Biomedical Assignment 4

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INTRODUCTION

This assignment is based on segmentation of the lungs in Chest X-rays using active contour method.Here Boundary information will be used to extract the information in the image and used for segmentation

1 Part 1: Data labeling: Generate ground truth for the images given

In this step using the data of training set the mean shape is calculated.The algorithm for this is as given below,
Flow chart of mean shape calculation is 1

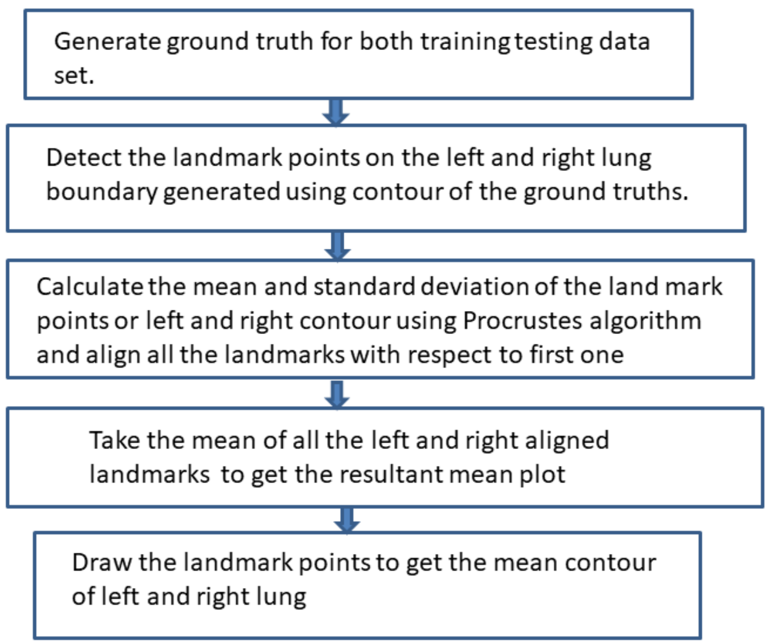


Figure 1: Flow chart for data labelling and mean shape generation

Algorithm for mean shape calculation-

STEP 1- First the ground truth of training and testing images are labelled. For this part I have used manual method for labelling ground truth

STEP 2-The boundary of the ground truth is generated by taking its contour.Landmark points are detected on the generated boundary.I have taken 40 points as land mark on the boundary in each left and right lung.The detected points are as shown in figure 2 and 3.

