SEGMENTATION AND GRADING SINUS IMAGES

EISAK SAGIMAN

ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS

JUNE 2010

SEGMENTATION AND GRADING OF SINUS IMAGES

By

EISAK BIN SAGIMAN

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Segmentation and Grading of Sinus Images

by

Eisak bin Sagiman

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:

____

Project Supervisor
Dr Aamir Saeed Malik

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Eisak bin Sagiman

ACKNOWLEDGEMENTS

This project would not have possible without the help of a few important people and I would like to express my gratitude to all of them.

First of all, my deepest appreciation goes to my project supervisors, Ms Lila Iznita Izhar and Dr. Aamir Saeed Malik who took me under their wing, and continuosly monitor my progress and guided me throughout this project. I would like to thank them for all the advices and support.

Next, I am grateful to Pantai Hospital and Fatimah Hospital, Perak, for consenting to collaborate in this project. I am also thankful for valuable knowledge-sharing with them and the data obtained.

I would like to take this opportunity to thank my family and my friends for their never-ending support in every challenge I face in my life. They were always there for me, sharing the delight of a new experience and also the difficulties that came with it. Thank you.

Finally, thank you to all who have directly or indirectly assisted me throughout this project. Your kindness will always be remembered.

ABSTRACT

This report discusses the research done and basic understanding of the proposed topic, which is **Segementation and Grading of Sinus Images.** The objective of the project is to experiment and explore the usage of wavelets to improve the flaws of the existing techniques. In this project, a trajectory-learning algorithm using contourlets is proposed to enhance the CT sinus image without sacrificing accuracy. The challenge in this project is to find the most favorable contourlets that will result in high accuracy. Watershed segmentation was used to segment the images into meaningful regions for the detection of sinusitis. MATLAB is used as the platform for the whole project.

Keywords: **sinusitis, segmentation, contourlet, watershed**

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Computed Tomography is a noninvasive medical test that helps physicians diagnose and treat medical conditions [1] such as sinuses. The images from CT scan of the face will show a patient's paranasal sinus cavities. These paranasal sinuses are the hollow, air-filled spaces located within bones of the skull, and the moist. There are four pairs of sinuses that each is connected to nasal cavity by small openings which are namely the frontal sinuses, the maxillary sinuses, the ethmoid sinuses, and the sphenoid sinuses. The CT scan images is reliable in detection of sinusitis, therefore CT scan is usually used by physicians than X-ray and magnetic resonance imaging (MRI) [1].

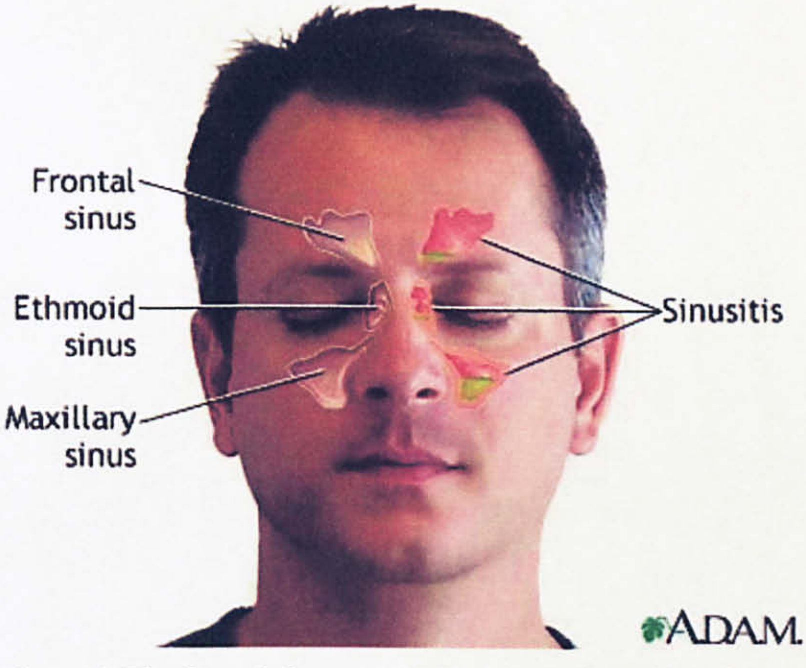


Figure 1: The frontal sinus, ethmoid sinus and maxillary sinus

1.2 Problem Statement

In general, there are two main problems for detection of sinusitis using CT scan sinus images. First, they are difficult to diagnose sinusitis and the second are problems with manual segmentation of sinus images. Images of sinusitis that be taken using CT scan must be interpreted by doctors manually and this gives room for inconsistency or in some cases, inaccuracy. There may be different interpretations from one doctor to another. This variable can be caused by quality of the images and different levels of experiences. Due to complex anatomy paranasal sinuses, the variability may be particularly high. Therefore, this will affect the efficient detection and diagnosis of sinusitis through CT scan images.

The segmentation is used for diagnosis and surgical planning. At present, manual segmentation and semi-automatic are used. These segmentations are taking too much time, so it's not reliable for everyday surgical workflow. There is a great need to enhance the CT scan sinus images, so the efficiency for detection of the sinusitis will be much better. The automatic and reproducible algorithms should be developed to increase the efficient diagnosis of sinusitis.

