Editorial

Recent Advances in 3D Medical Image Generation and Analysis

Medical imaging is a field of enormous development and change. Novel imaging modalities are introduced, and performance of existing techniques is improved continuously yielding novel application for research, diagnostics and teaching. Both, image formation and analysis are supported nowadays by complex algorithms, which became the core part of image-based diagnostics. In particular, three-dimensional (3D) data is acquired and processed.

Over the past 20 years, the German Workshop on Medical Image Processing (BVM) has been established as an important forum for innovation, where novel ideas are presented and first experiences of applications are reported. In recent years, the workshop has transformed into a double-track conference reaching international outstanding level [1, 2, 3, 4, 5].

This Hot Topic presents selected work from the BVM 2012 meeting that was held at Charité – Universitätsmedizin Berlin, Germany, particularly focusing on 3D imaging and novel analysis approaches as well as fast visualization techniques. The best conference papers have been invited to submit a full article to this special issue. Acceptance was based on double-blinded peer review.

The review paper of Deserno *et al*. is presenting several personal viewpoints on medical imaging and medical image computing, which all follow the general theme "From Science to Application" [6]. The topics include diffusion weighted imaging, multi-modal and multi-resolution registration and segmentation, model-based analysis, information retrieval from endoscopy, and virtual reality and robotics.

Since morphologic and functional 3D imaging is a key issue in medical research and diagnostics, novel imaging modalities and techniques are proposed continuously. Fieselmann and Manhart are using C-arm X-ray equipment for 3D imaging [7]. Erbe *et al.* present pioneering research on magnetic particle imaging, a tomographic imaging technique that measures the magnetic fields generated by super-paramagnetic nano-particles (iron oxide) as tracers [8]. This idea has been born just recently in 2005 [9] and hence, research and application development are expected to stay active in future.

Another 3D method of medical imaging is given when two-dimensional (2D) images are acquired over time (2D + t). For instance in video microscopy, living cells are to be tracked. Algorithms that allow robust applications must handle occlusion, mitosis, and/or cell fusion. Scherf *et al*. combine fluid models and segmentation methods yielding robust mitosis detection [10].

In [6] the importance of multi-modal registration and fusion has already been emphasized. Accordingly, Haase *et al*. combine time-of-flight (ToF) techniques with optical imaging for real time, minimal-invasive 3D imaging [11]. Again, the challenge is coping with large differences in resolution and signal-to-noise ratios of the data that needs alignment.

Once morphological 3D data has been acquired, segmentation of regions of interest, organs, or pathological modified areas is one of the most important tasks in medical imaging. Habes *et al*. present a novel approach to automated skull and cavity segmentation from ultra short MRI sequences, which are used for PET/MRI fusion scanners [12], which again is an application field that was identified by the personal viewpoints in [6]. Cone-beam CT, a modality that has been established primarily in dental radiology, delivers the data used by Gollmer and Buzug proposing a novel statistical shape model for 3D image segmentation [13]. Gross, Klein and Schneider present 2D image segmentation methods based on data-inherent characteristics [14]. Phase symmetry of complex logarithmic Gabor wavelets is used to extract the vessel tree from retinal fundus images.

The last papers that have been included in this hot topic deal with image-based modeling of processes and education of physicians by means of virtual reality. Particularly, tumor growth is an important measurement in cancer research and diagnostics. Toma *et al*. present a mathematical model that certainly will be applied in near future, since the authors could validate their approach based on 2D *in vivo* experiments, which have been recorded using light microscopy [15]. Also, 3D models can be derived with this approach. Fortmeier, Mastmeyer, and Handels apply virtual reality techniques for the training of needle insertion interventions [16]. As novelty, force-feedback for haptic interaction now models the complex mechanic interactions of the needle with skin and muscle, providing realistic system behavior on both visual and haptic output channels.

In summary, medical imaging and image computing is an active field in research and application. This CMIR Hot Topic presents a current review followed by nine selected papers covering the entire processing chain from image acquisition to analysis, modeling and simulation, and training. In other words, the collection of papers exemplifies how image data is transformed to image-based information and knowledge.