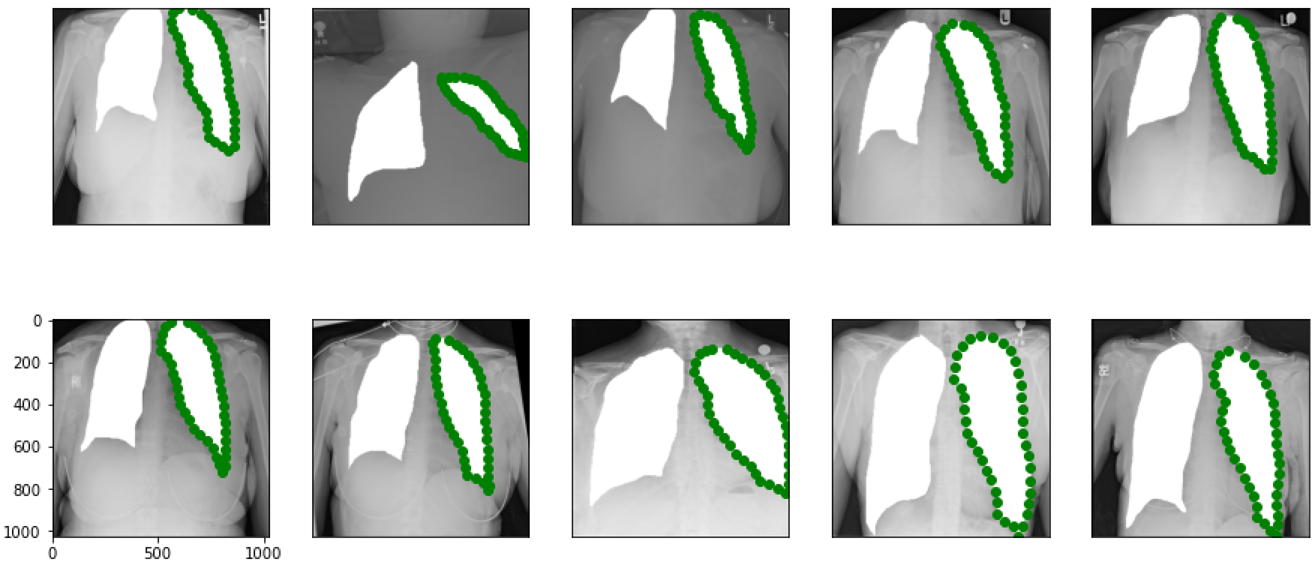


Figure 2: Landmark detection in left lung for all 10 training data set

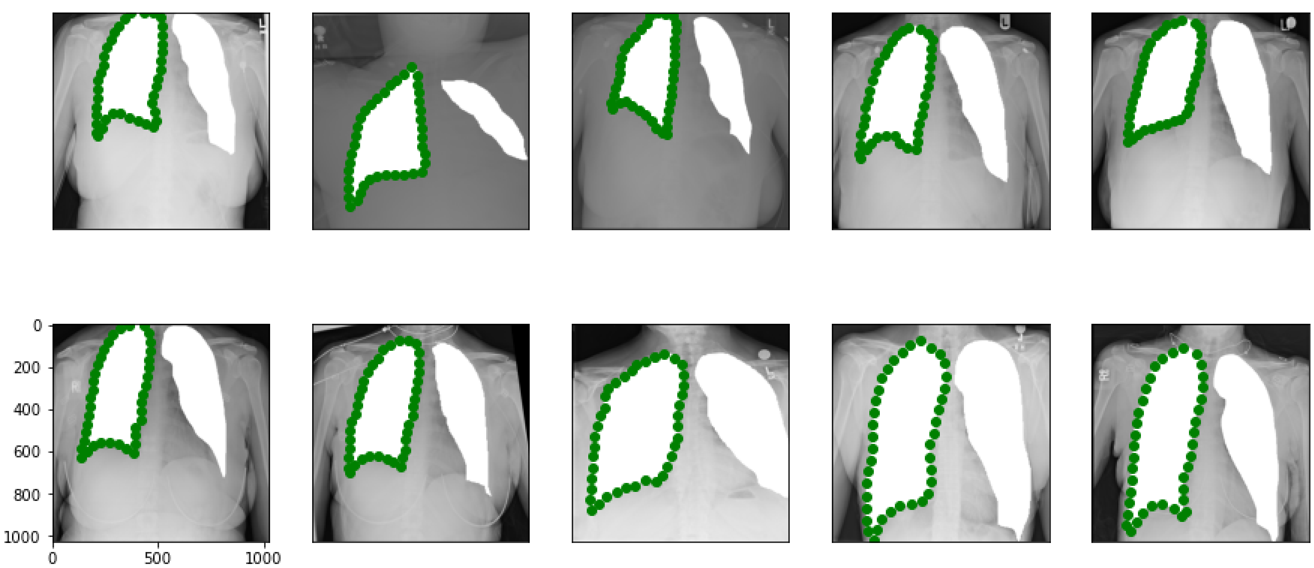


Figure 3: Landmark detection in right lung for all 10 training data set

STEP 3-Reorient the left and right lungs with respect to the first image for alignment.This can be done using Procrustes algorithm. The aligned shapes with respect to first one for right lung is as shown in 4. Similarly the aligned shapes of left lung is determined.

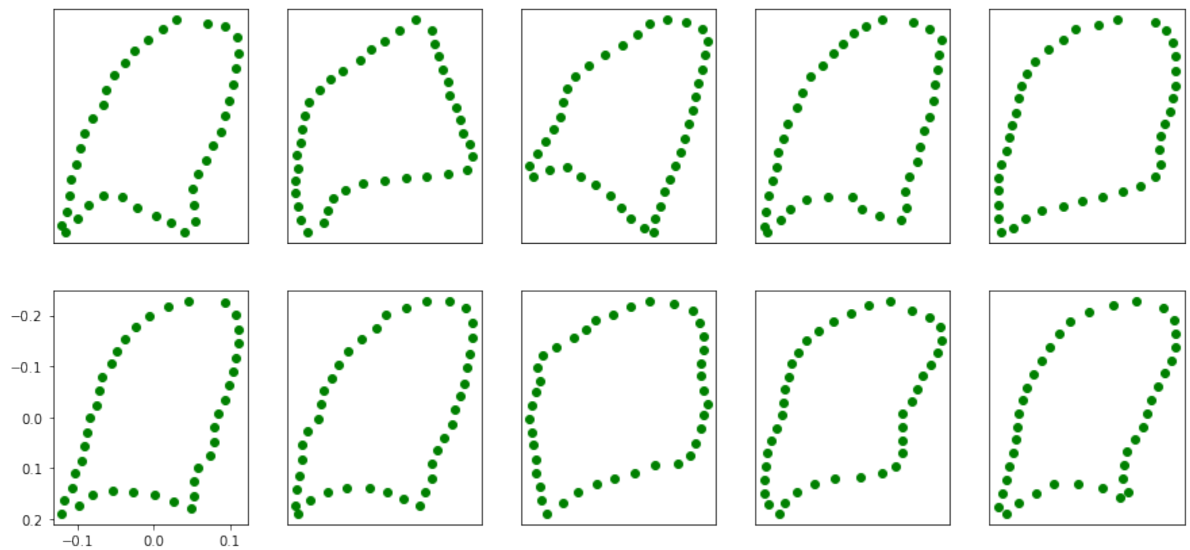


Figure 4: Reorientation of landmarks of right lung with respect to its first one.

