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# Computer Aided Analysis of Chest X-Ray Images for Early Detection of Cardiomegaly using Euler Numbers

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**ABSTRACT**

Cardiomegaly is an unusual cardiac condition in which the human heart grows larger in size and becomes bigger than it usually is. Cardiomegaly can be detected early by computing Cardiothoracic Ratio(CTR) from chest X-ray images (CXR).As it is difficult for medical experts to examine CXR manually, a Computer-Aided Diagnosis (CAD) system is required to precisely calculate the Cardiothoracic ratio and accurately predict the onset of Cardiomegaly. In this paper, we use euler number based thresholding method for lung region segmentation from CXR images. The resultant binarized image is used for calculating Cardiothoracic Ratio using a computational algorithm. The proposed method is experimented on two datasets: JRST and India. JRST contains 247 chest X-rays and India set contains 100 chest X-rays. An overall accuracy of 96.25% and the overall (lung segmentation time + CTR computation time) average computation of 0.8215 seconds was acheived. The proposed method is compared with existing methods and it gives high accuracy and high performance.

**Keywords :** Chest X ray images; Computer Aided Analysis;Euler number; Cardiomegaly; Cardiothoracic Ratio Computation.

## I. INTRODUCTION

Cardiomegaly or Enlarged heart is a medical condition in which heart size increases which may be due to various factors such as high blood pressure, abnormal heart valve, HIV infection, Kidney disease or genetically inhetited. It is of vital importance to detect Cardiomegaly in early stages as it may give rise to other serious heart diseases like congestive heart failure.

Cardiomegaly is not a disease itself but rather a symptom which marks the onset on various other kinds of diseases like coronary artery disease or congestive heart failure. Therefore early detection of cardiomegaly results in diagnosis of underlying symptom. Heart diseases are life threatening diseases, and it is important to detect their symptoms early. Treatment of the disease at an early stage yeild positive results. 



Although Computed Tomograph (CT) and Magnetic Resonance Imaging (MRI) can be more efficient than X-ray, the latter is more generally available and doctors often rely on CXR for making quick decisions in emergency situations. Cuurently medical doctors perform preliminary diagnosis for heart diseases based on chest X-ray images (CXR). The manual process is not only time consuming but also error prone. It is difficult to analyze the chest X-ray images if they are huge in number, which is a common situation in populous countries. To overcome the difficulties, computerised analysis of CXR images can be adopted. CAD improves the diagnostic accuracy and can assist the medical doctors to come to the right conclusion.

Cardiothoracic Ratio (CTR) calculation is a simple, cost-effective yet efficient approach to detect the increase in heart size[16].CTR can be used for predicting cardiomegaly with 95.8% accuracy[1]. The CTR is the ratio between the maximum transverse cardiac diameter (CD) and the maximum thoracic diameter (TH) which is measured between the inner margins of the ribs. It is computed using posteroanterior chest radiography (PA-CXR).

## II. RELATEDWORK

The problem of detecting cardiomelagy from chest X-ray using a computer can be further divided into two subproblems. Cardiomegaly can be detected from X-ray images by calculating CTR and following are important steps.

- ✓ Segmentation of the X-ray image
- ✓ Computation of Cardiothoracic Ratio(CTR)

In the first step, the lung region is seperated from the X-ray image. Researchers used different techniques to seperate the lung region. Method of segmentation largely depends on the image which is going to be segmented. Histogram based thresholding methods are most commonly used. But the limitation of this method is that accurate threshold is not guarenteed. Euler number based thresholding was used for real time applications[2, 3]. For chest X-ray segmentation, euler min max function was used[4].

As a second step, CTR is calculated from the segmented lung region. In the past years, several methods were proposed to calculate Cardiothoracic Ratio (CTR) from chest X-ray using a computer [5]. Early work was by Becker, H. C., et al. [6] in 1964, who digitized 70-mm photofluorograms and computer was used to find out the cardiothoracic ratio (CTR). The first derivative of the horizontal spatial signature was used to find out the cardiac boundaries and lung margins.

