Cascaded ResNets for Joint Liver and Hepatic Vessel Segmentation

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Biography – My name is Omar Ali, I am a second year PhD student working on the development of deep learning algorithms for the curative treatment of primary liver cancer. Prior to my PhD in medical imaging, I received a bachelor of engineering in Mechanical Engineering at the American University of Beirut and a master's degree in Biomechanical Engineering at Ecole Polytechnique. This PhD is currently funded by Guerbet, a world leader in medical imaging, and by the Ile de France Region as part of the Paris Region PhD call for projects in 2019.

Summary :

Background Liver and hepatic vessel segmentations are of fundamental importance for the diagnosis and surgical planning of liver diseases [1]. However, unlike liver segmentation which has been vastly studied and produces remarkable results [2], vessel segmentation, particularly hepatic vessel segmentation using deep learning techniques, remains an active research area requiring further performance enhancement [3].

Methods We propose an automatic liver and hepatic vessel segmentation approach using cascaded convolutional neural networks for portal and hepatic veins segmentation. This working pipeline consists of two separate major steps: (i) automatic segmentation of the liver, and (ii) automatic segmentation of the vessel structures within the liver region. This cascaded architecture is adopted to help avoid over-segmentations outside the region of interest (ROI), and to ensure hierarchical learning of the different features in the input data [4].
Two fully convolutional neural networks are sequentially constructed and trained to segment 2D CT slices. These Residual Networks (ResNets) are designed with short and long skip connections, and two deep supervision layers [5]. The architecture of both networks is detailed in Figure 1(A), and the overall cascaded architecture can be seen in Figure 1(B).
In the first step developed to automatically segment the liver region, Model 1 is fed an axial CT slice and outputs its prediction of the liver mask. On the other hand, Model 2, designed to segment the hepatic vessels, takes the axial CT slice as input along with the features-rich output of the last convolutional layer from the pretrained frozen liver model, and yields its prediction of the hepatic vessels mask [6].

Results and Discussion The liver segmentation model trained on an internal dataset with more than a thousand annotated abdominal CT volumes, achieved an overall dice coefficient of 91% and 93% when evaluated on the LiTS and IRCAD public datasets respectively. Additionally, the proposed cascaded network approach, achieved an average dice coefficient of $53 \pm 13\%$ on the validation set.
However, the task of hepatic vessel segmentation is of particular complexity because of the large anatomical variability in the size, position and branching of the different vessels namely the portal and hepatic veins. Nevertheless, the cascaded network remains capable of detecting the most important hepatic vessels (Figure 2), which consist of the portal vein, the inferior vena-cava and the hepatic veins (right, middle, and left).

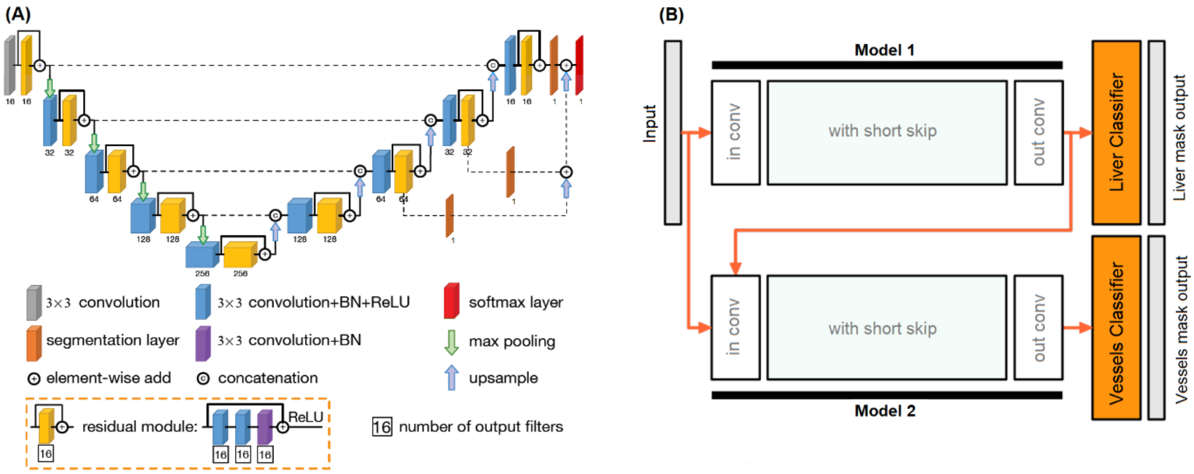

Figure 1: (A) Liver and vessel networks architecture (modified from [5]), (B) Cascaded networks architecture (modified from [6]).

