A MOBILE COLLABORATION AND DECISION SUPPORT SYSTEM FOR THE MEDICAL EMERGENCY DEPARTMENT

Dominique Brodbeck[1], Markus Degen[1] and Maximilian Reiß[2]
[1]*University of Applied Sciences Northwestern Switzerland, Olten, Switzerland*
[2]*Technical University of Munich, Munich, Germany*

Keywords: Mobile technologies for healthcare applications, Medical informatics.

Abstract: A hospital emergency department is a complex work environment, where the availability of the right information at the right time is crucial for efficient and safe operation. The current technology in use for communication and information management is mostly based on telephones and stationary personal computers. Modern smartphones with their computational power, voice, image, and video capabilities have the potential to play a significant role in improving the flow of information in the emergency department. We developed a system that explicitly supports the work flows of an emergency department. In addition to mobile access to patient data and notifications about the availability of diagnostic findings, it provides the possibility to supply media captured on-site to the patient record, and directly supports the consultation process.

1 INTRODUCTION

The treatment of emergency patients is an important function of hospitals. The operation of an emergency department is different from that of other departments in several ways. Events are not foreseeable and actions are often time-critical. Furthermore, doctors typically treat emergency patients in a parallel way. After the anamnesis, diagnostic test (x-ray, lab test, MRI, etc.) are administered. Patients need to wait until the results are ready and then a doctor sees them again to decide on treatments. Meanwhile, the doctor is caring for other patients. During this process, the doctors on duty in the emergency room need to consult with experts from specialized disciplines (e.g. orthopedics). The experts are typically difficult to reach, not present on site or in a mobile situation. Another aspect of hospitals is that doctors' competence development is not based on formal acts of education, but rather embedded in daily practice and brought on by cooperation and communication with colleagues and experts. Because of these characteristics, the efficient operation of an emergency department is highly dependent on the availability of the right information at the right time, and the availability of multimedia communication channels.

At the University Hospital Basel, we encountered several issues where the flow of information is not optimal. The problem with standard diagnostics is that processes are still paper-based or server-centric. Doctors don't receive information about the results - or even about the availability of the results - at the time it is available at the place where they currently are, but instead have to remember and go and look for it. The problem with expert consultations is that experts are often not available (especially at off-hours) or remote. The consultations however are carried out by phone or paper-based channels (fax) with no support for media such as images or video. All these processes are not integrated well, and the generated knowledge can not be captured or managed to support doctors' learning.

We presume that the situation is similar in other hospitals as well. We therefore set out to conceptualize, develop, and evaluate a distributed, mobile decision support system for the emergency department. The system has the following goals:

- Improve the flow of information by pushing notifications about new information to doctors and making it available in mobile contexts
- Support the consultation process by providing workflow-aware and multimedia enriched communication
- Provide integrated access to the system on different mobile and stationary platforms

In the following sections we describe related work, the techniques we used to develop the concept, and the system that we built based on this concept.

Brodbeck D., Degen M. and Reiss M..
A MOBILE COLLABORATION AND DECISION SUPPORT SYSTEM FOR THE MEDICAL EMERGENCY DEPARTMENT.
DOI: 10.5220/0003780102370242
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2012), pages 237-242
ISBN: 978-989-8425-88-1

2 BACKGROUND

The main technology for communication in a typical hospital today is still the voice-based telephone.

With smartphones (e.g., iPhones) becoming more and more widespread among medical doctors working in hospitals, they not only begin to replace the ”phone-only” devices for every-day work use, but with the possibility to tailor them with specialized applications, they are now also becoming an information access tool.

There are a number of medical applications available for the iPhone today. They range from electronic versions of compendia (PSPsmartsoft, 2011), over mobile viewers for DICOM images (Pixmeo_SARL, 2011), to specialized software packages for emergency doctors (Pepid, 2011).

Morán et al. showed (Morán et al., 2007) that a typical hospital worker is using more time to manage information than on direct patient care. Also their work showed, that there is a constant need for access to relevant information in a heterogenous device environment.

Several publications researched the use of Personal Digital Assistants (PDAs) and smartphones in hospitals (Gamble, 2010), (Fischer et al., 2003) and identified a big potential for their use in clinical daily work. The work of (Carroll et al., 2002) discusses some important issues that can arise when using PDA devices to access patient records and inputing data, primarily due to the physical limitations of the devices (e.g. small screen, input of long texts is tedious).