STEP 4- The mean of the re oriented shapes are calculated to determine the mean left and right lung 5.he landmarks of mean of the re oriented shapes are joined to get the final mean lung region 6

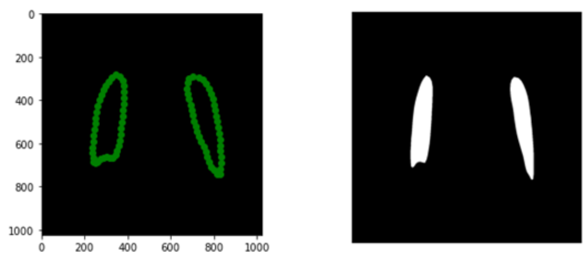


Figure 5: Mean of landmarks of right lung and left lung.

2 Part 2: Segmentation: Create a shape prior using the ground truth, use this as initialization for Active contour model to segment the lungs.

The mean shape generated in previous step is used as initial level set for finding the segmentation in this method.The flow chart for active contour model is as shown in figure 6

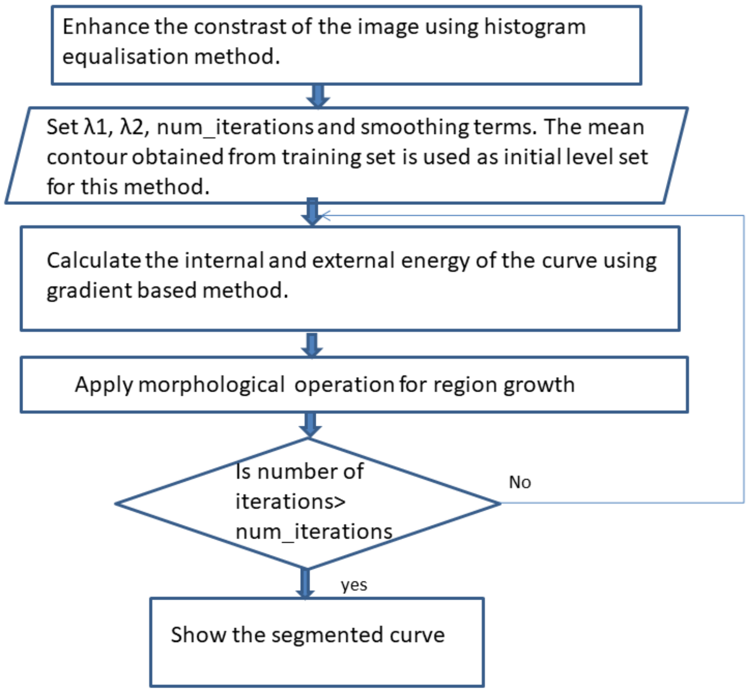


Figure 6: Flow chart of active contour model

Algorithm for active contour model-

STEP 1- First the input test image is enhanced using histogram equalisation method so that the gradient can be detected easily 7.

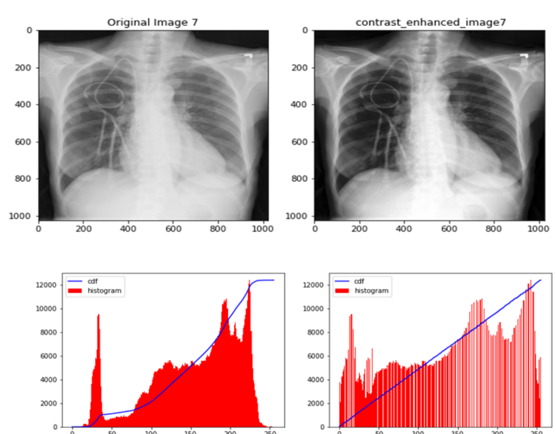


Figure 7: Contrast enhanced lungs x-ray image of 00006717007

STEP 2- Initial parameters number of iterations, smoothing term, λ_1 and λ_2 are chosen.λ_1 and λ_2 are positive weighting parameters for intensity fitting terms defined by the users to control the movement of the contour curve.Its default value is chosen as 1.