1.3 Objective

The objective of this Final Year Project is to develop method for computerized segmentation of CT sinus images. The input images will be segmented into three distinct regions; the bone, mucous and the hollow area of the sinuses. From the output images, it should be able to apply for grading the sinusitis. In addition, this application can develop the standard of grading to help the doctors nowadays.

1.4 Scope of Study

The scope of the project is primarily to approach the method for removing the noise and enhancement the input images before segmentation. The input images will be processed and analyzed by computerized system using MATLAB.

CHAPTER 2

LITERATURE REVIEW

2.1 Sinusitis

Sinusitis simply means the paranasal sinuses are infected or inflamed which may be infected from bacteria, fungal, viral, allergic or autoimmune issues. There are two types of sinusitis; acute and chronic sinusitis. Acute sinusitis happens for less than 4 weeks and if the sinusitis happens more than 4 weeks, it will know as chronic sinusitis. Acute sinusitis is normally caused by viral infection and the chronic can be caused by allergy, bacterial and fungus infection. The prevalence rate of sinusitis refers the estimated population of people who are managing the disease at any given time. Based\ on this calculation, the estimated prevalence rate in Malaysia is 3,199,749 people, or approximately 12.8% [2].

2.2 CT Scan

Computed Tomography (CT) scan is more useful in visualizing sinusitis and commonly used by physicians. CT scan is more sensitive compared to X-rays and the sinus CT scanning has a high sensitivity but a low specificity for diagnosis acute sinusitis [3]. In children and adults without symptoms of sinusitis, the prevalence of sinusitis on CT images is 45% [4]. CT scan is the main tool for diagnosis the sphenoid sinusitis. CT scan establishes the presence of sphenoid sinusitis disease and provides information on bony erosion [5]. An air-fluid level usually is observed in acute sinusitis, while complete opacification is more common in chronic sinusitis [5].

2.1 Contourlet Transform

2.1.1 Background

The transform represents images as a linear combination of basic functions. Those basic functions are localized in spatial domain, and have elongated supports at various scales, direction and aspect ratios. Thus, the basic elements are similar to contour segments and hence the name – "contourlets". The idea behind the development of this transform is to create a transform that uses basis functions that resemble the localization, orientation and directionality properties of the human visual system (HVS). By that, which means representing a given natural images by a small number of significant coefficients.

2.1.2 The Technique

The transform is constructed by iterated double filter bank. Each iteration of decomposition is constructed of two main stages; Laplacian pyramid (LP) and Directional filter bank (DFB). The LP is used in order to achieve the multiscale property of the transform. Once an image passes the LP, it is decomposed into an approximation image which contains low frequencies, or alternatively, is a coarse scale image and a detail image which contains the complementary high frequencies, or alternatively, can be regarded as a fine scale image. The detail image contains point discontinuities in the image, namely edge points. The detail image is then fed to the DFB. The DFB is a set of filters that partition the 2D frequency domain into wedges at different orientations, since every filter has a wedge like support in frequency domain (Figure 2)

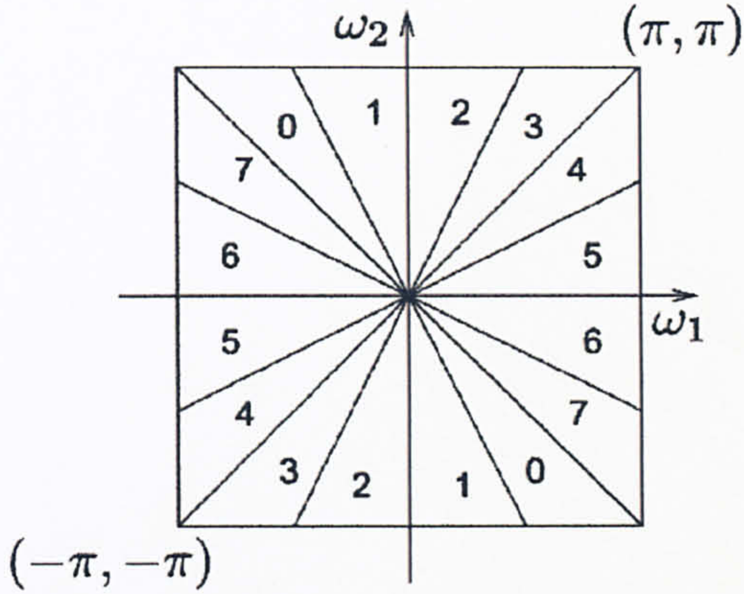


Figure 2: Frequency partitioning into 8 directional subbands by a DFB. This DFB contains filters with a real values frequency responses, hence the symmetry in frequency domain.

Another important property of the directional filters is that their impulse response is well localized in spatial domain. In addition, due to the wedge like support in frequency domain, the DFB impulse responses exhibit directionality (Figure 3).

Figure 3: Impulse reponses of 32 directional filters. Those filters correspond to mostly horizontal directions.

Therefore, the DFB decompose the image into different orientations, thus grouping the point discontinuities revealed by the LP into linear structures at different orientations. Those linear structures represent contour segments. Then this procedure is performed iteratively on the approximation image until the desired level of decomposition is achieved (Figure 4).

