. Out of 11 design issues, 54.5% of the problems occurred during the implementation of task T1. Even though T1 is not in the field of disaster location, users must need all the related information to decide whether to accept or decline the notification. Users faced three unique problems while they were performing the task

Table 4: Problems Encountered By Users

Problem ID	Task ID	Users										Problem Hit-rate	Task Hit-rate
		U1	U2	U3	U4	U5	U6	U7	U8	U9	U10		
		iPhone 6			Galaxy S8		iPad Mini		iPad	Nexus 9 Tablet			
P1	T1	Y			Y	Y	Y	Y		Y		6	16
P2	T1		Y	Y								2	
P3	T1		Y						Y			2	
P4	T1								Y	Y	Y	3	
P5	T1		Y				Y					2	
P6	T1		Y									1	
P7	T2	Y			Y	Y			Y			4	10
P8	T2	Y			Y				Y			3	
P9	T2		Y		Y		Y					3	
P10	T3			Y		Y		Y		Y		4	5
P11	T3			Y								1	
User Hit-rate		3	5	3	4	3	3	2	4	3	1	31	
Device Hit-rate		11			7		5		4	4			
Average Device Hit-rate		3.67			3.5		2.5		4	2			

T2. Four out of 10 users, would like to visualize the location of other respondents on the device for practical use of resources in the disaster location. Three users faced design issues related to T2 which are uploading and sending multiple files to the admin at a time.

We also observed that the users had other design issues with the task (T3) such as sorting and filtering the images or videos based on the disaster type. None of the users have any issues with performing the last task (T4).

Table 4 presents the problems encountered by the users. It also shows the problem hit-rate, task hit-rate, individual user hit-rate, and average device hit-rate. The 'Y' in a cell indicates that the user has encountered the corresponding design issue while performing the task on a particular mobile device. A hit-rate is defined as the number of times a problem occurred with its respective category. The hit-rate for task T1 is 16 which is approximately 50%, shows that several users faced issues while performing this task. The hit-rate for tasks T2 and T3 are 10 (32%) and 5 (16%) respectively. Our results clearly show that the users have more design issues during the notification time, rather than during the reporting a disaster. In our study, it is the users choice to choose their devices or use their mobile device for usability testing. We cannot generalize the device-hit rate or the average device hit-rate.

4.1 Guidelines

We explain the general guidelines for designing mobile apps for rescue team members in the emergency disaster management system form our case studies by answering our research questions.

RQ1. Can the users understand the information and perform the task on the mobile devices?

At the time of notification, users faced 54% of design issues. Due to these issues, users' were unable to perform the task from Table 2 quickly. We provide the following recommendations for the user interface designers based on our results and observations. At the time of notification, provide more information about the disaster on the following to the rescue team member.

The rescue team member should be able to know how many respondents have already accepted or denied to help. The rescue team members should be able to access the directions to reach out to the disaster location from the current position of the respondent. In addition, all the necessary safety measures to be taken at the disaster location must be shown. To represent the intensity and the damage of the disaster, it recommended using the triage tag colors. Provide an option for the user to change their response to a notification.

RQ2. What are the appropriate GUI components to enter data? At the disaster location, users encountered approximately 46% of design issues in entering the multimedia data such as images, videos, and visualizing maps. Based on our findings from our case study we propose the following GUI components.

Rescue team members use mobile devices in the disaster location to report the disaster. For effectiveness of prompt communication of the emergency, minimize the use of external devices (keyboards, stylus, etc.) to enter the data. Eliminate form fill-in's that have free text fields and drop-down menus on the user interface instead use the auto-populate feature. Speech transcription techniques are helpful in case of any injuries to the rescue team members. Providing the flip selectors, spinners, and slider would help in the better use of screen space. To represent the intensity and the damage of the disaster, it recommended using the triage tag colors. The only active or ongoing disaster should be shown on the dashboard. Other disasters on the dashboard are distractions to the rescue team member.

5 Conclusion and Future Work

We presented the guidelines for designing mobile user interfaces for rescue team members in an emergency situation. The findings and observations of our research conclude that we should eliminate form fill-in's and to use auto-populate the data. Displaying several disasters on the dashboard is not effective as it increases the rate of errors. Before participating in the disaster location, the rescue team member should take less time to accept or deny the notifications. The subjective satisfaction on the app design is not critical. However, the high speed of performance and the low to zero rate of errors are the critical usability measures.

In the future, we incorporate the feedback from users and results from this study to develop the EDMS system and conduct a post-mobile usability testing. We also extend our case studies to conduct mobile usability testing with the users who participate in the Missouri Hope event on different devices.

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