Strategies for Developing a Mobile e-Health Emergency Response Consultation System

Ann L. Fruhling
University of Nebraska – Omaha
afruhling@unomaha.edu

Sharmila Raman
University of Nebraska – Omaha
sraman@unomaha.edu

Anthony R Sambol
University of Nebraska Medical Center – Omaha
asambol@unmc.edu

Abstract

This research presents a case study examining mobile guidelines and strategies used in the development of a mobile e-health Emergency Response System (ERS). The system reviewed in this study is a public health ERS, called STATPack™ that utilizes video telemedicine technology for microbiology laboratory diagnostics and consultation relating to suspicious organisms. A major goal of STATPack™ is to enhance remote laboratories’ ability to communicate information and make decisions in biosecurity and biosafety scenarios.

The main contribution of this research is two-fold. First, it provides further understanding of the key issues and unique requirements in developing mobile delivery systems and it provides strategies to assist developers in better designing future mobile applications. Second, this study provides an example for practitioners to see how a mobile e-health system can be applied to processes unique to a laboratory setting as a proof of concept for other healthcare diagnostic applications.

1. Introduction

Recently, many new e-healthcare information systems are emerging as a result of the American Recovery and Reinvestment Act of 2009. A majority of these systems are fully embracing the latest advances in technology. One of the fastest growing areas is mobile healthcare applications. A mobile application is code that runs on a mobile phone or PDA. It does not necessarily require wireless or networked communications to be a mobile application, although many have that capability. Given recent improvements in mobile device displays, data bandwidth and affordability, there is increased opportunity for expanding the utility of desktop applications to mobile devices.

Mobile device usage continues to grow at an exponential pace due to the variety of features and new capabilities available. Today there are approximately 9.6 million Converged Mobile Devices (e.g. smartphones, PDAs, Blackberry’s) in use around the world [1]. By 2011 it is expected worldwide that there will be 82 million mobile devices in use with an anticipated compounded growth rate of 54% in the next four years [1].

There are many challenges when dealing with mobile user interface design and system development projects. Even with the recent improvements compared to desktops, mobile devices have lower network bandwidth, smaller displays, limited user input capacity (keyboard, mouse), and nominal design standardization to name of few. One of the more important challenges of mobile devices is designing an effective and efficient user interface. In the past often the design strategy for smart phone applications was to simply adopt the user interface design of the desktop system counterpart. This is proving to be less than satisfactory. Accommodations need to be made to adapt the desktop application to mobile delivery.

Designing and implementing mobile desktop e-health information systems complements are an emerging field and calls for further study. There are several notable studies on how to design and code mobile systems so that they are robust, useful, and perform effectively for the user [2][3]. Never-the-less, there continues to be a need to better understand how various mobile user interface guidelines can be effectively applied. In addition, there are few studies to our knowledge that specifically focus on mobile healthcare information system development. This research addresses both these needs.

Hence, the purpose of this research is to present insights learned from the application of proposed mobile user interface guidelines to a new healthcare emergency response information mobile system interface. Specifically, we designed and implemented mobile browser functionality for an e-health securely networked desktop information system. We illustrate how both the critical functional requirements and various mobile design practices have to be taken into account to guide the design and development of the mobile system interface.

The remainder of the paper is structured as follows. The next section presents background of the system under study. We then focus our attention on mobile UI and system design guidelines. Section 4 presents our
research method. Section 5 discusses the system requirements and the UI design details. Section 6 analyzes the application of the mobile system design guidelines. Lessons learned and strategies are summarized in Section 7. The paper concludes with closing remarks of key points, limitations, and directions for future research.

2. The system under study: public health emergency response information system

This case study focuses on a public health emergency response information system, called STATPack™ that was designed to increase timely communication among laboratorians who need advice on potential hazardous organisms from medical experts in pathology, microbiology and epidemiology at state public health laboratories.

The seriousness of a potential situation is that the organisms in question could be possible bioterrorism organisms, although, it is most likely they were acquired from endemic sources. Regardless, this situation requires immediate attention. A mobile system is needed so that experts in the field can respond even quicker in the case of an emergency. Currently, they need to have a laptop computer and internet access to respond.[14]

Many hospital and private reference laboratories use what are called the “rule out and refer” (ROAR) guidelines as defined and made available by the Centers for Disease Control and Prevention (CDC)[4]. The laboratories that use these procedures are referred to as “Sentinel laboratories” in the CDS’S Laboratory Response Network (LRN) [4]. The guidelines are utilized to rule out the presence of biologic agents with the use of just a few rapid method biochemical reactions. If the organism cannot be ruled out, the sentinel laboratory’s role is not to identify the organism but rather is required to refer to the state’s public health laboratory where confirmation can be achieved by advanced biochemical tests, gene amplification and other molecular methods.

