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CARDIAC@VIEW The User Centered Development of a new Medical Image Viewer

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Abstract

The quality of the work of physicians is heavily influenced by the usability of their available viewers. In this paper we describe the implementation of a new viewer, exactly suited to the needs of the cardiologists at Graz University Hospital and the County Hospital Graz West. Applying a User Centered Development process, we studied the workflows of the end users and involved them in the design from the beginning. The software was adapted in an iterative process, including rapid prototyping and agile methodologies. All the results of the analysis made during the pre-stages of the project were integrated into the application, step-by-step during the development. The software tests were supplemented by the use of video analysis and interviews with the target group. The experiments resulted in deep insights into how to develop an appropriate viewer for the specific target end user group.

Categories and Subject Descriptors (according to ACM CCS): D.2.10.i [Rapid Prototyping], D.2.5 [Usability], H.1.2.5 [Human-Centered Computing], H.5.2.k [Prototyping], I.3.c [Medical Information Systems].

1. Introduction

The opportunities for computer graphics and visualization to improve Health Care are dramatic: medical procedures can greatly benefit from improved visualization, navigation, interaction and from enhanced decision support [Rho97]. However, the developers of software applications for Health Care must understand not only the technology they support and the limitations of the techniques they use but also the physicians who will use their software. Consequently, Usability Engineering Methods (UEM), which include the end users in the development from the beginning, are becoming more and more important [Hol05]. The work, presented in this paper, was motivated by two different points of view.

1.1. Motivation from the viewpoint of Software Development

At the Institute for Medical Informatics, Statistics and Documentation (IMI), DICOM Viewers have been developed for the study of radiological images (X-Rays, CT images, etc.) for more than a decade. These are now implemented in the routine operations of Graz University Hospital and 20 County hospitals in Styria.

However, due to this long experience, there is always the risk of assuming that technical similarities, (e.g. the same display format) imply similar user requirements. This risk can be drastically reduced by the application of User Centered Development methods (see Section 2).

1.2. Motivation from the viewpoint of the cardiologists = End user

Diagnostic imaging plays a fundamental role in the initial screening and the subsequent management of heart disease patients [GZM97].

Previously, the cardiologists of the two hospitals involved had no economical and stable possibility of viewing cardiological images, except at their own workstations. Therefore, it was necessary to provide a solution to fulfill this requirement.

On the one hand, a viewer should offer the possibility of viewing images from every workstation within the cardiologists' departments and, at the same time, it must be possible to forward the images, using a suitable medium (e.g. CD-ROM), to referring medical doctors both within and without the hospitals. The instability and the platform dependency, as well as the restrictions pertaining to opening the images from more than one study concurrently, were considered particularly troublesome. Therefore, a simple, economical viewer needed to be developed, in co-operation with experienced developers and future end users, which offered the possibility of viewing images away from the workstation and was stable enough for routine operations both in the integrated IT environment of the clinical centers and compatible with the IT equipment of the referring department or medical doctor.

However, it is worth mentioning that access to the Cardiac@View Medical Image Viewer can be integrated into various existing Internet applications in use at the Graz University Hospital and we are currently investigating the possibility of mobile multimedia services.

2. User centered Development

Human-Computer Interaction (HCI) has been a primary area for innovative, multidisciplinary research in Computer Science and specifically in software development during the past twenty years [DN84], [SA03]. Although approaches for the application of Human Centered Development have been around for most of the time, a rift still exists between these theories and the current practice. Either software engineers concentrate on software development, or usability experts concentrate on design, they rarely work together [SM04].

User Centered design processes are basically defined in ISO 13407 and the associated ISO TR 18529. This international set of design processes provides some definitions of the capabilities required by an organization in order to effectively implement UCD and assess its employment. Parts of the Human factors community regard this a constraint [EJB01].

3. Design & development of CARDIAC@VIEW

3.1. Level 1: Requirements analysis

Our first goal was to provide specifications of the tasks that the end users must perform in order to support problem solving [Lev00].

We first discussed the system with all the people involved i.e. the cardiologists, who expressed their demands of what the system must be able to do – which functionalities it should provide and how these should work. During the requirement analysis, which was made with the help of video recordings of clinicians in real work situations, a verbal description of the system emerged.

