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Framework for progressive segmentation of chest radiograph for efficient diagnosis of inert regions

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ABSTRACT

Segmentation is one of the most essential steps required to identify the inert object in the chest x-ray. A review with the existing segmentation techniques towards chest x-ray as well as other vital organs was performed. The main objective was to find whether existing system offers accuracy at the cost of recursive and complex operations. The proposed system contributes to introduce a framework that can offer a good balance between computational performance and segmentation performance. Given an input of chest x-ray, the system offers progressive search for similar image on the basis of similarity score with queried image. Region-based shape descriptor is applied for extracting the feature exclusively for identifying the lung region from the thoracic region followed by contour adjustment. The final segmentation outcome shows accurate identification followed by segmentation of apical and costophrenic region of lung. Comparative analysis proved that proposed system offers better segmentation performance in contrast to existing system.

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1. INTRODUCTION

Irrespective of presence of various forms of radiological evaluation, chest x-ray is one of the most frequently prescribed by the doctor [1]. It is because chest x-ray is one of the most economical imaging practices that reveal multiple set of clinical information about chest e.g. blood vessels, problems associated with heart, possible fracture of rib cages, actual condition of lungs, outline of heart, any form of calcium deposit, any abnormal changes after surgery, position of implantable devices, etc [2], [3]. However, a chest x-ray also consists of various problems e.g. illumination, rotation of object, opacity, abnormality in contrast and brightness, etc. Such problems acts as an impediment towards accurate diagnosis of any disease related to chest. Hence, for an effective diagnosis, it is necessary that the focus of the radiologist / physician should be only concentrated to identify the correct location of chest. This problem is effectively solved by segmentation process [4]. Basically, when a chest radiograph is subjected to segmentation, it can be expected that the outcome result should be splitting of the chest radiographs into its smaller component in the form of object or region [5]. It basically assists in segregating unnecessary detailing (i.e. background) from the essential object (foreground), so that the diagnosis can be carried out with better accuracy. Another benefit of carrying out segmentation process in chest x-ray is that it assists in quantifying the tissues, identification of any oddities, estimating volume of target object (e.g. malignant / benign masses), etc [6]. In a nutshell, the core objective of the image segmentation methods is to construct a simpler representation of the targeted object or region and therefore the outcome of segmentation process is never single unit. It is a set of component that could collectively formed the actual image. In existing system, there are various authors that have carried out research work towards segmentation considering medical images e.g. [7]-[9]. However, complexities associated with the chest x-ray are quite different compared to other medical images. At present times, there are only two fixed positions for capturing chest x-ray i.e. posterior-anterior position and lateral position. Although, these positions offers 90% visualization to maximum clinical problems associated with chest, but sometime it veils visualization to some critical problems e.g. nodules, masses, lumps, lesions owing to presence of bones (i.e. rib cases, clavicle bone, etc). Therefore, the bigger challenge in performing segmentation is to find such occluded objects and extract the targeted object as foreground.

Due to complexity associated with performing segmentation of such inert region of the chest, majority of the existing research work is found to adopt machine learning techniques or iterative techniques on the basis of certain predefined information. Although, all these existing techniques are claimed to offer good segmentation performance, but their computational performance is quite questionable owing to involvement of higher degree of recursive operation. Therefore, the present manuscript introduces a simple and cost effective framework that is capable of performing segmentation using progressive approach that has acted as a better alternative of recursive approach in existing system. The proposed system also introduces an analytical model to claim the segmentation performance. Section 2 discusses about the existing research contribution followed by brief outlining of problems associated with existing system in Section 3. Adopted research methodology of proposed system is briefed in Section 4 followed by elaborated discussion of algorithm design in Section 5. Discussion of results accomplished in the proposed study is carried out in Section 6 and finally the concluding remarks is done in Section 7.