The hospital laboratorians rarely encounter these organisms during their routine workflow. Experts are trained to recognize the colony morphology and other trigger factors which assist in recognizing the hazard. Many sentinel hospital laboratories in rural settings are not equipped with such training. Nor, do they have staff specialized in microbiology. More often, the laboratorians are generalists who cover all sectors of the laboratory. The STATPack system can be essential in affording expertise and consultation in these circumstances.

2.1. Need for mobile capabilities

In order for state public health experts to offer timely assistance to their sentinel laboratorians, they must have immediate internet access to the STATPack™ system. Currently, this access requires a laptop or desktop computer in order to view the organism images sent for consultation. However this is not always convenient or possible due to the microbiology experts other duties that frequently take them outside of the office. For example, one public health microbiology expert reported having a number of requests for consults at a time when she was traveling and did not have access to a laptop and the internet. However, if she had had the capability to access the STATPack™ system to retrieve the images using a mobile device, she could have responded within minutes and thus saved valuable time, reduced anxiety, and minimized concern of those involved.

2.2. Proposed mobile solution

As a solution, the developers recommended enhancing the STATPack™ desktop system so that it would run in a mobile environment. This new system is referred to as STATPack™ Mobile. This required the developers to customize the desktop STATPack™ system to display in the mobile browser on a mobile device. What is especially unique and challenging about this project is that microscopic and macroscopic images must be also be projected at a level where the clarity and quality of the image is at a level that microbiology experts can confidently provide consultation to the laboratorians. The user must also be able to pan and magnify the image at various intervals.

The corresponding part of the desktop STATPack™ functionality that the developers wanted to provide via a mobile device was currently provided using the desktop browser. Following the same overarching architecture seemed to make the most sense instead of starting from scratch (e.g. building a new mobile application). The developers first needed to determine what functionality should be included and then analyze how to design the user interface so that enough information was presented and that the images to be viewed were of a quality that is needed to confidently consult.

3. Mobile UI and system design guidelines

The ease of use and the ease with which the user can learn to use an application are essential factors for an intelligent interface [2]. This especially applies to mobile user interfaces (UI). Effective user interfaces
allow users to perform a task in the way that makes the most sense to them. Often, user interfaces are specifically designed for frequent users. The intent is to maximize what we know about human strengths, for example, analysis and decision-making. Well-designed user interfaces take the environment, tasks, and experience of the people using the interface into account. As a result this process reduces errors, training time and costs. Intelligent user interfaces often make people more productive which can result in better customer services. In one report the authors state that the characteristics of a good user interface are based on five major principles which are simple, aesthetic, productive, customizable and others [2]. Other important consideration for a good UI design of mobile devices includes making the UI as user-friendly as possible and maximizing code-optimization [2]. Code-optimizing is crucial because of the small screen size and limited memory capacity.

Touch-screen-based user interface designs are thought to be the best choice for mobile devices primarily because touch screens eliminate the requirement of a physical keypad. This helps reduce the size of the device and equivalently increase the screen size. [2]

The multilayer structure of the mobile user interface design makes it difficult for the user to use the various functionalities that are present on the device as they are not always user-friendly. In a multilayered structure the user has to know where that function is and how to find it. [2] This adds additional cognitive overload on the user.

Users generally do not prefer to browse large lists of complex menu features. Searching can be time consuming and require extra effort to search menu features that are not explicitly visible. Moreover, exploring multiple levels menus can be stressful and unproductive. [3]

An alternative solution to this problem would be to implement a single-layer based UI. In this single-layer approach all the functions are right in front of the user, so users can easily find and choose the desired function [2].

4. Method

This research represents a single descriptive case study, i.e. a detailed examination of one setting, or a single subject, a single repository of documents, or one particular process or event [5]. We choose a descriptive case study, because it is particularly well suited to support learning by answering how and why questions [6]. Case studies may explain the reasons for a problem, the background of a situation, what happened, and why. Further advantages of the case study approach that apply to our study include access to a wide variety of information sources, and analysis and deliberation in retrospect leading to insights that are useful for the present and future. In summary, descriptive case studies evaluate, summarize and conclude, thus increasing their potential applicability [5].

