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L I T H U A N I A

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PANCREAS SEGMENTATION IN CT IMAGES: STATE OF THE ART IN CLINICAL PRACTICE

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Abstract. Pancreas adenocarcinoma is a lethal condition with poor outcomes. With increasing incidence worldwide, it predicted to become the second leading cause of cancer death in many countries. The main factor influencing disease outcome is tumor stage at the time of diagnosis. The first step to successfully diagnose and treat the pancreatic cancer, is the efficient recognition and segmentation of the target organ. Several methods based on deep learning for pancreas segmentation have been developed and applied over the years. This paper presents a state of the art application of the existing methods that have been presented for pancreas and pancreatic cyst detection and segmentation.

Keywords. Pancreatic Segmentation, Pancreatic Cancer, Deep Learning, Artificial Intelligence, Convolutional Neural Networks.

1. Introduction

Pancreatic cancer is one of the leading causes of cancer-related deaths in the world. According to the data of the National Cancer Institute, about 450-500 people in Lithuania get pancreatic cancer every year. It is known, that men get this disease more often than women. Pancreatic cancer mortality is quite high, as most patients (>80%) have cancer-specific symptoms only at an advanced stage. World survival rate for pancreatic cancer patients over five years is just 6%, but it may range from 2% to 9% (McGuigan et al., 2018). Unfortunately, pancreatic cancer often presents late, and only 20% of patients with pancreatic cancer have surgically resectable disease at the time of presentation. For patients who can undergo successful surgical resection, the 5-year survival is 27%.

Due to pancreas anatomical location, inner-patient variability in both shape and volume in the abdominal cavity, automatic pancreas segmentation in radiology images is frequently a challenge. However, computer-aided screening, preoperative diagnosis and pancreas as an organ quantitative assessment is essential for establishing a treatment plan. Having pancreas segmented provides a reliable and quantitative representation than cross-sectional measurements. In addition, computer automated, reliable, rapid and accurate segmentation of pancreas processing thousands of image scans can provide new diagnostic information, assist in preoperative surgical planning and be adopted in clinical practice.

The purpose of this paper is to review different mathematical methods that have been developed and applied in pancreas segmentation problems. There will be pros and cons presented for each analyzed research.

The remaining part of the paper is organized as follows: first, Section 2 presents available previous studies. Then the various issues and suggestions are discussed in Section 3. Finally, Section 4 presents the concluding remarks and future work.

2. Previous studies

Recently, the computer-aided diagnosis (CAD) is becoming a new fashion as the deep neural network as deeply evolving and medical needs are increasing. The high incidence of pancreatic cancer leads to interest in the development of CAD methods useful for diagnosis and treatment, in which it is very important to accurately identify pancreatic segments. Therefore, it is necessary to develop advanced method of pancreas segmentation.

2.1. Pancreas segmentation

Segmentation of the pancreas from computed tomography (CT) images is a big challenge due to its shape, size and location in the abdomen.

Research by Holger R. Roth et al. (Roth et al., 2015) entitled “Deep convolutional networks for pancreas segmentation in CT imaging” presents a fully-automated bottom-up method for pancreas segmentation using CT abdominal images. The authors extract super-pixels from the abdominal region and classify them by using hierarchical coarse-to-fine classification.

Convolutional neural network is trained with a standard architecture for binary image classification and ends with two SoftMax layer for “pancreas” and “non-pancreas” classification. Dropout method is then used to avoid overfitting.

The proposed method was evaluated on CT images of 82 patients. The dataset was split into training, validation and testing sets with a proportion of 60/2/20. With this data, authors achieved average Dice score of 68% ± 10% in testing. This result is a promise that CAD can be used for accurate pancreas segmentation. Figure 1 shows the segmentation results. Dice score for the third patient is the worst, which could be caused by the lesser amount of visceral fat.

The work showed that the convolutional neural networks (ConvNet) can be easily used in medical image analysis. The proposed approach could be also applied to multi-organ segmentation.