Banitsas et al. showed in (Banitsas et al., 2006) and (Banitsas et al., 2004) the potential of the use of mobile video conferencing devices in the process of medical consultations. They also showed, that the current available speed of wireless transmission networks is sufficient for most tele-consultation processes.

Two major trends seem to emerge in the mobile device market:

- With the smartphones adapting more and more of the traditional PDA (Personal Digital Assistant) functionality, they will replace the PDA-only devices eventually.
- Because telecom providers offer products that allow the use of mobile phones on a campus setting for unlimited cost-free internal calls, they will take over the role of the traditional cordless phone systems

The system described in (Hameed et al., 2008) is somewhat similar to the one presented here, with one major difference: Instead of focusing on platform independence and using web technologies, our approach is to make best use of the native user interface elements available on the client target platforms. This approach allows to create an optimal user experience on every platform.

(Choi et al., 2006) proposed a mobile information system that is integrated in the clinical IT environment, and uses the HL7 message stream to generate notifications (e.g., when new lab results for a given patient are available).

3 DEVELOPING THE CONCEPT

In order to account for the transformative potential of the system and the wide range of stakeholders involved, we chose a decidedly user-centered approach to developing the concept and building the system.

Contextual observations and inquiries were performed by spending several days in the emergency department, following doctors as they performed their duties. This resulted in a good understanding of the existing user tasks and workflows, and formed a basis for the development of scenarios. We developed both text and video scenarios that show a series of envisioned use cases for the new system (Pimmer et al., 2011).

The scenarios were presented to the doctors and their feedback captured in semi-structured interviews. Analysis of the interviews showed (Pimmer et al., 2011) that features such as

- mobile access to patient data and findings,
- notifications about the availability of diagnostic findings,
- possibility to supply media captured on-site to the patient record,
- possibility to ”bookmark” cases with associated data for later use in different contexts,
- and dedicated support of the consultation workflow

were considered the most useful by the doctors. Other features such as three-way video conferencing, whiteboard functionalities, or video streaming were assigned less potential.

From these insights we were able to extract a list of prioritized requirements. For the implementation of these requirements we chose an agile development process with four-week iteration cycles. The mobile and desktop user interfaces were conceptualized and verified using paper prototypes. The prototypes were evaluated with doctors on duty in the emergency department using think-aloud protocols.

3.1 Consultation Process

Consultation is one of the key processes to be supported by the system. Emergency departments are often staffed with junior doctors. If they encounter a situation outside of their medical expertise, they need to consult with a senior doctor or a medical expert from a specialized discipline. At the hospital that we observed, this consultation process is currently performed through phone calls and paper forms. Observations about injuries or symptoms need to be communicated with written or spoken words.

We analyzed the consultation process and identified the four different states shown in Figure 1.

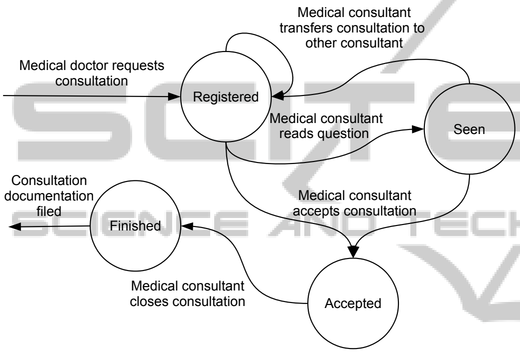


Figure 1: The consultation process modeled as a state-machine.

The functionality to support the consultation process in our system was modeled after this concept, and is fully integrated with the rest of the functionality. Requests for consultation can be initiated and received directly on the smartphone. The inquiring doctor is able to see the current state of a consultation at all times. The medical consultant is reminded by the system if an action is outstanding. Consultations can be enriched by media files to facilitate the voice communication.

4 HIGH-LEVEL ARCHITECTURE OF THE SYSTEM

Figure 2 shows the high level architecture of the system. The communication between the backend system and the end-user clients was realized using a custom message protocol, based on an efficient wire protocol (See Section 4.5).

One of the non-functional key requirements was, that the system should be accessible by different clients. We therefore defined a message protocol and implemented several different clients for the system. In order to increase acceptance and usability,

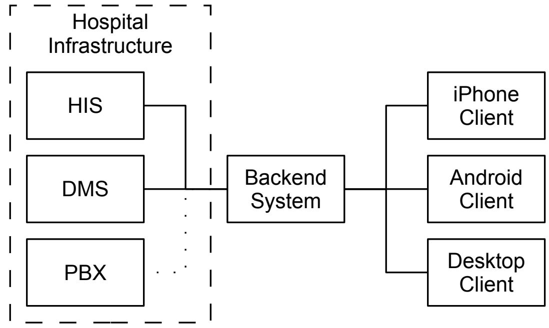


Figure 2: High-level architecture of the system, and integration into the hospital IT infrastructure. The backend system connects to the Hospital Information System (HIS), the Document Management System (DMS) and the Telephone System (PBX, planned)

the client applications were developed to have the look&feel of their respective platforms, rather than a ”one for all GUI”.