5. STATPack™ mobile system requirements and UI design details

5.1. STATPack™ mobile functionality selection and prioritization

Specifically, the STATPack™ consultation process involves taking macroscopic (gross) as well as microscopic digital images of culture samples, or possibly original clinical specimens, and sending them electronically to experts at state public health laboratories. STATPack™ enables microbiology laboratories around the state (and now the region) to send pictures of suspicious organisms to the state public health laboratory, instead of the samples themselves, thus lessening the risk of spreading potentially deadly bioterrorism agents or infectious diseases and likewise decreasing the feedback time on the consult. After seeing images via STATPack™, however, the state public health laboratory may still request a physical sample be sent to its lab as a precautionary measure for CDC confirmatory testing and subsequent reporting. The STATPack™ system includes an alert process that is bi-directional and has various levels of priorities (drills, emergency, urgent, and routine).

The functionality for the new STATPack™ Mobile system was prioritized and determined by what functions are most likely to be used during an emergency consultation. Seven key functions were identified which were System Login, Main Menu, Message History, STATPack™ Message Details, Image Details, Send Message, and Message Sent Status. Based on these seven functions the project team wrote corresponding scenarios. The scenarios were used to develop mockups. Examples of the desktop UI and the corresponding mobile UI screens can be found in the Appendix. As you will notice, the text in STATPack™ Mobile is abbreviated. While, in most cases provides the same functionality.

In parallel with the requirements analysis, the development team decided to use existing server code and extend it to the mobile platform. They arrived at this decision because the desktop system had an existing application and database layers that were fully-functional and thoroughly tested.

STATPack™ Mobile was implemented in modules.
Each module included a specific set of functionality and the corresponding user interface. Each module was integrated with the next module that was implemented. The integrated modules were tested.

Blackberry Smartphone simulators were used to test the application before it was tested on an actual blackberry device. The initial phase of design was specific to the Blackberry 9500. After this was implemented, the developers sought additional user feedback focusing specifically on the presentation and ease of use of the graphical user interface. Downsizing of the screens required use of abbreviations and different placements of text and icons on the mobile system. The image size, clarity, and quality were carefully evaluated.

The modules implemented on the Blackberry 9500 were then customized to other devices such as the 8800, 8820, and 8830 devices. Automatic screen rendering was implemented to avoid having to download a specific application to a particular Blackberry device. This also provides an option to customize STATPack™ Mobile to future Blackberry devices without impacting the current users.

5.2. Technical architecture issues

This project involved issues similar to past heavy client versus light client architecture debates. There were several reasons for choosing the mobile browser architecture over developing a custom mobile application. First, the project team already had system code in place that they could reuse. Second, there was not a lot of heavy client side processing that would favor a custom mobile application. Third, there was not any need for specialized interfaces or device functionality that would require a custom mobile application. Fourth, a browser based application provides better compatibility with a larger variety of devices. Fifth, given that the devices for our user population are government (state) owned, using the browser platform simplifies the need for permission and security certifications for installing third-party software. And finally, with mobile devices, people tend not to switch devices as often, so pre-loading software is less of a concern.

6. Mobile UI and system guidelines

Before any analysis or design of the mobile GUI occurred, the developer researched literature on mobile UI and system design guidelines. The developer most closely followed the recommendations of [7] [8] because they seemed to apply best to this project.

Next we discuss the recommended guidelines from the literature and comment on how the STATPack™ mobile team implemented the recommended guidelines and if there were any deviations. The discussion is organized into three categories: 1) no guideline variation, 2) guideline implemented with modifications, and 3) guideline still under consideration.

6.1. No guideline variation

Guidelines: Minimize scrolling. Users often have difficulties in scrolling more than 4-5 times. They lose their concentration span while scrolling through lengthy screens and get easily distracted.

Implementation Comments: The content is organized in a manner that occupies the central part of the screen where the user concentrates. The screens are also designed to minimize scrolling. Most of the screens require no scrolling or no more than 3 scrolls per screen.

Guidelines: Ease of use. Avoid using complex menu options or functionalities that are difficult to use.

Implementation Comments: Screens are designed in a simple manner. Complex submenus were avoided.

Guidelines: Provide meaningful error messages.

Implementation Comments: The application provides meaningful error messages when the user enters the wrong username password or enters the wrong data. This helps users understand what they keyed in wrongly. It also helps them easily correct their mistakes.

Guidelines: Strike a perfect balance between screen content and the number of screens used.