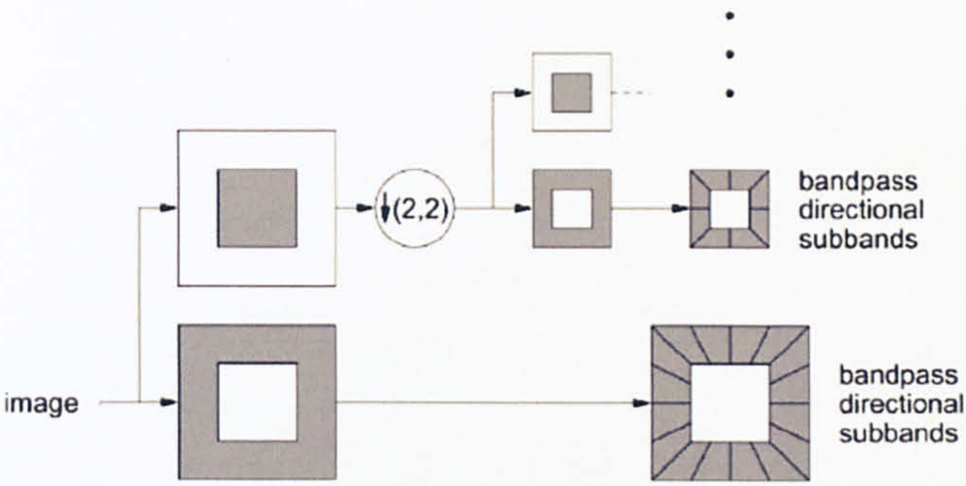


Figure 4: The contourlet filter bank diagram. First the LP is applied to the image. Then, a DFB is applied to the bandpass image. The procedure is iteratively repeated using a decimated version of the lowpass image as input to the next stages

2.4 Watershed Segmentation Methods

A grey-level image may be seen as a topographic relief, where the grey level of a pixel is interpreted as its altitude in the relief. A drop of water falling on a topographic relief flows along a path to finally reach a local minimum. Intuitively, the watershed is a relief corresponds to the limits of the adjacent catchment basins of the drops of water.

In image processing, different watershed lines may be computed. In graphs, some may be defined on the nodes, on the edges, or hybrid lines on both nodes and edges. Watersheds may also be defined in the continuous domain. There are also many different algorithms to compute watersheds. For a segmentation purpose, the length of the gradient is interpreted as elevation information.

Different approaches may be employed to use the watershed principle for image segmentation [6];

- Finding the markers and the segmentation criterion (the criterion or function which will be used to split the regions - it is most often the contrast or gradient, but not necessarily).
- Perform a marker-controlled watershed with these two elements.