4.1 Backend

The backend provides several functions:

- Aggregation of the data of several hospital IT systems
- Bi-directional data transformation for the hospital IT systems' data from and to the mobile devices
- Authentication for the mobile devices via the hospital IT authentication system
- Support for the discussion conference feature as well as the enhanced consultation feature
- Sending of notifications to the clients, e.g., if new data is available or if some action is overdue

The reason for the data aggregation of the different IT systems of the hospital is that the mobile devices should present one aggregated access to the patient, in contrast to the legacy desktop approach in which every data supplier has its own interaction user interface. On a mobile device where one app is a mental equivalent to a tool for a specific task, different apps to access the patients' data would break with the users' expectation. Given the two choices to aggregate the data either on the mobile device or in the backend, the system was designed to aggregate in the backend. The reason for this decision was the heavy load (CPU, memory and storage) that this operation causes.

The second backend part, the bi-directional data transformation, is needed for several reasons. There are several data formats that the mobile device cannot display directly, and even if it can display the format, it might have issues with the large size of the data (e.g., there is a limitation on the mobile device for how large an image can be). Another reason for the data adaptation is, that depending on the network connection (and other factors) the data might not be available fast enough on the mobile device, even though a reduced version of this data (that can be transferred faster) would still be sufficient for the current use case of the doctor. In the other direction, the mobile devices might produce data in a format that the IT systems of the hospital do not understand. In this case the backend would transcode the data into a format that the hospital systems can understand.

Since the backend is the one place to monitor all events and notifications in the system, it observes these and can issue special notifications for a mobile device of a specific doctor, e.g., ”New MRI images are available for patient X”. In case that a mobile device client is not reachable, most notifications are queued until the mobile device becomes available again. If the notification passes an ”importance” filter, a short version of the notification is additionally sent to the mobile device as push notification, via the platform's push notification service.

4.2 Mobile Client on iOS (iPhone)

The primary mobile client was developed for the iOS platform, mainly focused on the iPhone. With the iPhone client it is possible to participate in the three main activities that our system supports:

- It is possible to view patient record data aggregated from several backend systems (document management system, RIS, etc.),
- it is possible to actively supply diagnostic findings (images, videos, audio recordings, etc.),
- and it is possible to participate in the medical decision making process by helping with the consultation workflow, and by providing audio conferences with the possibility to share and discuss patient data in this conference.

Figure 3(a) shows the typical listing of a doctor's current patients. In this view and the views reachable from this list, the doctor can access the patient record data, the patient master data, the previous cases with their diagnostics and documents, and the lab record and current consultations, as shown in Figure 3(b).

The third main activity is the discussion support. On a shared document, the doctor can mark regions, as shown in Figure 3(c). These markers are visible to the other doctors participating in the discussion conference. In this way, our system uses a distributed discussion model - each doctor can supply her own data, and if she wants to show the data to others, then she can draw their attention to the data supplied by her. This can be done via the audio connection.

4.3 Mobile Client on Android

Since not only iOS-based smartphones but also Android-based ones are present in the clinical landscape, it was a requirement to also implement a mobile client for Android systems, at least as a ”proof of concept”.

We opted to not simply port the user interface of the iPhone to the Android platform, but reimplemented the interface using the look and feel of Android applications. Because the implementation language for the desktop client was also Java, much of the code talking to the backend system could simply be reused in the Android client.

4.4 Desktop Client

While doctors are frequently on the move, there are still situations where they sit near a desktop computer, or where larger input and output hardware is more convenient for a task (e.g. text entry), or where patient cases are discussed in front of larger audiences (e.g. morning status report). We therefore decided to develop a desktop client for stationary use that takes advantage of the increased computational resources compared to the mobile clients.