2. RELATED WORK

This section briefs about the existing research techniques carried out towards segmentation techniques in medical images. Researchers have reviewed about existing imaging techniques of chest radiographs [10] and thereby extend the discussion in the line of chest radiograph explicitly. At present, there are various ranges of techniques implemented for segmentation. The work carried out by Wang and Guo [11] have presented a combined implementation of identifying skin boundary, segmenting contour regions, and refinement of lung region. Most recently, a unique segmentation process of segregating heart from the lung field was introduced by Dai *et al.* [12]. The authors have used convolution-based segmentation technique in order to construct a network that can discretize between the ground truth information and synthesized mask. Adoption of threshold-based segmentation scheme can be observed in the work of Shi *et al.* [13]. The authors have used random walk algorithm in order to segment lung from chest region further curvature-based technique was utilized to smoothen the contours. A non-conventional technique of vector quantization has been found to assist in segmentation as well for chest radiographs as seen in the work of Han *et al.* [14]. The work carried out by Shen *et al.* [15] has used a chain coding technique along with supervised learning algorithm for carrying out lung segmentation focusing on accuracy. Similar direction of emphasis towards accuracy in segmentation performance was also carried out by Chae *et al.* [16]. The author contributed to present a technique for reconstructing region of segmentation thereby enhancing segmentation performance.

Gill *et al.* [17] have presented an atlas-based model for carrying out segmentation using affine transformation scheme. Ngo and Carneiro [18] have presented a deep learning mechanism using level set method for lung segmentation. The technique presents good optimization towards shape features during segmentation. Filho *et al.* [19] have implemented singularity-based technique integrated with region-growing method and thresholding scheme together to perform lung segmentation. Ruiz *et al.* [20] have presented a heart segmentation technique using thresholding based scheme, filtering, and morphological operations. Farag *et al.* [21] have introduced a model that implements shape module along with statistical information about the intensity. The technique also uses a density estimation method using non-parametric approach for effective lung segmentation. Lassen *et al.* [22] have adopted a watershed algorithm for achieving better classification of lung section during transformation process. However, the process involves lack of efficiency in learning process prior to perform segmentation. Such problems of learning were addressed in the work of Feulner *et al.* [23], [24] by using discriminative approach for segmenting lymph node. The authors have utilized graph cut algorithm for carrying out segmentation. Jirapatnakul *et al.* [25] have used surface estimation technique to identify and segment pulmonary masses from chest portion. Lo *et al.* [26] have used region growing mechanism along with morphological operation in order to perform segmentation. The technique also uses fuzzy logic as well as anatomical modeling using semantic features for enhancing the segmentation performance. Usage of fuzzy theory has also been reported in the work of Zhou *et al.* [27] for assisting in segmentation. The technique uses correlation of pixels in order to perform detection. Fuzzy clustering technique was also reported to be used in the work of Ji *et al.* [28] for addressing segmentation problem.

Pu *et al.* [29], [30] have presented a unique tree-based scheme considering curvature of human airway for assisting in threshold-based lung segmentation. The scheme also proved that adoption of radial-basis function can significantly assist in identification of fissures over lung surfaces. Usage of neural network and wavelets is reported to enhance the segmentation methods as discussed in work of Ceylan *et al.* [31]. The authors have also used region-growing method for performing segmentation. Shikata *et al.* [32] have discussed a tree-based algorithm that works along with Eigen values for constructing terminal portions of the tissues on lungs. Chen *et al.* [33] have presented a technique that uses energy function along with kernel for assisting in segmentation. The complete modeling is carried out considering statistical approach. Adoption of region growing technique has also been reported in the work carried out by Jiang *et al.* [34]. Thresholding-based segmentation scheme was witnessed to offer better system performance during segmentation process as seen in the work of Liu *et al.* [35].

There are various literatures towards segmentation problems that has also been considering different medical case study apart from lungs. Enikov and Anton [36] have used machine learning technique for segmenting images with cervical spines. Thresholding-based scheme was adopted by Wang *et al.* [37] for faster process of medical image segmentation. Jiang *et al.* [38] have used level set method along with region growing for performing segmentation of brain images. Incorporation of game theory for improving segmentation was discussed in work of Zhong and Wu [39]. Integrated implementation of edge as well as region was reported in the work of Luo *et al.* [40] where the segmentation performance has been optimized using swarm intelligence. Benefits of multi-thresholding schemes for segmenting brain images was discussed by Liu *et al.* [41]. Study towards automated segmentation is put forward by Mechrez *et al.* [42] considering brain images. The authors have used a recursive patch of images in order to perform segmentation. Similar brain images were also investigated for segmentation by Cong *et al.* [43] who used field estimation technique. Akhavan and Faez [44] illustrated the segmentation algorithm for Retinal blood vessel image by using Fuzzy and medial filter approach and found effective in detection of retinal blood vessels. A research towards automatic medical image segmentation is found in Seada *et al.* [45] and named the model as "ascending aorta". The model outcomes with nealy 95% of accuracy in segmentation. A Doubly truncated K-mean clustering and Laplace mixture model is presented for image segmentation by Jyothirmayi *et al.* [46]. In this, different pixelled images were analyzed the for superiority of model in segmentation.