An automated diagnosis for rheumatic heart disease was developed by HALL et al. [7] and KRUGER et al. [8]. They computed CTR and other cardiac parameters to locate cardiac boundaries using a gray-scale threshold method. Discriminant function was used to classify cardiac silhouettes.

Sezaki and Ukena [9]in 1973 designed a practical instrument for automated mass screening of heart disease. CTR was computed by a scheme that detects the vertical boundary of the rib cage and the heart by analyzing the horizontal profiles. .

Recent work related to chest x-rays is automated approach [10, 11, 17]. However the existing approaches[12] have accuracy range varying from 73% to 86% , which needs to be improved in order to detect the cardiomegaly using computer. Here, in this paper, all the computations are performed by our self-designed image analysis tool: MedIT which is specifically designed to detect and predict the onset of Cardiomelagy. Lung field segmentation using Boundary Map and Snake Segmentation Algorithm 3 In this paper, details about a CAD tool for detection of early symptoms of cardiomegaly are given. The paper is organised as follows. Section 2 describes the preprocessing method for lung segmentation. Once lung objects have been isolated, the prevalence of Cardiomegaly will be identified by measuring the cardiothoracic ratio. Section 3 presents the self-designed partially automated software: Medit for analysing CXR and predicting about the existence of cardiomegaly based on Cardiothoracic ratio computation. Later sectiospresent the results and conclusions.

## III. COMPUTER ASSISTED PROCESSING OF CHEST X-RAY IMAGES

The first step towards automated computation of Cardiothoracic Ratio is to create a binarized CXR image having lungs extracted out from the background. Many techniques can be employed to carry out lung segmentation. Euler number based thresholding technique is used to carry out image segmentation. Once the lungs are isolated, then the image can be analysed for detecting cardiomegaly.

### 3.1 Preprocessing

In order to enhance the quality of the segmented images, the CXR images need to undergo a preprocessing phase. The chest area needs to be cropped out fromCXRimages if theCXRcontains unnecessary background. The contrast of the image is enhanced using histogram equalization. 2-D Gaussian operator is used not only to get smooth image but also to preserve the edge features. Using the Gaussian operator, noise is also removed.

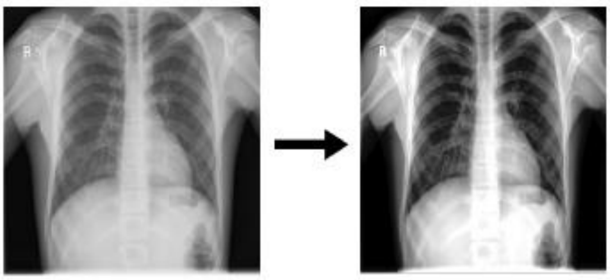

**Figure 1.** Preprocessing the Lung image. Left image is the image before preprocessing and the right image is the image after preprocessing.

### 3.2 Lung Segmentation using Euler numbers

Segmentation divides the image into a set of regions R , which consists of homogenous, non-overlapped, connected subregions $R_i$

$$R = \{R_i : i = 1, 2, 3, ..., N\} \quad (1)$$

The union of all subregions forms the original image i.e.

$$I = R_1 \cup R_2 \cup R_3 \cup ... \cup R_N \quad (2)$$



The regions Ri should be connected for all i = 0; 1; 2...N and each region $R_i$ should be homogenous. Different adjacent regions $R_i$ and $R_j$ should be disjoint i.e.

Lung boundary segmentation in Chest X-ray is a problem focused by a number of research groups over the past decade. Different kinds of solutions were proposed. These solutions can be broadly categorized into categories like rule based methods, pixel classification-based methods, deformable model-based methods, and hybrid methods. Here we use Rule-based segmentation method involving thresholding or morphological operations Inspite of existence of various approaches for segmentation, Thresholding is the most common method used. Thresholding converts an input image I to a binary image B as follows:

$$R_i \cap R_j = \phi \quad (3)$$

where T is the threshold, B (i, j) = 1 for foreground and B (i, j) = 0 for background.

