Deep Learning Approaches for Lung Cancer Detection from CT Images: A Review of Challenges and Emerging Research Perspectives

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Abstract: Lung cancer is a predominant universal illness and is an underlying cause of a number of cancer deaths annually. One of the most effective solutions is early detection which may significantly improve treatment and lower mortality, though not as easy as the number of medical imaging data increases continuously and experienced radiologists are scarce. Such impediments (among others) imply that in most rural and resource constrained healthcare facilities, access to advanced investigative facilities is inadequate. CT imaging has been deemed as a potent tool that can be used to identify lung cancer that correlates pulmonary nodule and manual analysis of the CT scans is very tedious and can be characterized by clinical interpretation variability. The current state of research in algorithms in the field of artificial intelligence, deep learning, proved itself to be highly promising in assisting the analysis of medical images and clinical decision-making. These models, however, are based on complicated structures where they demand the utilization of high-performance computing devices and substantial memory space that makes it unfeasible to be utilized daily in clinical practice and edge-based healthcare services. Further, the works that concentrate on advancing accuracy are numerous compared to the effort being put on the efficiency of the models that can be deployed in practice.

In this review, the current research trends in automatic lung cancer detection are discussed, and the major weaknesses of the current approaches limiting its practical implementation are identified. This study identifies the main issues that demand more universal, lightweight and effective solutions, for early diagnosis applications when access to such intelligent health care systems is most crucial.

Keywords: Lung Cancer Detection; CT Image; Medical Image Processing; Deep Learning; Lightweight.

Introduction

Lung cancer is still ranked among the most important global health threats and persists as the primary root of mortality associated with cancer. As per the latest global cancer statistics published in 2023, lung cancer is diagnosed nearly 2.4 million times a year and has reported nearly 1.8 million deaths each year, with around 11.4% of altogether cancers diagnosed globally [1]. Non-small cell lung cancer (NSCLC) reflects approximately 85% of all reported cases of malignancy. This section spans three major genetic subtypes: adenocarcinoma, squamous cell carcinoma, and large-cell carcinoma [2]. More than 70 percent of patients in many developing countries are diagnosed with an illness at a progressive phase where therapies are partial and endurance rates are much lower in the long-term [3].

Accurate and timely diagnosis is essential for improving treatment results and patient survival rates. One of the imaging modalities employed regularly to diagnose pulmonary nodules and early tumor occurrence is Computed Tomography (CT) that produces cross-sectional images of lung tissues at a high quality [4]. Nevertheless, manual analysis of CT scans is a complicated and lengthy operation relying on the radiologists experiences that add to diagnostic diversities and work burdens in the clinical practice.

With the further rise of the deep learning techniques, they provide new opportunities in improving the work with medical images. The deep-learning models are capable of processing large quantities of medical images and identifying the hidden patterns that are associated to the initial phases of the diseases and assist clinicians to make improved decisions regarding diagnosis [5-6]. Such techniques were promising in the field of automatic discovery and categorization of lung nodules assignments. The combination of lightweight deep learning models with healthcare systems has also been approached by researchers in recent years. Such systems offer remote medical screening, real time monitoring and quicker diagnostic services in areas where specialized health care facilities are deficient. The incorporation of deep-learning structures and interconnected healthcare systems has a chance to transform the process of accessing and implementing the process of lung cancer diagnostics on a geographical level.

Motivation and Problem Statement

Despite the advancement of medical imaging technology, early diagnosis of lung cancer is extremely difficult even in rural or health care setting-resource limited setting. One of the major problems is the lack of the qualified radiologists that can cause delays in the recognizing procedure and decrease the efficiency of the early treatment. As a result, many patients were recognized at more progressive phases when there are few treatment options available. In clinical practice, the manual analysis of CT scans is labour-intensive and time-consuming, as radiologists must search through numerous image slices to find any abnormalities. This limitation creates an increased workload and potential variability in diagnosis due to exhaustion or subjective interpretation. Worldwide, lung cancer is the topmost cause of cancer related fatalities, with the potential for early diagnosis and treatment to reduce mortality rates. Lung CT scans are frequently utilized in routine practice as part of early lung cancer detection efforts, making them an important focus for deep learning algorithms that have shown success in detecting various cancers from medical imaging data in previous studies. While numerous state-of-the-art models fall back on difficult architectures with high computational load, which typically requires strong GPU and large memory capability. These constraints would restrict their applicability in real-time clinical implementations and edge-based healthcare architectures.

Moreover, most of the literature in the field tends to work more on the issues of improving detection accuracy without giving due consideration to the practical aspects of deployment such as inference speed, computational efficiency, or scalability of the system. They are not applicable in remote diagnostic settings since they are not integrated with the infrastructures of the IoT based healthcare.

We therefore need to have a lightweight and scalable diagnostic model capable of identifying and categorizing the ruin on the lungs accurately with low computational complexity. The design of such a system must enable it to be deployed on the edge devices and IoT-enabled healthcare systems to ensure it is accessible and can be used to provide rapid diagnostics in various clinical settings.

