Chapter XV

HCI: The Next Step Towards Optimization of Computer-Assisted Surgical Planning, Intervention and Training (CASPIT)

Rudy J. Lapeer, Polydoros Chios, Alf D. Linney, Ghassan Alusi and Anthony Wright

INTRODUCTION

The introduction of computerized systems in medicine started more than a decade ago. The first applications were mainly focused on archiving and the general database management of patient records with the aim of building fully-integrated Hospital Information Systems (HIS) and fast transfer of data and images (e.g. PACS - Picture Archiving and Communication Systems) between HIS. In parallel with this more general development, specialized computer systems were built to process and enhance image data from such systems as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scanners. The use of enhanced CT and MRI images led to the birth of Image Guided Surgery (IGS). Other terminology for similar concepts has since been used, e.g. Computer-Assisted Surgery (CAS), Computer Integrated Surgery and Therapy (CIST) (Lavallée et al, 1997) and Computer-Assisted Medical Interventions (CAMI). In this chapter, we shall look mainly at Computer-Assisted Surgery (CAS) systems and related systems which are aimed at the training of surgeons and the simulation and planning of surgical interventions. The emphasis will be on the Human-Computer Interaction (HCI) aspect rather than the technological issues of such systems. The latter will be briefly discussed in the next section, to make the reader familiar with the terminology, the history and the current state of the art in CASPIT.
COMPUTER ASSISTED SURGICAL PLANNING, INTERVENTION AND TRAINING (CASPIT) - BACKGROUND

One of the early applications of computer-assisted surgery (CAS) was in the field of stereotactic neurosurgery where 3D visualization of anatomical structures on computer was used as a guidance to navigate the surgical tool to the target area. Today, CAS has become popular in a variety of surgical fields including cranio- and maxillo-facial surgery, ENT (ear, nose and throat) surgery, orthopaedic surgery, cardiac surgery, laparoscopy, interventional radiology and several other surgical disciplines (Lapeer et al, 2000a).

The term ‘assisted’ in CAS implies that the operator, i.e. the surgeon, is still responsible for the outcome and the overall control of the operation. The system is there as an aid; thus, the surgeon has to decide as to whether the information provided by the system is reliable or not.

Surgical simulation and planning was developed in parallel with CAS, possibly because of its solid base for testing new technologies which might prove too unreliable for direct use in a real clinical intervention. At the end of the 80’s, simple 3D visualization of the anatomy of the patient, mainly obtained from Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) images, was already a major step forwards in the planning and simulation of surgery. A few years later, image guided surgery (IGS) systems came in the development which allowed to display a virtual surgical tool into the 3D virtual scene, hence allowing more realistic planning and execution of such interventions like stereotactic and endoscopic surgery which previously provided the surgeon with only local visual information. Displaying the trajectory of the surgical tool in 2.5/3D was a useful aid to the surgeon even if the accuracy was not much better than a few millimetres. Nowadays, computer-assisted surgery (CAS) systems are still not accurate enough to be fully relied upon by the surgeon. However, they are a useful aid to provide the surgeon with spatial image formation which he/she previously had to reconstruct mentally, i.e. by observing a series of 2D images and then trying to mentally visualise the 3D anatomy.

The computer proves useful not only for major surgical interventions but also for smaller-scale and non-invasive interventions or examinations, e.g. interventional radiology, videostroboscopy, etc. Also, training of junior surgeons and nurses, be it in major or minor interventions, can be significantly improved using interactive and multimedia computer-based training (CBT) software.

The concept of augmented reality (AR) has become the new challenge in microsurgical disciplines such as ENT- and neurosurgery, which target the patient’s head and involve the use of a surgical stereo microscope. The stereo images as obtained through the microscope are augmented with a virtual image from 3D rendered patient data, e.g. from MRI or CT images. This allows the surgeon to view structures which are not visible in the original image, thus providing him/her with more anatomical information. However, it is hardly necessary to mention that one crucial problem in CAS applications using AR is the accuracy of the overlay of the real image with the virtual image; poor registration of the two images may result in less reliable feedback than the original system would have provided.

Robotic surgery is one step further towards the minimization of human error during surgery. Currently, there are only a few surgical interventions, e.g. stereotactic neurosurgery, where the entire operation can be done by a robot. Even then, the robot is still supervised by a surgeon. Not only is the necessity for further technological developments
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