Figure 1: *A view onto the paper mock-up of the Viewer. All interactions were examined by allocating tasks to the end-users.*

3.2. Level 2: Low-Fi prototyping (Paper Mock-up)

First, screen designs and dialogues were sketched on paper. Then a paper mock-up, which can be adjusted whilst working with the cardiologists, was created. The use of paper mock-ups provides a first usability feedback with minimum effort and maximum results.

Figure 2: *The cardiologist augments the Paper Mock-up by means of a functionality rehearsal.*

Further, a working prototype, for studying the interaction of the end users, was created. During this phase the programmers were able to concentrate on the hi-fi prototype and adapt the choice of software tools to the technological requirements.

The advantage of this approach–as opposed to the usual methods–can be seen in the fact that the graphical user interface was available before the full implementation, subsequently the end users knew, in advance, exactly what was being provided and how it looked. In the traditional way, the prototype develops from an idea although the design is predetermined by the data for which the programmer has to provide the interaction. Our application (Figure 3) consists of two windows; the Search Mask and the Main Window. The Search Mask is an input form by which the user can *search for* the medical data. It is displayed immediately on starting the application. Subsequently, the application switches to the main window to display the data, and an overview list (directory tree), subject to requested filters, is displayed.

The **Search Pop-Up** is a self-opening search form, in which the user can enter parameters for a search in the data base.

The **Viewer Window** is a *screen-within-a-screen* containing the actual image data within the main window. An individual viewer window is opened for every patient or patient study.

The **Player** is a window, within which the selected images can be played, started/stopped, navigated etc.

The **Toolbox** contains all the tools (functions), which the user requires to manipulate the images.

The **Symbol Bar** is a toolbar in the main window, adaptable to be above or beneath the overview list. It contains extra tools, which are not found in the Toolbox, for example: grid alignment, navigation, etc.

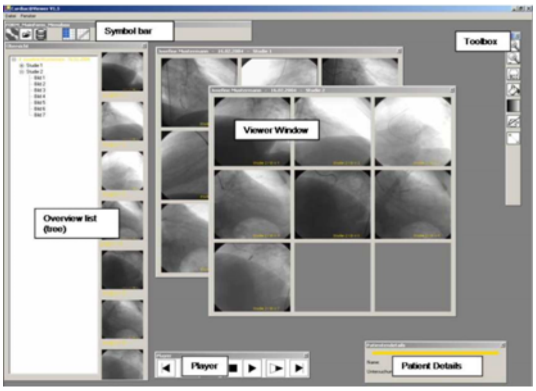

Figure 3: *The different parts of the Viewer, seen in the Hi-Fi Prototype.*

3.3. Level 3: Hi-Fi Prototyping

Within this project, state-of-the-art Usability Engineering Methods [Hol05, Hol02] were used, following the practical experience which has been acquired in User Centered Development [ND86], [Kar97], [Hol03], including rapid prototyping [Hol04]; always together with the end users and studying their interaction. This involvement of the end users from the very beginning of a project is necessary in order to understand how the end users work and to be in a position to provide an easy and pleasant-to-operate system, with a minimum necessary learning effort.

3.4. Level 4: Implementation

From the viewpoint of Software Engineering the most essential specifications were:

- Platform independence (Mac, Windows, Unix, Linux);
- Support for the most important display formats, including DICOM, BMP, JPEG, GIF, PNG, TIFF, AVI, MPEG 4.

The software tools used were:

- Qt (this is a platform independent $C++$ GUI-Toolkit for the creation of graphic user interfaces, developer license, see http://www.trolltech.com);
- DICOM Toolkit (OFFIS Oldenburg, platform independent, available without charge at http://dicom.offis.de/dcmtk.php.en);
- Graphic libraries (JPEG, TIFF, GIF, PNG, AVI, platform independent, freely available without charges or license fees).

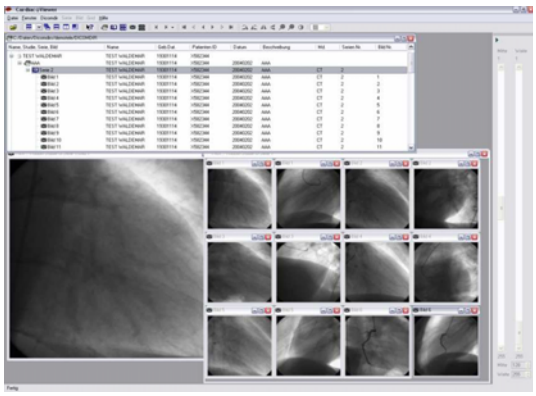

Figure 4: *The new viewer in real-life use.*

4. Lessons learned

Generally, during the development of software systems, the software engineers, together with the physicians, are confronted with the problem that insufficient time is available for the specification of the system details and individual end user studies. Apart from the normal working hours, medical doctors are also continually subjected to interruptions, in the form of acute medical demands, (e.g. emergencies, instantaneous sections, etc.), and in a clinical setting, the periodic pressure of teaching and supporting students.

