Medical Imaging Informatics :

From Digital Anatomy to Virtual Scalpels and Image Guided Therapy

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Medical imaging informatics will bring about a revolution to the medicine of the 21st century, introducing a collection of powerful new tools designed to better assist the clinical diagnosis and to model, simulate, and guide more efficiently the patient's therapy. A new discipline is emerging in computer science, closely related to others like computer vision, computer graphics, artificial intelligence and robotics.

What will be a plausible scenario in the hospital room of tomorrow? First, all imaging modalities will be interconnected to fuse the available anatomical and functional data of a patient and exploit them in a coherent manner. The images involved will not only be radiographs, computed tomographies, magnetic resonance, nuclear medicine, or ultrasound images, but also video, endoscopic, confocal, microscopic, histological, or molecular images. This information will be processed in 3-D, as most imaging modalities are volumetric, but also in 4-D whenever temporal sequences are available, either to detect subtle changes or to quantify a dynamic motion (typically for cardiac analysis). The physician will therefore be provided with new sets of quantitative measurements to assess a more accurate and objective diagnosis. Digital image processing will often play at this stage the role of the microscope in the 17th century, allowing one to visualize details or changes which would have remained invisible through a direct visualization of the original images(*).

When a therapy is decided, diagnosis images will then be exploited as pre-operative images to prepare an optimal planning of the therapy. Mostly interactive, the software tools will enhance the capacities of the physicians, offering the possibility to experiment various approaches before selecting the best one. Virtual reality display and force feed-back (haptic) devices will provide a realistic training for therapy, allowing the surgeon to practice with virtual but highly realistic models and scalpels. Once the actual treatment has to be delivered, image-guided therapy procedures will rely on various types of intra-operative images. Augmented reality tools will enhance the perceptual capacities of the physician, by fusing these intra-operative images with pre-operative images and models, including for instance high resolution digital atlases.

High speed networks will permit the transmission of images and gestures to remote sites, where medical robots will enhance or replace the physician's gestures, often with the help of real-time processing of intra-operative images. This will allow one for instance to compensate for the motion of a moving organ (e.g. the beating heart), offering the possibility for a surgeon to operate on a quasi-still image while a robot will combine to his gestures the required additional computed motion. Finally, post-operative images will be automatically compared to pre-operative images, in order to better assess the efficiency of the therapy. This will also be useful to measure objectively the efficiency of a drug treatment, and thus better control the design of new medicines and therapeutic protocols.

Is this scenario a dream? Certainly not, as we know that some parts of it are already operational in a few leading medical centers, and that the research on these topics is more active than ever all over the planet, on all aspects of medical image processing and analysis, covering acquisition, reconstruction, enhancement, compression, storage, transmission, visualization and understanding of medical images. Active methodological research topics have emerged like segmentation, registration and fusion, dynamic analysis from temporal sequences, modeling of anatomy and physiology from anatomical or functional images, content-based indexing, statistical analysis of shapes and signals, surgery simulation, image-guided medical robotics, etc. These topics often involve interdisciplinary methodologies: for instance, surgery simulation requires the geometric modeling of the anatomy from the various modalities of medical images, the biomechanical modeling of the soft tissues, and the physiological modeling of the organs and vessels, in order to create a digital model whose behavior mimics as well as possible the actual body of a given patient.

The various chapters of this book describe the state of the art developments in some of the most advanced research centers in medical informatics, and tell us what will be some of the contours of this upcoming revolution.

(*) Citation from Gilles Kahn, Scientific Director of Inria.

References (articles, journals and conference)

I. Bankman, Editor, Handbook of Medical Imaging – Processing and Analysis, Academic Press, 2000.

J. Duncan and N. Ayache. *Medical Image Analysis: Progress over two decades and the challenges ahead*. IEEE Transactions on Pattern Analysis and Machine Intelligence, 22(1):85-106, 2000.

E. Grimson et al., *Image Guided Surgery*, Scientific American, June 1999.

J. Marescaux et al., *Virtual Reality Applied to Hepatic Surgery Simulation : The Next Revolution.* Annals of Surgery, 228(5):627-634, November 1998

R.A. Robb : *Biomedical Imaging, Visualization and Analysis.* John Wiley and Sons, Inc., New York, NY, 1999.

R.H. Taylor, S. Lavallee, G. Burdea, and R. Mosges, eds. *Computer-Integrated Surgery.* . 1996, MIT Press: Cambridge, Massachusetts.

CAS: Int. Journal of *Computer Aided Surgery*, Wiley, http://www.interscience.wiley.com:83/cas/

TMI: IEEE *Transactions on Medical Imaging*, http://www.ieee.org/organizations/pubs/pub_preview/mi_toc.html

MedIA: Int. Journal on *Medical Image Analysis*, Elsevier. http://www.elsevier.nl/locate/media

Medinfo'01: 10th World Congress on Health and Medical Informatics http://www.medinfo2001.org/

MICCAI'01: 4th Int. Conf. on Medical Image Computing and Computer-Assisted Intervention Conference, Utrecht, Holland, Oct. 2001; http://miccai.isi.uu.nl/