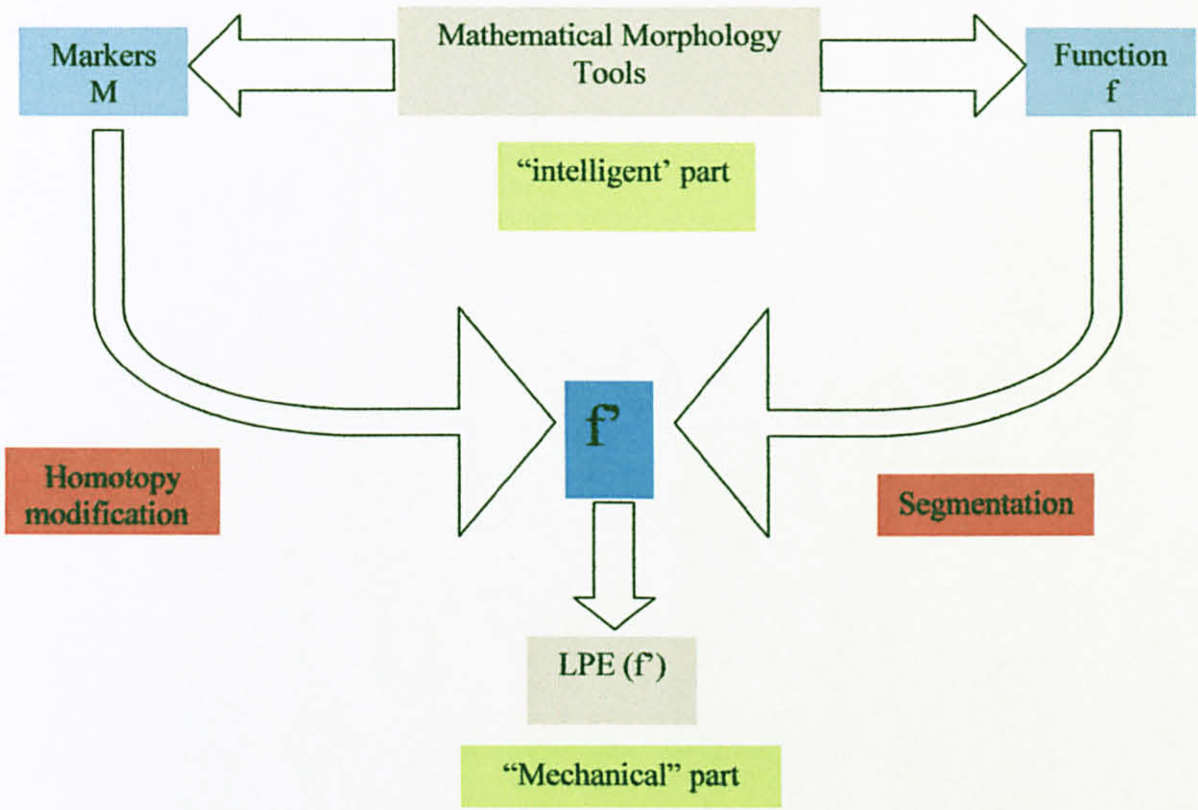


Figure 5: The segmentation paradigm

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

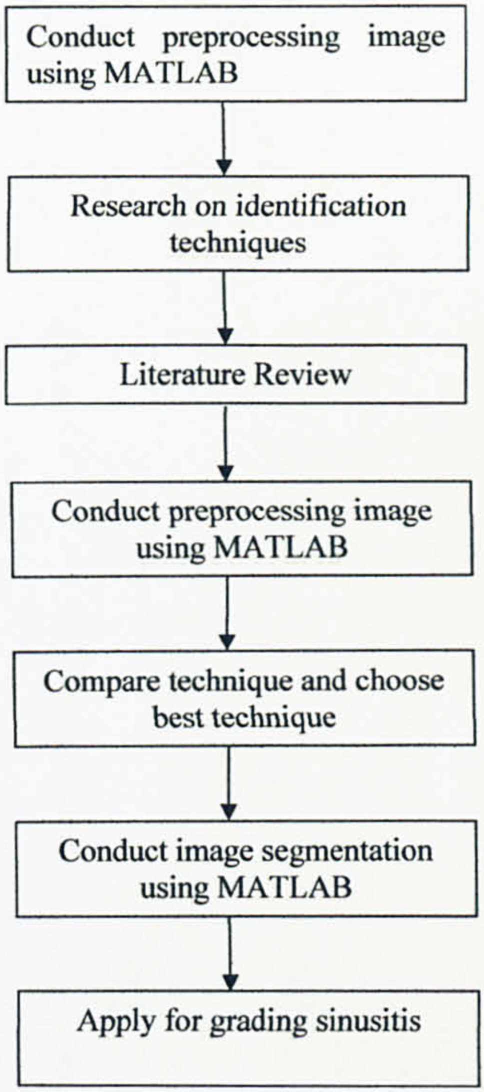


Figure 6: Project flow chart

3.2 Research Methodology

This study used CT scan sinus images as input images. Firstly, noise reduction and image enhancement will be using the contourlet transform. After that, watershed algorithms will be used for the segmentation of sinuses images. The segmented images will be used for the applications which are grading of sinusitis. The research methodology is summarized in the following flowchart.

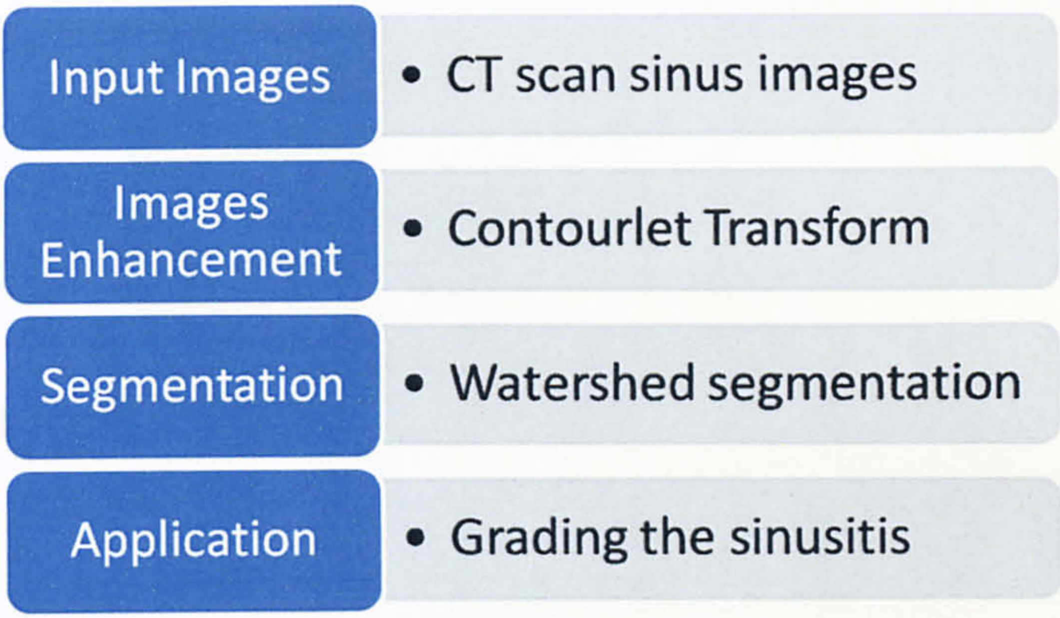


Figure 7: Research Methodology

3.3 Tools

3.2.1 Software

The software used to perform simulations is the MATLAB 7.4.0 (R2007) software.

