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International Journal for Modern Trends in Science and Technology, 9(04): 339-344, 2023

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0904049
Available online at: http://www.ijmtst.com/vol9issue04.html

Automated Detection of Cardiomegaly & Calculation of CTR using Chest X-Ray Images

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To Cite this Article
Vanathi P, Suresh Babu M, Karthick M, Nishanth S and Ramprasath M. Automated Detection of Cardiomegaly & Calculation of CTR using Chest X-Ray Images. International Journal for Modern Trends in Science and Technology 2023, 9(04), pp. 339-344. https://doi.org/10.46501/IJMTST0903049

Article Info
Received: 16 March 2023; Accepted: 14 April 2023; Published: 18 April 2023.

ABSTRACT

Deep learning or DL which is a growing trend in medical image analysis. An automated procedure to determine the presence of cardiomegaly on chest X-ray (CXR) image using deep learning. This paper proposed a deep learning algorithm i.e., Convolutional neural network (CNN)which is for cardiothoracic ratio (CTR) calculation in CXR. A convolutional neural network (CNN) with ResNet-34 model was employed to segment chest X-ray images and calculate CTR. The cardiothoracic ratio is automatically measured by extracting lung and heart regions in a chest X-ray image and measuring their diameter. OpenCV method is used to Denise and maintain the precision of region of interest once minor errors occur. The Measurement time by deep learning was significantly less than that of the manual method. The values of Diagnostic accuracy, specificity, and positive predictive value were comparable between the two methods. However, deep learning showed relatively higher sensitivity and negative predictive value compared with the manual method. The segmentation-based methods by Deep learning could detect cardiomegaly; however, the feasibility of computer-aided detection of cardiomegaly without human intervention was limited. This result translates to a large amount of time and manual power saved for radiologists using an automated tool.

Keywords: X-ray images; Cardiothoracic ratio; Cardiomegaly; Deep learning; segmentation

1. INTRODUCTION

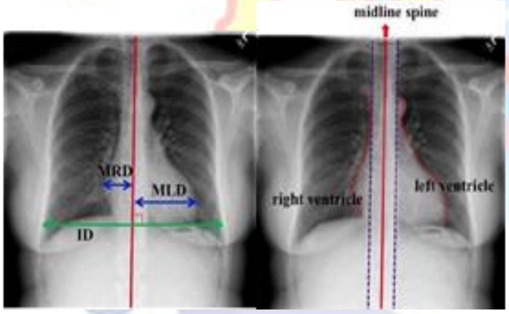
Cardiomegaly, which is an enlarged heart. It is a symptom of cardiac insufficiency that occurs in various diseases and conditions, including high blood pressure, coronary artery disease, heart valve disease, and pulmonary hypertension. Due to its non-invasive nature, minimal radiation exposure, and economic considerations, chest X-ray imaging (CXR) is one of the most widely used medical imaging tests for early cardiomegaly detection. Radiologists routinely perform CTR measurement on anteroposterior chest radiographs to diagnose Cardiomegaly. Manual detection of organ boundaries and calculation of CTR is lead to error and can lead to faulty interpretations. Recent advances in Deep learning have introduced a variety of computer vision methods that can be used to aid this process simple. A convolutional neural networkhas been used to yield competitive performances in an automated detection of diseases in X-ray images. In this work, we shown an automatic approach to calculate CTR from CXR film utilizing deep learning models.In CNN algorithm ResNet-34 model is used for the segmentation purpose. we extract lung and heart regions from the Chest X-ray film. The heart and lung diameters are then calculated from the segmented regions.

1.1 Cardiothoracic Ratio:

Chest X-ray images not only allow subjective assessment of heart size, but also allow measurement of the heart's contour, which may be related to the size of the thorax, Studies have also shown that there is a sufficient correlation (>0.7) between the size of the heart measured on chest X-ray images and that measured at autopsy. therefore, chest X-ray images are the most used to detect cardiac enlargement, and the cardiothoracic ratio (CTR), which evaluates the size of the heart and rib eage, is also an important index for determining cardiac enlargement. The cardiothoracic ratio is the ratio of the width of the heart to the width of the thorax. The cardiothoracic ratio can be calculated using Equation

$$CTR = \frac{MLD + MRD}{ID}$$

As shown in figure 1, ID(Inner Diameter) is the largest horizontal width of chest.MLD (Maximum Left Diameter) and MLD (Maximum Right Diameter) are the distance from spine midline to most lateral left ventricle



and right ventricle, respectively. The definitions of the midline spine and the left and right ventricle are shown in fig.