STEP3-Internal and external energy of the curve is calculated using [1].It defines an energy functional for image segmentation which takes into account the content of the interior and exterior regions of the curve (or surface) in contrast to the Geodesic Active Contour (GAC), which only take into account the places where the curve (or surface) passes. The ACWE(Active Contours Without Edges) functional of a curve C is,

$$F(c_1, c_2, C) = \mu.length(C) + \nu.area(inside(c)) + \lambda_1 \int_{inside(c)} ||I(x) - c_1|| dx + \lambda_2 \int_{outside(c)} ||I(x) - c_2|| dx \quad (1)$$

where the non-negative parameters $\mu, \nu, \lambda_1 and \lambda_2$ control the strength of each term. The three-dimensional version of this functional F(c1, c2, S) is obtained by replacing the operators length by area and area by volume.
STEP-4- Morphological operation is implemented to expand or shrink the boundary as suggested in [2] .The morphological ACWE algorithm is given by the following three steps8:

$$u^{n+\frac{1}{3}}(\mathbf{x}) = \begin{cases} (D_d u^n)(\mathbf{x}) & \text{if } \nu > 0 \\ (E_d u^n)(\mathbf{x}) & \text{if } \nu < 0 \\ u^n(\mathbf{x}) & \text{otherwise} \end{cases}$$

$$u^{n+\frac{2}{3}}(\mathbf{x}) = \begin{cases} 1 & \text{if } |\nabla u^{n+\frac{1}{3}}|(\lambda_1(I - c_1)^2 \\ & \quad -\lambda_2(I - c_2)^2)(\mathbf{x}) < 0 \\ 0 & \text{if } |\nabla u^{n+\frac{1}{3}}|(\lambda_1(I - c_1)^2 \\ & \quad -\lambda_2(I - c_2)^2)(\mathbf{x}) > 0 \\ u^{n+\frac{1}{3}} & \text{otherwise} \end{cases}$$

$$u^{n+1}(\mathbf{x}) = \left((SI_d \circ IS_d)^{\mu} u^{n+\frac{2}{3}}\right)(\mathbf{x}).$$

Figure 8: The morphological ACWE algorithm

STEP 5- The above process is repeated with the number of iterations.And finally the segmented object is obtained.
The implementation of above method is as shown in figure 9

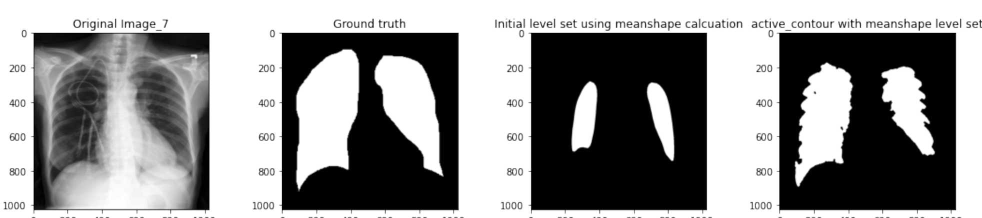


Figure 9: The morphological active contour segmentation with mean shape level set of 00006717007

[1]Chan and Vese proposed algorithm for using internal energy for image segmentation. https://ieeexplore.ieee.org/document/902291.

[2]Chan and Vese proposed algorithm for using internal energy for image segmentation. https://ieeexplore.ieee.org/document/902291.

Along with the above level set I have tried active contour segmentation with circular level set and k means segmented level set.For circular level set I have defined a circle at the center of the image and its radius as 0.35 of the minimum side of the image.For k-means, clustering is done for 3 centers and the cluster containing the lungs region is considered.The k-means segmented region is as shown in figure 10 with black region showing region of interset.

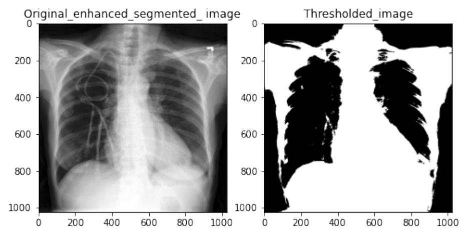


Figure 10: The k-means segmentation of 00006717007

The result of these two level set for test image 00006717007 is as shown in figure 11 and 12.

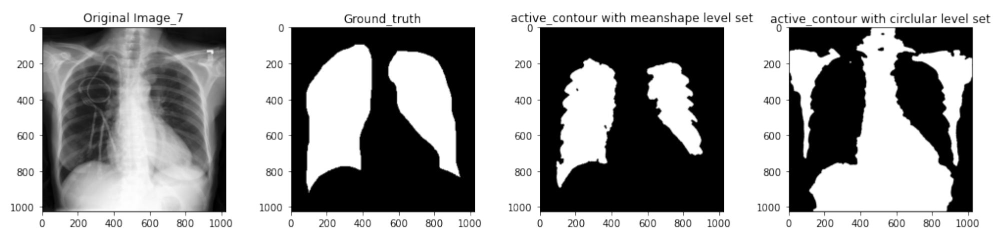


Figure 11: The morphological active contour segmentation with circular level set of 00006717007

