A Hierarchical Segmentation Model for the Lung and the Inter-costal Parenchymal Regions of Chest Radiographs

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Abstract

A hierarchical image model is used for segmenting chest radiographs. First, we use an Active Shape Model (ASM) to segment the lungs. Then, using the segmented lung, we initialize the segmentation of the inter-costal parenchyma regions, using another four ASM models. We have found that the overall segmentation system is robust, and has been able to adapt to variations in lung height and in the number of inter-costal parenchyma regions.

1. INTRODUCTION

Segmentation is a very important step in the development of an automatic classifier system for grading chest radiographs of pneumoconiosis (a dust exposed lung disease). It is the first step for feature extraction and classification. The inter-costal parenchyma contain important diagnostic information such as opacities and lesions which make it necessary for them to be segmented. Active Shape Modeling (ASM) is the tool used here for segmentation.

A number of investigators have been successful in applying active shape models for segmentation of medical images [1]. Here, we use the ASM model developed by Cootes et al. [2]. In this study, we use the ASM model to segment chest radiographs. The radiographs come from a cohort of miners who have been exposed to silica dust particles.

The segmentation model is based on the ILO standard database of chest radiographs. The standards were created in 1980 by the International Labor Organization (ILO) to implement a "reading" system [3] and to standardize the interpretation of chest radiographs associated with pneumoconiosis. The ILO standard was designed specifically to systematically record radiographic changes that reflect the inhalation of dust [1, 4] in order to assess the progression of the disease through the objective, though qualitative, evaluation of abnormalities in the chest x-rays.

An automatic lung and parenchyma segmentation system is developed and tested. A series of experiments for developing the system and establishing its robustness is presented in Section 2. The results of these experiments are summarized in Section 3. Concluding remarks are presented in Section 4. The research presented here is a continuation of our prior work presented in [4,5].

2. MATERIALS AND METHODS

2.1 Data Set

The ASM model for all the tests was derived from 14 "standard" chest x-rays. The ILO standard x-rays consist of 14 films that are representative of the three main profusions (1, 2, and 3), and the six size and shapes of the opacities (p, q, for rounded and s, t, u for irregular).

2.2 Ground Truth

A trained medical research assistant performed the manual segmentation of the ILO standards and 50 chest radiographs from the database. The manually segmented x-rays were reviewed by two B-certified radiologists.

The ground truth was performed manually, by segmenting 16 parenchyma regions in each lung. To be able to identify the same ASM points in each radiograph, training points included extremities in the parenchymal regions, points where posterior and anterior ribs met. The lungs were divided into four parenchymal regions, two for the left and two for the right lungs. Each parenchymal region included four parenchymas.

2.3 Experiments

The segmentation process was sub-divided into a number of steps, aimed at complete segmentation of the lungs and parenchymal regions. The basic idea is to first segment the lung. Once the lung has been segmented, we automatically estimate the height of the lung. Then, the parenchyma regions are segmented according to a sub-model

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based on height. The steps are summarized below:

Step 1. Segment the lung
Step 2. Initialize parenchyma models
Step 3. Classify the lung as tall/short.
Step 4. Center the parenchyma models
Step 5. Segment the parenchyma.

Lung Segmentation

The first step towards automatic segmentation was to determine whether the lung model had to be centered or not (for each lung). Then, if it had to be centered, determine a method for centering.

ASM training based on ILO images, testing on Raton images

The first experiment was to calculate the RMS errors for segmentation based on images from two separate databases. The scanned images from the ILO database were used for training. Then, the segmentation was tested on 25 images from the Raton database. Using the manually segmented images, the error was calculated for all the four sides of the lung; top, bottom, left and right and finally the mean error of all the four sides.

ASM training and testing on Raton images

The second experiment conducted was to calculate the RMS errors when both the training and test sets were chosen from the Raton database. In this experiment, 25 images were used for training and the rest were used for testing. For testing, the same 25 images were used as in previous experiment.