3.3 Image Enhancement

3.3.1 Contrast Image Enhancement

The main procedure for edge based contrast enhancement is to implement the desired transform at first, applying the enhancement function to transform coefficients. Commonly uses GAG enhancement function is as follows [7]:

$$E(v) = \begin{cases} 0 & |v| < T_1 \\ sign(v)T_2 + \tilde{a}(sign(c(u-b)) & \\ -sign(-c(u-b)) & T_1 < |v| < T_2 \\ v & otherwise \end{cases} \quad \text{..................(1)}$$

where $v \in [-1,1]$, $\tilde{a} = a(T_3 - T_2)$, $b \in (0,1)$, $u = sign(v)(|v| - T_2) / (T_3 - T_2)$, c is a gain factor and the value of parameter a is chosen so that the enhancement function will be continuous.

The proposed enhancement function is much faster and simpler:

$$E(u) = u \cdot sign(u) \cdot tanh(b \cdot v) \cdot (1 + c \cdot exp(-v^2)) \quad \text{..............................(2)}$$

where $v = 2.5 \cdot u/(t \cdot M)$, in which u is a coefficient amplitude in transform domains, M is the magnitude of the maximum coefficient amplitude. In this formula, $t \cdot M$ is a threshold which shows that the coefficients larger than this threshold will be linearly amplified. The parameter b and c together, determine the gain needed in each amplitude interval. The output of this function for M = 1, b = 1, t = 0.8 and different values of the parameter c are shown in Figure 6.

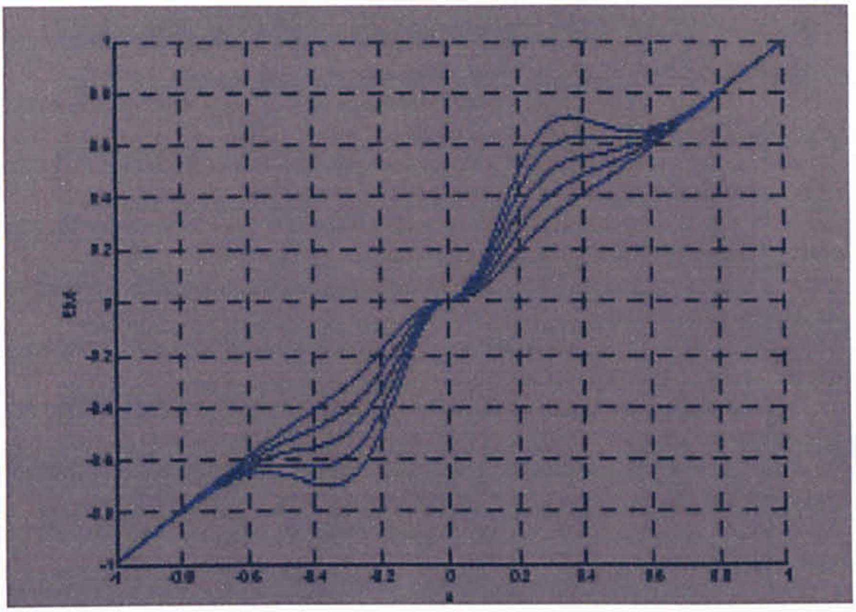


Figure 7: The output of the enhancement function for M = 1, b = 1, t = 0.8 and c = 1, 2… 5.

As it is clear, the enhancement curve is monotonic for the lower values of c, but for larger values, a local maximum is generated. This local maximum can give rise to larger amplification of the middle interval than the first or last interval. Sometimes this local maximum is undesired and rejected. It means that these local maxima may change the location of edges in the image. To achieve this goal, the lower value or equal to 3 of c will be used.

Main advantage of this method is its simplicity and infinitely differentiability. Since the locations of discontinuities must remain unchanged after this function, the importance of this property will be clear. The other important advantage of proposed function is its ability for denoising. As depicted in Figure 6, this function can remove very small values of the transform coefficient which usually are related to image noise. Even in natural noise free images, this small interval just clarifies the input image by removing tiny noise-like object. To change the threshold of this interval, the parameter can be adjusted or make use of piecewise form of this function.

3.4 Image Segmentation

3.4.1 Watershed Segmentation

Location of the watershed in an image can be determined from the watershed segmentation algorithm. Using this information, the image can be separated into different regions using their own set of closed curves. This principle shows that the image can be viewed as a surface. In addition, the gradient local minimum of each region as a hole from which the water will rise up. Therefore, the two basins will converge on interchange, so a dam will be built up to the highest elevation as watershed line [8]. The watershed line shows as Figure 8.

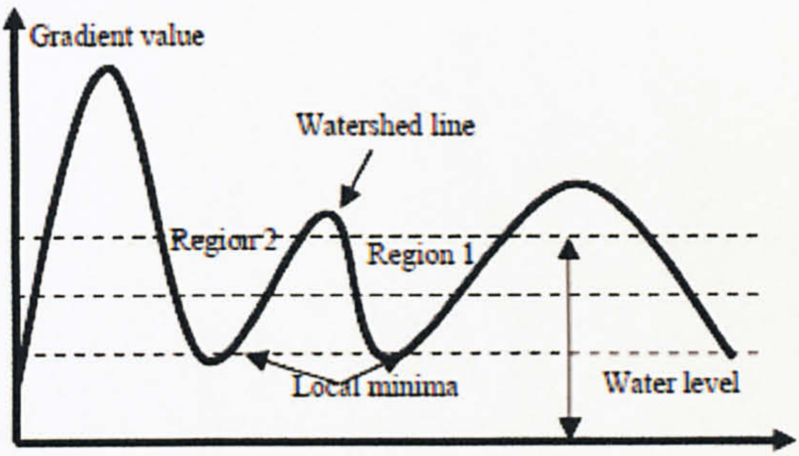


Figure 8: The scheme of watershed algorithm

This process will be repeated until the entire image is completely immersed in water. Thus, watershed line which represents a segmented region will surround each local minimum. In the project, two approach of watershed segmentation has been performed.

