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学 位 論 文 題 目	Research on Intravascular Optical Coherence Tomography Image Analysis
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論文内容の要旨

The title of my investigation is "*Research on Intravascular Optical Coherence Tomography Image Analysis*".

Clinical examinations show that the morbidity of coronary artery disease (CAD) is gradually increasing in many countries every year, and it causes hundreds of thousands of people all over the world dying for each year. As one kind of CAD, atherosclerosis plaques contain three main types: lipidic, fibrotic and calcified plaques. With the new imaging modality named intravascular optical coherence tomography (IVOCT), clear imaging presenting the inner vessel micro-structure and morphology can be obtained. Hundreds of IVOCT image frames are generated at one time to every patient for every treatment, therefore, it is a huge laborious work for specialists to manually analyze the enormous images. Developing automatic methods for the quantitative measurement and assessment of human vessel morphology and lesion tissue is necessary and significant.

At the beginning study, I learned about the imaging principle of OCT system and surveyed a lot of studies which present related work on OCT clinical knowledge, lumen border and stents detection methods, vessel lesion tissue identification and classification, as well as the deep learning papers., and understood the advantage and disadvantage of these approaches applied. A review paper about the current situation was published in a journal named "*Computer System Application*". (Depicted in chapter 1)

Corresponding to the work requirements of the clinical specialists with analyzing IVOCT images, I proposed methods and algorithms to overcome the existing problems.

To obtain processed IVOCT images for the lumen boundary segmentation, I decided to remove the catheter imaging, guide-wire and human artifacts first. Here, by considering the formation of the IVOCT image and the shape of catheter imaging, I constructed a circle detector for matching the circle pattern of the catheter imaging and built a circle-ring detection model for the guide-wire shadow region. After the removal of the catheter and guide-wire, residual blood is eliminated through the Otsu method and morphological operations. These methods were published in a journal named "*Computing Technology and Automation*". (Described in chapter 2)

In 2017, I used a traditional method to segment the lumen border and detect stents. Based on the analysis of the intensity changing of the A-line profile, the intensity in the lumen, vessel tissue and the stent with shadow region present a big difference. I chose the statistic variable (standard deviation) as the basic analysis factor to form a final value with thresholds and coefficients for the lumen border and stents detection. In our stent detection method, the stent covered with neointima could also be identified. This result was published in an article published in the *International Workshop on Frontiers of Computer Vision 2018*. (Chapter 3 introduces these models)

From May 2018 to Dec. 2018, I focused on the task of vessel lesion tissue recognition and classification. The light attenuation coefficient and the thickness corresponding to the lesion plaques were analyzed. I proposed a local multi-layer model using the A-line sub-region (ALSR) as its basic element for feature extraction research. Different features were exanimated along the radial and circumferential dimensions to discuss the statistical information of intensity of three types of plaques. I utilized a machine learning method (random forest) to classify the extracted features from superficial layers based on ALSR. This outcome was published in a journal named "*IEICE Transaction on Information and System*" in 2019. (Chapter 4)

Except using the conventional approaches applied for the lesion plaques identification, our group also tried to employ the deep learning methods on plaque recognition. Moreover, to investigate the effect of the texture information to the plaque classification result, three types of the input channel were respectively applied to a designed deep learning model (VGG-like model). In this research, Local Binary Pattern (LBP) was used to generate an single-channel input data, and it was also merged with RGB channels to produce a four-channel input data. I tested input with three kinds of channel (LBP, RGB and LRGB) in the defined and learned 11-layer deep learning model. The experiment showed that four channels performed better than other two types. This outcome was published in an international conference named *International Forum on Medical Imaging in Asia 2019*. (Chapter 5 gives out the detail)

Now, I am researching on the pixel-wise classification of lesion plaques with semantic segmentation technique of deep learning. With the level-set method, I firstly obtain a outer border of region of interesting (ROI) to combine with the lumen boundary to form ROI. To crop a square region with a fixed size based on its center point belonging to ROI. The cropped input then is fed into a designed deep learning model (DB-SegNet) for the pixel classification. (Chapter 6 illustrates the detail content, and is now preparing for the journal submission)

In summary, my research is to investigate the IVOCT images analysis and propose methods for the automatic approaches instead of human work for the IVOCT images diagnosis and clinical research, simultaneously, improve the accuracy of the detection and classification for every task, and reduce the processing time.

論文審査の結果の要旨

論文では，光干渉断層法（Optical Coherence Tomography）で撮影された血管内画像において，カテール，ガイドワイヤーなどの人工物の検出・除去，内腔境界検出などの画像処理技術を開発し，統計処理と機械学習によるステントや動脈硬化性プラーク（脂質性，線維性，石灰化）の抽出方法を提案し，その効果や課題を示した。予備審査で指摘された，論文の一部構成や細部のミスについてはもともと限定的であり，提出された論文では解決された。動脈硬化性プラークの抽出能力は高く，医師の診断支援に有効である。学位論文に値するものと認められる。

最終試験の結果の要旨

2021 年 2 月 19 日午前 10 時 45 分より公聴会をオンラインで日本と中国を結んで実施し，論文，口頭発表および質疑応答を最終試験として評価した。発表者と審査委員を含め８名が参加した。機器の性能向上や機械学習技術の進展が本研究の将来に及ぼす影響や，機械学習データ量の妥当性に関して質問があったが，いずれも，丁寧で詳細かつ的確な回答が得られた。上記の結果を総合的に判断し，学位申請者は博士の学位を得るに足る学識・能力を有していると判断したため，最終試験は合格と判定する。