Editorial

Special Issue on biomedical image segmentation using variational and statistical approaches

Technological advances in medical imaging have been extremely fast over the last decades, making human observation possible at different scales from molecular to cellular to organ even the whole body. According to the modality, imaging is able to furnish morphological, structural, metabolic and functional information, which can be conjointly exploited to improve the understanding of the disease and assist the medical expert in the decision-making. As a consequence, usage of medical imaging has greatly increased to play today a key role in clinical practice in all phases of the management of the disease. These include prediction, diagnosis, therapy planning, therapy guidance, intervention guidance, monitoring. . .

However, a major challenge is how to deal with the big amount of available data, interpret and exploit them in order to really bring a valuable help to medical experts whether in the decision-making or for improving the procedure safety and outcome.

To deal with the technological problems of image analysis, computer aided systems have been developing for advanced applications dedicated to image guided diagnosis (CAD), therapy and intervention, including planning treatment. However, the complexity of image content, their size and their number impose to design processing tools that meet the clinical requirements (accuracy, robustness, and computation time). Among these tools, the segmentation appears as a prerequisite and a key step for all these applications. A lot of work have been devoted to this segmentation and continue to be developed. Despite advances in the mathematical tools as well in the image resolution, segmentation still remains an open problem. The challenges of medical image segmentation are often related to the low contrast, the presence of noise and different kinds of artefacts (presence of extrinsic objects, motion. . .) but also to the shape complexity of the structure of interest, its contrast and geometry variability over time or in the course of the treatment, and the tissue environment into which this structure stands.

This issue includes a special session on the segmentation stage. It came out after a workshop on image segmentation, which was jointly organized by the GdR ISIS (CNRS structure for animation of research on Information, Signal, Image, ViSion) and the GdR STIC Santé (CNRS and INSERM structure for animation of research on health engineering) and held at Telecom ParisTech, on June 6, 2013. The goal was to give a review of recent developments, in France, on variational and statistical approaches dedicated to medical imaging but also to present the needs and expectations of clinical users.

Six articles compose this special session, which cover the main topics of the considered domain, as outlined below. They are the output of a regular review process from 11 submitted papers. We believe that the selected papers present rigorous techniques and are of interest for medical applications. Three articles are positioned at the diagnosis stage and three on radiotherapy guidance.

The first one by Xu and al. introduces a generative probabilistic atlas for labelling brain tissues in T1 MRI imaging. It makes use of a Stochastic Approximation Expectation-Maximization (SAEM) algorithm to build the atlas and exploits dense deformable templates, representing different kind of observed tissues in the training images. Inputs are grey level data whereas the atlas is composed of both an estimation of the deformation metric and the probability map for each tissue (called class). This atlas is then used as an anatomical prior to guide the segmentation of new set of images via a non-rigid registration process. Evaluation was carried out on data sets issued from Miccai 2012 grand Challenge on multi-atlas labelling and the Internet brain segmentation Repository site.

François Lecellier et al. present an overview on statistical region-based active contour methods with a comparison that illustrates their behaviour according to the considered prior and noise model (Poisson, Gaussian, Rayleigh). Results are provided on MRI and US imaging for brain tissue and cardiac chamber segmentation. An interesting discussion is introduced on the optimization schemes to solve variational problems.

Maciej Orkisz et al. propose the use of variational region growing for the segmentation of the pulmonary vascular trees in 3D CT images. The clinical objective is to quantify the aeration of lung parenchyma of patients suffering from an acute respiratory distress syndrome. This task requires lung delineation as well as elimination of airways and vessels. The segmentation process is performed within a lung mask, where the airways and bronchial walls were previously eliminated by adaptive

multi-scale morphological operations. The region growing relies on a vesselness map, preliminary built from the Hessian matrix, and a region descriptor to control the propagation. Evaluation is carried out on 20 chest cans issued from the Vessel12 challenge and a comparison is provided with methods that competed within this challenge.

Pierre Buyssens et al. address the segmentation of the liver and lung in the frame of a selective internal radiation therapy program (SIRT). A semi-supervised organ segmentation scheme is proposed that gives the control of the segmentation to the radiologist. A first Eikonal-based region growing clustering algorithm is applied to build meaningful regions called superpixels. Criteria, such as proximity, intensity similarity and compactness (for regularizing region size and shape), are associated with a fast marching algorithm to outspread superpixels. Then, a semi-supervised segmentation is carried out on the resulting Region Adjacency Graph to label the region using Dijkstra algorithm. Evaluation was carried out on Miccai 2007 grand Challenge and Berkeley CT data sets.

Joël Castelli et al. present an overview of the place and role of imaging at the different steps of head and neck cancer radiotherapy (HNC RT), from a medical point of view. Indeed, HNC RT appears particularly challenging due to the complexity of the shape of the anatomical structures, which changes in the course of the treatment. Advances in imaging, modalities, processing and integration at the different RT steps are crucial to develop a new image and dose guided adaptive RT (ART) strategy.

Bernard Dubray et al. discuss the advantages and limits of nuclear imaging to assist the radiation oncologist in planning radiotherapy for lung cancer. This review emphasizes how FDG PET/CT is determinant for initial staging and indication of curative-intent radiotherapy. It deals with the technical difficulties, which still have to be overcome, such as image fusion registration and their segmentation to adapt the dosimetry to changes in tumour shape in the course of the treatment.

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Disclosure of interest

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