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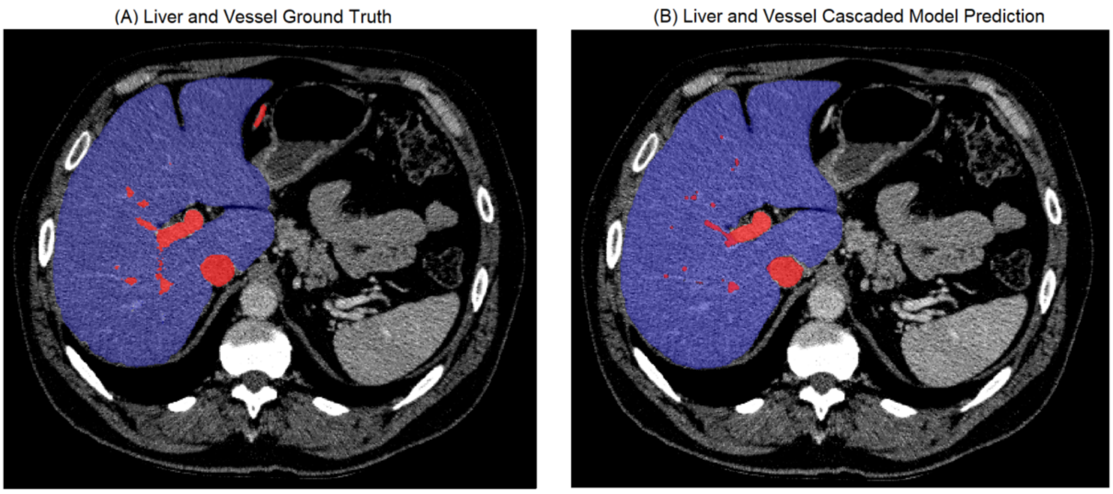

Figure 2: (A) Ground truth vessel segmentation (B) Cascaded network prediction

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Conclusion The developed networks are able to generate accurate liver segmentations (>90%) and decent hepatic vessel segmentations (53%). Other methods are being tested to improve the current vessel segmentation results i.e. 2.5D and 3D approaches, multi-input approach, and a cascaded multi-input approach.

References

[1] Sara Moccia, Elena De Momi, Sara El Hadji, and Leonardo S. Mattos. Blood vessel segmentation algorithms — Review of methods, datasets and evaluation metrics. *Computer Methods and Programs in Biomedicine*, 158:71–91, 2018.

[2] Xiaomeng Li, Hao Chen, Xiaojuan Qi, Qi Dou, Chi-Wing Fu, and Pheng-Ann Heng. H-denseunet: Hybrid densely connected unet for liver and tumor segmentation from ct volumes. *IEEE Transactions on Medical Imaging*, 37(12):2663–2674, 2018.

[3] Abir AFFANE, Marie-Ange LEBRE, Utkarsh MITTAL, and Antoine VACAVANT. Literature review of deep learning models for liver vessels reconstruction. In *2020 Tenth International Conference on Image Processing Theory, Tools and Applications (IPTA)*, pages 1–6, 2020.

[4] Patrick Ferdinand Christ, Florian Ettlinger, Felix Grün, Mohamed Ezzeldin A. Elshaera, Jana Lipkova, Sebastian Schlecht, Freba Ahmaddy, Sunil Tatavarty, Marc Bickel, Patrick Bilic, Markus Rempfler, Felix Hofmann, Melvin D Anastasi, Seyed-Ahmad Ahmadi, Georgios Kaissis, Julian Holch, Wieland Sommer, Rickmer Braren, Volker Heinemann, and Bjoern Menze. Automatic Liver and Tumor Segmentation of CT and MRI Volumes using Cascaded Fully Convolutional Neural Networks. pages 1–20, 2017.

[5] Wei Yu, Bin Fang, Yongqing Liu, Mingqi Gao, Shenhai Zheng, and Yi Wang. Liver Vessels Segmentation Based On 3D Residual U-Net College of Computer Science , Chongqing University , Chongqing 400044 , China Chongqing Key Laboratory of Computational Intelligence , Chongqing University of Posts and Telecommunications , Chongqing 4. *2019 IEEE International Conference on Image Processing (ICIP)*, pages 250–254, 2019.

[6] Eugene Vorontsov, An Tang, Chris Pal, and Samuel Kadoury. Liver lesion segmentation informed by joint liver segmentation. *Proceedings - International Symposium on Biomedical Imaging*, 2018-April:1332–1335, 2018.