US-Cut: Interactive Algorithm for Rapid Detection and Segmentation of Liver Tumors in Ultrasound Acquisitions

Jan Egger [a,b], Philip Voglreiter [a], Mark Dokter [a], Michael Hofmann [a], Xiaojun Chen [c]
Wolfram G. Zoller [d], Dieter Schmalstieg [a], Alexander Hann [d]

[a] TU Graz, Institute for Computer Graphics and Vision, Inffeldgasse 16, 8010 Graz, Austria
[b] BioTechMed, Krenngasse 37/1, 8010 Graz, Austria
[c] Shanghai Jiao Tong University, School of Mechanical Engineering, 800 Dong Chuan Road, Shanghai 200240, China
[d] Dept. of Internal Medicine and Gastroenterology, Katharinenhospital, Kriegsbergstrasse 60, 70174 Stuttgart, Germany

Introduction

Ultrasound (US) is the most commonly used liver imaging modality worldwide. It plays an important role in follow-up of cancer patients with liver metastases. We present an interactive segmentation approach for liver tumors in US acquisitions. Due to the low image quality and the low contrast between the tumors and the surrounding tissue in US images, the segmentation is very challenging. Thus, the clinical practice still relies on manual measurement and outlining of the tumors in the US images. We target this problem by applying an interactive segmentation algorithm to the US data, allowing the user to get real-time feedback of the segmentation results. The algorithm has been developed and tested hand-in-hand by physicians and computer scientists to make sure a future practical usage in a clinical setting is feasible. To cover typical acquisitions from the clinical routine, the approach has been evaluated with dozens of datasets where the tumors are hyperechoic (brighter), hypoechoic (darker) or isoechoic (similar) in comparison to the surrounding liver tissue. Due to the interactive real-time behavior of the approach, it was possible even in difficult cases to find satisfying segmentations of the tumors within seconds and without parameter settings, and the average tumor deviation was only 1.4mm compared with manual measurements. However, the long term goal is to ease the volumetric acquisition of liver tumors in order to evaluate for treatment response. Additional aim is the registration of intraoperative US images via the interactive segmentations to the patient's pre-interventional CT acquisitions.

Methods

The algorithm presented here belongs to the class of graph-based approaches, where an image is interpreted as a graph, consisting of nodes and edges[1-5]. The overall workflow of the presented approach for interactive detection and segmentation of liver tumors is presented in Figure 1. The left image of Figure 1 shows a circular template that is used for the underlying graph. The second image of Figure 1 represents the principle of the graph construction that is based on the underlying circular template. Rays are sent out radially from the center point of the circle and along these rays, the nodes for the graph are sampled. The inter- and intra-edges are constructed between the nodes, whereby the construction of the inter-edges depends on the delta value Δr. The third image of Figure 1 shows a complete graph (green) that is constructed in an ultrasound image (note: in general, the graph is not displayed to the user, rather the segmentation result is directly shown). The position of the graph depends on the interactive placement of the mouse cursor (center point of the circle/graph) by the user[6,7]. The rightmost image of Figure 1 presents the segmentation result (red) displayed to the user based on the current center point of the circle/graph, the seed point (white).