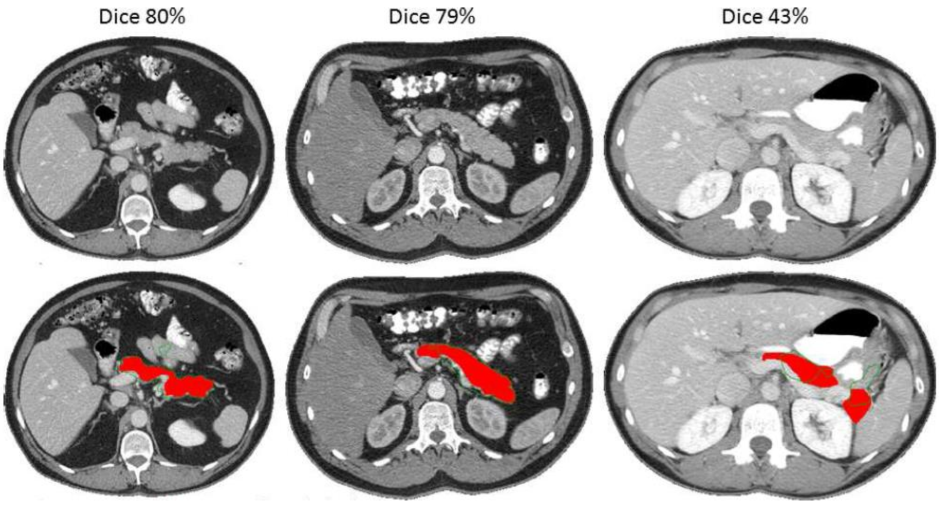

Figure 1. Examples of pancreas segmentation using the proposed ConvNet approach (green outline). Red solid denotes manual ground truth annotations (Roth et al., 2015).

Another segmentation method was proposed by Min Fu et al. (Fu et al., 2018) in paper “Hierarchical combinatory deep learning architecture for pancreas segmentation of medical computed tomography cancer images”. There authors extend the Richer Feature Convolutional Network (RCF) and put a new pancreas segmentation network. They use this method for edge detection. It this work, authors improve RCF network with multi-layer up-sampling structure and get over 1% better performance in pancreas segmentation compared to the old RCF network.

The dataset consists of 59 patients, including 15 patients with non-pancreas diseases, and 44 with pancreas-related diseases. With the designed architecture, authors get a Dice score (DSC) of 76.36% which significantly higher than the result from previous research. Some examples of the output are presented in Figure 2. Moreover, this result is more reliable as the data contained not only healthy pancreas. Five different pancreas-related diseases were included, therefore the model could learn different scenarios which leads to the reliability and robustness.

The most recent work on pancreas segmentation is presented by Ningning Zhao et al. (Zhao et al., 2019) in their paper “Fully automated pancreas segmentation with two-stage 3D convolutional neural networks”. Authors propose a two-stage method for automated pancreas segmentation on 3D CT images. First stage is based on down-sampled 3D volumes segmentation for candidate region generation, while the second stage is to refine the pancreas segmentation on smaller regions of interest.

Dataset consists of 82 abdominal CT scans, where 20 was chosen for validation. The average Dice score of the proposed method reaches 85.99% which outperforms the previous results. Moreover, authors are using 3D scans, where the location of pancreas on 3D volumes of different subjects are more consistent than that on 2D slices. Some examples of the segmentation results are presented in Figure 3.