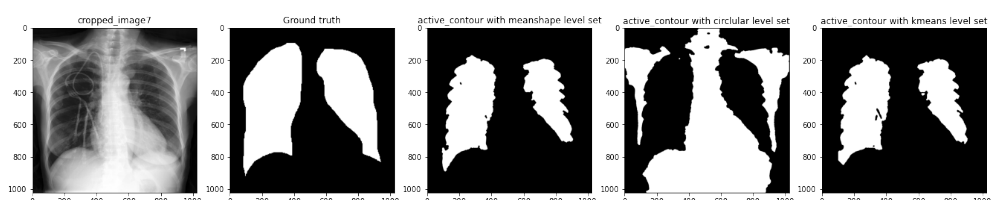


Figure 12: The morphological active contour segmentation with k-means level set of 00006717007

Observation-As there is a gradient between body and the background so the circular level set being initialised at the center diverge towards the outer gradient.Both k-means and mean shape based level set performed well but k means has small hole in it where as mean shape is more continuous.K-means level has to be cropped to only lung segmented area which requires more manual implementation.

3 Part 3: Validation: Compare the segmentation results with the ground truth using metrics

Let X be the segmented image and Y be the ground truth for the following.
Dice similarity coefficient -
The Dice similarity coefficient, also known as the Sorensen–Dice index or simply Dice coefficient, is a statistical tool which measures the similarity between two sets of data.The equation for the concept is,

$$Dicesimilarity = 2 * \frac{(\mid X \mid \cap \mid Y \mid)}{(\mid X \mid + \mid Y \mid)} \tag{2}$$

Jaccard index (JAC) - The Jaccard similarity index (sometimes called the Jaccard similarity coefficient) compares members for two sets to see which members are shared and which are distinct. It's a measure of similarity for the two sets of data, with a range from $0 to 100$ percentage. The higher the percentage, the more similar the two populations.

$$JaccardindexJ(X, Y) = \frac{(\mid X \mid \cap \mid Y \mid)}{(\mid X \mid \cup \mid Y \mid)} \tag{3}$$

Accuracy - It is the percent of pixels in your image that are classified correctly.

$$Accuarcy(X, Y) = \frac{(TP + TN)}{(TP + FN + FP + TN)} \tag{4}$$

sensitivity - Sensitivity: the ability of a test to correctly identify patients with a disease.

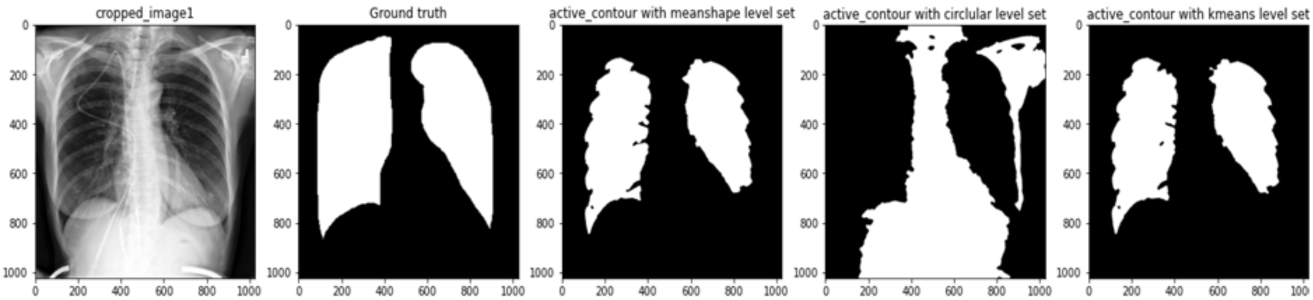
$$Sensitivity(X, Y) = \frac{(TP)}{(TP + FN)} \tag{5}$$

Specificity - Specificity: the ability of a test to correctly identify people without the disease.The specificity between two binary datasets which denotes the fraction of correctly returned negatives. The specificity is not symmetric.

$$Specificity(X, Y) = \frac{(TN)}{(FP + TN)} \tag{6}$$

where TP is true positive= X and Y
TN is true positive= $\sim Xand \sim Y$
$FPisfalsepositive = Xand \sim Y$
$FNisfalsenegative =\sim XandY$

Observations:
00006717001:

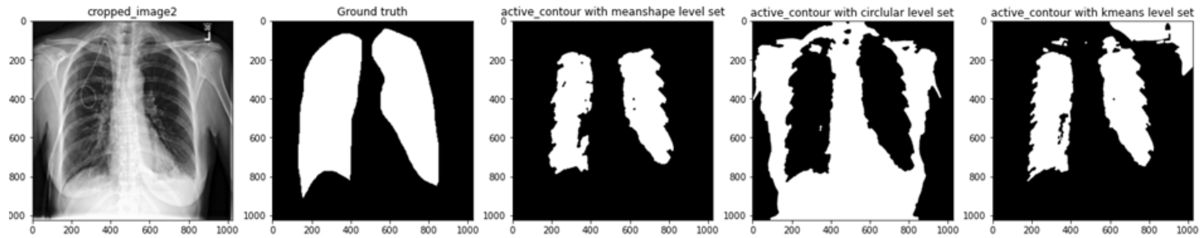


1.00006717_001	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.877716	0.309308	0.880131
SPECIFICITY	0.997247	0.433203	0.997247
SENSITIVITY	0.665019	0.088845	0.671730
JACCARD COEFFICIENT	0.661777	0.088845	0.668456
DICE COEFFICIENT	0.796469	0.084719	0.801287

