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Short Communication

Image-guided surgical microscope with mounted minitracker

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Abstract
A new image-guided microscope using augmented reality overlays has been developed. Unlike other systems, the novelty of our design consists in mounting a precise mini and low-cost tracker directly on the microscope to track the motion of the surgical tools and the patient. Correctly scaled cut-views of the pre-operative computed tomography (CT) stack can be displayed on the overlay, orthogonal to the optical view or even including the direction of a clinical tool. Moreover, the system can manage three-dimensional models for tumours or bone structures and allows interaction with them using virtual tools, showing trajectories and distances. The mean error of the overlay was 0.7 mm. Clinical accuracy has shown results of 1.1–1.8 mm.

Key words: Surgery; Computer Assisted; Otorhinolaryngologic Surgical Procedures

Introduction

Image-guided surgery or computer aided surgery technology has emerged in the last 10 years and is used increasingly for surgery of the anterior and lateral skull base. Different detection systems can localise an instrument in the space: electromechanical, electromagnetic, optical or ultrasound. The principle underlying these different systems is that the exact position of the marked surgical instruments can be followed 'on-line' on images (CT or magnetic resonance [MRI]) during surgical intervention.

Surgical microscopy has been used in many complex procedures for many years in the area of otorhinolaryngology and could also be integrated into a computer assisted system.[1,2] To avoid the need to look away from the surgical scene, guidance information can be overlayed directly onto the surgical microscope view. In order to display a correct overlay image changes in patient position must be determined. Several approaches have been developed, using mainly external tracking systems. An augmented reality system should enable surgeons to view hidden critical structures such as pathologies (e.g. tumours) and dangerous structures (e.g. arteries and nerves).

Here we present a new image-guided microscope system using augmented reality image overlays directly added onto one of the views of the operating microscope. Unlike other systems that use an external tracking device for optical localisation of an instrument or are based on image information, the novelty of this design consists of mounting a precise minitracker directly on the microscope, in parallel to the optical axis, to track the movements of the surgical tools and the patient.[3,4]

Materials and methods

The implementation of the image-guided surgical microscope is based on a Leica M500™ surgical microscope (Leica-Microsystems, Heerbrugg, Switzerland), equipped with an image-injection module which allows the injection of colour overlay images into one of the eyepieces. The surgeon has the option of changing the zoom, the working distance and the possibility of modifying the brightness and the opacity of the overlay. The minitracker used for optical detection, developed at the Swiss Federal Institute of Technology in Lausanne, is rigidly mounted onto the microscope (weight: 1.3 kg, accuracy $<$0.3 mm up to 75 cm in distance) (Figure 1).

The assembly of the microscope and the tracking camera is the cornerstone of the system. The optical tracker is attached to the right side of the microscope, assuring the rigidity of the fixation by using screws from the microscope's handle. The rigid connection of the tracker with the microscope eliminates the need to externally track the position of the microscope, thereby bypassing the greatest source of error. The calibration of the system is performed initially using a grid and afterwards moved to the operation room and sterilised with a plastic bag. A balancing of the microscope-tracker system for optimal handling is necessary.

The registration procedure is an essential part of the image-guided surgery system. It concerns the matching between pre-operative images and the physical space occupied by the patient and is founded on a reference base. In our system, the reference base consists of an upper jaw transitory dental cast with a carrier of four light emitting diodes permitting free-head movement. The registration procedure is performed by means of a needle pointer using paired-point and surface matching.[5] Paired-point matching determines the relation between two objects (e.g. CT and patient) by a number of discrete points (e.g. anatomical points) given in the virtual and real world.[6] Surface matching is used for refinement by taking 15 points well distributed over the face, thus reducing the

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FIG. 1

Visible is the surgeon operating with the microscope on the anterior skull base, holding a tracked tool in the right hand. Looking through the microscope with the lateral fixed mounted minitracker (long arrow), the surgeon receives information as to the exact position of the tracked tool in one of the eyepieces. The reference base (small arrow) necessary for navigation is a dental splint equipped with light emitting diodes.

registration error (0.5 mm). As the microscope and patient are now registered, the system is ready to work, providing the surgeon with an augmented reality i.e. different colour overlays such as tumour size, pathway and the possibility to interact with tracked tools. Additionally, a laser beam is coupled into the optical path and can be used to measure the active working distance to the target by triangulation (Figure 2).

The precision of the overlay in different anatomical parts shows a mean overlay error of 0.7 mm. The results of the first clinical cases ($n = 5$) are promising and have shown an accuracy of 1.1–1.8 mm for position detection matched with the augmented reality.

Discussion

Several methods have been proposed previously for integrating the operating microscope into the computer aided surgery system. Different technical approaches have been used clinically, such as passive mechanical arms,[7] active robotic arms,[8] ultrasonic,[9] electromagnetic[10] and optical digitising systems.[2] Currently, three-dimensional digitisers based on optical sensor technology are judged to be the most accurate systems because they are less affected by disturbing environmental factors compared to the others. Furthermore, in contrast to mechanical arms, they allow an unobstructed view of the surgical site and a straightforward surgical procedure in the operative field. The new generation of image-guided microscopes enables the viewing of different structures, extracted from multiple image modalities such as CT or MRI, directly in the microscope. Hidden line removal and stereo projection provide depth perception, showing the three-dimensional relationship between image structures and the patient in the operating room.

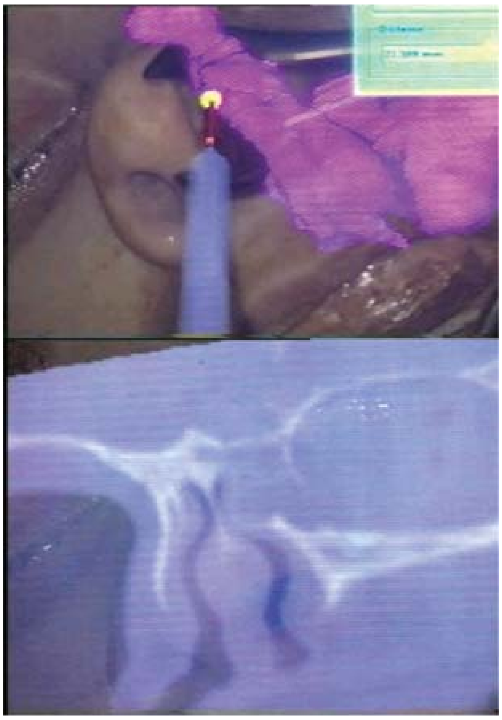

FIG. 2

Visible is the surgeon's operating view in the microscope with the three-dimensional model of the target (adenocarcinoma of the nose), segmented from the CT dataset of the patient. A virtual model of the tool is overlayed to the real tool. Trajectory (red) and intersections (yellow) are displayed, as well as distances calculated (top right position). Cut-views of the pre-operative CT stack can also be displayed as an overlay to the real microscopic view.

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With the integration of the small low-cost camera (USD 7000 [easyTrack 200^{TM}, Atracsys SaRL, Bottens, Switzerland]) to the microscope for computer aided surgery, two goals were achieved: a more advantageous ergonomic way to work in the operating room and, secondly, reduced costs. Additionally, with the incorporation of augmented reality from multimodal datasets (CT, MRI, planning), image-guided surgery will evolve more and more into 'information-guided surgery'.

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