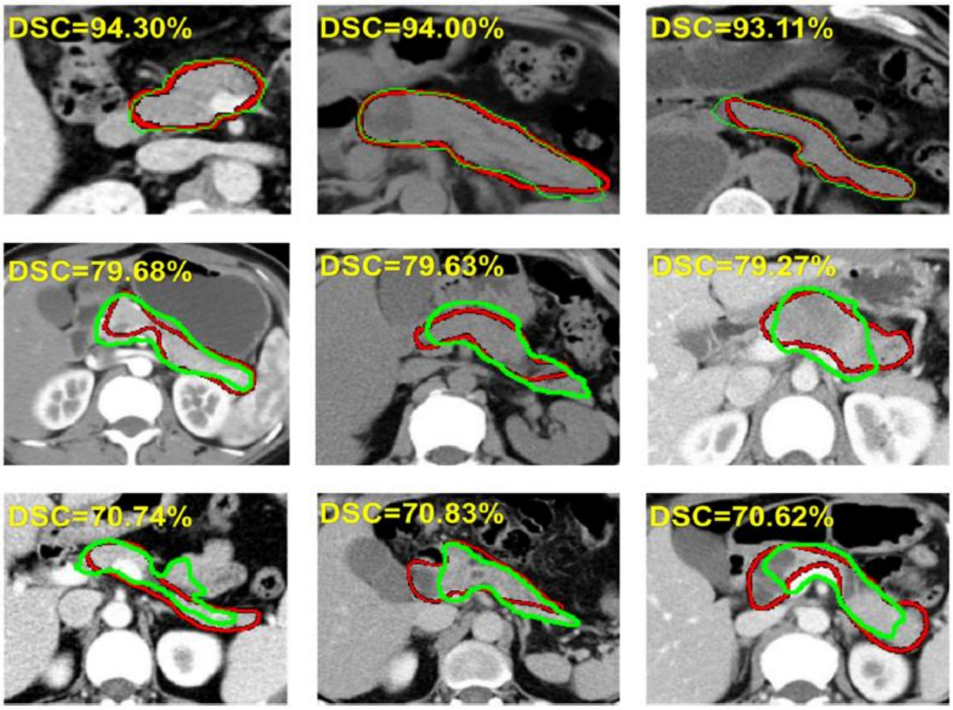

Figure 2. Some examples of pancreas segmentation result. Red curve shows the ground truth while green for the predicted. Row1 are in the best performance, row2 are on the quartile2 and row3 on the quartile1 (Fu et al., 2018).

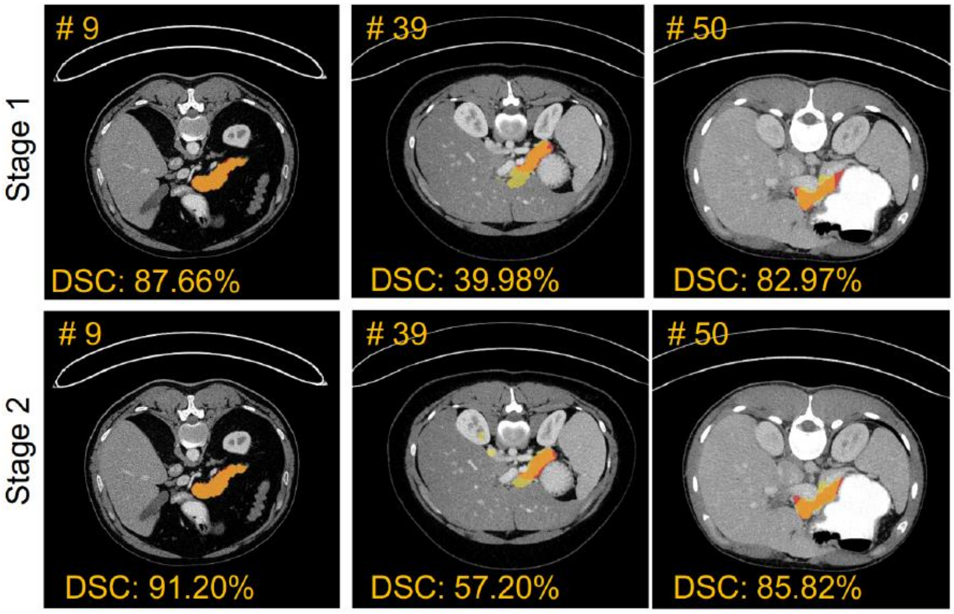

Figure 3. Examples of segmentation results of the proposed method. Red and yellow mask indicate the ground truth, prediction regions respectively (Zhao et al., 2019).