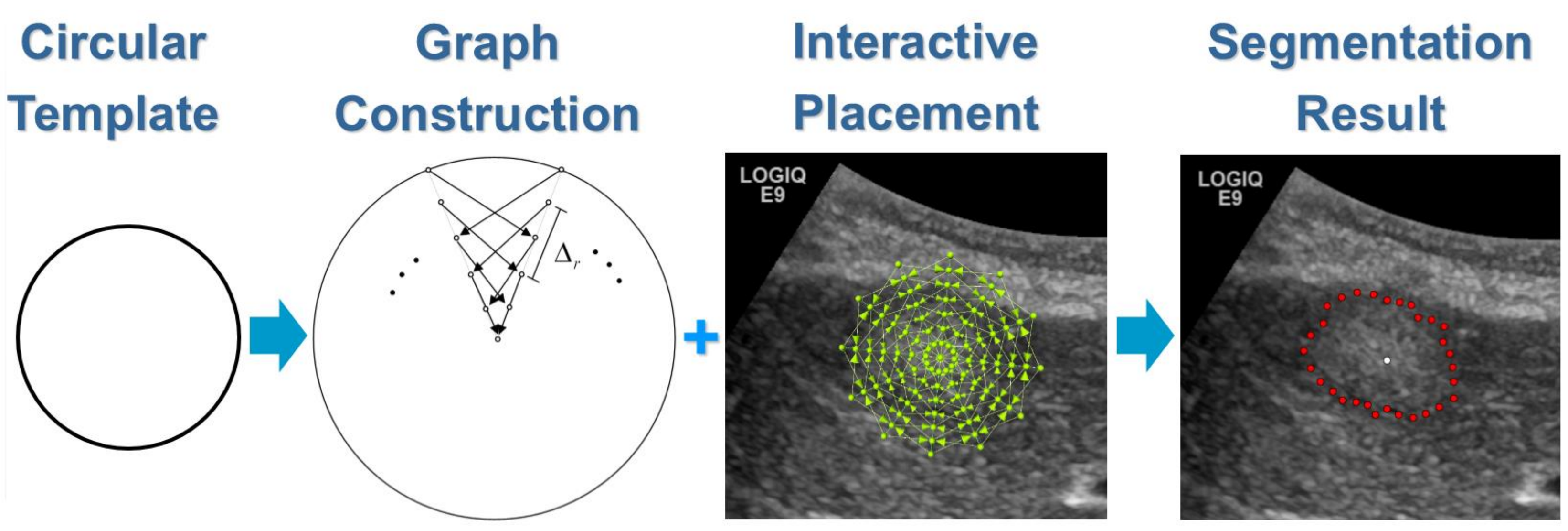

Figure 1 – Overall workflow of the presented approach for interactive detection and segmentation of liver tumors.

Results

Ultrasound examinations were performed using a multifrequency curved probe, which allows ultrasound acquisitions with a bandwith of 1 to 6 MHz (LOGIQ E9/GE Healthcare, Milwaukee, Il, USA, and Toshiba Aplio 80, Otawara, Japan). Using the digital picture archive of our ultrasound unit we retrospectively selected images of liver masses examined by Dr. Hann in the year 2013 that fulfilled the following criterion to ease the segmentation: The main criterion consisted of the echogenicity class of the lesion (hypo-, hyper and isoechoic). During the selection process, we excluded cystic or marked calcified masses, so that the chosen lesions appeared relatively homogenous. Pictures with visible marker or text overlaying the target lesion were excluded. After identifying one lesion per echogenicity class, the selection process was stopped, patient information was removed from the image and the anonymized picture was subsequently processed by the segmentation algorithm. For evaluation, algorithmic segmentations have been compared with the manual segmentations from a physician, which lead to an average deviation of 1.4mm. Figure 2 presents a direct side-by-side comparison of the interactively achieved segmentation results (right side) and a manual expert measurement (left side) for two liver metastases. The presented approach was realized in C++ within the medical prototyping platform MeVisLab[8-12].