1.2 Automated CTR Calculations

Currently there are many system and algorithm that can automatically calculate CTR. Konica Minolta, Inc. has developed a system that can calculate the thoracic and cardiac widths necessary for cardiothoracic ratio measurement by applying its thoracic lung field extraction technology and display the cardiothoracic measurement line following the slope of the lung field and the calculated measurement values.In a recent study, a high accuracy of 87[%] was obtained in the detection of cardiac enlargement in 600 images selected from a chest X-ray Image database called Chest X-ray8 Published by the NIH using the transfer deep learning method. Therefore, this study focuses on image segmentation methods based on deep learning. And furthermore, an automatic CTR measurement method using cardiothoracic measurement lines following the slopes of the segmented lung field.

2. RELATED WORK

1.T. Gupte, Mrunmai NiljikarDeep Learning Models for Calculation of Cardiothoracic Ratio from Chest Radiographs for Assisted Diagnosis of Cardiomegaly

An automated method based on deep learning to compute the cardiothoracic ratio and detect the presence of cardiomegaly from chest radiographs. To develop two separate models to demarcate the heart and chest regions in an X-ray image using bounding boxes and use their outputs to calculate the cardiothoracic ratio.To obtain a mean absolute error of 0.0209 on a held-out test dataset and a mean absolute error of 0.018 on an independent dataset from a different hospital. It also compares three different segmentation model architectures for the proposed method and observe that Attention U-Net yields better results than SE-Resnext U-Net and EfficientNet U-Net. By providing a numeric measurement of the cardiothoracic ratio, instead of just providing presence or absence, hope to mitigate human subjectivity arising out of visual assessment in the detection of cardiomegaly.

2.D. Cárdenas, J. F. Ferreira Júnior, R. Moreno, M. Rebelo, J. Krieger, M. GutierrezMulticenter Validation of Convolutional Neural Networks for Automated Detection of Cardiomegaly on Chest Radiographs

On validating five convolutional neural network models to detect automatically cardiomegaly, a health complication that causes heart enlargement, which may lead to cardiac arrest. To do that, trained the models with a customized multilayer perceptron. Radiographs from two public datasets were used in experiments, one of them only for external validation. Images were pre-processed to contain just the chest cavity. The EfficientNet model yielded the highest area under the curve (AUC) of 0.91 on the test set. However, the Inception-based model obtained the best generalization performance with AUC of 0.88 on the independent multicentric dataset. Therefore, this work accurately validated radiographic models to identify patients with cardiomegaly.

3. Mu Sook Lee, Yong Soo KimEvaluation of the feasibility of explainable computer-aided detection of cardiomegaly on chest radiographs using deep learning

The proposed work examined the feasibility of explainable computer-aided detection of cardiomegaly in routine clinical practice using segmentation-based methods. Overall, 793 retrospectively acquired posterior–anterior (PA) chest X-ray images (CXRs) of 793 patients were used to train deep learning (DL) models for lung and heart segmentation. The training dataset included PA CXRs from two public datasets and in-house PA CXRs. Two fully automated segmentation-based methods using state-of-the-art DL models for lung and heart segmentation were developed. The diagnostic performance was assessed and the reliability of the automatic cardiothoracic ratio (CTR) calculation was determined using the mean absolute error and paired t-test. The effects of thoracic pathological conditions on performance were assessed using subgroup analysis. One thousand PA CXRs of 1000 patients (480 men, 520 women; mean age 63 ± 23 years) were included. The CTR values derived from the DL models and diagnostic performance exhibited excellent agreement with reference standards for the whole test dataset. Performance of segmentation-based methods differed based on thoracic conditions. When tested using CXRs with lesions obscuring heart borders, the performance was lower than that for other thoracic pathological findings. Thus, segmentation-based methods using DL could detect cardiomegaly; however, the feasibility of computer-aided detection of cardiomegaly without human intervention was limited

4.P.Saiviroonporn, Suwimon Wonglaksanapimon A clinical evaluation study of cardiothoracic ratio measurement using artificial intelligence