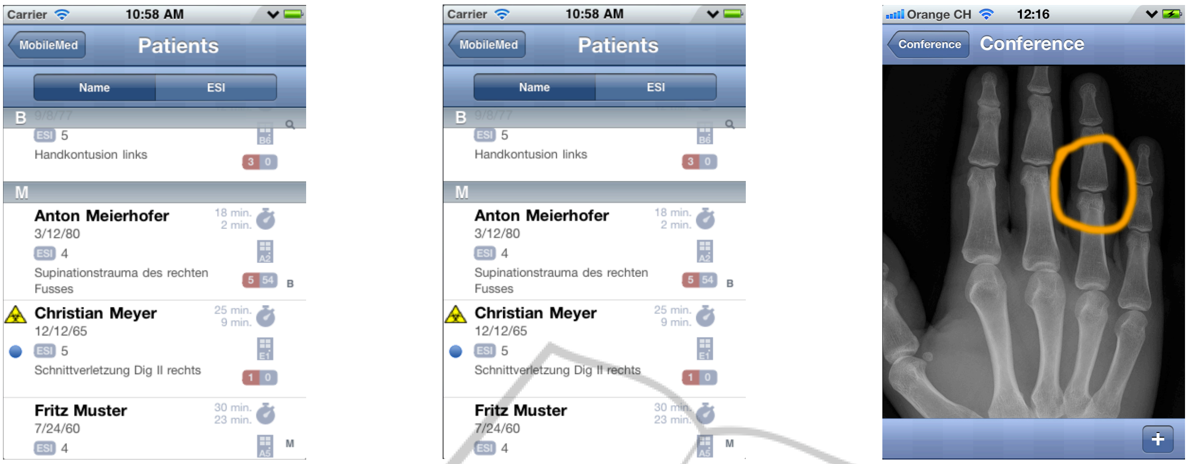
In particular, there are less screen space limitations for the desktop client, and the most important information can always be shown on the main screen, providing an ”at a glance” overview while at the same time allowing quick and easy access to details.

Figure 4 shows the user interface of the desktop client. On the left side, a list with all current patients in the emergency department is shown. More information can be obtained by simply hovering over a patient entry. In the lower left, a spatial overview of all beds in the emergency department is shown, together with the current state (red: occupied, green: free). The right side shows a patient's details, including the master data, data from the current as well as from previous cases, and all the information about pending and finished consultations. All the views are tightly linked through interactions to provide the big picture.

4.5 Communication Protocol

The communication between the clients and the backend is twofold:

- A set of control messages were defined to synchronize the application data between the clients



(a) Patient Overview (b) Patient Case Data (c) Conference discussion

Figure 3: (a) Screenshot of the iPhone UI showing the patient overview (b) Screenshot of the iPhone UI showing the patient's data sections. The actual document group names are pulled from the hospital systems. (c) Screenshot of the iPhone UI showing a media discussion in a conference.

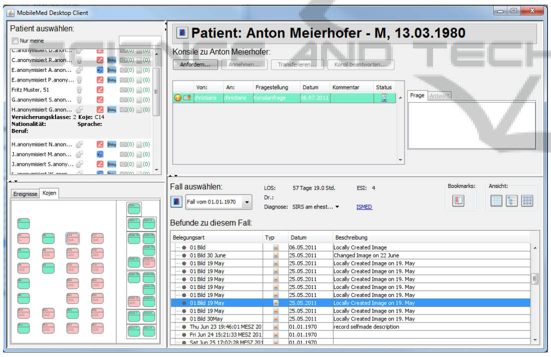


Figure 4: User interface of the desktop client.

and the backend. These messages were transmitted via socket connections, and Google Protocol Buffers (Google_Protocol_Buffers_Team, 2011) were used for efficient bit stuffing.

- Since there would be little gain to transfer media data (images, audio, video etc.) via the bit stuffing channel, it is retrieved via an HTTPS connection by the clients. Sending JPEGs etc. encoded with Protocol Buffers would only marginally improve the message size with some conversion overhead.

4.6 Connection to the Hospital IT

Since our system relies on live data, it has to be connected to the hospital's IT systems. The connections are made via "adapters" in the backend that are interchangeable, should the system be used in another hospital with a different IT infrastructure.

4.6.1 Hospital Information System (HIS)

The "information backbone" of a typical hospital consists of an HL7 message stream connecting all subsystems, and parsing this stream is the best information source, if live data of a patient is needed. We wanted to know the current location (i.e., bed) of every patient, in order to provide a graphical layout of the load of the emergency department. In our case however, this information is not communicated via HL7 but handled within the HIS directly. We therefore had to connect to the HIS instead of listening to the HL7 stream, using a database connection with read-only access, and polling it regularly by the backend to detect changes in patient location.

