Virtual Reality Hysteroscopy Training Simulator

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Abstract. Rapid development of medical field, expanding knowledge base and new technologies require continuing medical education to achieve life long learning and to keep the surgeons up to date. Consequently, specific training is necessary to guarantee qualification of the surgeons. To overcome the current drawbacks of traditional training systems (on-the-job training, plastic models etc.) for hysteroscopy an intelligent adaptable training environment has been realized using Virtual Reality (VR), Multimedia (MM) technology, and Intelligent Tutoring Systems (ITS).

1. INTRODUCTION

This work has been influenced by two paradigm shifts: in medicine there was a transition from open surgery to minimally invasive surgery - surgical interventions are done through small incisions in the body in which a miniature camera and surgical tools are manoeuvred – these complicated techniques require a specific training; and in computer graphics 2-D interaction was replaced by 3-D interaction using Virtual Reality techniques.

These innovative technologies open up new possibilities in medicine including anatomical education, preoperative planning, intraoperative support, and surgical training. VR based medical simulation provides a highly realistic surgical environment including anatomical structures and surgical instruments. Especially, a “natural” interaction is guaranteed considering the various human senses. The applicability of VR for rehearsing minimally invasive interventions is proven by a variety of surgical simulators [1], [2], [3], [4], [5]. Billinghurst et al. took the first step towards integration of VR simulation and Intelligent Tutoring Systems for training of ENT surgeons [6].

The LAHYSTOTRAIN training system is an advanced simulation environment for hysteroscopic procedures combining virtual reality (VR), multimedia (MM) and intelligent tutoring techniques (ITS). Based on ESHRE (European Society of Human Reproduction and Embryology), the user requirements are specified. Starting with diagnostic procedures and ending with complex therapeutical interventions the whole educational process is covered. In general, due to the various levels in difficulty and complexity the training course can be individually adapted to the level of the trainee addressing all potential „learners“ as students, novices, and experts. The training environment is divided into two scenarios: The basic training system consists of a Web-based training system addressing novice users and focusing on the theory and conceptual aspects of laparoscopy and hysteroscopy. The advanced training system using VR technology addresses more experienced surgeons who want to acquire or improve their skills on minimally invasive techniques. It provides a realistic training environment for rehearsing the various interventions and gives a more intuitive 3-D interaction. The intelligent tutoring architecture detects superficial errors and infers their cause. A tutor proposes different training sessions and exercises according to the user's expertise.

2. METHODS

The Advanced Training System (ATS) provides an intuitive training environment for the users of LAHYSTOTRAIN. Moreover, the set up of the training system is similar to the real surgical environment during laparoscopic or hysteroscopic procedures. In general, this environment consists of the patient, the medical instruments - including the endoscope -, video monitor, assistant surgeons, nurses, and the anesthetist. This situation is simulated by the ATS**,** the VR Simulator **-** representing the virtual patient, the virtual instruments and the graphics monitor (see Figure 1) and the Intelligent Tutoring System (ITS) - including the assistant surgeons, nurses and the anesthetist.

2.1 Virtual Reality (VR) simulator

The VR Simulator contains virtual anatomical structures and simulates endoscope, surgical instruments, and object behaviour (collision detection, deformation, and cutting). It provides a realistic surgical environment in which training of the various hysteroscopic interventions is possible. Similar to a real hysteroscopy, the trainee is able to use surgical instruments interacting with the anatomical region of interest - the virtual situs. The development of the VR simulator is divided into two parts: the generation of the Virtual Environment (VE), and the realization of the 3-D interaction.

Figure 1: The hysteroscopy training simulator

Due to analysis of real surgical environment during hysteroscopy, the Virtual Environment requires a realistic 3-D representation of the abdominal region. Input data for the generation of the virtual situs are CT or MR scans as well as video sequences of hysteroscopic procedures (see figure 2).

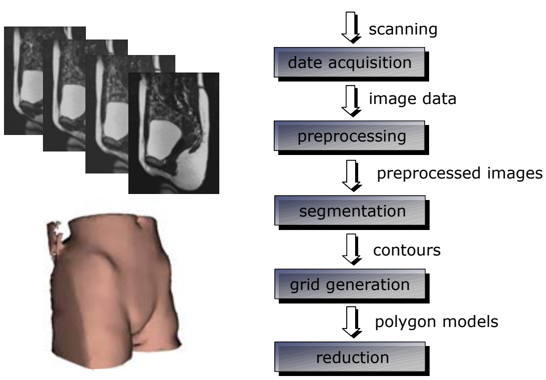

Figure 2: The 3-D reconstruction pipeline

Based on this image data a virtual situs has to be reconstructed suitable for real-time simulation. To provide organ specific textures is indispensable in hysteroscopic simulation in order to enhance a realistic appearance and to represent pathological tissue. Input data for the texture generation algorithms are pictures taken from endoscopic video recordings. Finally, these textures are mapped on the virtual anatomical structures (see figure 3).

The simulation model allows a simulation of both rigid instruments and those with moving parts. In addition a virtual endoscope with different optics (e.g., 0°, 12°, 30°) is realised. The hysteroscopic procedure is appropriate for simulation of therapeutic interventions since endoscope and tools are integrated in one single instrument - the resectoscope. Position, orientation and the opening angle of the resectoscope have to be monitored. Providing the simulation origin instruments of KARL STORZ GmbH are integrated into the "Laparoscopic Interface" from Immersion Corporation.)