$$B(i,j) = \begin{cases} 1 & \text{if } I(i,j) \geq T \\ 0 & \text{if } I(i,j) < T \end{cases} \quad (4)$$

To find T value histogram based approaches were used. But the main disadvantage is that coherency of image is not guarenteed. Holes and extragenous pixels may appear in the segmented image. To preserve the coherency of image, we propose euler number based technique to find the threshold T. Although euler number based thresholding was applied for real time applications[18], it is not used for image thresholding. The Euler number of an image is an important feature that can be used to describe the topological structure of that image[19]. It is known that this describing feature is invariant up to several image transformations such as translations, rotations, scale changes, affinities, projections and even some non-linear transformations such as deformation of the shapes contained in the image. Mathematically, the Euler number of a binary image can be calculated either by using global computation or by local computations. The following equation is used for computing euler number globally.

$$E = C - H \qquad (5)$$

where C is the number of regions of the image (number of connected components of the object) and H is the number of holes in the image (isolated regions of the imageâĹ™s background). Euler number E of an binary image can be calculated using local computations.

$$E(t) = \frac{1}{4}[q_1(t) - q_3(t) - 2q_d(t)] \qquad (6)$$

where t is the threshold value which is used to obtain the binary image from a gray level image, $q_1$ denotes the number of 2x2 matrices in the image with one 1 and remaining 0's. There are four different possible matices which count as $q_1$ .$q_3$ denotes the number of 2x2 matrices in the image with three 1's and remaining one 0. There are four such different possible matices which could be counted as $q_3$. $q_d$ denotes the number of diagonal 2x2 matices. There are two different possible matrices of qd type. Equations 3.5 and 3.6 are expected to give same Euler number E for a given binary image. For chest X-ray, it is expected to seperate two lung regions from the given image using segmentation technique. Therefore, Lung field segmentation using Boundary Map and Snake Segmentation Algorithm 5 the expected euler number is 2, since the expected number of connected components are 2 and the expected number of holes are 0. Using equation 3.5, Euler number E can be calculated in the following manner.

$$E = C - H = 2 - 0 = 2 \qquad (7)$$

Since equations 3.5 and 3.6 are expected to give the same Euler number E for a given binary image, Equation 3.6 can be made equal to 2.

$$1/4[q_1(t) - q_3(t) - 2q_d(t)] = 2 \qquad (8)$$

From equation 3.8, required threshold is the threshold th at which the Euler number becomes 2 i.e.

$$E(t_h) = 2 \qquad (9)$$

Let us assume that $T_h$ is a set of all thresholds $t_h$ for which equation 3.9 is true. There are two possible cases: $T_h$ may be a singleton set or $T_h$ may contain multiple values. It has been proved that the graph containing different threshold values on X-axis and corresponding euler numbers on Y-axis for a given image is decaying exponential. Hence, for a given euler number, a corresponding threshold value can be found. With this observation, second case is ruled out and $T_h$ is a singleton set and contains single value which is the required threshold value.

**Algorithm Lung Segmentation Algorithm:**

**Algorithm** Lung Segmentation Algorithm:

1: Convert the CXR image from RGB format to Gray Scale by taking the weighted average. Let R, G, B represents the levels of red, green and blue respectively. Then, the grayscale image can be obtained by

2: grayscale image = ( ( 0.3*R ) + (0.59*G ) + (0.11*B) )

3: Once the grayscale image is obtained, it need to be converted into binary image. Thresholding converts an input image I to a binary image B as follows:

$$B(i,j) = \begin{cases} 1 & \text{if } I(i,j) \geq T \\ 0 & \text{if } I(i,j) < T \end{cases}$$

where T is the threshold, B (i, j) = 1 for foreground and B (i, j) = 0 for background.