2.2. Pancreatic cyst and tumor segmentation

Convolutional neural networks has been developed and applied for pancreas segmentation quite successfully. However, pancreas cyst and tumor segmentation topic is less studied. The following are the most recent researches that were reviewed.

Yuyin Zhou et al. (Zhou et al., 2017) in their work "Deep supervision for pancreatic cyst segmentation in abdominal CT scans" focus on segmenting the pancreatic cyst which is a more challenging but very useful task. Authors introduce an approach that takes into consideration pancreas and the cyst. First of all, pancreas is found and localized. Then the cyst is being segmented based on the predicted mask. Experiment was done on 131 pathological samples from CT scans. Since there was not enough training data, authors cut each 3D volume into a series of 2D pieces. The proposed method achieved Dice score of 63.44%. However, at the first stage where authors investigated pancreas segmentation, Dice score reached 79,23%. Figure 4 shows some the segmentation results. In the last example, pancreas segmentation fails in this slice, resulting in a complete failure in cyst segmentation.

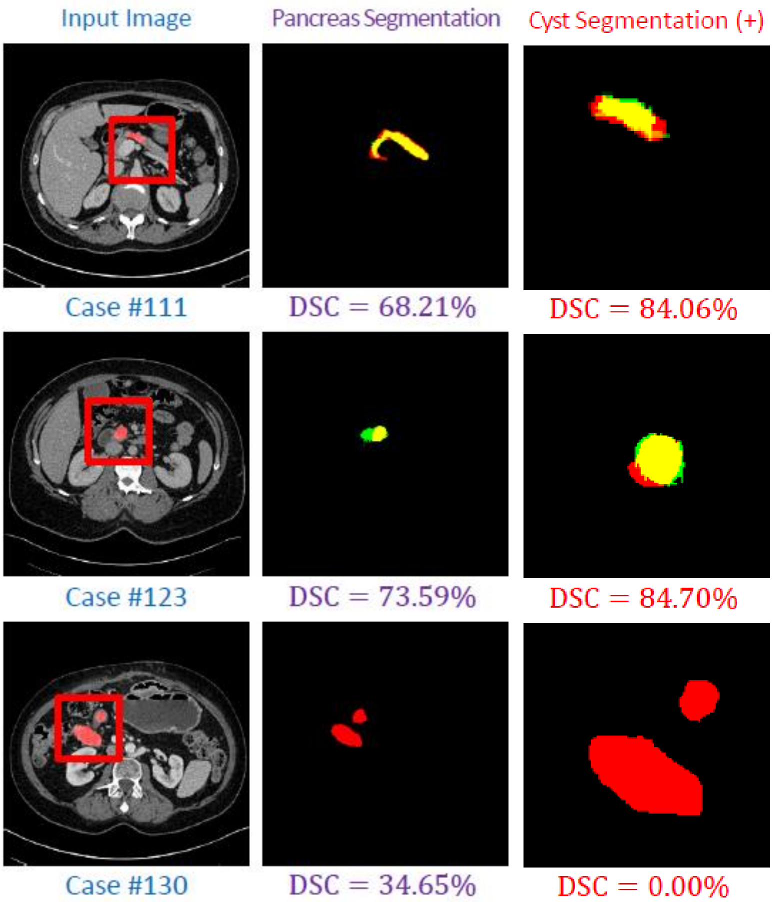

Figure 4. Sample pancreas and pancreatic cyst segmentation results. From left to right: input image (in which pancreas and cyst are marked in red and green, respectively), pancreas segmentation result, and cyst segmentation results when we apply deep supervision. The figures in the right three columns are zoomed (Zhou et al., 2017).

The most recent work related to pancreatic tumor segmentation are Wei Zhao et al. (Zhao et al., 2019) paper "Marker less pancreatic tumor target localization enabled by deep learning" and Zhengdong Zhang et al. (Zhang et al., 2020) research "A novel and efficient tumor detection for pancreatic cancer via CT images".