Hence, there are multiple techniques for assisting in segmentation of medical image in literatures. The next section outlines the problems associated with existing system.

3. PROBLEM IDENTIFICATION

After reviewing the existing system of segmentation, following problems has been identified: i) usage of thresholding, rule, model based, edge-based, pixel-wise classification, and region-based schemes are frequently used for performing segmentation. The significant problems of all the adopted methods are its assumptions being highly heuristic. Hence, they are not much applicable for performing scalable segmentation performance and can be used only in preliminary stages. This problem is more high for rule-based techniques. ii) usage of deformable model-based techniques suffers from significant limitations of higher contrast and prominent occlusion caused by edges of rib cases, higher dependency of reference model, and scattered solution from multiple internal attributes during segmentation, iii) usage of machine learning approach also results in higher dependencies on training operation to be carried out on dataset, iv) lower convergence speed performance, v) majority of the schemes perform segmentation based on pixel related information that increases accuracy of segmentation at the cost of computational complexity. Existing machine learning mechanism performs highly iterative operation that increases the execution time of the segmentation process. Therefore, there is a need of process that performs less iterative operation and more progressive segmentation steps that could offer a better balance between accuracy and computation time. We put forward logic that an effective segmentation algorithm always demand a good equilibrium between computational complexity and accuracy and thereby maintain an optimal scalability performance. The next section discusses about the adopted research methodology in order to address such problems.

4. PROPOSED METHODOLOGY

The proposed study is an extension of previous work [47] where the emphasis was on incorporating multi-level of image pre-processing of chest radiograph. This part of the study introduces a simple and yet novel segmentation policy as showcased in Figure 1. Adopting analytical research methodology, the proposed system takes the input of a queried image and is capable of extracting horizontal and vertical pixel information associated with either intensity or projection. Adoption of this strategy ensures mitigating any form of adverse effect of rotations in the chest radiographs. The proposed system also introduces usage of content-based image retrieval technique in order to narrow down the matching images. The narrowness of the matched image is further boosted with an aid of similarity score between the queried image and dataset. The outcome of this process results in set of 5 matching images arranged on the basis of their ranks. The image with 1st rank is considered for further processing where an extraction of feature is carried out using visual descriptor. Finally, a simple image registration process is implemented that could further ascertain the mapping of input to target image. In the entire process, accuracy of the matched image is highly ensured and therefore a contour-based adjustment is further carried out to eliminate any selection of unnecessary boundary or region of the lung. Applying cubic spline interpolation further make the system more enhanced enough to perform segmentation. The proposed system is also capable of performing segmentation as following i) segmenting complete lung region, ii) segmenting apical region, and iii) segmenting costophrenic region in order to ensure further application of the outcome with respect to clinical inference of chest radiographs.

