VR Simulation of Fluorescence Endoscopy for Surgical Training in Urology

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German Abstract

In der Methode der induzierten Fluoreszenzendoskopie wird ca. 2 Stunden vor der Blasenspiegelung eine 3%-ige Aminolovulinsäure in die Blase instilliert. Durch eine biochemische Reaktion mit dem Tumorgewebe kommt es zur roten Fluoreszenz unter Beleuchtung mit Blaulicht (380-440 nm). Die Blasenspiegelung ist nur mit spezieller Endoskopieausrüstung möglich (Endoskop, Lichtkabel, Lichtquelle, ggf. Videokamera). Im Projekt »Urolo-Trainer« wird ein solcher fluoreszenzendoskopischer Eingriff mit Hilfe von VR-Techniken simuliert. Dabei werden die spezifischen Aspekte der Fluoreszenzendoskopie illustriert und dem Chirurgen wird der aktuelle technische Stand vermittelt.

Motivation

Endoscopy of the urinary tracts is performed through physiological openings of the lower urinary tract and represents a minimal invasive procedure. For a fluoroscopic intervention, sodium monohydrogen phosphate has to be instilled into the patients intravesically two and a half hours earlier. A special light source provides blue light (375 to 440 nm) for fluorescence excitation. Suspicious sites are identified by their red fluorescence contrasting against the backscattered blue light. The endoscopic examination requires special surgical skills for endoscope handling and remote instrument control. The standard training methods used for training in clinical practice to acquire these skills expose the patients to higher danger. The widespread use of cadaver studies, or training on animals, is limited by availability and ethical problems. Other training methods such as training on plastic models tolerate reckless usage of the instruments. There is no modality to control the procedure and to evaluate the progress of the trainee. To overcome these current drawbacks of traditional training methods, VR techniques are used for the simulation of several endoscopic interventions. Thereby, the »Urolo-Trainer« focuses on the simulation of fluoroscopic interventions. The use of different light sources is simulated and illustrated. The trainee has the possibility to experience a fluoroscopic intervention.

Methods

The development of the »Urolo-Trainer« VR Training System can be divided into two parts: First, the generation of the Virtual Environment and second, the realization of the 3-D Interaction System. The generation of the Virtual Environment is a preprocessing step. Data models to be used within the VR simulator are generated. The input data for this preprocessing step is the mechanical instruments, 2-D construction plans of the instruments, computer tomography (CT) or magnetic resonance tomography (MR) scans, and video sequences from endoscopic procedures. The Virtual