The first work focuses on developing a network to localize pancreatic tumor target for image guided radiation therapy. It is important to accurately localize the tumor in order to have a successful radiation therapy. Authors propose a strategy which is based on synthetically generated digitally reconstructed radiographs without relying on the use of a vast number of clinical kV x-ray images. The accuracy of the model was evaluated using Lin's concordance correlation coefficient between the predicted and actual positions. It was found that the coefficient is better than 93%, which means that the proposed model has been successfully developed for pancreatic tumor target localization. Furthermore, authors foresee how to implement the deep learning based model into the radiation therapy workflow, in order to have a benefit in patient care.

Authors in the second research propose a new pancreatic tumor detection framework, where it is designed to fully exploit the context information at multiple scales. The proposed method consists of augmented feature pyramid networks, self-adaptive feature fusion and a dependencies computation module.

The dataset contains 2890 CT images. The model performance was measured based on AUC which was reached 94.55%. Some of the examples are showed in Figure 5. The result was compared with other classical object detection algorithms that were trained and tested with the same pancreatic CT dataset. It showed that the new approach outperforms other method, which leads to conclusion that the new one is currently the most accurate to use in pancreatic tumor segmentation.

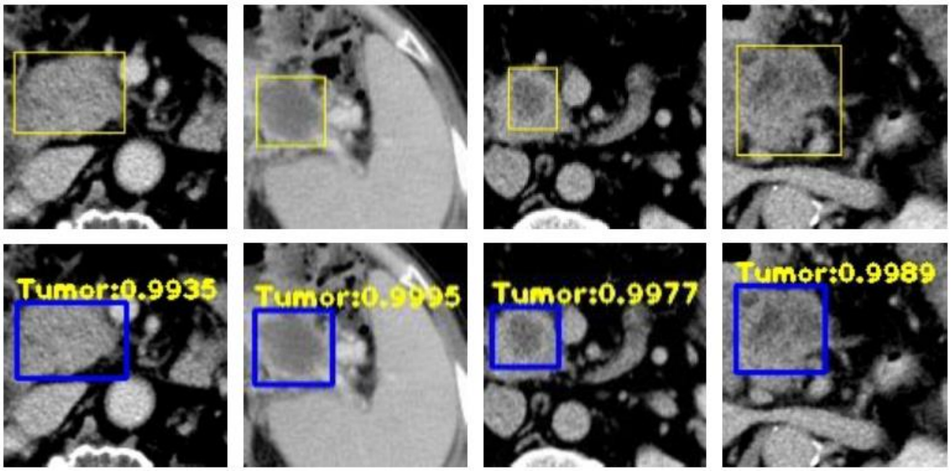

Figure 5. Example results of tumor detection. The first row are the ground truth, the second row are the corresponding detection results of the proposed method (Zhang et al., 2020).

3. Issues and suggestions

The following section presents various issues and suggestions based on the previous work on pancreas segmentation.

First of all, there are several discussion on whether to use 2D or 3D scans, as both have advantages and disadvantages. Since 3D CT scans have high dimensionality, it can lead to high cost of computational power and memory, which limits the depth and architecture of the networks. On the other hand, there are usually more training samples for 2D network.

Secondly, most of the research are lacking data. First analyzed work (Roth et al., 2015) is using only healthy pancreas; if the method would be applied to the wider data, it is questionable how it would work. Even though the second work (Fu, 2018) is using patients with non-pancreas diseases and with pancreas-related diseases, there are only 59 patients. This leads to the same issue as previous. Pancreas can vary depending on the patient, so it is very important to have as different patients as possible to get a most reliable result.

4. Conclusion and future work

While pancreas remains a challenging abdominal organ due to its individually based anatomical placement in the abdominal cavity, accurate automatic segmentation is helpful not only for surgical planning but also for image-guided radiation therapy.

In conclusion, this short overview provided a proof of concept that pancreas segmentation can be applied in multidisciplinary management of pancreas cancer (such as early cancer detection, preoperative planning or image-guided radiation therapy).

List of abbreviations

CT Computed tomography
CAD Computer-aided diagnosis
ConvNet Convolutional neural networks
RCF Richer feature convolutional network
DSC Dice score

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