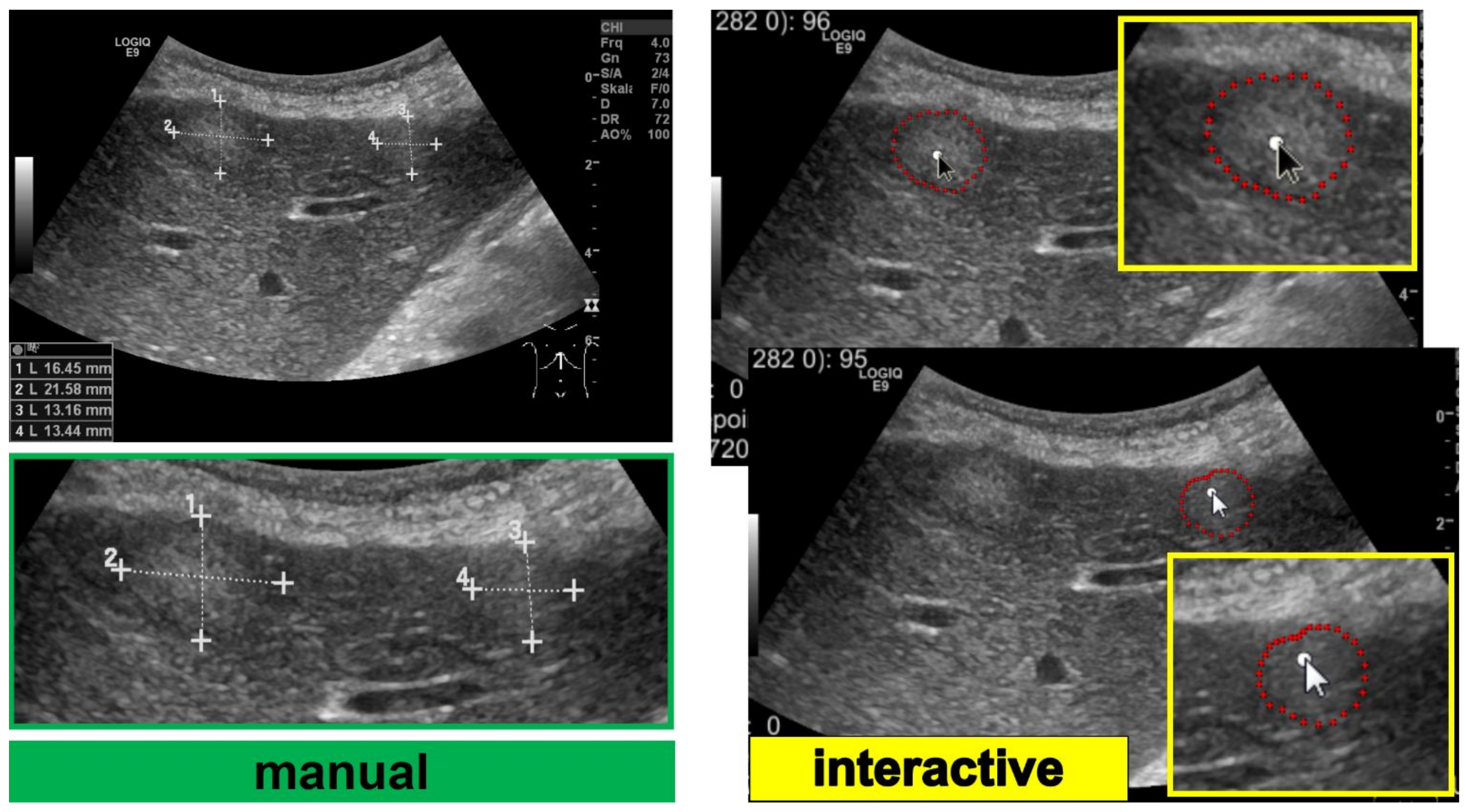

Figure 2 – Side-by-side comparison of manual (left) and interactive (right) segmentation results for the two liver metastases.

Conclusions

In this study, we present the results of an interactive segmentation approach for liver tumors in US acquisitions. This is a very challenging problem and still under active research, because of the low image quality and the low contrast between the tumors and the surrounding liver tissue in US images. As a consequence, in clinical practice, the tumors are still outlined and measured purely manual, which leads to poor inter-observer agreement regarding the tumor size. We supported the manual segmentation task by applying an interactive segmentation algorithm to the US data, so the user gets real-time feedback of the segmentation results. To ensure a future practical usage in a clinical setting, the approach was developed and tested hand-in-hand by physicians and computer scientists. To cover typical acquisitions from the clinical routine, the approach was tested with data where the tumors are hyperechoic (brighter), hypoechoic (darker) or have a nearly isoechoic (similar) appearance to the surrounding liver tissue. The approach's interactive real-time performance enabled satisfying segmentations within a few seconds even for difficult cases and without new parameter settings.

References

1. Egger, J. “PCG-Cut: Graph Driven Segmentation of the Prostate Central Gland,” PLOS ONE 8 (10), e76645 (2013).
2. Egger, J. et al. “Pituitary Adenoma Segmentation,” In: Proceedings of International Biosignal Processing Conference, Charité, Berlin, Germany (2010).
3. Schwarzenberg, R. et al. “Cube-Cut: Vertebral Body Segmentation in MRI-Data through Cubic-Shaped Divergences,” In: PLoS One (2014).
4. Schwarzenberg, R. et al. “A Cube-Based Approach to Segment Vertebrae in MRI-Acquisitions,” Proceedings of Bildverarbeitung für die Medizin (BVM), Springer Press, 69-74 (2013).
5. Bauer, M. et al. “Boundary estimation of fiber bundles derived from diffusion tensor images,” International journal of computer assisted radiology and surgery 6 (1), 1-11 (2011).
6. Egger, J., Lüddemann, T., Schwarzenberg, R., Freisleben, B. and Nimsky, C. “Interactive-cut: Real-time feedback segmentation for translational research,” Comput Med Imaging Graph. 38(4):285-95 (2014).
7. Egger, J. “Refinement-Cut: User-Guided Segmentation Algorithm for Translational Science,” Sci. Rep. 4:5164 (2014).
8. Egger, J. et al. “Integration of the OpenIGTLink Network Protocol for image-guided therapy with the medical platform MeVisLab,” The International Journal of Medical Robotics and Computer Assisted Surgery, 8(3):282-90 (2012).
9. Egger, J. et al. “Simulation of bifurcated stent grafts to treat abdominal aortic aneurysms (AAA),” Proceedings of SPIE Medical Imaging Conference, Vol. 6509, pp. 65091N(1-6), San Diego, USA (2007).
10. Lu, J. et al. “Detection and visualization of endoleaks in CT data for monitoring of thoracic and abdominal aortic aneurysm stents,” Proceedings of SPIE Medical Imaging Conference, Vol. 6918, pp. 69181F(1-7), San Diego, USA, (2008).
11. Egger, J. et al. “Preoperative Measurement of Aneurysms and Stenosis and Stent-Simulation for Endovascular Treatment,” IEEE International Symposium on Biomedical Imaging: From Nano to Macro, Washington (D.C.), USA, pp. 392-395, IEEE Press (2007).
12. Greiner, K. et al. “Segmentation of Aortic Aneurysms in CTA Images with the Statistic Approach of the Active Appearance Models,” Proceedings of Bildverarbeitung für die Medizin (BVM), Berlin, Germany, Springer Press, pages 51-55 (2008).

SPIE. MEDICAL IMAGING

Town & Country Resort and Convention Center
San Diego, CA, United States
27 February - 3 March 2016