

# Assessing Quality of Computer Systems and User Interfaces of Future Medical Workplaces – Augmented Reality for Minimally Invasive Therapy

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## ABSTRACT

This positioning paper describes the challenge of assessing usability or plan ergonomic research from not yet existing technology. It proposes a methodology for quality assessment of future computer systems for minimally invasive therapy. The multidisciplinary ARIS\*ER research team aims to give “super vision” and “super sensing” to the surgical team by augmented reality technology and robotic applications. The team consists of specialists on robotics, 3D visualization and tracking, segmentation, rendering as well as ergonomics and design. This paper drafts the design methodology and the applied ergonomic methods. It points out aspects that were taken into account to deal with the multi-disciplinarity of the users as well as the developers. The paper is summarized with general aims of planned usability studies and ergonomic research.

## Author Keywords

Minimally Invasive Therapy (MIT), Ergonomics, Design process, Multidisciplinary Research and Development, Knowledge transfer, Usability

## INTRODUCTION

Minimally invasive therapy (MIT) is an important trend in modern medicine. It is performed through one or several small incisions, using specialized medical instruments such as endoscopic videos and robotic tools. Recently new materials and technologies led to new developments in the domains of computer guided surgery and computer-enhanced surgical robotic systems. Samset describes the current key limiting factors of MIT by: *immature and unreliable tools for real-time 3D-navigation, fragmented research (geographically and disciplinary) and lack of researchers capable to operate across the integrated fields (3D visualization, image processing, robotics and*

*radiology) and having sufficient insight into relevant ergonomic aspects for MIT* [1].

The European research training network “*Augmented Reality in Surgery*” (ARIS\*ER)<sup>1</sup> aims to fill this gap [2]. Human factor specialists are equal partners in the ARIS\*ER consortium; research in the core technologies goes parallel with ergonomic research. The design of the user interfaces is effectuated by a user centered approach in iterative steps [2] and involves all eight partners: engineers (image processing (segmentation and registration), haptics, robotics, 3D visualization and tracking), surgeons and human factors specialists.

ARIS\*ER is working on a computer system that might be the first working version that integrates several novel technologies (e.g. real time image fusion, real time segmentation, real time haptics feedback). We are faced with a combination of new technology; therefore we have to ask ourselves the question how we can ensure quality. To fulfill the high aims to face the lack of sensory feedback and information support for the surgical team, the system will have to achieve highest quality as well in ergonomic (usability, safety), medical and technical aspects.

## Ergonomics in MIT

Actual computer systems that support the most advanced MIT are Mixed Reality Systems (MRSs). They are computer systems that merge **real environments** (e.g. endoscopic video, real-time ultra sound picture, direct vision of the surgeon or interventionist, screen with preoperative pictures (static information)) with **virtual environments** (e.g. segmented tumors (on preoperative pictures), displayed tracking of organs or surgical tools,

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<sup>1</sup> <http://www.ariser.info/>

displayed data of fused modalities after registration, displayed tracking data of tools or organs).

The technology that makes this possible is still rather young. History of ergonomics has shown that when a new technology emerges, ergonomic research is first focused on health related (physiological) aspects and time shifted cognitive and organizational aspects (e.g. evolution of research computer work: Displays, Interface design, Information presentation, Networks etc.).

Actual MITs, e.g. for endoscopic surgery, consists of demanding work tasks for the surgeons and the surgical team. These tasks and the work environment itself contain already challenging aspects for an Ergonomist (e.g. posture, hand-eye-video-coordination, and workload). It is obvious that in such a working environment the system should aim to support the users in the best possible way and aim to reduce their workload. By no means should it be a source of new problems.

At this moment there are still important sensorial problems for 3D representations in MRSs. E.g. The use of stereoscopic visual displays (e.g. HMDs) can create significant perceptual problems. This is one reason why at this moment 3D representations generally have poor usability ratings [3]. Only few usability studies on applied MRSs are yet published. The community could not yet agree on specific common *usability criteria* for MRSs [3, 4]. On the other hand all five quality components from Jakob Nielsen's definition of usability (learnability, efficiency, memorability, errors, satisfaction) [5] can be rated as highly important for applied MRSs in the medical field (e.g. learning curve, operation time, surgical errors, ease-of-use, safety, and trust).