4: The value of T is found out using Euler number based thresholding. T is the threshold corresponding to euler number 2 for a given chest X-ray. The Euler number is calculated by using E = C - H, Where E denotes Euler number,C denotes number of connected components and H denotes number of holes. In a given chest X-ray there are two connected components without holes. Hence Euler number is E = 2 - 0 = 2

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**Algorithm** Lung Segmentation Algorithm: contd

5: Remove the dark region at the four corners of the CXR by using Breadth First Search Algorithm.
6: Smoothen the lung boundaries by some erosion and dilution process using disk as the structuring element.
7: Erosion is an operation which is applied on a binary image B by a structuring element S (denoted B⊖S). It generates a new binary image $B_e$ = B⊖S. This $B_e$ has ones in all locations (x,y) of a structuring element's origin at which that structuring element fits the input image B, i.e. B(x,y) = 1 if S fits B and 0 otherwise. It repeats for all pixel coordinates (x,y).
8: Dilation is an operation which is applied on image B by a structuring element S(denoted B⊕S). Dilation produces a new binary image $B_d$ = f⊕s.$B_d$ contains ones in all locations (x,y) of a structuring element's origin at which that structuring element S hits the the input image B, i.e.$B_d(x,y) = 1$ if S hits B and 0 otherwise. This process repeats for all pixel coordinates (x,y). The effect of Dilation is opposite to erosion. Dilation adds a layer of pixels to both the inner and outer boundaries of regions.
9: Analyse the image obtained for diagnosis of various diseases.

**Figure 2.** Lungs are segmented from the preprocessed image. First image is the preprocessed image. Second image is obtained using Euler numbers. Third one is the final image obtained by further filtration

### 3.3 Measuring Cardiothoracic Ratio (CTR)

For calculating the cardiothoracic ratio, first cardiac diameter and thoracic diameter needs to be computed. The maximum transverse cardiac diameter (CD) can be represented as a sum of MRD (greatest perpendicular diameter from midline to right heart border) and MLD (greatest perpendicular diameter from midline to left heart border).

CD = MRD +MLD (10)

Thoracic diameter (TD) is the widest distance between the internal surfaces of the ribs on the left side and the right side. The Cardiothoracic Ratio (CTR) can then be calculated as

$$CTR = \frac{CD}{TD} \quad (11)$$

Lung field segmentation using Boundary Map and Snake Segmentation Algorithm 7

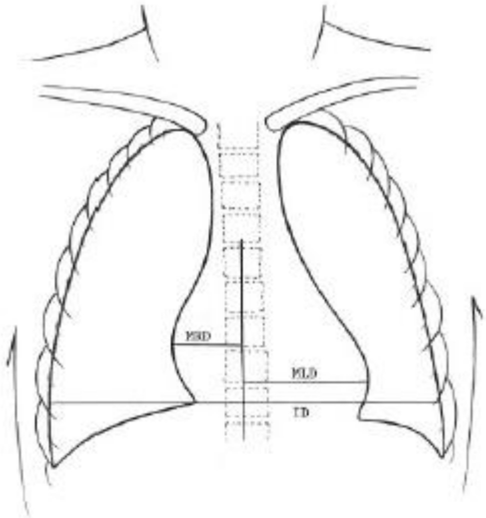


**Figure 3.** Figure depicting the MRD (maximum right diameter), MLD (maximum left diameter) and TD (thoracic diameter).

**Algorithm** Proposed Algorithm for computing Cardiothoracic Ratio:

1: Use the âŁœLung SegmentationâŁž algorithm to segment out the lung regions and create a binarized image.
2: Let the dimensions of the image be $H \times W$ where $H$ represents the height of the image (in pixels) and $W$ represents the width of the image (in pixels).
3: The number of horizontal scanlines used will be $H + 1$ starting from $SC0$ to $SCH$.
4: Draw a midline passing through $W/2$.
5: For each scanline from $SC0$ to $SCH$ do:
6: • Start scanning from left to right upto midline and detect the first black pixel. Label it $L$.
• Start scanning from right to left upto midline and detect the first black pixel. Label it $R$.
• Compute $R$ - $L$.
7: Let $SCM$ denote the scanline for which $R$ - $L$ is maximum. This maximum value of $R$ - $L$ will be Thoracic Diameter (TD).