Figure 13: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006717001

Comment- From figure 13 using unsupervised metric concept it can be seen that the k-means based segmentation has more continuity than the mean shape one.Circular level set has diverged and segmented the body region rather than the lungs.from table accuracy of k-means level set and mean shape is more as it has segment the true positive and negative part correctly.As I have generated the ground truth manually so true positive and true negative ratios can be used as metrices in this case. So accuracy and sensitivity can be used to determine comment upon the result. Also Positive predictive value(ppv) can be used for comparision as it will show the true positive w.r.t total positive values.

00006717002:

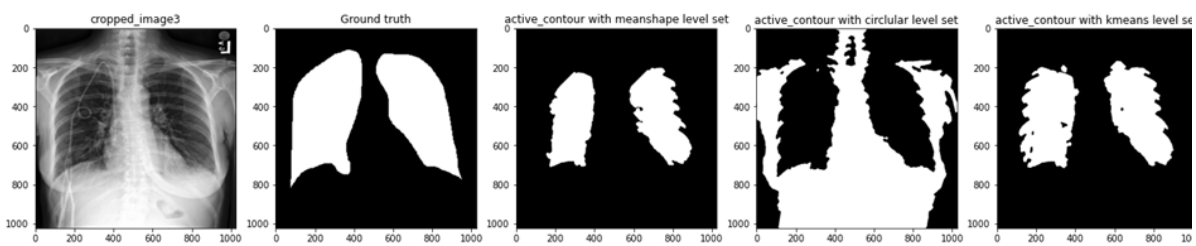


2.00006717_002	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.849819	0.353142	0.821814
SPECIFICITY	0.998539	0.399265	0.924918
SENSITIVITY	0.553819	0.261342	0.61660
JACCARD COEFFICIENT	0.552213	0.119026	0.212732
DICE COEFFICIENT	0.711517	0.212732	0.698288

Figure 14: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006717002

Comment- From figure 14, the k-means level set falsely detected the positive regions along with true long segmentation.The circular level set has diverged towards outer body region and the mean shape based segmentation has worked properly which can also verified from metrics table.Sensitivity of k-means based method is more as it has covered more true positive area.

00006717003:

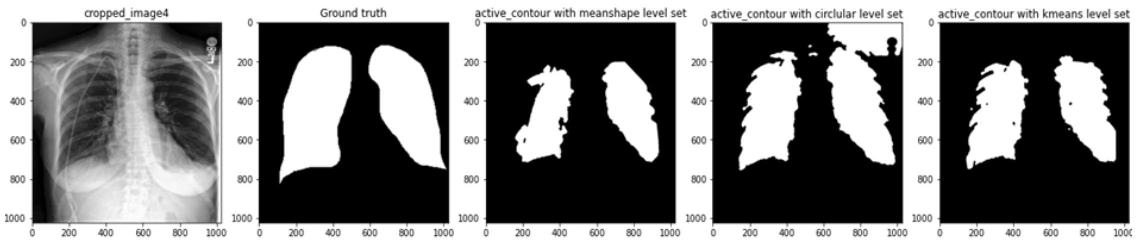


3.00006717_003	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.855037	0.305035	0.895116
SPECIFICITY	0.998988	0.368277	0.998044
SENSITIVITY	0.539349	0.166342	0.669393
JACCARD COEFFICIENT	0.538154	0.069734	0.666533
DICE COEFFICIENT	0.699740	0.130376	0.799904

Figure 15: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006717003

Comment- From figure 15 using unsupervised metric concept it can be seen that the mean shape based segmentation has less hole in the lungs region than k means one, so its specificity is more.Circular level set has diverged and segmented the body region rather than the lungs.From table accuracy of k-means level set and mean shape is more as it has segment the true positive and negative part correctly.

00006717004:

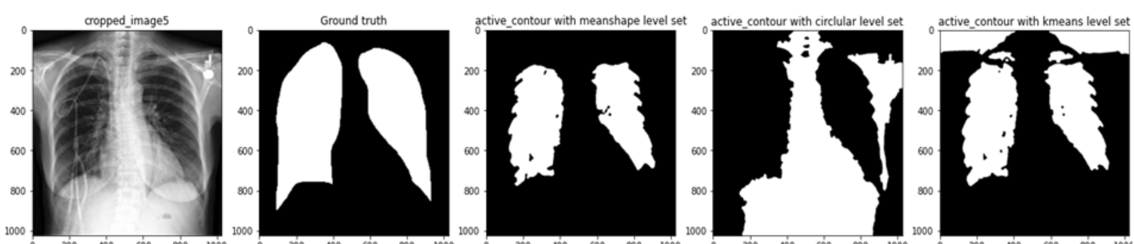


4.00006717_004	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.851264	0.869191	0.891884
SPECIFICITY	0.998870	0.919796	0.997618
SENSITIVITY	0.544761	0.764111	0.672327
JACCARD COEFFICIENT	0.543485	0.655021	0.669018
DICE COEFFICIENT	0.704231	0.791556	0.801690

