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Article / Book Information

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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Urinary stones are common encountered abnormality in the urinary system and can cause significant pain and discomfort. This disease affects 12% of the world population and is linked with various diseases; therefore, early diagnosis is necessary to treat patients before the disease becomes severe. Medical imaging modalities like CT scanning, ultrasonography, and x-ray imaging are used to detect them. Diagnosis is typically done with ultrasonography and CT scanning, while x-ray imaging is less expensive but not frequently used because of less accuracy. Computer-aided diagnosis (CAD) is necessary to assist doctors in screening, diagnosis, and treatment planning. There are many challenges of automated urinary stones segmentation from plain abdominal radiography. In this image modality, stones and other anatomical structures are projected in a 2D image; hence small stones have limited visibility due to overlapping bones or bowel gas. There is limited availability of dataset due to the high cost of data acquisition, privacy restrictions, and difficulties associated with image annotation, which require experts. Additionally, class imbalance is a prevalent issue in medical image domains, where normal samples significantly outnumber samples with lesions, and variations in size and shape of urinary stones, with large stones often overshadowing small ones, also reduce the segmentation performance of the small stones. Deep learning has been widely used in medical imaging tasks due to its high accuracy, but the availability of medical image datasets is usually limited and imbalanced. Therefore, many techniques have been proposed to generate new positive samples, such as simulation using a mathematical model and inserting the new lesion into existing medical images by GAN-based inpainting frameworks. Class imbalance is also a common problem in many medical imaging applications, and multiple stages pipeline has been proposed to segment small lesions more precisely.

We proposed a pipeline for automatically segmenting urinary stones in abdominal x-ray images using two stages of U-Net-based models. The first stage model was trained to generate the stone location map, representing the approximate location of urinary organs including kidneys, ureters, and bladder from full abdominal x-ray images. Then, these maps were utilized to generate KUB (Kidney, Ureters, and Bladder) region maps using in the augmentation and image partitioning process. Additionally, we proposed a GAN-based inpainting network to fill the missing region based on the stone-masked or non-stone-masked region, and the surrounding context. The generator was trained by a combination loss from local discriminator, global discriminator, L1, and content loss. Then, the trained inpainting network from GAN model was utilized to generate the augmented training images, which can increase the number and diversity of training samples. The second stage network was trained to segment urinary stones from the partitioned input created by the KUB region maps from the first stage network. The segmentation model was trained by both real and synthesized images. We also proposed the modified focal Tversky loss function for using in the second stage model by implementing the stone size re-balancing approach, which could improve both class imbalance and lesion size imbalance problem. In post-processing, we trained a VGG16 classification model to distinguish between bladder stones and which can detect and remove the false positive lesions from the second stage network in the bladder partition.

We evaluated segmentation results by 1,156 stone-contained samples (I_{sc}) using five-fold cross-validation. The dataset was divided into 64% training images, 16% validating images, and 20% testing images. Based on the experiments, the segmentation model trained using our proposed pipeline outperformed the baseline 2.88 % pixel-wise (68.40 % to 71.28%) and 7.63% region-wise F2 score (62.19 % to 69.82 %), respectively. In overall results, the baseline method and our proposed method segmented the large stones very well; however, our method could improve the segmentation performance in difficult cases, such as small stones or obscure stones located near other anatomical structures. The urinary stones segmentation network in the cascaded framework, processed partitioned images instead of full images, could improve segmentation results by reducing class imbalance problem and processing images at higher resolution. Stone-embedding augmentation was implemented to increase the number and variety of positive training samples during the training process, which was important for improving the performance, especially for stones in rare locations. Our lesion-size reweighting approach used with the focal Tversky loss could significantly improve the detection performance for small stones. Furthermore, the experimentation with other U-Net variants segmentation models such as ResUnet, Attention Unet, Unet++, MultiResUnet, TransUnet and UTNet also showed that our proposed pipeline could improve pixel-wise and region-wise F2 score for urinary stones segmentation, significantly.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。
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