**Algorithm** Proposed Algorithm for computing Cardiothoracic Ratio: contd

8: Now, for each scanline from $SC0$ to $SCM$ do:
9: • Starting from the midline, scan from left to right and detect the first black pixel on the right side of midline. Label it $LD$.
• Starting from the midline, scan from right to left and detect the first black pixel on the left side of midline. Label it $RD$.
10: Let MLD denote the maximum left Diameter of heart which is max($LD$) and Let MRD denote the maximum right Diameter of heart which is max($RD$). The cardiac diameter (CD) will be obtained by equation 1.
11: The Cardiothoracic Ratio can be computed using equation 2.

The prevalence of Cardiomegaly can be detected if the Cardiothoracic ratio is $\geq 0.5$. Nakamori et al. [1] have emphasised on the usefulness of Cardiothoracic Ratio in detection of Cardiomegaly. They have shown in their work that accuracy of CTR in detection of Cardiomegaly is 95.8 %. Studies [13, 14] have shown that CTR can be influenced by many cardiac and extracardiac factors. Some of the factors that influence CTR are the examination technique, the patient's biotype, the patient's physiological status, thoracic alterations, the size of the lungs, the breathing phase, the cardiac cycle phase, and heart rate at the time of examination. But the classic criterion of 0.5 has been adopted as the most appropriate value for Cardiomegaly predictions.

Figure 4 and Figure 5 illustrate the difference between CXR of a normal heart and enlarged heart.

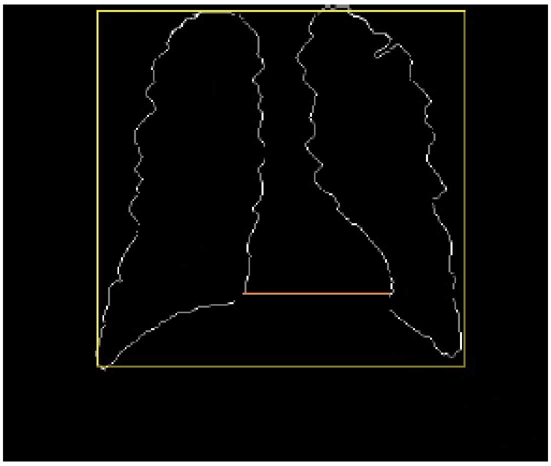

**Figure 4.** CXR of a Normal Heart.

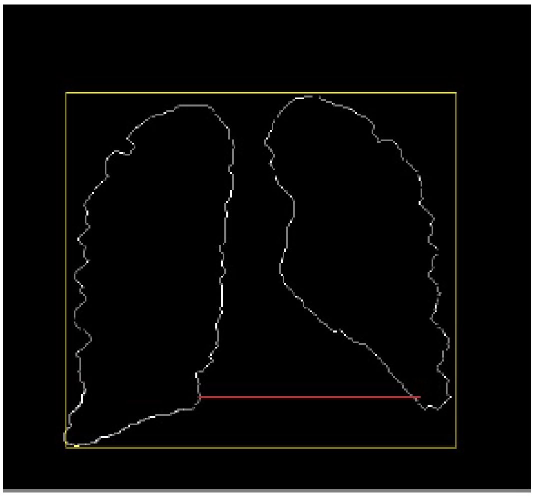

**Figure 5.** CXR of a Enlarged Heart.

Lung field segmentation using Boundary Map and Snake Segmentation Algorithm 9

## IV. EXPERIMENTAL RESULTS

### 4.1 MedIT : A Tool to detect Cardiomegaly

Based on the above mentioned algorithms, we implemented it in matlab and designed a software named MedIT. Snapshots of the software are shown below.

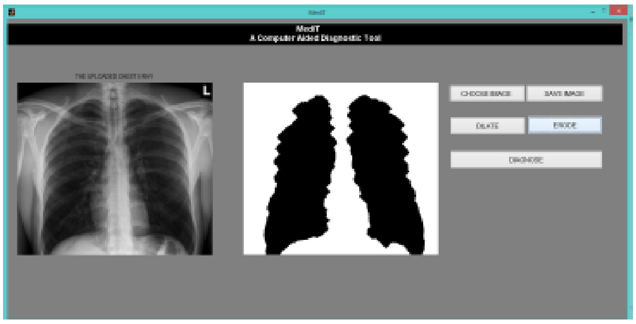


**Figure 6.** Lung segmentation from the CXR image.

Further fine tuning of the morphed image can be done using Dilate and Erode option buttons provided in the software. Dilation and Erosion are the most basic morphological operators. Pixels are added to the boundaries of objects in an image using Dilation whereas pixels are removed from object boundaries using Erosion.