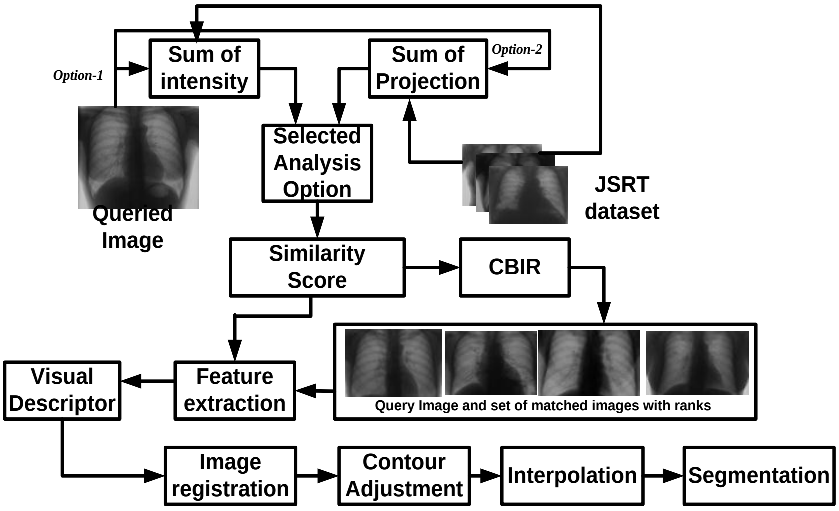

Figure 1. Schematic representation of process flow of proposed segmentation

5. ALGORITHM DESIGN

The proposed system emphasizes on the incorporating a precise segmentation process that can finally assists in disease diagnosis from the given chest radiographs. The mechanism assists in formulating a better search condition by focusing on the entire process of making the input image ready for segmentation. The proposed system consists of 5 sequential algorithms in order to perform an effective segmentation different from existing system i.e. i) Algorithm for processing the input image, ii) Algorithm for content-based image retrieval, iii) Algorithm for local feature selection, iv) Algorithm for image registration process, and v) Algorithm for segmentation. This section discusses about all the algorithms in brief.

1. Algorithm for processing the input image
Input: *I*
Output: H_1, H_2
Start
1. *init* I
2. I=r(I)
3. $S_r=\sum I$
4. 4.$S_c=\sum(I,2)$
5. $[H_1\ b_1]=hist(S_r\ max(S_r))$
6. $[H_2\ b_2]=hist(S_c,\ max(S_c))$
End

The algorithm takes the input I (Input Image) that after processing results in H1 (Horizontal Projection), H2 (vertical projection). The input image I is digitized followed by applying resizing operation r (Line-2). The algorithm computes the summation of row wise elements (Line-3) as well as column wise elements (Line-4). Histogram is formed considering the row elements corresponding to Sr (Line-5) and column section consists of all the maximum values of Sc (Line-6). This operation is essential in the proposed system as it offers the complete segmentation process to be undertaken either on summation of horizontal-vertical elements or on projection of horizontal-vertical elements. The projection operation assists in mitigating any form of rotations in the input image using vertical and horizontal orthogonal projection. This makes the input image free from any forms of rotational effect. The next stage of the algorithm is to apply content-based image retrieval process as shown below:

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2. Algorithm for content-based image retrieval
Input: ϕ
Output: S_{ro}, S_{co}, β
Start
1. For i=1: ϕ
2. $[(H_{10}\ b_{10})\ (H_{20}\ b_{20})] \rightarrow \phi(m\ i)$, where a=1, 2, 3, 4
3. $S_{ro}=\sum(a\ \phi)$, a=5
4. $S_{co}=\sum((a\ \phi), 2)$
5. End
6. For n=1:p
7. $ix_1=b_1==p(n)$, $p_1(n)=H_{10}(ix_1)$
8. $ix_2=b_{10}==p(n)$, $p_2(n)=H_{10}(ix_2)$
9. End
10. For n=1:q
11. $ix_1=b_2==q(n)$, $q_1(n)=H_1(ix_1)$
12. $ix_2=b_{20}==q(n)$, $q_2(n)=H_{20}(ix_2)$
13. End
14. get rw=n/(n+m)
15. For (x y)=1:(n m)
16. $p_t=p_t+\sqrt{\{p_1(x).p_2(x)\}}$
17. $q_t=q_t+\sqrt{\{q_1(x).q_2(x)\}}$
18. End
19. $\beta \rightarrow \alpha.q_t+(1-\alpha).q_t$
20. (m_I m_m)$\rightarrow \phi$ (a ix(1)), where a=5 and 6
21. $(S_{ro}\ S_{co})=\sum$(m_I)
22. obtain $(S_{co}\ H_{10}\ b_{10}\ H_{20}\ b_{20}) \rightarrow \phi$(a, ix(1)),where a=1-4