Related Works

Over the last few years, much effort has been put into the implementation of deep learning in the automatic recognition of lung cancer and pulmonary nodule analysis with CT images. The objectives of these studies are to assist in the early diagnosis, enhance detection and eliminate the use of manual assessment by radiologists. Based on the complex neural network models, scientists have tried to design a system that can detect minute irregularities in CT scans that are related to lung nodules.

In 2025, Prithvika et al. [7] have recently introduced a segmentation model, which combines multi-scale features extraction and U-Net and Feature Pyramid Network (FPN) to identify lung nodules. The model proposed enhances better segmentation capacity by extracting features at various scale but segmentation of the boundaries has a low accuracy as there are not enough attention mechanisms.

In 2025, Zhu et al. [8] suggested a real-time pulmonary nodule detection framework which is based on the YOLOv8 architecture. The system has excellent detection capability and high processing rate therefore can be used in combination with rapid screening. However, it is hard to detect very small nodules and minor abnormalities. In 2024, Jadhav and Makandar [9] came up with an improved lung cancer detection technique using YOLOv8 and generative adversarial networks to augment the data. Even though the approach enhances the performance of the detection systems by expanding the training set, the application of artificial data could cause a change in distribution that affects the application of the model.

In 2024, Majumder et al. [10], developed MENet, a framework of an ensemble convolutional neural network that classifies lung cancer on the basis of CT scans. Combining several networks with the ensemble approach results in a high level of accuracy in classifications, although it raises the cost and time of inference. In 2024, Lin et al. [11] suggested a modified three-dimensional region proposal network to detect nodules of the lung in CT scans. The technique will be shown to have a better detection ability as it uses volumetric data, however, the architecture is computationally and memory-intensive on the GPU.

In 2024, Lin et al. [12] introduced a hybrid framework of diagnostic models as a combination of deep learning models and radiomics features with clinical information to classify the nodules in lungs. Even though this combined method enhances the accuracy of a diagnosis, it is highly reliant on the accessibility of clinical information, which is not always available within some healthcare settings.

In 2023, Ma et al. [13] came up with a fusion-based CNN to classify benign and malignant lung nodules. The algorithm is a combination of multiple feature extraction algorithms to enhance the classification performance, though the multiple network complication makes the model difficult to follow and provides the chance of overfitting.

Knowledge Gap

Recent studies on the identification and classification of lung nodules have developed considerably in the form of deep learning models. Most existing techniques are based on fusion-based techniques, multi-model ensemble techniques or highly complex structures. These methods often lead to increased processing and inference times, and cannot be used in real-time clinical use or in clinical settings with limited computer capacity. Moreover, the detection systems of a number of types include the problem of small nodules or indistinct lesions in CT images detection. The other methods are premised on alternative data like radiomics or clinical data that may not always be present in the actual screening scenario in real life. All these impose a need to develop a lightweight yet effective deep learning model that can be depended upon to detect lung cancer. In this work, the author suggests a deep learning model named LiteSOS Net, which is aimed at offering good performance with minimum computational complexity.

Proposed Methodology

To apply the image preprocessing, lung segmentation, and lightweight deep learning-based features extraction together in a single diagnostic pipeline, the proposed framework as depicted in Figure1 addresses the challenge of determining accurate and computationally efficient lung cancer detection.

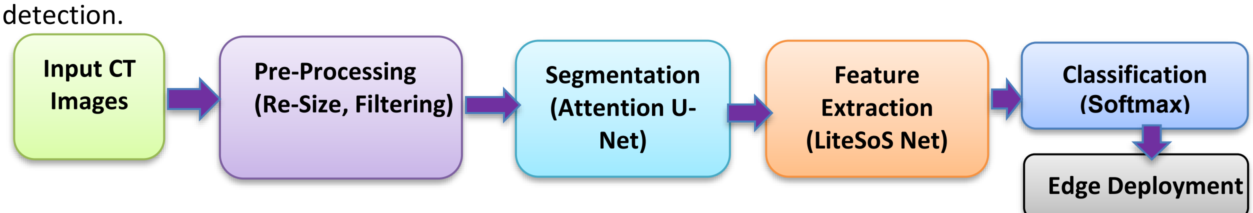

Figure 1. Lightweight Deep learning Proposed Framework

Pre-processing CT images is the initial step of the methodology as it enhances the quality of the images and provides consistency of the dataset. In this step, the image dimensions and intensity values are rescaled and finally the samples are normalized so that they are uniform. Besides, the contrast augmentation is performed with the combination of directed filtering and multiple-peak generalized histogram equalization to improve the visual quality and emphasize the potential abnormal areas. The images are then improved and then an Attention U-Net model is applied to segment the lung areas. This segmentation method is effective in isolating the lung tissues and other related structures by focusing on the relevant areas and doing away with irrelevant background knowledge.

Consequently, features of the segmented images are extracted using LiteSOS-Net, which is a lightweight convolutional neural network designed to analyze the data without compromising too much processing. To extract initial features, the network uses stem convolution layers that follow grouped and depth-wise convolutions that are inspired by Shuffle Net to enable the network to reduce computational costs without removing useful features. The system is a combination of edge assisted IoT architecture on remote healthcare applications whereby the lightweight model is executed on embedded edge devices. The results of the diagnostic are uploaded to the cloud servers to enable it to reduce the latency, bandwidth and computational load in addition to making the screening of lung cancer close to real-time.

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