CSE 591 Project Proposal: Retinal Vessel Segmentation Using Fully Convolutional Neural Networks

Sangdi Lin, Yanzhe Xu

Abstract—Retinal vessel segmentation is important for medical diagnostic. In this project, we plan to apply a fully convolutional neural network (FCN) to perform vessel segmentation for retinal images. A conditional random fields (CRF) method will be used to enhance the smoothness of the segmentation. FCNs have achieved state of the art results in multiple image segmentation tasks. In addition to retinal images, we plan to extend its applications to other types of medical images.

Index Terms—Retinal vessel segmentation, Convolutional neural networks, Conditional random fields

1 Introduction

Retinal vessel segmentation is important for medical diagnostic since it is commonly used for many diseases diagnostic. However, traditional method is to manually do segmentation and it is too time-consuming for doctors to diagnosis. From last decades many new methods are published for assisting this medical task by using automatically segmentation for retinal vessels.

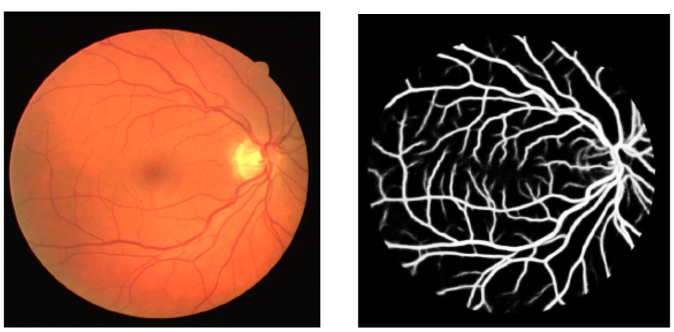

Fig. 1: An retinal vessel image example and its segmentation output in [1]

2 Literature Review

Diegon et al. [2] use a uses neural network scheme for pixel classification and computes a 7-D vector composed of gray-level and moment invariants-based features for pixel representation. Gehad et al. [3] use mathematical morphology and K-means clustering to segment vessels. Jose et al. [4] combine different kinds of vessel features and segment them with fully connected conditional random fields. Those work inspire us to explore the performance of deep learning method applying on vessel segmentation.

3 Main Experiment

In this project, we will mainly study and implement the method proposed by [5]. The proposed method consists of two steps. At the first step, fully convolutional neural network (FCN) [1] is trained to produce a vessel probability map. At step two, the conditional random fields (CRFs) is used to generate the final precise segmentation.

3.1 Fully convolutional neural network

The traditional convolutional neural network (CNNs) reduce the width and height of the feature maps as they extract high-level features from an input image. On the contrary, FCN can produce an output of the same size as the input image without patch sampling, which is desirable especially for image segmentation. The architecture of FCN is presented in Fig. 2. More specifically, FCN combines the information from different convolutional layers to generate the final segmentation. It matches the input size by upsampling those layers with different scales. More details about FCN can be found in [1], which will be studied thoroughly in this project.

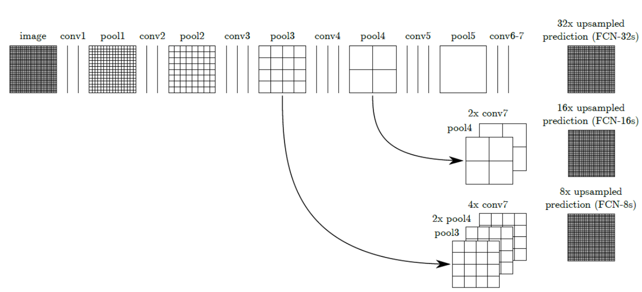

Fig. 2: The architecture of FCN [1]

- *S. Lin is with the Department of Industrial Engineering, Arizona State University, Tempe, AZ, 85281.*
  E-mail: slin63@asu.edu
- *Y. Xu is with Department of Computer Science, Arizona State University, Tempe, AZ, 85281*

Submitted on Feb. 19, 2017.

3.2 Conditional Random Fields

CRFs are popular probabilistic graphical models for image segmentation. Similar model has been used the in famous "GrabCut" paper [6]. It imposes the spatial constraint for the smoothness which FCN doesn't have, and it takes into account both the probability map generated by FCN and some other image features.

3.3 Datasets

We will use a couple of public datasets for this project. First is DRIVE dataset [7] which contains 40 images and have been divided into training set and testing set. Both contains 20 images. Second is STARE dataset [8] which contains around 40 hand labeled images for blood vessel segmentation. Third is CHASE_DB1 dataset [9] which contains 14 images.

4 Possible extensions

Our primary task is to study and implement the method presented in [5]. Upon the successful implementation of the method and obtain the paper's result, some possible extensions are stated below, but will be adjusted according to the real time availability.

