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A novel approach for diabetic foot diagnosis: Deep learning-based detection of lower extremity arterial stenosis

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ABSTRACT

Purpose of the study: Assessing the lower extremity arterial stenosis scores (LEASS) in patients with diabetic foot ulcer (DFU) is a challenging task that requires considerable time and efforts from physicians, and it may yield varying results. The presence of vascular wall calcification and other irrelevant tissue information surrounding the vessel can further compound the difficulties of this evaluation. Automatic detection of lower extremity arterial stenosis (LEAS) is expected to help doctors develop treatment plans for patients faster.

Methods: In this paper, we first reconstructed the 3D model of blood vessels by medical digital image processing and then utilized it as the training data for deep learning (DL) in conjunction with the non-calcified part of blood vessels in the original data. We proposed an improved model of vascular stenosis small target detection based on YOLOv5. We added Convolutional Block Attention Module (CBAM) in backbone, replaced Path Aggregation Network (PANET) with Bidirectional Feature Pyramid Network (BiFPN) and replaced C3 with GhostC3 in neck to improve the recognition of three types of stenosis targets (I: <50 %, II: 51 % – 99 %, III: completely occluded). Additionally, we utilized K-Means++ instead of K-Means for better algorithm convergence performance, and enhanced the Complete-IoU (CIoU) loss function to Alpha-Scylla-IoU (ASIoU) loss for faster reasoning and convergence. Lastly, we conducted comparisons between our approach and five other prominent models.

Result: Our method had the best average ability to detect three types of stenosis with 85.40% mean Average Precision (mAP) and 74.60 Frames Per Second (FPS) and explored the possibility of applying DL to the detection of LEAS in diabetic foot. The code is available at github.com/wuchongxin/yolov5_LEAS.git.

1. Introduction

DFU is a medical condition that involves infection, ulceration, or tissue destruction in the foot, which is typically associated with neuropathy of the lower extremities or peripheral arterial disease in people with diabetes [1]. Diabetes mellitus (DM) will cause nerve injury (or dysfunction) and peripheral arterial disease ischemia, and both of them are related to DFU [2]. It is characterized by three typical triads of neuropathy, ischemia, and infection [3]. 30 % of people with diabetes will develop chronic wounds of DFU [4]. It was estimated that 500 million people worldwide suffered from DM in 2019, which was expected to increase by 25 % by 2030 [5]. With a high incidence rate, difficult treatment, and huge cost [6,7], the healing rate of DFU in DM was 46 %, while 15 % of patients died, and nearly 17 % – 25 % of patients needed lower extremity amputation [4]. The five-year mortality rate among patients with ischemic DFU has exceeded 50 %, while patients with diabetes and lower extremity arterial occlusion have experienced a mortality rate exceeding 60 %.

DFU is usually graded by the Wagner grade method [8]. However, the DFU scoring system exhibits regional variations, and the treatment and prognosis assessment for DFU patients is comprehensive, requiring reference to LEASS. In addition, when a lower extremity

Abbreviations: LEASS, Lower extremity arterial stenosis scores; LEAS, Lower extremity arterial stenosis; DL, Deep learning; DFU, Diabetic foot ulcer; DM, Diabetes mellitus; TTT, Tibial transverse transport; CBAM, Convolutional Block Attention Module; BiFPN, Bidirectional Feature Pyramid Network.

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