Figure 16: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006717004

Comment- From figure 16 using unsupervised metric concept it can be seen that the mean shape based segmentation has less hole in the lungs region than k means one, so its specificity is more.Circular level set has segmented the lungs but diverged due to less separation of body and lung region.Considering overall parameters k-means performed better than others in this case.

00006717005:

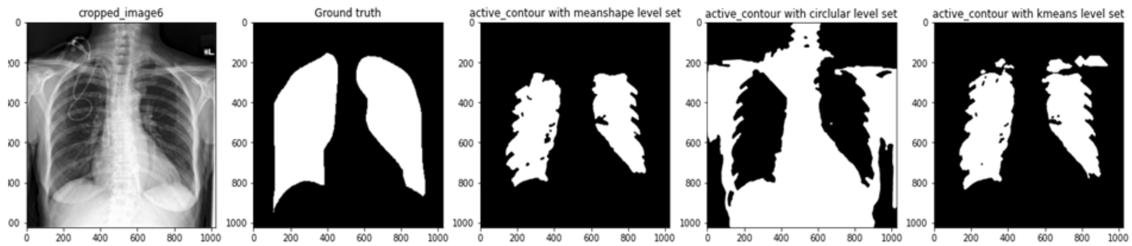


5.00006717_005	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.870887	0.310445	0.813871
SPECIFICITY	0.999990	0.421669	0.882562
SENSITIVITY	0.630006	0.102921	0.685708
JACCARD COEFFICIENT	0.629994	0.049504	0.562463
DICE COEFFICIENT	0.773001	0.094338	0.719970

Figure 17: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006717005

Comment- From figure 17 using unsupervised metric concept it can be seen that the k-means based segmentation has more continuity than the mean shape one.Circular level set has diverged and segmented the body region rather than the lungs.k-means has also diverged towards body.Mean shape has segmented true positive and negative region more accurately than the other two.

00006717006:

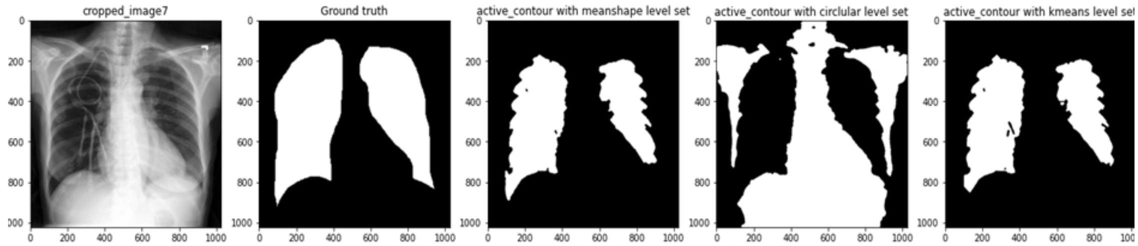


6.00006717_006	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.868206	0.328147	0.884255
SPECIFICITY	0.999276	0.351575	0.989275
SENSITIVITY	0.580880	0.276788	0.654037
JACCARD COEFFICIENT	0.579960	0.114307	0.639013
DICE COEFFICIENT	0.734145	0.205163	0.779754

Figure 18: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006717006

Comment- From figure 18 Circular level set has diverged and segmented the body region rather than the lungs.k-means has also diverged towards body a bit but has covered more positive region than the other two and hence have more accuracy.

00006717007:

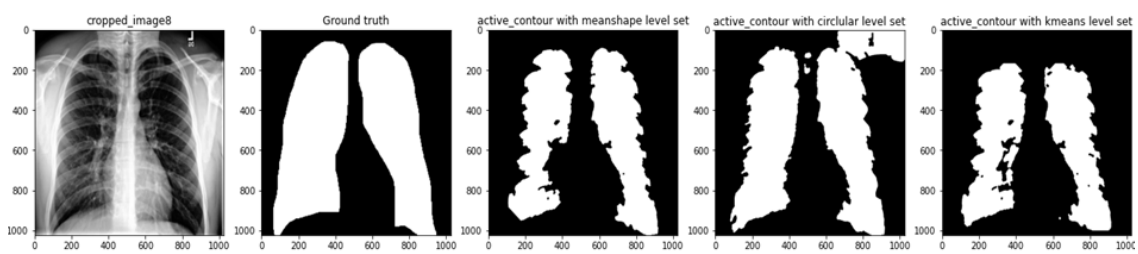


7.00006717_007	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.879489	0.292111	0.875203
SPECIFICITY	0.999923	0.355337	0.999991
SENSITIVITY	0.649203	0.171216	0.636592
JACCARD COEFFICIENT	0.649108	0.076686	0.636582
DICE COEFFICIENT	0.787223	0.142449	0.777940

Figure 19: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006717007

Comment- From figure 19 using unsupervised metric concept it can be seen that the k-means based segmentation has more continuity than the mean shape one.Circular level set has diverged and segmented the body region rather than the lungs.Both k-means and mean shape level set performed well in this case.

