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Thesis Outline

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The thesis entitled “Study on Generative Adversarial Network (GAN) based Domain Adaptation for Advanced Medical Image Processing” contains 7 chapters.

Chapter 1 “Introduction” consists of the background, motivations, and objectives of this work. It also describes the novelty of our research. Nowadays, deep learning is being utilized for different medical image processing applications immensely because of the number of advantages it provides such as high accuracy, robustness and so on. Along with so many advantages, it also has some disadvantages for example hyperparameter tuning, requirement of large computation power and being dependent on the large number of labeled data for obtaining efficient performance. In clinical study, integrated information of images having different properties has very significant implications. Sometimes integrated information of CT and MRI, Micro-CT and histopathology and differently stained histopathological images are important for disease diagnosis, prognosis and treatment planning. Methods for obtaining such properly aligned multi-domain images are highly dependent on the availability of large-scale labeled data. Obtaining such labeled data is laborious and expensive. This study aims to reduce the dependency on the large-scale paired data by adopting unsupervised CycleGAN based domain adaptation technique for advanced medical image processing such as stain conversion, spatial registration of histopathological images, and detection of GGO lung nodule. Most of the previous studies have applied CycleGAN for images obtained with identical imaging technology such as RGB-to-RGB or gray-scale to gray-scale. But in our study, we have adapted CycleGAN architecture for images captured with multiple imaging technology such as hyperspectral and RGB which has non-identical channel dimensions. We have proposed methodology for feature-based image registration utilizing CycleGAN based domain adaptation such that better registration results can be obtained without requiring prior aligned paired training data. Moreover, for some diseases, the data is difficult to obtain as the frequency of happening a disease itself is rare. This study proposes CycleGAN based data augmentation technique without requiring additional annotation information that provides better disease detection results of rare cases.

Chapter 2 “Theoretical Background” presents some general theoretical background which are closely associated with this dissertation. Domain shift problem has been defined at first. Then, we have explained how domain adaptation techniques reduce the adverse effect of domain shift problem and contribute to improve the model performance. This chapter also includes the basic methodology of GAN and Conditional GAN (CGAN) which is the base of CycleGAN.

Chapter 3 “Domain Adaptation with CycleGAN” describes the architecture and methodology of CycleGAN (Cycle Generative Adversarial Network). Then, it presents previous research where CycleGAN has been utilized for domain adaptation in different medical image processing applications. Next, we have also discussed the limitation of the current approaches and future scopes of CycleGAN to be applied for more advanced applications.

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Chapter 4 “Staining Conversion with CycleGAN” describes our first experiment where we have investigated the effectiveness of deploying CycleGAN for digital stain conversion. Previous studies show that abnormality of elastic fiber is highly correlated to different diseases for example pancreatic ductal carcinoma (PDAC). H&E staining is the most used staining technique which is routinely used for disease analysis. But it cannot differentiate elastic and collagen fiber because of their similar color (pink) and pattern. In hospitals, special type of staining such as EVG staining is used for observing elastic fiber as it shows elastic in deep blue color and collagen in orchid color thus makes them easily differentiable. The conventional procedure of EVG staining is very expensive, labor-intensive and time consuming. This study proposes a two-step GAN based method for generating RGB EVG stained image from hyperspectral H&E stained image so that cost and time of conventional EVG staining can be reduced. The dataset involves H&E stained hyperspectral image (HSI) which is obtained by hyperspectral camera corresponding to the wavelength 420nm to 720nm with 5nm interval (61 channels) and RGB EVG stained image (3 channels) obtained by Whole Slide Image (WSI) scanner. Equivalent areas of spatial dimension 128x128 have been cropped from H&E and EVG stained images to prepare training data. Training data consists of two parts: large-scale (9800) unpaired data for unsupervised learning and small-scale (772) paired data for supervised learning. At first, the CycleGAN model is trained with a large-scale unpaired data (unsupervised) and in the second step, the generator HE-to-EVG is re-trained with a small-scale paired data (supervised). As we have utilized the complete spectral information of the HSI, we had to calculate the identity loss explicitly. Calculating identity loss requires reducing the channel dimension of hyperspectral H&E stained image from 61 to 3 and increasing the channel dimension of RGB EVG stained image from 3 to 61. The channel dimension of RGB EVG stained image has been increased by concatenating 58 channel same spatial dimensional zeros to the RGB EVG stained image. Whereas to reduce the channel dimension of hyperspectral H&E stained image, we have obtained a set of three basis function that better retains the important features of HSI within the reduced dimension. From the experimental result it has been observed that our proposed method outperformed state-of-the-art methods in generating realistic EVG stained image with better identification of elastic and collagen fibers.

Chapter 5 “Improving Registration Accuracy using CycleGAN” investigates the effectiveness of leveraging CycleGAN based domain conversion technique for improving the accuracy of spatial registration between heterogeneous stained histopathological images. Our proposed method involves two parts: CycleGAN based conversion of H&E to EVG stained image as the preprocessing step of registration and the registration framework itself where SURF-features have been detected, extracted and matched. From the matched features, geometric transformation function is obtained according to which the original EVG stained image is transformed to obtain registered EVG stained image. The CycleGAN based domain conversion part helps to detect larger number of matched features from both image which contributes significantly to improve the registration result. As the proposed method is unsupervised and leverages hand crafted features, it has nullified the dependency of prior aligned paired training data. We tested 85 pair of images obtained from four different tissue slides. The experimental results have shown that the proposed method has obtained 4% improvement in the image alignment than the baseline method.

Chapter 6 “Domain Adaptation for Data Augmentation of Rare Cases (for GGO Nodule Detection)” investigates the effectiveness of applying CycleGAN based domain adaptation for the detection of GGO lung nodules. Some studies found that GGO has more potential to be malignant, but it is difficult to detect GGO type of lung nodule because of its hazy opacity and unclear margin. GGO

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is also less frequently found disease than solid type nodule. So, it is difficult to obtain enough GGO training data. This study aims to improve the training data quantity by adapting the domain of non-GGO to GGO and vice-versa. A CycleGAN based domain adaptation model has been trained with GGO and non-GGO nodule data. Once the model is trained, only the nodule part of each CT scan has been converted to its counterpart nodule type to prepare the augmented data. The deep learning model has been trained with both original and augmented data. The results show more than 10% at FP/S 0.125 and overall, 2% improvement with our proposed method than the baseline one. As our proposed data augmentation technique only change the nodule type without modifying its original location, the original annotation information can also be used for augmented data.

Chapter 7 “Discussion and Conclusion” discusses the significance, limitations and future scopes of this research and concludes this dissertation. The proposed method can be very useful for other types of medical image modalities for example, MRI, X-ray, macropathology and so on. The experimental results prove the effectiveness of applying CycleGAN based domain adaptation technique for stain conversion, image registration and GGO lung nodule detection while alleviating the dependency of deep learning model on the availability of large number of labeled training data.