REFERENCES

[1] Horsch A, Deserno TM, Handels H, Meinzer HP, Tolxdorff T. IJCARS special issue editorial. BVM 2007 German conference on medical image processing. Int J Comput Assist Radiol Surg 2008; 2(2): 253-4.
[2] Tolxdorff T, Deserno TM, Handels H, Meinzer HP. Advances in medical image computing. Methods Inf Med 2009; 48(4): 311-3.
[3] Handels H, Meinzer HP, Deserno T, Tolxdorff T. Advances and recent developments in medical image computing. Int J Comput Assist Radiol Surg 2010; 5(6): 555-556.
[4] Deserno TM, Aach T, Amunts K, Hillen W, Kuhlen T, Scholl I. Advances in medical image processing. Comput Sci Res Dev 2011; 26(1): 1-3.
[5] Handels H, Deserno TM, Meinzer HP, Tolxdorff T. Image analysis and modeling in medical image computing. Recent developments and advances. Methods Inf Med 2012; 51(5): 395-7.

[6] Deserno TM, Handels H, Maier-Hein KH, Mersmann S, Palm C, Tolxdorff T, Wagenknecht G, Wittenberg T. Viewpoints on medical image processing. From science to application. Current Medical Imaging Reviews 2013; this issue, ref 9999.
[7] Erbe M, Weber M, Sattel TF, Buzug TM. Experimental validation of an assembly of optimized curved rectangular coils for the use in dynamic filed free line magnetic particle imaging. Current Medical Imaging Reviews 2013; this issue, ref 1970.
[8] Fieselmann A, Manhart M. Interventional perfusion imaging using C-arm CT. Current Medical Imaging Reviews 2013; this issue, ref 1001.
[9] Gleich B, Weizenecker J. Tomographic imaging using the nonlinear response of magnetic particles. Nature 2005; 435(7046): 1214-7.
[10] Scherf N, Ludborzes C, Thierbach K, Glauche I, Roeder I. A fluid registration approach to cell tracking. Current Medical Imaging Reviews 2013; this issue, ref 1951.
[11] Haase S, Forman C, Kilgus T, Bammer R, Maier-Hein L, Hornegger J. ToF/RGB sensor fusion for 3D endoscopy. Current Medical Imaging Reviews 2013; this issue, ref 1903.
[12] Habes M, Rota Kops E, Bahr J, Kühn J, Hoffmann W, Lipinski HG, Herzog H. Automated skull and cavity segmentation from ultra short TE sequence images. Current Medical Imaging Reviews 2013; this issue, ref 1889.
[13] Gollmer ST, Buzug T. Relaxed statistical shape models for 3D image segmentation. Application to mandible bone in cone-beam CT data. Current Medical Imaging Reviews 2013; this issue, ref 1938.
[14] Gross S, Klein M, Schneider D. Segmentation of blood vessel structures in retinal fundus images with logarithmic Gabor filters. Current Medical Imaging Reviews 2013; this issue, ref 1861.
[15] Toma A, Cisneros Castillo LR, Schuetz TA, Becker S, Mang A, Régnier-Vigouroux A, Buzug TM. A validated mathematical model of tumour-immune interactions for glioblastoma. Current Medical Imaging Reviews 2013; this issue, ref 1972.
[16] Fortmeier D, Mastmeyer A, Handels H. Image-based soft tissue deformation algorithms for real-time simulation of liver puncture. Current Medical Imaging Reviews 2013, ref 1902.

Thomas M. Deserno (né Lehmann)
Department of Medical Informatics, RWTH Aachen University, Germany

Heinz Handels
Institute of Medical Informatics, University of Lübeck, Germany

Hans-Peter Meinzer
Medical and Biological Informatics, German Cancer Research Center, Heidelberg, Germany

Thomas Tolxdorff
Institute of Medical Informatics, Charité – Universitätsmedizin Berlin, Germany