The trainee handles the instrument and controls the virtual electrodes which are used for the resection of pathologic tissue along the resectoscope´s axis. (see figure 4)

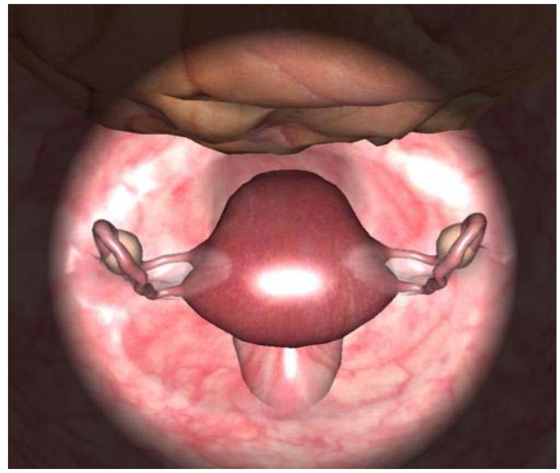

Figure 3: The virtual uterus

2.2 Intelligent tutoring system (ITS)

The ITS includes the Assistant**,** the Tutor and three Agents. The Assistant controls and supervises the trainee´s execution of exercises detecting superficial errors, inferring their cause and providing explanations and remedy suggestions. It provides two types of assistance: reactive and proactive. Proactive assistance consists in the generation of explanations about different aspects of the procedures the surgeons have to carry on. Reactive assistance consists in the generation of explanations whenever the user makes a mistake, or something anomalous is happening at the VR simulator.

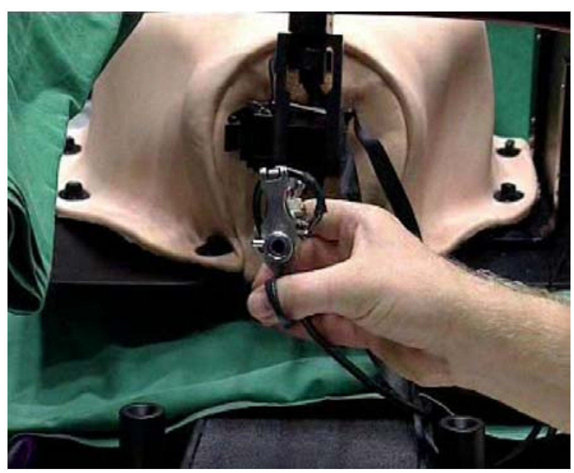

Figure 4: 3-D interaction with resectoscope

The Tutor is in charge of managing the whole training process: rostering and registering student information, acquiring trainee performance data and generating and executing the session according to the user's expertise. The Tutor dynamically modifies this plan adapting it to the trainee's performance during a training session.

Three Agents (Assistant Surgeon, Nurse, and an Anesthetist) will reproduce and emulate the behaviour of some persons of the operating theatre. Surgeons must learn their individual role in the team as well as how to co-ordinate their actions with their team-mates. Intelligent virtual agents, that interact with students through face-to-face collaboration on the virtual world, have already proven in this role [7]. The final subsystem of the LAHYSTOTRAIN architecture is the Student and Instructor Interface which handles all input and output from the advanced training environment:

- Is the navigation of the endoscope appropriate? What is about the visibility of the therapeutic target in the endoscopic output?
- Has the intervention been performed in an appropriate time?
- Has all the pathologies been identified correctly?

The data for these endoscopic aspects are collected and analyzed by the affiliated Intelligent Tutoring System. The trainee receives an evaluation score of her/his session. Only if she/he has proven her/his skills can she/he pass over to the next level.

3. RESULTS

The first prototype of LAHYSTOTRAIN includes the treatment of the ovarian cyst. The WWW component provides the learning environment for knowledge acquisition, and the VR simulation system is suitable for skill training. The VR training environment contains virtual anatomical structures and simulates endoscope, surgical instruments and object behavior (collision detection, deformation, cutting). In addition, a force feedback device is integrated into the training system; thus, the trainee is able to feel the give and resistance of the anatomical structures via instruments. The intelligent tutor system guides as the "surgical expert" during the various levels of the training process. Current work is focusing on the implementation of this training environment on low-cost-platforms.

4. CONCLUSIONS

This integrative and adaptable training environment provides new opportunities in medical education. Combining intelligent tutor, VR, WWW, and multimedia, this approach demonstrates that the complete educational process can be covered considering the individual training level of the trainee. The LAHYSTOTRAIN system has been validated across European member states in various healthcare environments with existing working methods and practices. Results of the first evaluation showed that the use of medical training simulators has an overall high acceptance. This concept has general applicability to other medical specialties providing standard training situations for objective assessment.

The LAHYSTOTRAIN project shows that such surgical simulators are appropriate for practicing surgical techniques without having to advance the learning curve on humans. Considering that several decades were necessary to develop high sophisticated flight simulators, which are available today, rapid developments in recent years and the promising results presented herein give hope that VR based training simulators will be integrated into the medical curriculum in the near future.

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