Implementation Comments: User review sessions were conducted. Required data was collected to finalize display on STATPack™ Mobile screens. The numbers of screens were decided according to the criteria of one function per screen. Feedback from the users indicated we have the right balance.

Guidelines: Consistent navigation throughout the system.

Implementation Comments: The STATPack™ Mobile application design gave high priority to consistent navigation on all the screens. The users are familiar with several other applications that they use on a day to day basis. We have taken this into consideration and have implemented the navigation accordingly. We have provided a button that assists the user with navigation on the right hand corner of the screen. This is consistent with respect to all the screens which help the user to navigate easily. The users often subconsciously click the buttons as they are very familiar with this form of navigation.
Guidelines: Avoid ambiguous references. The options provided in the application need to be named in such a way that explicitly specify the exact operation that they would perform.

Implementation Comments: Names of buttons are consistent with the desktop application. During the initial development of the desktop system In-depth usability analysis was done to ensure the best naming selections [9]

Guidelines: Security is an important issue that needs to be addressed. Password characters needs to be visible to the user for a few seconds before they are marked in the asterisk format.

Implementation Comments: STATPack™ mobile application facilitates the user to view the alphabetical characters keyed in password for a few seconds and then they turn to the asterisk format.

Guidelines: Logout option needs to be explicitly specified.

Implementation Comments: The logout option is provided in the application so that the users can logout whenever they desire to do so. This is also an important security measure.

Guidelines: Allow user customization

Implementation Comments: STATPack™ mobile consists of a new home screen which helps the user access the feature of their choice. They can either view only the latest messages received or view the message history.

Guidelines: Provide user feedback for operations that take a long duration.[11]

Implementation Comments: Feedback is provided when a delay is caused during the process of sending a message. The user is kept informed about the current status of the message through the display of a progress bar.

Guidelines: Elements of mobile applications such as names, color schemes must be similar to that of the desktop application [11]

Implementation Comments: Consistent color schemes and naming conventions were followed while implementing STATPack™ Mobile. They map to the desktop STATPack™ system. We did remove images in the logo so that it would load faster and reduce clutter.

Guidelines: Provide an option to use the same login ID and password for both the desktop application and the corresponding mobile application.

Mobile Implementation Comments: The users can use the login with the same credentials for both system platforms.

6.2. Guideline Implemented with Modifications

Guideline: Avoid long text entry. Provide a list of options to select from if the data to be entered has common text entry pattern. For example, the application needs to be designed to reduce the instances where the user needs to enter long text data (e.g. a long URL).[16]

Implementation Comments: A STATPack™ mobile executable can be downloaded onto a blackberry device. This allows the user to click on the STATPack™ logo and start the application. This eliminates the need to type in a lengthy URL which could lead to typos and frustration.

Modifications: The STATPack™ message field can also be lengthy. It is difficult to avoid this as this is an important aspect of the application. As much as possible, fields are pre-populated.

Guideline: Test application on many devices to serve increased number of user sector who possess a wide variety of devices.

Implementation Comments: The application is customized for a many varieties of blackberry devices (8800, 8820, 8830, 8900, 9500, 8330, and 8350). Thus provides a better look and feel to users who use these devices.

Modifications: Customized to Blackberry devices in use by state public health staff.

Guideline: Menu or options are clearly stated and are easily accessible to the user[10]

Implementation Comments: The user is provided with options to view only the new messages that have been sent the history of messages. These options are clearly stated as accessible to the user.

Modifications: Selected only the features for consultation and the desktop STATPack™ system has already addressed this guideline.

Guideline: Implement functionalities used most by the users

Implementation Comments: We collected the details regarding the important functionality that the users frequently used for consultations and wrote scenarios.[15]

Modifications: We do not intend for the mobile application to replace the desktop STATPack™system. Instead we are targeting the use of STATPack™ Mobile to speed up initial assessment when an emergency consultation is needed.

6.3. Guideline implementation under consideration

Guideline: Provide access to the main screen throughout the application

Implementation Comments: We are currently collecting user feedback regarding this. We might implement this if we get a positive feedback from our users.
Guideline: Application switching needs to be included as the user should not have any problems with the regular device functionality.

Comment: Application switching is given due importance and is considered in the design of STATPack™ Mobile. Lower priority - this guideline is not as much in our control because of the type of devices used by our users. We are still testing to see if there is an impact.

Guideline: Allow frequently used shortcuts

Comment: Some users would like to use only a few features. Once they are familiar with the application they may want to use a few shortcuts. Providing a few short cut keys without violating the regular hot key usage improves the ease of use. We will be planning to provide this feature in our later releases. This is something that was not initially considered so needs further investigation.