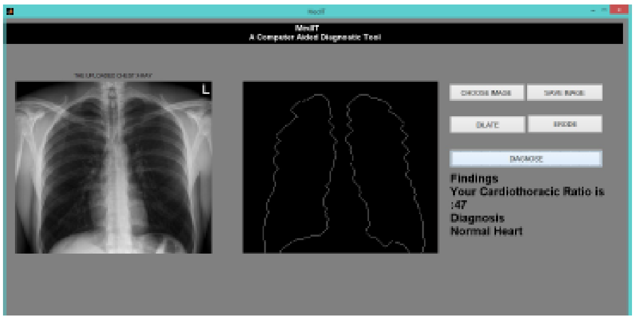


**Figure 7.** Analysing the CXR image of a Normal heart sample.

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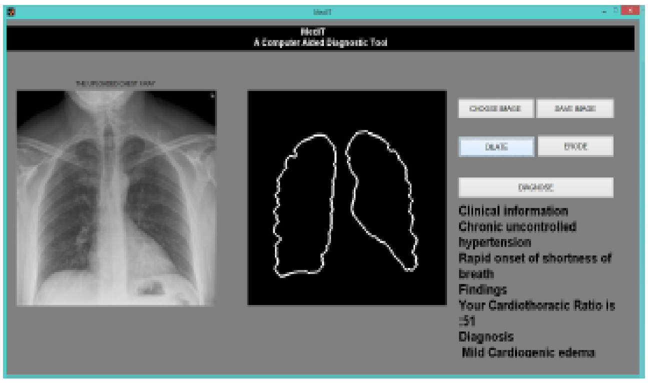


**Figure 8.** Analysing the CXR image of a Diseased heart sample.

### 4.2 Chest X-Ray Image Dataset

The proposed Cardiothoracic Ratio computation algorithm is evaluated using two different CXR datasets.

**1. JSRT DataSet:** This dataset was compiled by the Japanese Society of Radiological Technology (JSRT) [15]. The set contains 247 chest X-rays. Among 247 images, 154 have normal lungs and 93 have abnormal lungs. All X-ray images have a size of 20482048 pixels and a gray-scale color depth of 12 bit.

**2. India Set:** This dataset contains 100 chest X-rays which are collected from a private clinic in India with resolutions of 19201080 . The gray-scale color depth is 12 bit. The dataset contains 50 CXR images of normal patients and rest 50 of those who are medically diagnosed by doctors as patients of cardiomegaly. The dataset contains CXR images of both male and female patients of age ranging from 20 to 65 years.

### 4.3 Cardiothoracic ratio(CTR) computation

We examined the CXR images from the above mentioned datasets using MedIT. Each image is individually selected for testing, morphological operations namely Dilation and Erosion are applied and then finally assessed for Cardiomegaly. Table1 shows the results of computation of Cardiothoracic Ratio of 10 patients and Figure 7 depicts the input and output chest X-ray images of these patients.

In Table1, the CXR X5, X7 and X8 are having Cardiothoracic ratio greater than 50% .Our system has identified the prevalence of Cardiomegaly in these patients. The average computation time for lung segmentation is 0.82 seconds and the average computation time for calculating Cardiothoracic Ratio as per our proposed algorithm is 0.0015 seconds. In literature, many have presented good alorithms for computing Cardiothoracic Ratio but our proposed algorithm has achieved the best results so far.