4.6.2 Document Management System (DMS)

A major part of the clients handles the visualization of documents stored in the Document Management System (DMS). The DMS provides SOAP Web services that can be used to upload documents and to search and retrieve documents stored in the DMS. The documents retrieved from the DMS are stored in a smart cache in the backend for some time. Also, lower size versions of the images for the mobile clients are generated in the backend.

5 EVALUATION

The system will be evaluated in a trial in early 2012 in the emergency department of the University Hospital Basel. It is planned to involve several medical doctors that will be provided with smartphones running the application. The participants will follow their daily routine, treating patients in the emergency department, and use our system to record and store media files (photos, videos, audio files) and issue requests for consultations via the functions of our system.

Also several senior doctors and medical experts will be equipped with the desktop version of the client on their workstation. This ensures that they can be reached by requests for consultation.

All involved medical doctors will be asked to participate in a structured interview after the trial. The data from the interviews will allow us to evaluate the usability of the system as a whole, and of the specific client user interfaces in particular.

6 CONCLUSIONS AND FUTURE WORK

We have built a mobile collaboration and decision support system that can enhance and speed up the processes in an emergency department of a hospital.

The features of the system were defined and developed in close collaboration with the end users (medical doctors) and the first feedbacks were encouraging. The system will be evaluated in a trial in early 2012 in the University Hospital Basel. The data gathered from log files during the trial and the findings of the interviews conducted after the trial with involved medical doctors, will allow us to examine and judge the usefulness of the system.

ACKNOWLEDGEMENTS

This work was supported by funding from the Swiss Innovation Promotion Agency CTI. The authors would like to thank the University Hospital in Basel, the Academy for medical training and simulation AMTS and Agfa Healthcare for their support.

REFERENCES

Banitsas, K., Georgiadis, P., Tachakra, S., and Cavouras, D. (2004). Using handheld devices for real-time wireless teleconsultation. *Conf Proc IEEE Eng Med Biol Soc*, 4.

Banitsas, K., Georgiadis, P., Tachakra, S., and Cavouras, D. (2006). Mobile consultant: combining total mobility with constant access. In *Engineering in Medicine and Biology Society, 2006. EMBS '06. 28th Annual International Conference of the IEEE*, pages 5248 –5251.

Carroll, A. E., Saluja, S., and Tarczy-Hornoch, P. (2002). The implementation of a Personal Digital Assistant (PDA) based patient record and charting system: lessons learned. *Proceedings / AMIA ... Annual Symposium. AMIA Symposium*, pages 111–5.

Choi, J., Yoo, S., Park, H., and Chun, J. (2006). MobileMed: a PDA-based mobile clinical information system. *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society*, 10(3):627–35.

Fischer, S., Stewart, T. E., Mehta, S., Wax, R., and Lapinsky, S. E. (2003). Handheld computing in medicine. *Journal of the American Medical Informatics Association*, 10(2):139–149.

Gamble, K. H. (2010). Wireless Tech Trends 2010. Trend: smartphones. *Healthcare informatics the business magazine for information and communication systems*, 27(2):24, 26–27.

Google_Protocol_Buffers_Team (2011). Google Protocol Buffers Project Page. Available online at http://code.google.com/intl/de-DE/apis/protocolbuffers/ Visited on September, 6th, 2011.

Hameed, S. A., Hassa, A., Shabna, S., Miho, V., and Khalifa, O. (2008). An efficient emergency, healthcare, and medical information system. *International Journal of Biometrics and Bioinformatics (IJBB)*, pages 1–9.

Morán, E. B., Tentori, M., González, V. M., Favela, J., and Martínez-Garcia, A. I. (2007). Mobility in hospital work: towards a pervasive computing hospital environment. *International Journal of Electronic Healthcare*, 3(1):72–89.

Pepid (2011). iPhone Emergency Physicians SW. Available online at http://www.pepid.com/products/iPhone-Emergency-Physicians-Software.asp Visited on September, 6th, 2011.

Pimmer, C. P., Pachler, N., and Genewein, U. (2011). The potential of smartphones to mediate intra-hospital communication and learning practices of doctors. preliminary results from a scenario-based study. *Proceeding oft he Mobile learning conference: Crossing boundaries in convergent environments, Bremen*, pages 151–4.

Pixmeo_SARL (2011). Osirix HD Product Page. Available online at http://itunes.apple.com/app/id419227089 Visited on September, 7th, 2011.

PSPsmartsoft (2011). iKomp Product Page. Available online at http://www.appannie.com/ikomp/ Visited on September, 7th, 2011.