Guideline: Provide customer support or contact information

Comment: This is an important aspect that we discovered. We had not included this in our design. We have decided to include this as it will help the user contact the concerned person in case they have a problem using the application. However, it is a lower priority because we are on a first name basis with our current users.

7. Discussion

The mobile guidelines were a good starting point to ensure that the mobile user interface was well-designed. The guidelines also uncovered a few areas that the developers had not considered such as shortcuts and customer support.

We would be remiss if we didn’t mention the project team’s security strategy. STATPack™ Mobile is using the built-in security standards (SSL) that exists between the Apache web server and the browser. This does cause an inconvenience to the user by requiring certificate approval.

Several lessons were learned from this case study and each lesson learned in and by itself represents an interesting avenue for worthwhile future research.

The developers reported that having 1) a solid understanding of the STATPack™ desktop functionalities helped with a smooth transition determining what makes sense to implement in a mobile environment. A strategy that the developers found useful is that they focused on the most important features of the desktop application, instead of converting the whole application. This kept the project scope manageable and in line with the needs of the users. This was accomplished by examining which features were needed first during the most critical time in an emergency. Although not statistically proven, the developers basically followed the 80/20 rule where 20% of the functionality is used 80% of the time. STATPack™ Mobile provides around 30% of the functionality of the STATPack™ desktop capabilities. That said, it is important to note that STATPack™ Mobile was not intended to replace the STATPack™ desktop system rather enhance the current system.

One of the most interesting design considerations of the STATPack™ mobile project was the technical architecture debate of browser-based implementation version custom application or fat/client versus thin/client. Now that the developers are in beta testing, they are even more confident they made the best decision. This design has taken into consideration the rapid phase with which the mobile technology is changing hence STATPack mobile implementation is carried out in such a way that the existing code could be used on a wide variety of devices with just the UI changes. STATPack mobile was successfully tested on Android devices.[13]

Magnification of the images and sending messages back and forth to the server proved to be the most difficult coding tasks. The message communication was difficult because the original application code was not designed and written with a mobile application in mind. So a take away here is that for new applications it is important to consider all possible future implementation options.

Developers found that it was a better strategy to use an actual blackberry device instead of simulators for final testing. When testing using a simulator it is good to have simulated Blackberry be the actual size device on the screen. Size became a factor when they had hands-on testing with the user. They found that issues occurred when the user had to use her fingers for a touch screen. For example, the ease of use of typing in a password or entering a long url. Despite these problems, it is estimated that around 95% of testing can be done using a simulator.

8. Conclusion

The purpose of this study was to provide insights of developing an e-health mobile system. There were several key findings in this case study. First, it was found that the mobile guidelines suggested by [6] were helpful. Second, we found that using the application and database layer of an existing system and 2) modifying the desktop user interface for the mobile application were effective and efficient development strategies. Moreover, the results of this case study showed that using scenarios were helpful when
designing the initial mobile mockups. And also, mobile device simulators can be quite useful.

The limitations of this study are typical of case studies. Since our study represents a single case, it is difficult to generalize results or duplicate efforts. Moreover, during a case study, the researcher has limited control of the environment and events. Yet, we believe that the STATPack™ Mobile case presents a valuable example of the intricate issues involved in the design of mobile browser applications especially given the new and emerging nature of the field of mobile applications.

This research should be of interest to practitioners of the development, design and implementation of mobile applications, as well as academic researchers interested in the advancement of mobile technologies and e-health systems.

9. References


10. Acknowledgements

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The list of facilities and the corresponding list of new messages received is displayed.

STATPack mobile provided an additional screen which displays only the new messages. The user can opt to view just the new messages or can have a look at the complete list of messages by clicking on the Message History.
Figure 3. Priority/subject screen
The list of messages with along with the priority and a subject is displayed. The priority is color coded to help the user figure out the priority easily.

Figure 4. Mobile priority/subject screen
The user is provided with an option to sort the messages according to the priority, date and subject using the arrow keys. This helps in minimizing the scrolling. The messages are color coded to help user under the message priority as the priority is abbreviated.
The Message details with images if any along with the reply thread is displayed. The details provided helps the lab person analyse the image.

The message details and the image if any is displayed. The screen design took the user feedback session data which suggested that the reply thread was not as important as the message details. This was eliminated from the STATPack mobile screen due to space constraint.