Background Artificial intelligence, particularly the deep learning (DL) model, can provide reliable results for automated cardiothoracic ratio (CTR) measurement on chest X-ray (CXR) images. In everyday clinical use, however, this technology is usually implemented in a non-automated (AI-assisted) capacity because it still requires approval from radiologists. Methods are validated four proposed DL models (AlbuNet, SegNet, VGG-11, and VGG-16) to find the best model for clinical implementation using a dataset of 7517 CXR images from manual operations. These models were investigated in single-model and combined-model modes to find the model with the highest percentage of results where the user could accept the results without further interaction (excellent grade), and with measurement variation within ± 1.8% of the human-operating range. The best model from the validation study was then tested on an evaluation dataset of 9386 CXR images using the AI-assisted method with two radiologists to measure the yield of excellent grade results, observer variation, and operating time. A Bland–Altman plot with coefficient of variation (CV) was employed to evaluate agreement between measurements. Results The VGG-16 gave the highest excellent grade result (68.9%) of any single-model mode with a CV comparable to manual operation (2.12% vs 2.13%). No DL model produced a failure-grade result. The combined-model mode of AlbuNet + VGG-11 model yielded excellent grades in 82.7% of images and a CV of 1.36%. Using the evaluation dataset, the AlbuNet + VGG-11 model produced excellent grade results in 77.8% of images, a CV of 1.55%, and reduced CTR measurement time by almost ten-fold (1.07 ± 2.62 s vs 10.6 ± 1.5 s) compared with manual operation. Conclusion Due to its excellent accuracy and speed, the AlbuNet + VGG-11 model could be clinically implemented to assist radiologists with CTR measurement.

3. PROPOSED WORK

The Proposed system for cardiomegaly detection uses CNN based system for detection of cardiomegaly from the X-ray images. In CNN algorithm ResNet-34 model is used for the segmentation purpose. Then we find the ratio automatically using the formula MRD (maximum right diameter) &MLD (maximum left diameter) and ID(inner diameter).The ratio exceeding of 0.42-0.50 is results in cardiomegaly. The main advantages over the proposed work which is Significant reduction in time & labor, no error occurrence, gives high accuracy.The results of cardiomegaly detection using the cardiothoracic ratio measured by the proposed method showed a high degree of agreement with the judgment made by a physician.

4. SYSTEM ARCHITECTURE

5. IMPLEMENTATION

The proposed work has five stages of implementation.

1 Data pre-processing
2 Segmentation Models
3 Postprocessing
4 Cardiothoracic Ratio Calculation
5 Cardiomegaly Detection

1. DATA PRE-PROCESSING

Chest X-ray images in the dataset are taken with different machines across multiple hospitals.Therefore, their image intensity varies and needs to be normalized before feeding into a deep learning model. We apply Histogram equalization to normalize images. Specifically, we modify the value of each pixel with the following function:

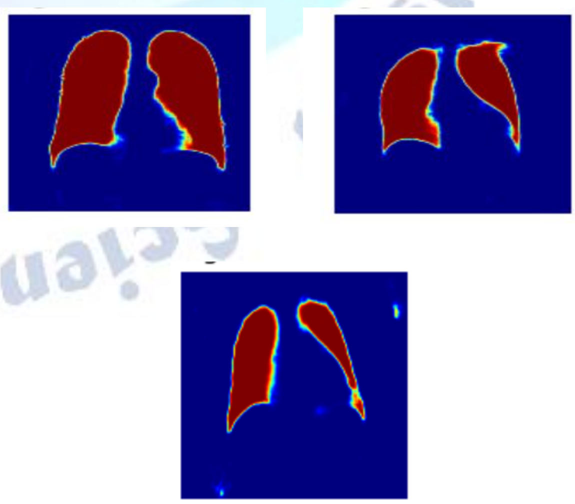
$$g_{i,j} = \left\lfloor (L-1)\sum_{n=0}^{f_{i,j}} p_n \right\rfloor, \qquad (2)$$

2. SEGMENTATION MODELS

In CNN ResNet-34 model is used for segmentation.ResNet-34 is nothing but architecture consists of 34 layers is used for image segmentation which gives us the accurate when output compared to other architectures.The both lung and heart regions are separated using this segmentation process, and gives the segmented output for both lung & heart.During this process, the input Image is given to the architecture and it goes through the each and every 34 layers and gives us the accurate segmented image.