Consequently, it was even more complicated to merge a representative group together, in order to enable an agile software development process. Not only that the software development team required a number of end users, their availability within an extremely narrow timeframe was also a serious problem. Due to the methods applied, the expenditure of 15 to 20 minutes of the physicians' time for each experimental session was considered acceptable. During a subsequent questioning, the physicians admitted a willingness to participate in experiments again.

The amount of information regarding implementation details, workflows and the cardiologist functions, which was acquired in advance by the use of paper mock-ups was extremely helpful for the software developers.

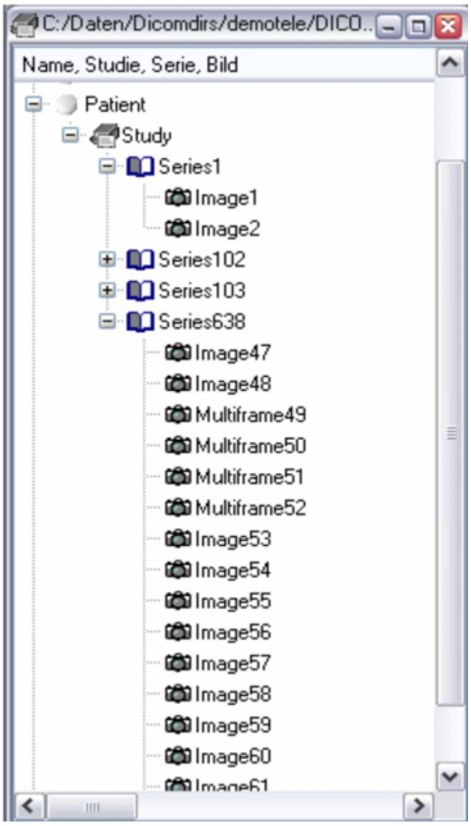

Figure 5: *The Hierarchy of a Patient Study*

The diverse structuring of a Radiology investigation can be used as an example of this. In radiology, the usual structure of a DICOM standard is "Study – Series –Image". A further division of the images into frames is currently the exception. In our observed field of cardiology however, the "Study" is also equivalent to the "Series", whereas the "Frame" is particularly important.

The hierarchy is, therefore, quasi shifted by one stage (Study ="Series – Image – Frame"). This hierarchy is of crucial importance, particularly for future steps, since the video functionality must be coordinated with the individual context.

Since the methods used in this project have proven to be compatible with the medical routine, these will continue to be put to use, in order to make the specification and adaptation processes as pleasant as possible for the medical doctors.

5. Conclusion

The design of the user interface and all function sequences and interactions with the user interface, which are most important to the end users, were compiled and completed together with the end user, whereby the experiences both of the end users and our software engineers were incorporated.

The working methods of the cardiologists could be surveyed and taken into consideration:

- without permitting the information already gained from the field of radiology to interfere with the objective evaluation during the investigation; and
- permitting implementation details to be specified without frustrating the end user.

As a result of the available experience within our institute, it was possible to access the previous experience and knowledge acquired from the field of Radiology and, after developing this basic viewer, to create a wider functionality by the inclusion of the existing image archives. The synthesis of these areas–without predefining the specific features–is also proposed. The final discussion and evaluation of the cardiac@viewer by the doctors and developers involved in the design and development was

The advantages of this in-house design over a commercial product are manifold. These include such items as:

- Cost-effectivity by non-complex integration into the existing infrastructure;
- Consolidation with existing viewers (PACSView & ArchView);
- Connection to other archives;
- Integration of the algorithms created with IDL (Research results);
- Mobile Computing application possibilities (Laptop & Tablet Applications);
- Terminal server features permit a complete network installation;
- Platform independence (Unix, Linux, Windows);
- Unlike a conventional viewer, the cardiac@viewer is able to display a wider range of images than just DICOM format or images with 8-Bit pixel depth – Bmp, Jpg, Pnm, Tiff, GIF, and Png (16 bit pixels depth) can be processed;
- The simultaneous view of a number of examinations is not affordably available for the cardiologists with the current commercial applications.

