CIR ESP. 2009;**85(3)**:129-131

CIRUGÍA ESPAÑOLA

www.elsevier.es/cirugia

Editorial

Fundaments and clinical value of Computer Assisted Surgery

Fundamentos y valor clínico de la cirugía asistida por ordenador

Computer assisted surgery (CAS) refers to a surgical concept and a set of methods that use computer technology for pre-operative planning and to guide or perform a surgical intervention. To some extent, one could think of the minimally invasive revolution occurred in the 1990's as the first appearance of CAS in our practice. In fact, without the chip-driven microcameras, light sources and high flow insufflators, advanced laparoscopy as we know it today would have not been possible. The shift to the information age of surgery has come at the expense of some of the established capabilities of traditional surgery: tactile feedback, stereoscopic vision, dexterity, and full visual control of the operative field. Overcoming of these drawbacks has partly occurred thanks to the development of energy-powered instruments for tissue dissection and sealing, to the recent advances of high-definition image acquisition and display and with the advent of robotic surgery. However, the partial loss of physical control of the intraoperative environment typical of laparoscopy, still restricts this approach to only a variable proportion of patients in the practice of general surgery. Costs play also a role in the current age of limited health resources, and adoption by health managers of new methodology for technological assessment and scientific validation is an advisable way to prevent uncontrolled diffusion of expensive, and soometimes useless, medical technology.

Given the unexpected and impressive evolution of the practice of general surgery we have wittnessed over the last 2 decades, one could wonder where are we now going from here, and what will come next to further improve our practice. Parallel to the profound technological progress that has permanently modified our profession, the world of or medical images acquisition and processing has also undergone a similar revolution. High definition multi-layer spiral Computed Tomography (CT), high resolution Nuclear Magnetic Resonance (NMR), functional images such as Positron Emission Tomography (PET) scan and the capability to process this dataflow to provide the final user with 3D reconstructions or with fused images, have become familiar to most surgeons, as we already base a large proportion of our surgical planning process on medical images. Despite this progress, there are still big challenges to meet in order to produce reliable systems easy to use and intuitive to interact with, in order to achieve the main three purposes crucial for the future of CAS: pre-surgical planning, augmentation, and intraoperative navigation. Nonetheless, I have little doubt that the next revolution in surgery will come from integration of pre- and intra-operative medical images occurring during the interventional procedure: in other words from CAS. This process of fusion between radiology and surgery, will also change the physical environment of our operating rooms.

ENDOCAS is the name of the Center for Computer Assisted Surgery based at the University of Pisa, Italy. The Center was established in 2003 primarily for the purpose of putting together people with different background that would otherwise hardly meet or work together: radiologists, engineers, computer scientists, and surgeons. It was the result of a joint proposal of the University of Pisa with the Scuola Superiore S. Anna and the Visual Computing Laboratory (ISTI-CNR) in the frame-work of the Italian Ministry of University and Research (MIUR) funding for centers of excellence. Its goals are to address key knowledge, technology, and systems design barriers that must be overcome in the development of CAS systems.

Pre-surgical planning

Using dedicatd software, the patient's CT dataset can be rendered as a virtual 3D model of the target anatomy. The recovery of the external surface of an organ or the 3D branching of an arterial tree might be relevant for pre-operative planning and can also be used to support quantitative diagnostic measurements, such as the volume of liver that will be resected to treat a tumor, or the proportion of parenchima the surgeon is going to leave behind. Pre-surgical planning does not add new information from the original CT source, ruther it presents the same amount of data in a better way that will be easily understood by the final user. However, this task can be challenging, even in the apparently easy case of visually uniform regions like vessels injected with contrast, and the extracting softwares available today still require experience of use and long processing time. At ENDOCAS we have developed a semi-automatic regional growing system based on the balloon algorithm. This consist in placing a very small deformable bubble inside the structure we intend to segment, eg, the aorta, the portal vein, or the splenic parenchima and then to inflate it. We implement the bubble as a triangulated mesh. The final goal of the process is to fit the bubble over the surface of the structure. This process provides very accurate and quick extraction of 3D model of the patient's internal anatomy from the CT scan dataset, that proved more accurate and reliable than usual segmentation systems. False colors can be added to facilitate organ recognition. These models are then manipulated by the surgeon to provide views from different angles. The surgeon can fly inside the anatomy to better assess the case and establish the treatment plan. In addition, the possibility to fuse morphological and functional images adds potential advantages in the specific setting of laparoscopic surgery. As an example, it is possible to mark with different colors the 3D reconstruction of the gastro-esophageal junction according to the varying intraluminal pressure detected by pre-operative manometry, when planning an Heller's miotomy for achalasia, or provide the surgeon with volumetric visualization of the hypermetabolic areas detected by the PET scan.

