

DEEP LEARNING BASED FRAMEWORK FOR AUTOMATED SCREENING AND MEDICAL ASSISTANCE: LUNG DISEASES FROM CHEST X-RAYS

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ASSISTANCE: LUNG DISEASES FROM CHEST X-RAYS

by

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Submitted
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Dedicated to my family...

Certificate

This is to certify that the thesis titled “**Deep Learning based Framework for Automated Screening and Medical Assistance: Lung Diseases from Chest x-rays**” being submitted by **Anushikha Singh** to the **Bharti School of Telecommunication Technology and Management**, Indian Institute of Technology, Delhi, for the award of **Doctor of Philosophy** is a record of bonafide research work carried out by her under my guidance and supervision. In my opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree. The work presented in this thesis has not been submitted elsewhere, either in part or full, for the award of any other degree or diploma.

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Abstract

Lung diseases have been a significant global health concern, and the COVID-19 pandemic has intensified this issue, resulting in a significant rise in respiratory-related deaths. Timely diagnosis and effective treatment of patients could potentially avert millions of deaths. Chest x-rays are a prevalent, rapid, and cost-effective medical imaging modality used by healthcare professionals for the screening of lung diseases. However, the interpretation of chest x-rays is challenging, time-consuming, and requires expertise that is often in short supply. This situation highlights the potential value of computer-aided diagnosis tools, which can automate interpretation and bridge the gap caused by a shortage of medical experts in a heavily populated country like India. Developing a diagnostic tool for lung diseases in the Indian context presents a challenge due to the inferior image quality and physiological variations in the population. India is also known for its high pollution levels, which can lead to respiratory symptoms in a significant proportion of the population. These physiological variations may affect the accuracy of the diagnostic tool, making it challenging to develop a tool that is effective in this population.

In this thesis, we propose a computer-aided diagnostic framework for the detection and severity assessment of lung diseases using chest x-rays in the Indian context. We break down our framework into three different stages: identification of lung diseases, localization of disease markers or abnormalities, and computation of diagnostic recommendation parameters for final inferences. To begin with, an input chest x-ray is classified as healthy or unhealthy along with a confidence score using a supervised deep neural network. If the chest x-ray is identified as unhealthy then it proceeds to the localization stage for further investigation into disease severity. We propose a single-stage object detection network to localize multiple abnormalities present in chest x-rays. Our focus lies on detecting common abnormalities such as cavities, opacity, effusion, and pneumothorax, which are prevalent features across various lung diseases including tuberculosis, lung cancer, pneumonia (including COVID-19), and others. In the last stage, the chest x-rays go through the severity assessment module to check the severity of lung diseases using diagnostic recommendation parameters such as the extent of lung involvement in disease manifestation, type of abnormality present in chest x-ray, and presence of disease in various lung zones.

The segmentation of lungs and bone structures in chest x-rays is an essential step for various applications such as severity assessment and bone suppression. Segmented lung area in chest x-rays are used to calculate the extent of lung involvement in disease manifestation. Segmentation of

bones is required to divide the lung area into upper, middle, and lower zones, and the presence of abnormalities is checked accordingly. We propose a novel encoder-decoder based semantic segmentation network to combine the strength of two existing networks (Deeplabv3+ and U-net) to achieve superior performance on healthy as well as unhealthy chest x-rays. Furthermore, suppression of bones in chest x-rays allows better examination of lung fields and ultimately improves diagnostic accuracy. We propose a novel approach, named multi-scale and dual attention guided image-to-image translation GAN for suppressing bones on chest x-rays. The goal of this work is to develop a bone suppression model that can generate bone-suppressed images of chest x-rays, particularly for datasets without ground truth such as the Indian dataset.

To summarize, this thesis proposes the identification and localization of lung diseases using chest x-rays, as well as segmenting lungs and bones, suppressing bones, and providing final inferences about disease severity assessment. Extensive experimentation with diverse datasets, including our in-house Indian dataset and standard public dataset has helped in developing robust and generic algorithms. The analysis and observations presented in this thesis aim to contribute to the medical community. An additional contribution of this thesis is the creation of an annotated dataset of Indian chest x-rays. The annotation process involved the expertise of experienced radiologists from Teleradiology Solutions in Delhi, India, as well as medical experts from Christian Medical College in Vellore, India. The dataset has been carefully annotated and validated by these professionals, making it a valuable resource for future research and advancements in the field.