Parenchyma model initialization

For comparing different methods of parenchyma region segmentation, we estimate the sensitivity of each method. Sensitivity was defined in terms of the number of pixels correctly segmented as parenchyma (true positive (TP)), and the number of pixels missed as part of the parenchyma (false negative (FN)). The sensitivity was computed using: Sensitivity = TP / (TP + FN).

ASM training based on the number of parenchyma regions

In order to improve the segmentation using ASM, a new training protocol was designed. One important feature which all the images had was that the each lung showed either 8 or 9 parenchyma regions, and the images were divided accordingly. Fourteen standard ILO images were used in the training set. Each lung was divided into two regions of 4 parenchyma regions each.

ASM training based on lung height In order to automatically determine whether a lung contains 8 or 9 parenchyma, we use the estimated lung height. Here, we assume that "short lungs" most often have 8 parenchyma regions, while "long lungs" have 9 parenchyma regions. Lungs were classified as "short" if their length was below a certain threshold. Otherwise, they were classified as "long". For minimum misclassification error, the optimal threshold was estimated over 200 images.

Lung classification

The basic problem was to design an algorithm which can estimate the height from the ground-truth or ASM point files, and then use the estimated height to classify lungs as wither "short" or "long". First, we estimate lung height from the extreme points of the lung model, and compare against manual measurements

Parenchyma segmentation

From the results of the lung-classification step, we select the appropriate parenchyma model (short or long). Then, we use the average translation vector used in segmenting the lung, to estimate a translation vector for initializing the parenchyma models.

3. RESULTS

3.1 Lung Segmentation

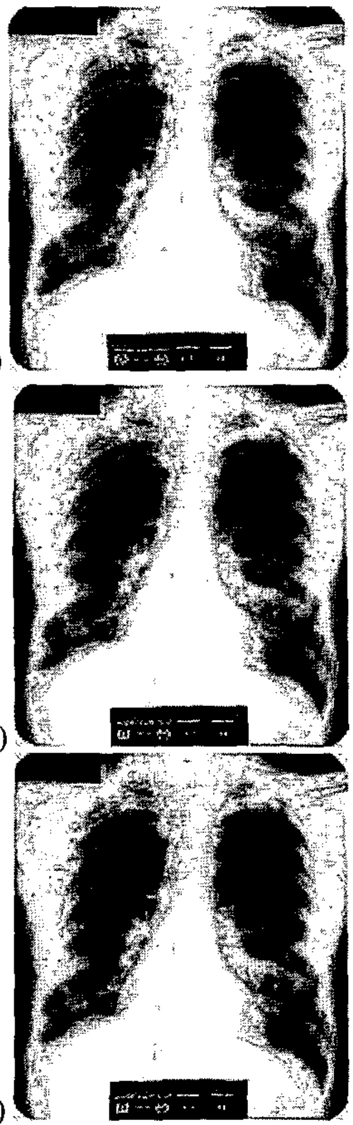
A comparison of the results in Table 1, suggests that the RMS errors in the second experiment were far less than for the first experiment. A t-test was also performed to establish that these two samples have a significant difference. At the 95% confidence level, ($p<.05$), the means were found to be statistically different. Thus, training and testing on the Raton dataset gave the best results.

Table 1. Errors for ILO (upper) and Raton (lower) training sets.

	Left	*Right*	*Bottom*	*Top*
Mean	48.24	41.16	70.52	73.32
Median	43.00	34.00	44.00	71.00
Std.Dev.	26.19	24.55	59.44	47.66

	Left	**Right**	**Bottom**	**Top**
Mean	52.41	35.66	49.20	45.88
Median	45.50	23.00	37.50	42.50
Std.Dev.	33.38	24.87	31.77	26.02

Figure 1. Comparison of baseline 2(a), parenchyma-number based 2(b), and height-based 2(c) segmentation for the same image 2(a).



(a) (b) (c)

The second result of this experiment was to show that there was no need to center the lung model. This eliminates the manual process of centering the lung model.