First, we will consider another retinal image dataset from a Kaggle challenge (https://www.kaggle.com/c/diabetic-retinopathy-detection), which contains the retinal images collected from various machines and lighting conditions. It represents a more realistic scenario. Furthermore, the segmentation output can be used to assist the classification task in the Kaggle challenge. In order to achieve that, a CNN model trained on the segmentation output could be used to do the final classification. We can compare classification accuracy to the CNN model which directly trained on the original retinal images.

Second, we will research some alternative approaches for the CRFs that could be used to refine the segmentation from the FCN.

Third, we will further experiment the applications of FCN in other related domains. For instance, the small blob (glomerulus) detection problem in kidney MRI images ([10]). See Fig. 3 as an example. The red dots in the image indicate the segmentation of the small blobs. A precious count of the blobs is very useful for the diagnosis of some kidney-related diseases. However, we are not sure if we could obtain some manually labeled ground truth for training, which unfortunately is the prerequisite for this experiment.

5 Tools

We plan to use Python package "Theano" and "Lasagne" to implement FCN, and use "PyStruct" to implement CRF.

6 Time line

- March 1st: Study the materials.
- April 1st: Implement the method for the main experiment, refine the goals for the extension work.
- Due date: Work on possible extensions and final report.

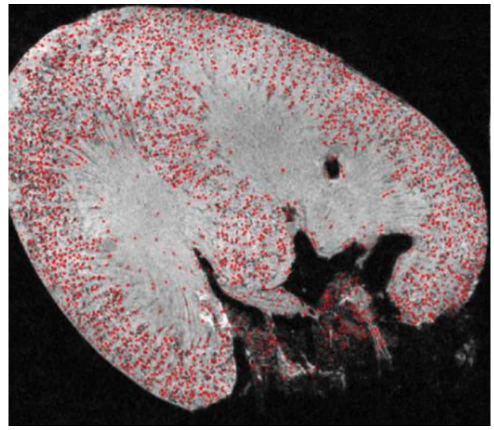

Fig. 3: Blob detection in kidney image [10]

7 Group Task Assignment

In our group, both of us will be in charge of building FCN. Sangdi Lin will be in charge of looking for improvement of FCN algorithm. Yanzhe Xu will be in charge of data preprocessing and using CRN to remove noise and also looking for alternative methods. Both of us will also work on further segmentation experiments.

References

[1] J. Long, E. Shelhamer, and T. Darrell, "Fully convolutional networks for semantic segmentation," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 2015, pp. 3431–3440.

[2] M. Diego, A. Arturo, E. G.-A. Manuel, and M. B. Jos, "A new supervised method for blood vessel segmentation in retinal images by using gray-level and moment invariants-based features," in *IEEE Transactions on Medical Imaging(TMI)*, vol. 30, 2011.

[3] H. Gehad, E.-B. Nashwa, E. H. Aboul, F. Ali, M. Abullah, and S. Vaclav, "Retinal blood vessel segmentation approach based on mathematical morphology," in *International Conference on Communication, Management and Information Technology(ICCMIT 2015)*, 2015, pp. 612–622.

[4] I. O. Jose and B. Matthew, "Learning fully-connected crfs for blood vessel segmentation in retinal images," in *Medical Image Computing and Computer Assisted Intervention (MICCAI)*. Springer, 2014.

[5] H. Fu, Y. Xu, D. W. K. Wong, and J. Liu, "Retinal vessel segmentation via deep learning network and fully-connected conditional random fields," in *Biomedical Imaging (ISBI), 2016 IEEE 13th International Symposium on*. IEEE, 2016, pp. 698–701.

[6] C. Rother, V. Kolmogorov, and A. Blake, "Grabcut: Interactive foreground extraction using iterated graph cuts," in *ACM transactions on graphics (TOG)*, vol. 23, no. 3. ACM, 2004, pp. 309–314.

[7] S. Joes, D. A. Michael, N. Meindert, A. V. Max, and v. G. Bram, "Ridge-based vessel segmentation in color images of the retina," in *IEEE Transactions on Medical Imaging(TMI)*, vol. 23, 2004.

[8] H. Adam, K. Valentina, and G. Michael, "Locating blood vessels in retinal images by piecewise thresh- old probing of a matched filter response," in *IEEE Transactions on Medical Imaging(TMI)*, vol. 19, 2000.

[9] M. F. Muhammad, R. Paolo, H. Andreas, U. Bunyarit, R. R. Alicja, G. O. Christopher, and A. B. Sarah, "An ensemble classification-based approach applied to retinal blood vessel segmentation," in *IEEE Transactions on Biomedical Engineering(TBE)*, vol. 59, 2012.

[10] M. Zhang, "Small blob detection in medical images," Ph.D. dissertation, ARIZONA STATE UNIVERSITY, 2015.