Augmentation

The use of preoperative visual information directly on the patient's treatment site in combination with the actual view of the area is known as mixed or augmented reality. Augmentation provides the surgeon with computer generated visual aid for the localization of internal structures that can be helpful in guiding the different phases of a given intervention. To achieve this task, the surgeon has to ware special glasses or a stereoscopic helmet where image fusion can occur. To match the surgeon's point of view with the appropriate reconstruction of the patient's anatomy, the movements of the surgeon's head have to be monitored by an optical or an electromagnetic tracking system. A computer will enable correspondence between real-time view and pre-operative image-based 3D reconstructions. Augmented reality will render our patients virtually transparent and will eventually substitute current display systems used to transfer morphological information, not only for the benefit of surgeons but also to simplify any imaging-based assessment. The intra-procedural fusion of CT images with real-time ultrasound scanning is another potentially useful application of aumentation technology.

Intraoperative navigation

Navigation technology uses a platform based on 3D virtual reality (VR) models of the patient's anatomy, where the surgical instruments operated by the surgeron are tracked by an optical localiser and their virtual image can be moved accordingly inside the model. The benefit of this technology in the setting of laparoscopic surgery is yet to be demonstrated, however one could anticipate an higher precision in localizing the target anatomy and in guiding the intervention. The main obstacle to the use of intraoperative navigation technology in general surgery is organ shift and tissue deformation, caused by pneumoperitoneum, gravity and tissue handling. To overcome this problem surgeons need to update their 3D model based on actual patient data after organ deformation has occurred. Today, routine use of computer assistance in surgery is still limited to diagnostics and surgical planning and to interventions on mostly rigid structures, notably for orthopedics of neurosurgical diseases. At ENDOCAS we are trying to address this problem through different approaches. One entails adapting the VR model to physiological movements, such as breath excursions and vessels pulsation, detected and anticipated by monitoring ventilation and pulse rate. Most importantly, we are also loading intraoperative depth information, by the development of a real-time optical 3D depth and motion recovery system. This, will allow a continous updating of the VR model during the procedure to match the current view seen by the endoscopic camera. Additional systems to accomplish similar results can also use intraoperative x-ray or open NMR, but with other type of limitation that so far have restricted their practical use.

Conclusion

The information technologies described in these notes are not yet fully available to general surgeons but will quickly develop and translate into products that will become familar to us in the next generation of our operative rooms. These, will probably be interventional suites capable of imaging fusion and navigation technology not only for the benefit of general surgeons, but for all the different professionals that already base their treatment modality on images. We do not need to invent new technology, since most of what is needed to accomplish this change, and that was described above, has already been developed or theorized. It is only necessary to decide how to use existing technology to create new devices and develop clinical applications for their use that will make our profession easier to practice and safer for our patients. This is our mission at ENDOCAS.

REFERENCES

Baumhauer M, Feuerstein M, Meinzer HP, Rassweiler J. Navigation in endoscopic soft tissue surgery: perspectives and limitations. J Endourol. 2008;22:751–66.

Breitenstein S, Nocito A, Puhan M, Held U, Weber M, Clavien PA. Robotic-assisted versus laparoscopic cholecystectomy: outcome and cost analyses of a case-matched control study. Ann Surg. 2008;247:987–93.

Feuerstein M, Mussack T, Heining SM, Navab N. Intraoperative laparoscope augmentation for port placement and resection planning in minimally invasive liver resection. IEEE Trans Med Imaging. 2008;27:355–69.

Holly LT. Neurosurgical robotics. Int J Med Robot. 2006;2: 105–6.

Langø T, Tangen GA, Marvik R, Ystgaard B, Yavuz Y, Kaspersen JH, et al. Navigation in laparoscopy-prototype research platform for improved image-guided surgery. Minim Invasive Ther Allied Technol. 2008;17:17–33.
Merrell RC. Telemedicine and telesurgery in the operating room. Bull Am Coll Surg. 2005;90:8–13.
Minami Y, Chung H, Kudo M, Kitai S, Takahashi S, Inoue T, et al. Radiofrequency ablation of hepatocellular carcinoma: value of virtual CT sonography with magnetic navigation. AJR Am J Roentgenol. 2008;190:W335–41.
Nakamoto M, Nakada K, Sato Y, Konishi K, Hashizume M, Tamura S. Intraoperative magnetic tracker calibration using a magneto-optic hybrid tracker for 3-D ultrasound-based navigation in laparoscopic surgery. IEEE Trans Med Imaging. 2008;27:255–70.
Stiehl JB, Heck DA. Computer-assisted surgery: basic concepts. Instr Course Lect. 2008;57:689–97.

Andrea Pietrabissa
Department of Oncology, Transplantation and New Technology in Medicine of the University of Pisa, ENDOCAS Center for Computer Assisted Surgery at the University of Pisa, Italy
E-mail address: a.pietra@med.unipit.it

0009-739X/$ - see front matter