End

This algorithm takes the input of ϕ (database) that after processing yields to Sro (sum of horizontal intensity), Sco (sum of vertical intensity), β (similarity measure). A specific image dataset ϕ is used where the first and second row element corresponds to horizontal projection H10 and b10 while third and fourth row elements correspond to vertical projection H20 and b20 respectively (Line-2). The algorithm also computes the summation of row-wise (Sro) and column-wise (Sco) element respectively (Line-3 and Line-4). However, the algorithm chooses to consider sum of horizontal and vertical intensity (i.e. Sro and Sco) only upon selection of summation of horizontal and vertical elements. On the other hand, the algorithm selects horizontal and vertical projects (i.e. b10, H10 and b20, H20) upon selection of horizontal-vertical projection. The next part of the algorithm considers similarity coefficient p that computes the common elements between the projections b1 and b10 (Line-6). Considering all the values of p, the algorithm checks the projection b1 of input image to be matching with unit value of projection in the database. Only the horizontal projections H10 are considered for further processing i.e. p1 (Line-7 and Line-8).The similar operation is carried out for vertical projection with similarity coefficient q (Line-10) for calculating q1 and q2 (Line-11 and Line-12). The algorithm also computes the relative weight rw using mathematical expression shown in Line-14, where the variable n and m corresponds to length of p and q. The next part of the algorithm calculates a temporary variables pt (Line-16) and qt (Line-17) in order to compute a final similarity coefficient β using the expression shown in Line-19. A sorting process in descending order is carried out for the obtained value of similarity coefficient. A matrix m_I and m_m represents matched image and (ongoing) matching image respectively (Line-20). Finally, summations of row-wise and column-wise elements are captured (i.e. Sro and Sco) from matched image m_I (Line-21) followed by acquiring of sum of horizontal intensity (Sro), sum of vertical intensity (Sco), horizontal projection (b10, H10), and vertical projection (b20, h20) as shown in Line-22. Therefore, the good availability of projection-based information significantly assists to mitigate any forms of misalignment in the image. At the same time, the algorithm of content-based image retrieval results in good number of most relevant images thereby reducing the effort of search towards

best fit image. The algorithm also makes use of similarity coefficient in order to confirm the relevancy score of the queried image with that of the dataset. Upon selection of the best matched image, the image is now ready to be extracted for its feature using the algorithm below:

---

3. Algorithm for local feature selection
Input: I
Output: im_3
Start
1. $[(im_1\ im_2)\ (des_1\ des_2)\ (loc_1\ loc_2)]=\sigma(p_1\ p_2)$
2. For i=1: des_1
3. [v. in]→sort(ic(dp))
4. If (v(1)<dR.v(2))
5. m(i)=in(1)
6. Else
7. m(i)=0
8. End
9. $im_3 \rightarrow p_1 \| p_2$

End

This algorithm is responsible for extracting local features from the matched image obtained from content-based image retrieval process. The algorithm design is based on visual descriptor of region-based shape method. The algorithm takes the input of I (processed input image) that after processing yields im3 (image with local feature). The variables p1 and p2 represents I*255 and m_I*255 respectively. The algorithm implements a function σ for performing the extraction of local features in the form of sets e.g. (im1 im2) (des1 des2) (loc1 loc2) as shown in Line-1. The algorithm computes the vector of dot product dp of first descriptor (des1) and transpose of second descriptor (Line-3). This operation is further followed by sorting operation in order to obtain v and in maps (Line-3). The algorithm then checks of the v(1) is found more than distance ratio dR multiplied with v(2) than the unit index is assigned to match (Line-5) or else zero is assigned (Line-7). The distance ratio dR only keep matches in which the ratio of vector angles from the % nearest to second nearest neighbour is less than dR. Both the images obtained i.e. p1 and p2 as the outcome. The processed image is further subjected to registration process as shown below:

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4. Algorithm for image registration process
Input: I, m_I
Output: I_{reg}, mw
Start
1. let I_1 and I_2 be I and m_I
2. $[I_{reg}\ m_2] \rightarrow \mu_1(I_2\ I_1, \rho)$
3. $t_{form} \rightarrow \mu_2(I_2\ I_1, \rho)$
4. $mw \rightarrow \gamma(m\_m, t_{form})$

End

This algorithm is mainly responsible for performing image registration process which takes the input of I (processed input image), m_I (Matched image) in order to generate the output of Ireg (registered image), mw (contour adjusted image). The proposed system implements a function as a configuration suitable for registering images using multimodal approach. This function formulates an optimizer as well as metric configuration in order to register the intensity-based image. The variable ρ depicts a set of both optimizer and a metric as a structure with explicit information about different optimizer properties for obtaining convergence over a global maximum. The algorithm implements a function μ1 for registering an image (Line-2) as well as function μ2 for estimating the geometric transformation require to stabilize the moving image (Line-3). The next step of the algorithm is to perform transformation of matched image m_m as per the geometric transformation exhibited by tform. Hence, the outcome mw (Line-4) can be considered as a transformed image that has better adjustment of the contours of the lung regions. The next part of the algorithm continues for final step of segmentation process as shown below:

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5. Algorithm for identifying upper and lower lung segment
Input: I, mw
Output: u, l
Start
1. $y \rightarrow \tau(I)$
2. $bw=\lambda(mw)$
3. $[(x_s\ y_s)] \rightarrow co()$, where $co=f(bw)$
4. $[x_{o1}\ y_{o1}] \rightarrow \Omega(y, var)$
5. 5.($m_1\ m_2) \rightarrow \{arg_{min}(y_{s1}\ y_{s2})\ arg_{max}(y_{s1}\ y_{s2})\}$
6. $u \rightarrow I(nr)$
7. $l \rightarrow I(end\text{-}nr)$

End

The algorithm considers the input as transformed image mw obtained from the prior algorithm (Line-2) and uses a function λ for binarizing the image and thereby resultant image of bw is obtained (Line-2). The next step is to obtain the binarized boundaries co of the processed image bw (Line-3). The system than extracts the binarized boundaries with respect to explicit rows in order to obtain (xs1 ys1) and (xs2 ys2). A filtering function τ is invoked on image I (Line-1) followed by applying recursive process Ω (Line-4) considering different variables var. Finally, the segmented image is generated by conjoining (xs ys) and (xo yo) points as follows: the algorithm extracts the minimum arguments of (ys1 ys2) and maximum arguments of (ys1 ys2) in order to form m1 and m2 respectively (Line-5). The algorithm extracts number of rows nr and number of columns nc from input image I and obtains the upper portion u (Line-6) and lower portion l (Line-7). A closer look into the algorithm shows that proposed segmentation technique is quite different from all conventional segmentation technique in following manner viz. i) it is progressive and not iterative as seen in existing techniques in literature, ii) the segmentation operation is more into optimizing the detection performance unless existing system that only focuses on detection, iii) the image registration process followed by contour adjustment further fine-tunes the edges of lung region without even applying conventional edge-based segmentation process. This causes the algorithm to obtain more accurate information about lung region and performs faster identification of it. The next section outlines the result obtained by proposed study.

6. RESULT ANALYSIS

The assessment of the proposed study has been carried out using Japanese Society Radiological Technology (JSRT) dataset of chest radiograph where the size of the images is 8,192 KB. All the images are gray-scale images with color depth of 12 bit. This size is quite bigger compared to conventional medical images.

The study outcome of the proposed system has been compared with the existing segmentation techniques. There are diverse studies in literatures pertaining to segmentation and hence we choose the one that is frequently adopted in segmentation i.e. edge based, threshold-based, and region-based schemes. Table 1 highlights the outcome of comparative analysis of proposed and existing system with respect to Edge-based, threshold-based, and region-based.

Table 1. Outcome of Comparative Analysis

Performance Factors	Existing [47]			Proposed
	Edge-based	Threshold-based	Region-based	
Execution Time (s)	1.01968	1.0265	4.2841	0.5487
Accuracy (%)	97%	98%	94%	99%

The region-wise segmentation process results in generation of too much redundant information on the basis of certain pre-defined factor. Therefore, execution time is more compared to others. Edge-based being the most frequently adopted technique that essentially depends on either histogram or gradient-based information that increases the accuracy compared to region-based. However, its performance is nearly similar to threshold-based segmentation technique. The prime reason for enhanced accuracy of proposed system are i) narrowing of search objects from dataset on the basis of similarity score, ii) usage of region-based shape descriptor for further ensuring the correct selection of lung region, iii) image registration process integrated with contour adjustment to finally identify the lung region followed by spine interpolation, and iv) capability to identify the apical and costophrenic regions. Moreover usage of features to perform segmentation further reduces the search time for similar object causing reduction in execution time for proposed system.

7. CONCLUSION

The contribution of existing literatures towards segmentation process in chest x-ray has not yet addressed the problem associated with the position of capturing the radiograph. The proposed study considers certain set of problems e.g. i) conventional position of capturing chest x-ray limits the visibility of certain inert object and may potential acts as impediment in segmentation process, ii) existing segmentation techniques are more inclined in using iterative operation that offers accuracy at the cost of computational complexity, iii) more frequently existing techniques e.g. rule based, machine-learning based, threshold-based, region-based, edge-based doesn't assist much in addressing the problem of progressive segmentation. A simple and novel progressive segmentation process is introduced where emphasis was on reduction of iterations towards segmentation process. The study outcome shows enhanced accuracy and reduced execution time as compared to frequently used segmentation algorithms.

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