3.4.2 Watershed Segmentation Algorithm1

The first proposed method as the flow chart show below:

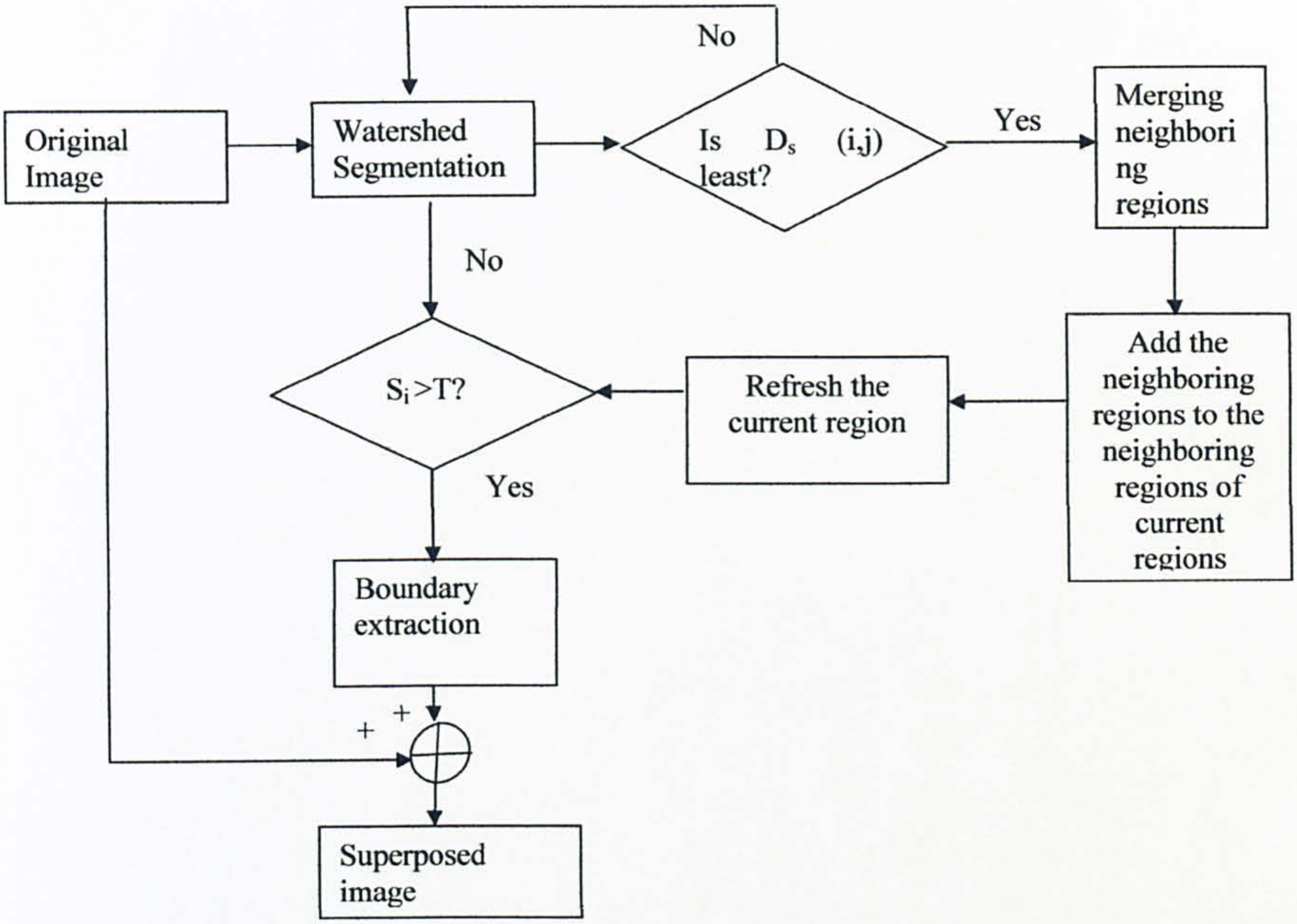


Figure 9: The flow chart of Algorithm 1

A comprehensive distance measure function Ds (i,j) of neighboring region has been defined based on image gray information, edge information and relationship between neighboring regions [8]. The formula is as below:

$$D_s(i,j) = D_e(i,j)\cdot D_T(i,j)\cdot m(i,j) \cdots\cdots\cdots\cdots\cdots (3)$$

Where De(i,j) = |mi-mj| denotes gray distance of two region, mi and mj is the mean of intensity values of region i and j respectively. A simple threshold based on the area of gray image is been used during the merging stop stage. The formula is as below:

$$T=\frac{S}{t} \quad \text{:} \cdots\cdots\cdots\cdots\cdots (4)$$

3.4.2 Watershed Segmentation Algorithm 2

The algorithm works on a gray scale image. During the successive flooding of the grey value relief, watersheds with adjacent catchment basins are constructed. This flooding process is performed on the gradient image.