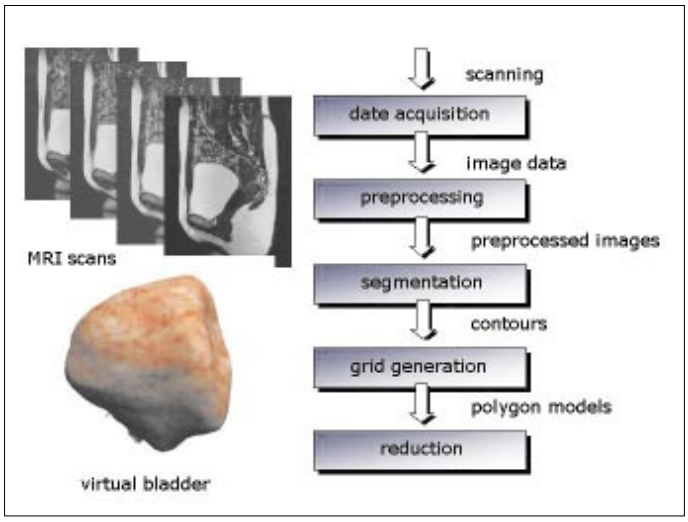

Figure 1: 3-D Reconstruction of the Virtual Situs

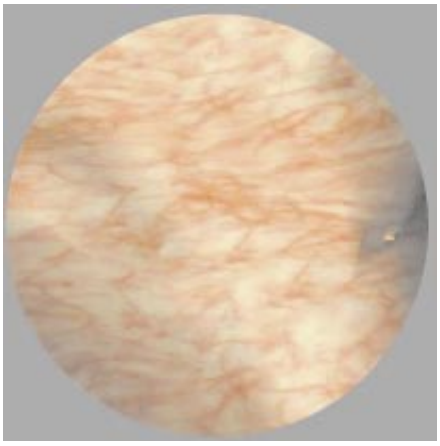
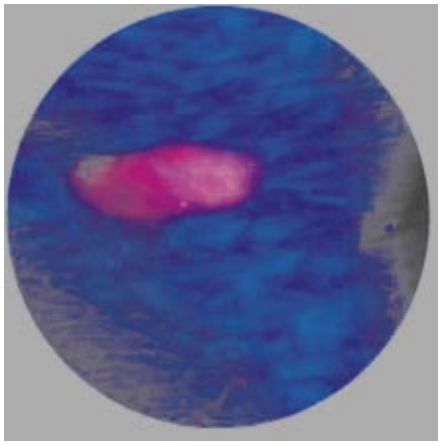

Figure 2: Confrontation of white and blue light endoscopic images

Environment provides virtual instruments (endoscope/surgical instruments) and the virtual situs.

– *Surgical instruments*
  The 3-D geometry of the instruments is generated via modeling systems. These representations must be integrated in the VR Simulator preserving both shape and function of the instruments.
– *Virtual Situs*
  Due to analysis of real surgical environment during endoscopic surgery, the Virtual Environment requires a realistic 3-D representation of the urinary tract. Input data for the generation of the virtual situs are CT or MR scans as well as video sequences of the endoscopic procedure. Based on this image data, a virtual situs suitable for real-time simulation has to be reconstructed (cf. figure 1).

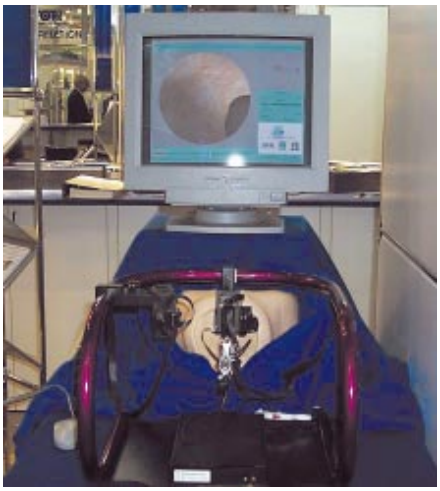

Figure 3: Setup of the »Urolo-Trainer«

The next necessary step for the generation of the Virtual Situs is texture mapping. To provide organ specific textures is indispensable in endoscopic simulation in order to enhance the realistic appearance and to represent pathological tissue. The fluoroscopic effect of the different light sources is also simulated using textures. The user has the possibility to switch between white and blue light (cf. figure 2). Input data for the texture generation algorithms are pictures taken from endoscopic video recordings. Due to the endoscopic light source, the illumination of the images is mostly punctual. Therefore, image manipulation algorithms have to be executed to homogenize the illumination as a first step. To generate textures with the required resolutions,the textures must be composed of tiles derived from the image as a second step. Lastly, the edges between tiles have to be smoothed.

The 3-D Interaction System simulation system meets the following requirements:

– *Simulation of endoscope/surgical instruments*
  The simulation model allows for the simulation of both rigid instruments and those with moving parts. In addition, a virtual endocope with different optics (e.g., 0°, 12°, 30°) has to be realized. The endoscopic intervention in urology is well suited for simulation of therapeutic interventions because here, endoscope and tools are combined into one single instrument – the resectoscope. Position, orientation, and the opening angle of the resectoscope have to be registered. For the simulation of the instrument, a real resectoscope from KARL STORZ GmbH is integrated into the »Virtual Laparoscopic Interface« from Immersion Corporation™ (cf. figure 3). The trainee handles the original instrument and moves the simulated electrodes, used for resection of pathologic tissue, along the resectoscope´s axis. The trainee has the possibility to switch between white and blue light endoscopy via the foot panel.

Results

The »Urolo-Trainer« contains virtual anatomical structures simulating endoscopy and surgical instruments. The system focuses on simulation of endoscopic fluorescence light and it's particular aspects. The »Urolo-Trainer« promises to foster fast and effective learning. Trainees are able to practice surgical techniques without having to advance their learning curve on humans. The concept has general applicability to other medical areas providing standard training situations for objective assessment.

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