NES – The Nasal Endoscopy Simulator

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Abstract
Rapid development in the medical field, an expanding knowledge base, and upcoming technologies require a continuing medical education to achieve life long learning and to keep the surgeons up to date. Consequently, specific training is necessary to guarantee the qualification of the surgeon. In recent years several training systems have been developed using Virtual Reality (VR) techniques to overcome the current drawbacks of traditional training systems (on-the-job training, plastic models, etc.). In a cooperative project of the University Hospital in Mainz (Department of Otolaryngology Head and Neck Surgery) and the Technical University in Darmstadt, the Nasal Endoscopy Simulator (NES) has been developed. Similar to a scenario in a computer game, several tasks grouped into levels have to be solved during the training process. These levels start with simple tasks in abstract virtual environments to train the handling of the endoscope and they end with scenarios using complex models of the endonasal sinus to train orientation as well as diagnostic and therapeutic procedures. During simulated interventions, trainee errors, for example collisions of instruments and high sensitive tissues, are detected and evaluated. The integrative adaptable training environment provides new opportunities in medical education and enhances the medical standard curriculum. This concept has a general applicability to other medical fields.

Background
The »gold standard« of surgical training today remains cadaver dissection. Unfortunately, only a limited number of cadavers are available for each trainee, and some trainees may perform surgery on patients before having gained sufficient surgical skills. Moreover, it is most likely that a trainee will not see rare anatomic variations or perform revision surgery on a cadaver. A normal variant without disease will be found in most of the specimens, the tissue is often changed by formaline preservation, and no bleeding occurs. To overcome these traditional training methods, VR training simulators have been developed for several endoscopic procedures.

Simulation of surgery in a virtual environment for educational purposes has several advantages over cadaver dissection. VR simulators allow for unlimited numbers of procedures with a single system, every anatomic variation can be simulated, and conditions like massive polyps or a postoperative situation with missing landmarks can be included in the virtual environment.

Nasal Endoscopy Simulator (NES)
The VR Simulation not only simulates rhinoscopic interventions as realistically as possible, but it also tries to train endoscopic skills in several levels. The tasks in level one are established for the training of hand-eye coordination. According to the output on the 2D display, the user has to navigate through an abstract 3D world consisting of boxes and squares. This simple scenario is enhanced with force feedback using the »Laparoscopic Impulse Engine« immersion device. The 2D user interface offers the possibility of analyzing the training session, and it monitors detected errors and provides the ability to record and replay a training session (cf. Figure 1).

In the next level, some diagnostic tasks with 3D models of the nasal cavities and sinuses have to be performed. Using the rhinoscope, the trainee navigates through the virtual situs, identifying landmarks in some exemplary physiologic and pathologic cases. An electromagnetic tracking system is used to register the position and orientation of the endoscope. The trainee has the opportunity to

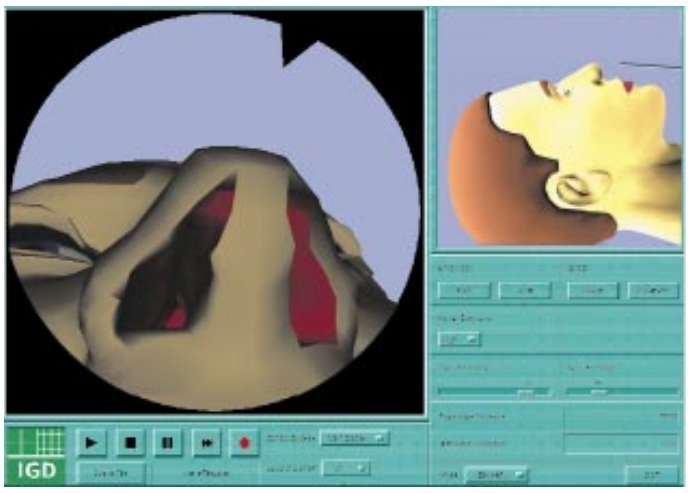

Figure 1:
NES Graphical User interface

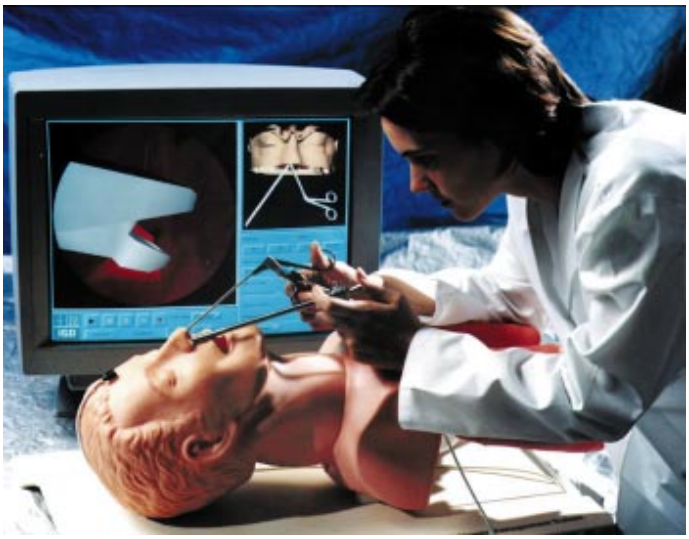

Figure 2: The Nasal Endoscopy Simulator (NES)

choose different optics (0°, 30°, 70°) to get familiar with their handling. To build up a database of exemplary cases, tomography data of interesting patients are collected at the University Hospital in Mainz. 3D reconstruction techniques are used to derive the virtual situs from tomography scans. Only the area of the sinuses is scanned in medical praxis to keep the radiation dose as low as possible. This is why the reconstructed sinuses are embedded into a dummy's head.

The third and final level of NES gives the trainee the opportunity to use surgical instruments to perform a therapeutic intervention on the virtual situs (cf. Figure 2). Therefore, not only does a model of the surgical instruments have to be generated, but the interaction of instruments and tissues also has to be taken into account. Simple instruments, like a scalpel or a liebling, are once again registered using the electromagnetic tracking system, but more complex instruments like scissors or gators are equipped additionally with a small potentiometer which registers the instrument's opening angle. An other challenging part is the simulation of tissue behavior caused by the instruments' constraints. During the rhinoscopic operation, the surgeon is deforming the endonasal tissues with the surgical instruments, e.g., he is pulling with scissors or pushing with a probe. To simulate these procedures, different approaches are implemented and tested. The tissue-specific characteristics should be taken into account, the realism of the simulation should be as great as possible, and the real-time condition should not be lost.

During a simulated intervention, trainee errors, for example collisions of instruments and high sensitive tissues, are detected and evaluated. After a simulated intervention, the trainee has to fill out a sheet to specify his diagnosis. An evaluation of the sheet and the errors is used to calculate a score for the trainee. Only if the score is high enough is the trainee allowed to enter the next level. This game-like scenario should give a higher motivation to the trainees.

Results and Future Work

The nasal endoscopy training simulator (NES) represents an advanced training system incorporating Virtual Reality and multimedia for training and for quality control in endonasal sinus surgery. The trainees are able to practice various surgical techniques without having to advance their learning curve on humans. Current work focuses on the integration of a haptic device, to feel the give and resistance of the anatomical structures. In that context, an adequate and more sophisticated description of the tissue-specific elastodynamic characteristics is necessary. In addition, the simulation of virtual cutting is under development. These medical simulators are on the way to founding an educational base which will be perhaps as important to surgery as flight simulators are to aviation.

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