सार

फेफड़ों की बीमारियाँ एक महत्वपूर्ण वैश्विक स्वास्थ्य चिंता रही हैं, और COVID-19 महामारी ने इस समस्या को और बढ़ा दिया है, जिसके परिणामस्वरूप श्वसन संबंधी मौतों में उल्लेखनीय वृद्धि हुई है। रोगियों का समय पर निदान और प्रभावी उपचार संभावित रूप से लाखों मौतों को टाल सकता है। छाती का एक्स-रे फेफड़ों की बीमारियों की जांच के लिए स्वास्थ्य पेशेवरों द्वारा उपयोग की जाने वाली एक प्रचलित, तीव्र और लागत प्रभावी चिकित्सा इमेजिंग पद्धति है। हालाँकि, छाती के एक्स-रे की व्याख्या चुनौतीपूर्ण, समय लेने वाली है और इसके लिए विशेषज्ञता की आवश्यकता होती है जो अक्सर कम आपूर्ति में होती है। यह स्थिति कंप्यूटर-सहायता प्राप्त निदान उपकरणों के संभावित मूल्य पर प्रकाश डालती है, जो व्याख्या को स्वचालित कर सकती है और भारत जैसे भारी आबादी वाले देश में चिकित्सा विशेषज्ञों की कमी के कारण उत्पन्न अंतर को पाट सकती है। भारतीय संदर्भ में फेफड़ों की बीमारियों के लिए निदान उपकरण विकसित करना जनसंख्या में खराब छवि गुणवत्ता और शारीरिक विविधताओं के कारण एक चुनौती पेश करता है। भारत अपने उच्च प्रदूषण स्तर के लिए भी जाना जाता है, जिससे आबादी के एक महत्वपूर्ण हिस्से में श्वसन संबंधी लक्षण हो सकते हैं। ये शारीरिक विविधताएं निदान उपकरण की सटीकता को प्रभावित कर सकती हैं, जिससे इस आबादी में प्रभावी उपकरण विकसित करना चुनौतीपूर्ण हो जाता है।

इस थीसिस में, हम भारतीय संदर्भ में छाती के एक्स-रे का उपयोग करके फेफड़ों की बीमारियों का पता लगाने और गंभीरता का आकलन करने के लिए एक कंप्यूटर-सहायता प्राप्त नैदानिक ढांचे का प्रस्ताव करते हैं। हम अपने ढांचे को तीन अलग-अलग चरणों में विभाजित करते हैं: फेफड़ों की बीमारियों की पहचान, रोग मार्करों या असामान्यताओं का स्थानीयकरण, और अंतिम अनुमान के लिए नैदानिक सिफारिश मापदंडों की गणना। आरंभ करने के लिए, एक इनपुट छाती एक्स-रे को पर्यवेक्षित गहरे तंत्रिका नेटवर्क का उपयोग करके आत्मविश्वास स्कोर के साथ स्वस्थ या अस्वस्थ के रूप में वर्गीकृत किया जाता है। यदि छाती के एक्स-रे की पहचान अस्वस्थ के रूप में की जाती है तो यह रोग की गंभीरता की आगे की जांच के लिए स्थानीयकरण चरण में आगे बढ़ता है। हम छाती के एक्स-रे में मौजूद कई असामान्यताओं को स्थानीयकृत करने के लिए एकल-चरण ऑब्जेक्ट डिटेक्शन नेटवर्क का प्रस्ताव करते हैं। हमारा ध्यान सामान्य असामान्यताओं जैसे कैविटीज़, अपारदर्शिता, बहाव और न्यूमोथोरैक्स का पता लगाने पर केंद्रित है, जो तपेदिक, फेफड़ों के कैंसर, निमोनिया (सीओवीआईडी -19 सहित) और अन्य सहित फेफड़ों की विभिन्न बीमारियों में प्रचलित विशेषताएं हैं। अंतिम चरण में, छाती का एक्स-रे गंभीरता मूल्यांकन मॉड्यूल से होकर गुजरता है ताकि निदान अनुशंसा मापदंडों का उपयोग करके फेफड़ों के रोगों की गंभीरता की जांच की जा सके, जैसे कि रोग की अभिव्यक्ति में फेफड़ों की भागीदारी की सीमा, छाती के एक्स-रे में मौजूद असामान्यता का प्रकार और उपस्थिति। फेफड़े के विभिन्न क्षेत्रों में रोग का पता लगाना।