3.2 Parenchyma model selection

The results of the 8-parenchyma and 9-parenchyma models are summarized in Tables 2 and 3. There is clearly a substantial improvement in parenchyma segmentation performance by using the two models, as opposed to using a single model (baseline) for all cases.

3.3 Lung classification

The results of estimating lung height from the ASM-segmented lung are shown in table 4. It is clear that the algorithm can successfully estimate the lung height, and thus be used for classifying images into tall and short. Then, using the lung classification result, we select the corresponding 8-parenchyma (for short), or 9-parenchyma (for long) model (see Figure 1).

3.4 Parenchyma model initialization

An example of the parenchyma model initialization is shown in Figure 2. Clearly, initializing the model can help model convergence.

3.5 Parenchyma segmentation

Strong improvements on classification performance were observer over the original single parenchyma model approach.

4. CONCLUSIONS

The necessity of using at-least two separate parenchyma models has been established. Furthermore, parenchyma model selection is done using a hierarchical approach. First, the lung is segmented, and the results of the lung segmentation are used to select the appropriate parenchyma model, as well as to initialize the parenchyma model to achieve convergence. The system is currently tested over 400 cases.

Table 2. Results for 8-parenchyma images.

New:	Baseline:
Average = 0.63	Average = 0.88
Std Dev = 0.04	Std Dev = 0.26
Median = 0.88	Median = 0.73

Table 3. Results for 9-parenchyma region.

New	Baseline
Average = 0.86	Average = 0.69
Std Dev =0.05	Std Dev =0.15
Median = 0.85	Median = 0.68

Table 4. Height measurement results.

	ground-truth	estimate
Average	10.22	10.18
Std Dev	0.97	0.96
Median	10.17	10.19

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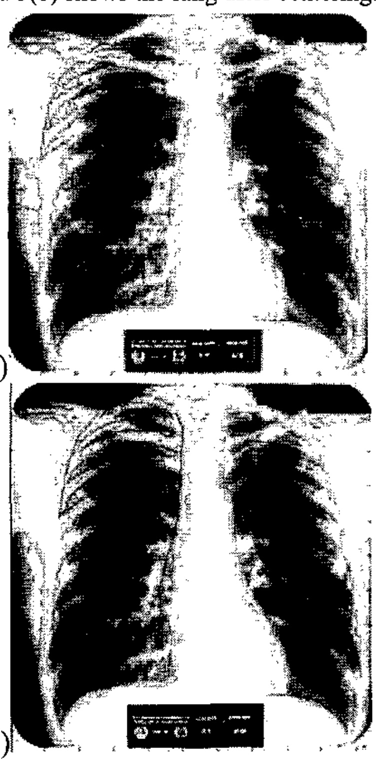
Figure 2. Centering the parenchyma model. In 3(a), the lung is shown before centering, and 3(b) shows the lung after centering.



(a)

(b)

References

[1] U. Grenander, Y. Chow, D. Keenan, HANDS. *A pattern theoretical study of biological shapes*, Springer Verlag,New York, 1991. 96

[2] T.F. Cootes, J. T. Taylor, D. H. Cooper and J. Graham, *The Use of Active Shape Models for Locating Structures in Medical Images.* Image andVision Computing, July 1994. 12(6): p. 355-356.

[3] *Guidelines for the use of ILO international classification of radiographs of pneumoconioses,* 1980. International Labour Office: Geneva.

[4] M. S. Pattichis, J. Ramachandran, M. Wilson, C. S. Pattichis, and P. Soliz, " Optimal Scanning, Display, and Segmentation of the International Labor Organization (ILO) X-Ray Images Set for Pneumoconiosis," in *Proceedings of the 14th IEEE Symposium on Computer-Based Medical Systems,* Bethesda, MD, July 26-27, 2001.

[5] J. Ramachandran, M. S. Pattichis, and P. Soliz, "Pre-Classification of Chest Radiographs for Improved Active Shape Model Segmentation of Ribs," in *5th IEEE Southwest Symposium on Image Analysis and Interpretation,* Santa Fe, New Mexico, 7-9 April, 2002, pp. 188-192.