#### Links to UITQ 2005 Workshop

Within the ARIS\*ER work package “*User Interfaces*”, a task “*evaluation protocol*” was described but not clearly defined. The first steps towards a general evaluation protocol of the system were done in a recent study [6]. The found four key requirements are: *user-centered design, information presentation, surgeons' workload and safety, and security aspects*.

During this work an interesting link to Timo Jokela's work has been experienced. His introductory questions was “*Could the usability and user acceptance of a software system be ensured during development, before the system is delivered and used?*” [7]. We realized, that our evaluation framework must take in account major advances in technology during the design process. *How to evaluate not yet existing technology? In considerations of the fact of multiple obstacles we had to focus first on certain aspect. Here in this paper we focus on usability and ergonomic research.* Our question also looks ahead: *How can we ensure usability of our computer system, which takes major breakthroughs in technology in account?*

Another link to mention is *User-centeredness*. Decisions on work organization, involved disciplines and partners as well as the foci have been taken as early as 2004 and 2005. Relevant aspects of the design methodology and human factors have been mainly treated by the co-authors Eigil Samset, programme coordinator and Adinda Freudenthal, user interfaces work package leader [1, 2].

ARIS\*ER has a focus on training of researchers (8 PhDs and 5 Post Docs) and less on management and other important industrial aspects. But the results from our four year experiment might give some input for Usability Maturity Models (UMMs) and Timo Jokela's and other related work [7].

#### USABILITY OF FUTURE MIT TECHNOLOGY

In our case research and development in multiple technologies goes parallel with ergonomic research and evaluation activities. We have the dilemma of two parallel tasks: an iterative design process that consists of parallel research and engineering tasks, and an evaluation task.

With each design and research iteration (1) **user requirements** are investigated, (2) **advances in technology opportunities** are matched, and (3) **possible solutions** are selected and evaluated [2]. Later in the text we'll come back to these three major tasks (Design loop). For all three tasks HF specialists, engineers and MD (surgeons, radiologists) work in close collaboration in focus groups.

Know-how transfer between the different involved disciplines is an important issue in ARIS\*ER. It is effectuated during other activities (research, design, engineering), within these focus groups as well as in regularly held thematic workshops and meetings. We have a three way exchange, between technology, medical and HF (Fig. 1). To assure a certain quality, e.g. lectures on design (user-centered design, co-design), ergonomics (usability, technology assessment, task analyses) have been given in the consortium with the start of the project. This education is an ongoing task throughout the project.

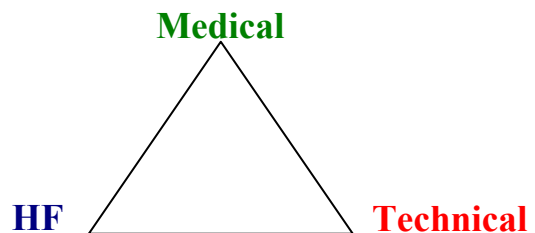


Figure 1. Education and know-how transfer between medical partners, technicians and human factors specialists.

As internal information platform and “shared workspace” a BSCW-server<sup>2</sup> (Basic Support for Cooperative Work) is intensively used. It enables collaboration with all partners over the Web with a standard Web browser.

**First design loop**

The first design loop can be characterized by its focus on methodology (participatory methods are e.g. task analysis, usability walkthroughs, functional descriptions of prototypes and demonstrators and storyboards), user requirement and context-of-use.

**(1) User requirements** (Fig.2: blue triangle) as well as the **Context-of-use** are investigated. Both steps take place in interdisciplinary workshops with developers and experienced users [6]:

- A **task analysis** (ISO 13407) of existing medical procedure, its environment and tools is effectuated. The assignment of tasks to roles, ISO 6385, was performed in a co-research setting with technologists, experienced surgeons and a HF specialist who moderated the session.
- A **critical incidents analysis** (ISO/TR 16982) was conducted. On the basis of the task analysis **ergonomic key requirements** for the design are analyzed.

The results were presented to experienced medical doctors in MIT and verified in **Interviews** (ISO/TR 16982).

**(2) The technology opportunities** (Fig.2: red dots) are elaborated. Future technical possibilities for selected key tasks were discussed in three different workshops (medical aspects, visualization, and robotics).