1. A set of markers, pixels where the flooding shall start, are chosen. Each is given a different label.
2. The neighboring pixels of each marked area are inserted into a priority queue with a priority level corresponding to the gray level of the pixel.
3. The pixel with the highest priority level is extracted from the priority queue. If the neighbors of the extracted pixel that have already been labeled all have the same label, then the pixel is labeled with their label. All non-marked neighbors that are not yet in the priority queue are put into the priority queue.
4. Redo step 3 until the priority queue is empty.

The non-labeled pixels are the watershed lines.

The paths of pixels that converge towards a common minimum constitute a catchment basin. The advantages using this method are it able to produce a complete division of the image in separated regions even the contrast is poor. In addition, it is fast, simple and intiutive method [9]. For the second watershed segmentation algorithm can be interpret as below;

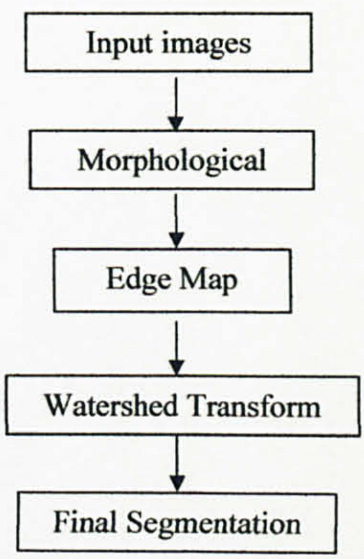


Figure 10: The flow chart of Algorithm 2

3.5 Grading of Sinusitis

After the segmentation, the Algorithm 2 gives a better result than Algorithm 1. Then, the grading algorithm was performed after the segmentation. The method for grading is region growing. Using this method, the seeds will be placed on the mucous areas and hollow areas. So, the total area of sinuses can be obtained. Extracting the mucous areas and hollow areas ensures that grading can be performed on sinuses of different sizes, making this method robust. This extraction can be obtained from the segmentation before.

The Equation (4) is showing how to calculate the severity factor. Therefore, the range of the ratio is from zero to one. The highest the ratio means the more affected the sinuses with sinusitis [10]

$$Severity\ factor = \frac{total\ area\ of\ mucous\ area}{total\ area\ of\ sinuses} \qquad \text{..................(4)}$$

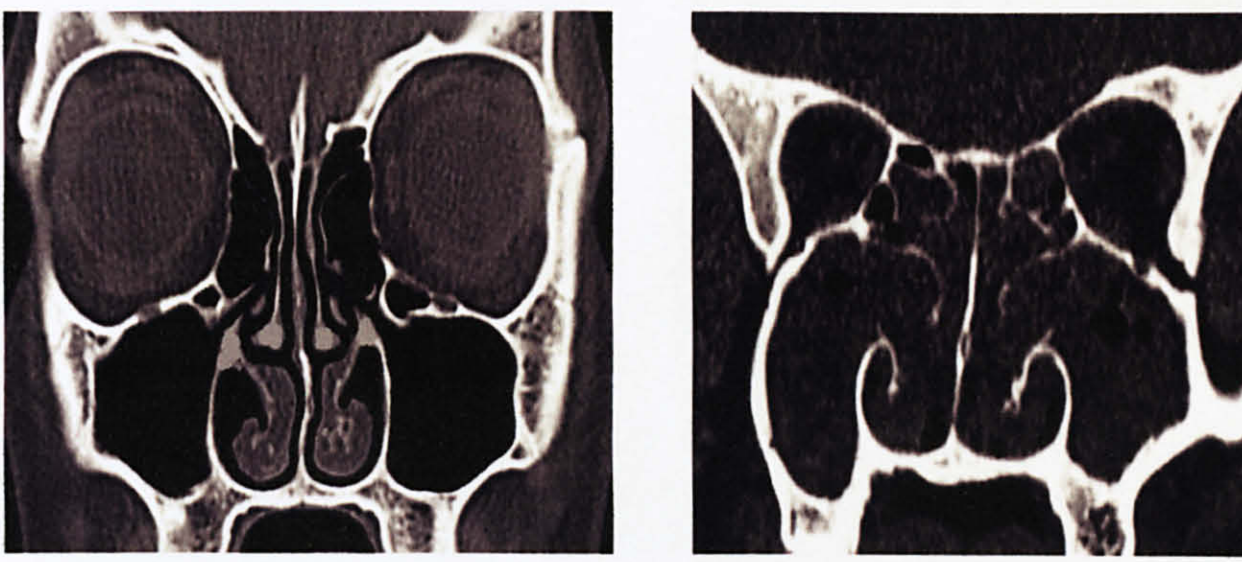
where

total area of sinuses = total area of mucous areas + total area of hollow areas

CHAPTER 4

RESULTS AND DISCUSSIONS

Simulations were performed on both images of healthy sinuses and sinuses with sinusitis. Based on Figure 10, the healthy sinuses are entirely black, indicating the absence of mucous while the sinuses with sinusitis are grey with patches of black, indicating a strong presence of mucous.