छाती के एक्स-रे में फेफड़ों और हड्डी की संरचनाओं का विभाजन गंभीरता मूल्यांकन और हड्डी दमन जैसे विभिन्न अनुप्रयोगों के लिए एक आवश्यक कदम है। छाती के एक्स-रे में खंडित फेफड़े के क्षेत्र का उपयोग रोग की अभिव्यक्ति में फेफड़ों की भागीदारी की सीमा की गणना करने के लिए किया जाता है। फेफड़ों के क्षेत्र को ऊपरी, मध्य और निचले क्षेत्रों में विभाजित करने के लिए हड्डियों के विभाजन की आवश्यकता होती है, और तदनुसार असामान्यताओं की उपस्थिति की जांच की जाती है। हम स्वस्थ और साथ ही अस्वस्थ छाती एक्स-रे पर बेहतर प्रदर्शन प्राप्त करने के लिए दो मौजूदा नेटवर्क (डीपलैबवी3+ और यू-नेट) की ताकत को संयोजित करने के लिए एक उपन्यास एनकोडर-डिकोडर आधारित सिमेंटिक सेगमेंटेशन नेटवर्क का प्रस्ताव करते हैं। इसके अलावा, छाती के एक्स-रे में हड्डियों के दबने से फेफड़ों के क्षेत्रों की बेहतर जांच हो पाती है और अंततः निदान सटीकता में सुधार होता है। हम छाती के एक्स-रे पर हड्डियों को दबाने के लिए मल्टी-स्केल और दोहरे ध्यान निर्देशित छवि-से-छवि अनुवाद GAN नामक एक उपन्यास दृष्टिकोण का प्रस्ताव करते हैं। इस कार्य का

लक्ष्य एक हड्डी दमन मॉडल विकसित करना है जो छाती के एक्स-रे की हड्डी-दबी हुई छवियां उत्पन्न कर सकता है, विशेष रूप से भारतीय डेटासेट जैसे जमीनी सच्चाई के बिना डेटासेट के लिए। संक्षेप में, यह थीसिस छाती के एक्स-रे का उपयोग करके फेफड़ों के रोगों की पहचान और स्थानीयकरण का प्रस्ताव करती है, साथ ही फेफड़ों और हड्डियों को खंडित करती है, हड्डियों को दबाती है, और रोग की गंभीरता के आकलन के बारे में अंतिम निष्कर्ष प्रदान करती है। हमारे इन-हाउस भारतीय डेटासेट और मानक सार्वजनिक डेटासेट सहित विविध डेटासेट के साथ व्यापक प्रयोग ने मजबूत और सामान्य एल्गोरिदम विकसित करने में मदद की है। इस थीसिस में प्रस्तुत विश्लेषण और टिप्पणियों का उद्देश्य चिकित्सा समुदाय में योगदान करना है। इस थीसिस का एक अतिरिक्त योगदान भारतीय छाती एक्स-रे के एनोटेटेड डेटासेट का निर्माण है। एनोटेशन प्रक्रिया में दिल्ली, भारत में टेलीरेडियोलॉजी सॉल्यूशंस के अनुभवी रेडियोलॉजिस्ट के साथ-साथ वेल्लोर, भारत के क्रिश्चियन मेडिकल कॉलेज के चिकित्सा विशेषज्ञों की विशेषज्ञता शामिल थी। डेटासेट को इन पेशेवरों द्वारा सावधानीपूर्वक एनोटेट और मान्य किया गया है, जिससे यह क्षेत्र में भविष्य के अनुसंधान और प्रगति के लिए एक मूल्यवान संसाधन बन गया है।

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