- Defining and coordinating **actual research questions**
- Results from all previous workshops and interviews were analyzed and combined to generate **estimated functionalities of future MIT computer systems**.

From this definition of estimated future functionalities on the discussions on technological aspects had two horizons: A smaller for actual goal for development and a bigger for estimated future technological possibilities (Fig.2: yellow arrows).

These different horizons allow focusing on actual research in the core technology and still giving an idea for functionalities of the future. Distinguishing those horizons also helps to plan and do punctual usability tests in the next design iteration as well as to plan more extensive experiments. In those research settings limitations as well as performance of the user are measured (e.g. physiological measurements) and the results are compared with the goals and tasks of the overall (work) systems.

For the overall evaluation of the system (evaluation framework) the functions and tasks of future systems can be compared with ergonomic, medical and safety standards.

**(3) Select and evaluate solutions** in early technology opportunities sessions is delicate. Early decisions are mostly most directive and therefore important. Descriptions of functions and tasks of future systems and an analysis of user requirements and context-of-use can be helpful and support the decision making process in the group (Fig. 2: red dot).

**Second design loop and future possibilities**

The second design loop will be characterized with usability and proof of concept studies. In our opinion it makes no sense to do ergonomic research or usability studies on current technology (first design loop) when major advances in technology can be expected. The benefit of looking into the future and describing future possibilities is that more precise and beneficial input for actual running system of the future can be given [6].

But development of MRS offers possibilities that are rare for normal computer systems: The information in MRS with virtual character is per definition modeled (computed) for this specific use. It can also be used to simulate certain work situation in the design process. **Virtual prototyping** is a widely used application for MR-systems [8].

High-tech methods are not necessary for the evaluation of MRS, for simple aspects experienced users can give a first feedback on functional description (text) of a task or a tool. Video from prototypes can be used for usability walkthroughs.

The third design loop will include ergonomic research and a general evaluation.

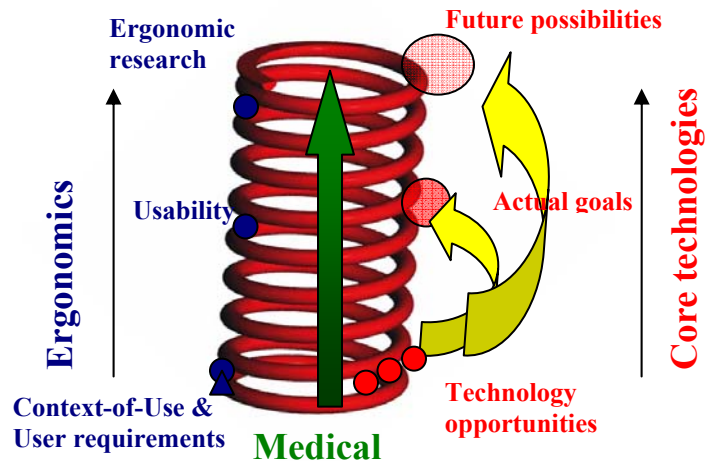


Figure 2. User-centered development and design process for MIT. Ergonomics activities are marked with blue dots in different stages of the design (loops). Technology opportunities with short horizon (actual research goals) and broad horizon on estimated future possibilities (yellow arrows).

<sup>2</sup> <http://bscw.fit.fraunhofer.de/>

## CONCLUSIONS

We evaluate systems quality up to a certain degree and with restrictions already during the design process. We do this based on descriptions of hypothetical functions, as well as on running prototypes and demonstrators.

In the first phases we see a lot of potential for quality enhancement by simple knowledge transfer from basic ergonomics know-how into the design process. This applies for all ergonomic domains (physiological, cognitive and organizational), as knowledge from various disciplines is required.

We aim to fulfil high aims on usability of MITs by focussing on the actual context-of-use. Future research will consist of a variety of different aspects: investigation on user's need, user behaviors in different levels of virtuality in MRS as well as usability testing with focus on a particular tool, or set of tools.

It would be “*nice to have*” technology independent experimental setups and evaluation techniques that allow transfer of knowledge from one into another stage of technology maturity (major advances in technology, or technology switch).

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