00006718000:

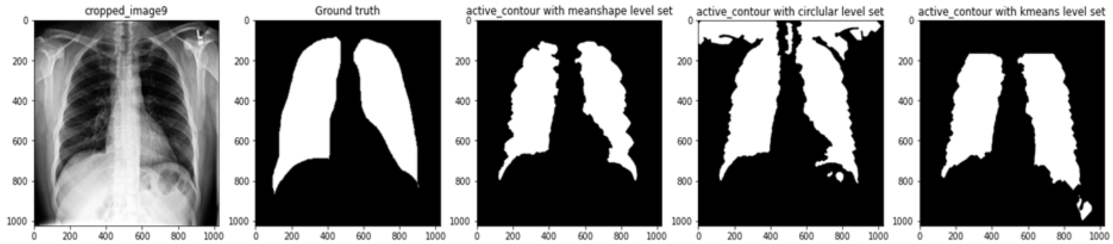


8.00006718_000	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.846035	0.847018	0.827474
SPECIFICITY	0.994719	0.902362	0.994122
SENSITIVITY	0.678690	0.784728	0.639910
JACCARD COEFFICIENT	0.674680	0.707031	0.635704
DICE COEFFICIENT	0.805742	0.828375	0.777285

Figure 20: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006718000

Comment- From figure 20 using unsupervised metric concept it can be seen that the mean shape based segmentation has less hole in the lungs region than k means one, so its specificity is more.Circular level set has segmented the lungs but diverged due to less separation of body and lung region.Considering overall parameters from the table mean shape performed better than others in this case.

00006719000:

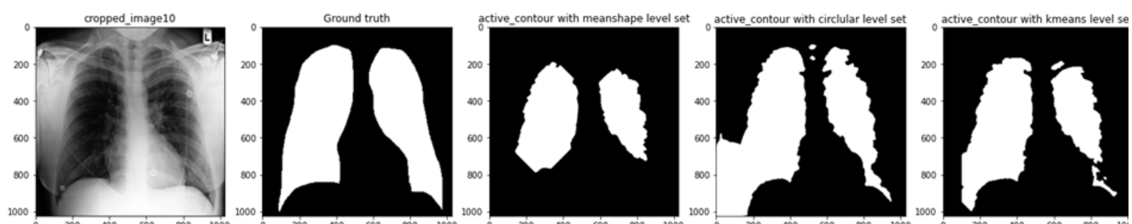


9.00006719_000	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.930755	0.857954	0.901861
SPECIFICITY	0.995531	0.865095	0.950339
SENSITIVITY	0.766442	0.839841	0.778891
JACCARD COEFFICIENT	0.757851	0.625719	0.691751
DICE COEFFICIENT	0.862247	0.769775	0.817793

Figure 21: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006719000

Comment- From figure 21 the mean shape based method has performed well with less false positive detection than the other two. Circular level set has segmented the lungs but diverged due to less separation of body and lung region.Considering overall parameters from the table mean shape performed better than others in this case.

00006720000:



10.00006720_000	Segmentation result of active contour model with Level set generated by mean shape calculation of training data	Segmentation result of active contour model with circular level set	Segmentation result of active contour model with k-means based level set
ACCURACY	0.817800	0.857637	0.871122
SPECIFICITY	0.991318	0.894455	0.974847
SENSITIVITY	0.534975	0.797626	0.702058
JACCARD COEFFICIENT	0.527511	0.680551	0.674409
DICE COEFFICIENT	0.690680	0.809914	0.805548

Figure 22: The morphological active contour segmentation (a)row-1 (i)original image and A comparison of (ii)Ground truth (iii)mean shape based (c) circular level set (d) k-means level set of 00006720000

Comment- From figure 17 the mean shape method has not able to cover the overall positive area i.e

couldn't expand.Circular level set has diverged and segmented the body region rather than the lungs.k-means has segmented true positive and negative region more accurately than the other two in this case.
Overall comment- From above observation, it can be stated that both k-means and mean shape method gives comparable results and the circle based level set gives very uncertain results and hence should not be preferred in this case. Other than above matrices PPV (positive predictive value) can also be referred for comparing the segmentation results. Other than histogram based method other edge enhancement method can be implemented to improve the segmentation performance.