6. Future research

The next step, and this is where the main difference between the purchase of a standard system and the in-house devel-

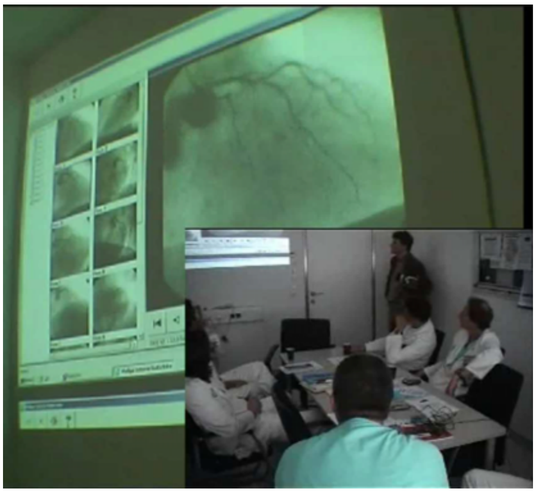

Figure 6: *The teams concluding discussion*

opment of a User Centered Development becomes obvious, an iterative and partly overlapping cycle of User Centered Design, development and detailed evaluation is intended.

The analysis of detailed log files is scheduled to be an important component during the evaluation phase. Excellent experiences have been made with these methods in other projects, where the fine tuning of functionalities and the advance recognition of difficulties was concerned and concomitant to optimizing direct methods (e.g. questionnaires, video recordings etc.). However, a controlled, comparative end-user satisfaction survey is currently being devised.

As a result of having built a fully functional viewer, we can concentrate our future efforts on the scientific questions concerning Human-Computer Interaction. An example of the type of questions which we plan to address and should be answered on the basis of xisting data:

Which variables are pertinent to evaluate the requirements and the ability of the referring physicians with regard to the frequency with which they view the images and/or medical reports of a medical investigation? Hypotheses include (1) the objective and the subjective ability and/or the confidence of the physician; (2) the available time; (3) the age/storage date of the study; (4) the existing equipment; (5) the admission diagnosis; (6) the medical problem.

As a consequence of point 3 (above), there must also be a connection with the type of the study, since images of instantaneous sections can be evaluated with simpler equipment than is necessary for a digital thorax images or mammography images. We have a large quantity of data available, which can be used to experimentally investigate these hypotheses.

The enormous practical use of these investigations could be the development of file/data/fetching filters for studies and images according to their medical relevance in the appropriate context. Accordingly, it would thus be possible to pre-fetch the studies and/or images and store a copy of these on the [local] server in order to make an optimal access speed possible.

Further questions, which we intend to explore include: When the images are viewed, how are they viewed? Are there differences in the viewing, once the images have been judged to be relevant?

We assume that the same factors, which are conclusive for the decision whether or not to view an examination, are also decisive for the type of study used to view it. Large quantities of PACSview log files are available as data sources. Optimized Viewers and formats for the transfer and viewing of images could be of great practical value.

7. Glossary

A **PATIENT** is the subject of one or more *medical studies* that produce medical images.

A **STUDY** is a collection of one or more series of *medical images*. Each study is associated with exactly one patient.

A **SERIES** is a sequential succession of images belonging to one study.

An **IMAGE** is related to a single series, and defines the *attributes* that describe the pixel data of an image. This data may be represented as a **single frame** of pixels or as **multiple frames** of pixel data (a cine run or the slices of a volume), which are sequentially ordered.

A **FRAME** is a detail screen containing a single shot. These can be combined to create a short video film.

LOW-FI prototyping includes inexpensive methods such as paper mock-ups and wire-framing.

HI-FI prototyping involves the use of sophisticated software tools on end-user devices.

PRE-FETCHING is the creation of an advance copy of a PACS picture on a Server, in order to make faster access possible.

A **FILTER** refers either to limiting the display of the available images or to the reduction of the Pre-Fetching to the medically relevant studies.

IDL is the Data Visualization & Analysis Platform Software for data analysis, visualization, and cross-platform application development.

PACSview is an in-house Picture Archiving System Viewer containing complete studies.

ARCHview is an Archive Viewer containing individual images.

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