3. POSTPROCESSING

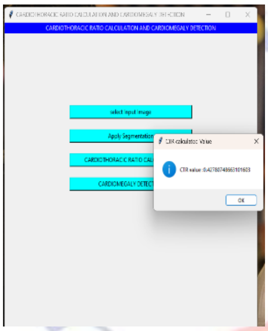
After heart and lung masks are computed, we performed dilation followed by erosion to fill holes in output mask [18], then we find the connected components of prediction masks from the lung mask, we chose the two largest connected components and disregarded others as noise. The connected component with a lower x-axis coordinate is designated as the left lung mask and the other as the right lung mask. From the heart mask, we chose the connected component larger than a given threshold and closest to the center and designate it as the heart mask.

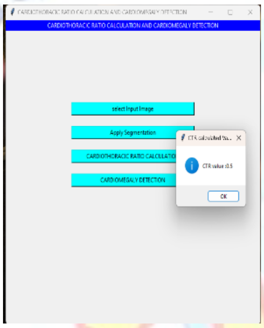


4. CTR CALCULATION

After obtaining the masks, we calculate CTR with equation 1. We calculate cardiac diameter, (MRD + MLD), by finding the extreme points on the x-axis of the heart mask and calculate their x-axis distance. Thoracic diameter, ID, is calculated from extreme points from the lung mask. The CTR measurement line is a straight line connecting the intersection of the two smallest circumscribing circles of the two connected components in the mask image of the lungs.

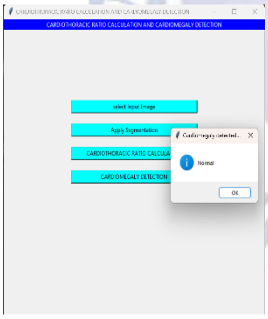
$$CTR = \frac{MLD + MRD}{ID} \qquad (1)$$

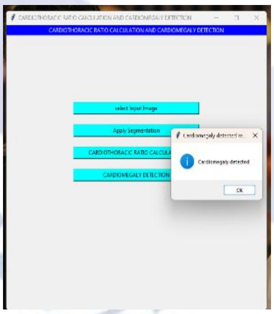




5. CARDIOMEGALY DETECTION

In typical diagnostic practice, a normal measurement of CTR should be less than 0.5, with CTR of 0.5 to 0.55 regarded as mild cardiomegaly and CTR of more than 0.55 regarded as cardiomegaly.Since mild cardiomegaly is also mentioned in radiologist reports and is regarded as cardiomegaly, we use the ratio of 0.50 as a cutoff value for the evaluation of cardiomegaly.

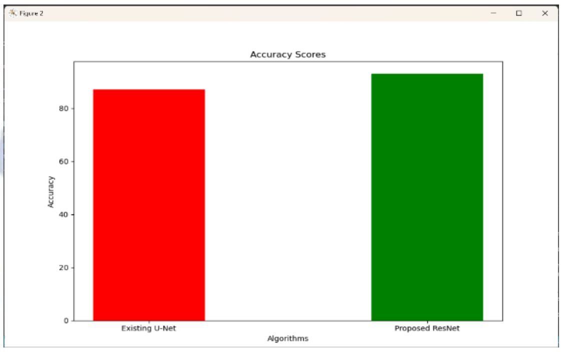




6. RESULTS

The result we obtained is the segmentation output, postprocessing output, cardiothoracic ratio(CTR) output, the cardiomegaly detection & the accuracy for the existing and the proposed method is shown in graph. The advantage of using this proposed method is getting high accuracy and the saving of training time of the dataset. Though this study, it can be concluded that there is high degree of agreement between the judgement made by the physician & the existing methods.

Therefore, this study, which quantitatively detects cardiac enlargement, has the potential to reduce the subjective diagnosis based on physician's experience.



7. CONCLUSION

Our work presents a simple approach to evaluate CTR automatically from chest X-ray images. It can save a significant amount of time for radiologists; our approach has additional benefits in that. Our deep learning algorithm can achieve high accuracy on images obtained from different hospitals even when trained with less than 400 labelled samples. So, the automated detection of cardiomegaly with high accuracy helps to aware the person to make it cure the diseases. The results showed that the detection od cardiac enlargement using the proposed method in this study was highly consistent with the judgement made by the physicians.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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