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An Enhanced Mask R-CNN Approach for Pulmonary Embolism Detection and Segmentation

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Abstract: Pulmonary embolism (PE) refers to the occlusion of pulmonary arteries by blood clots, posing a mortality risk of approximately 30%. The detection of pulmonary embolism within segmental arteries presents greater challenges compared with larger arteries and is frequently overlooked. In this study, we developed a computational method to automatically identify pulmonary embolism within segmental arteries using computed tomography (CT) images. The system architecture incorporates an enhanced Mask R-CNN deep neural network trained on PE-containing images. This network accurately localizes pulmonary embolisms in CT images and effectively delineates their boundaries. This study involved creating a local data set and evaluating the model predictions against pulmonary embolisms manually identified by expert radiologists. The sensitivity, specificity, accuracy, Dice coefficient, and Jaccard index values were obtained as 96.2%, 93.4%, 96.%, 0.95, and 0.89, respectively. The enhanced Mask R-CNN model outperformed the traditional Mask R-CNN and U-Net models. This study underscores the influence of Mask R-CNN's loss function on model performance, providing a basis for the potential improvement of Mask R-CNN models for object detection and segmentation tasks in CT images.

Keywords: pulmonary embolism; Mask R-CNN; CTPA images

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1. Introduction

Pulmonary embolism (PE) is the obstruction of blood arteries in the lungs caused by a blood clot [1]. Peripheral edema has the third-highest prevalence among cardiovascular illnesses. The disease has a death rate of 30% [2–4]. A delay in diagnosing the condition increases the likelihood of impairment and mortality [5]. Early diagnosis is crucial to treating the disease effectively [6,7], with computed tomography pulmonary angiogram (CTPA) being the preferred method for diagnosing PE due to its quick and detailed imaging capabilities [8,9]. Blood arteries appear bright in contrast-enhanced CT scans due to the contrast material, while the embolism appears dark because it does not absorb the contrast agent. Figure 1 displays pulmonary embolisms in a high-quality computed tomography scan.

The detection of PE in CTPA images is performed manually by experienced radiologists; therefore, it can be time-consuming and sometimes difficult [10]. Some studies have shown that there is a 13% discrepancy between overnight and daytime assessments for the detection of PE [11–13]. In addition, in some emergency situations, the rapid and accurate assessment of PE is of great importance [14]. Some semi-quantitative methods can be used to measure the degree of vascular occlusion and determine the severity of PE. The most common methods for this purpose are the Mastora score and the Qanadli score, also known as the Vascular Obstruction Index (VOI), which are measured by an expert [15,16]. However, there is inconsistency among different experts regarding the use of these methods [17]. Therefore, researchers have considered the use of computer-assisted systems to automatically detect PE.