**Table 1.** Computation time to measure CTR.

| CXR | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cardiothoracic Ratio(CTR) | 42.1 | 43.2 | 40.3 | 42.8 | 53.9 | 40.1 | 51.5 | 53.4 | 42.8 | 38.8 |
| Computation time for Lung Segmentation (in sec) | 0.86 | 0.84 | 0.81 | 0.84 | 0.91 | 0.79 | 0.82 | 0.77 | 0.76 | 0.72 |
| Computation time for CTR calculation (in sec) | 0.0014 | 0.0020 | 0.0011 | 0.0010 | 0.0019 | 0.0011 | 0.0013 | 0.0017 | 0.0018 | 0.0022 |

Lung field segmentation using Boundary Map and Snake Segmentation Algorithm 11

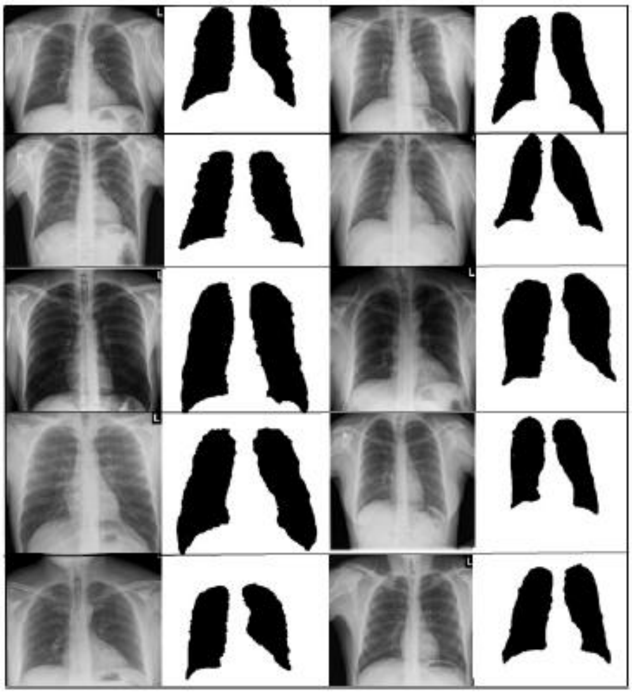

**Figure 9.** Depicting the input CXR images and their corresponding morphed images.

### 4.4 Test for Accuracy

If a system can differentiate the patient and healthy cases correctly, then the system is said to have high efficiency. In order to approximate the accuracy of a system, the proportion of true positive and true negative should be calculated in all evaluated cases. This can be stated mathematically as :

$$Accuracy = \frac{Tp + Tn}{Tp + Tn + Fn + Fp} \qquad (12)$$

where

True positive ($T_P$) denotes the number of cases which are correctly identified as patient

False positive ($F_P$) denotes the number of cases which are incorrectly identified as patient

True negative($T_n$) denotes the number of cases which are correctly identified as healthy

False negative ($F_n$) denotes the number of cases which are incorrectly identified as healthy

We have tested total 347 Chest X-ray images out of which 143 were of patients suffering from cardiomegaly and rest were of persons with normal cardiac size. Our system has correctly identified 138 out of 143 as patients of cardiomegaly and rest 5 have been incorrectly identified as healthy. This means TP = 138 and FN = 5 . Out of 204 normal X-rays, we have detected 196 X-rays as normal and rest 8 have been incorrectly identified as unhealthy. This means TN = 196 and FP = 8. So, our system was able to achieve an accuracy of 96.25% with a positive error of 3.92% and a negative error of 3.49%. Positive error occurs when the system incorrectly predicts normal as abnormal due to overestimation in calculation and negative error occurs when system incorrectly predicts abnormal cardiac conditions as normal.



## V. CONCLUSION

This paper presents a new method for computer assisted CXR analysis for diagnosing Cardiomegaly. Segmentation of the image is done using euler number based thresholding. An algorithm for Cardiothoracic Ratio(CTR) computation is developed and implemented. The experimental results obtained with the proposed algorithm are very encouraging. The proposed method outperforms the existing CTR computation algoritms on the chest x-ray images of different categories. We have achieved an overall accuracy of 96.25% and the overall(lung segmentation time + CTR computation time) average computation of 0.8215 seconds.

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