(a) (b)

Figure 11: (a) Input image of healthy sinuses (b) Input image of sinus with sinusitis

4.1 Results

4.1.1 Enhancement and Segmentation

Figure 12.1: Input image of sinus with sinusitis

Figure 12.2: Image after Contourlet enhancement

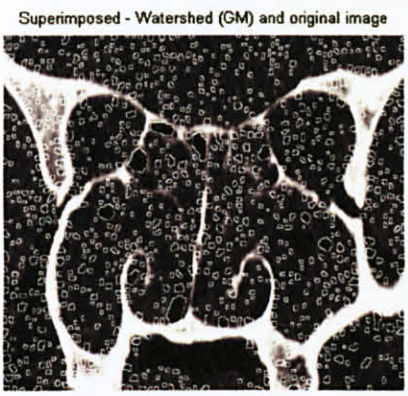


Figure12.3: Image after watershed segmentation using Algorithm 1

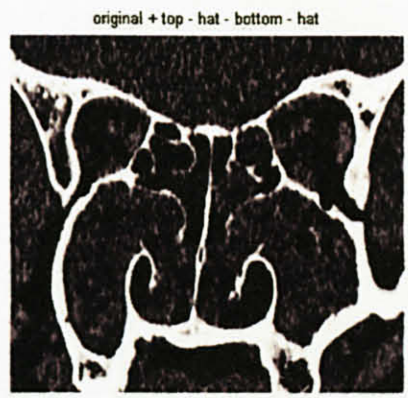


Figure 12.4: Image after watershed segmentation using Algorithm 2

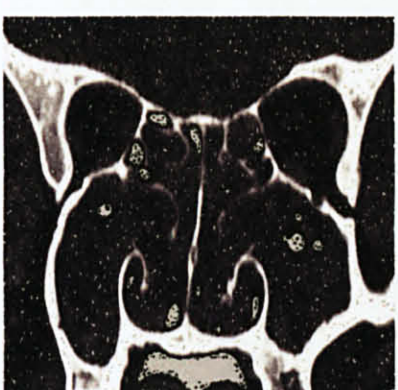


Figure 12.5: Image after Contourlet enhancement and watershed segmentation using Algorithm 1

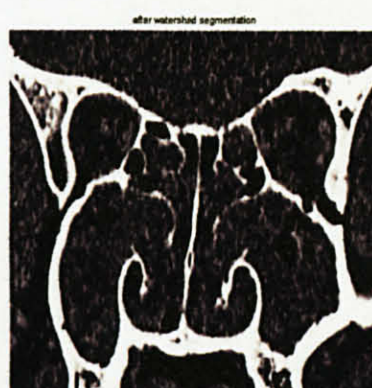


Figure 12.6: Image after Contourlet enhancement and watershed segmentation using Algorithm 2

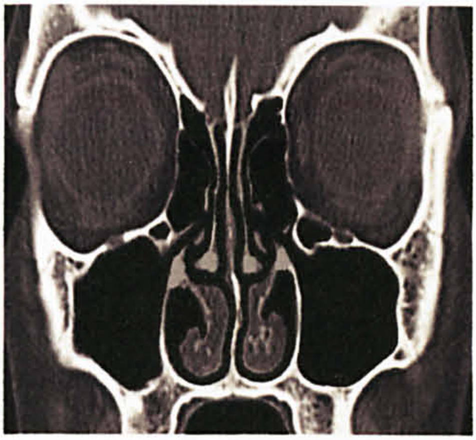


Figure 13.1: Input image of healthy sinuses

Figure 13.2: Image of healthy sinuses after Contourlet enhancement

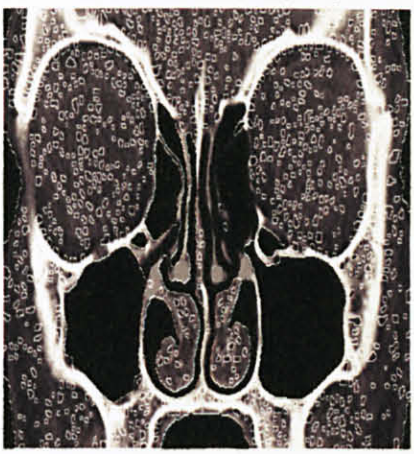


Figure 13.3: Image of healthy sinuses after watershed segmentation using Algorithm 1

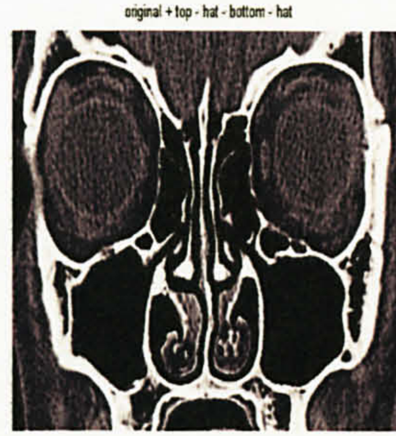


Figure 13.4: Image of healthy sinuses after watershed segmentation using Algorithm 2

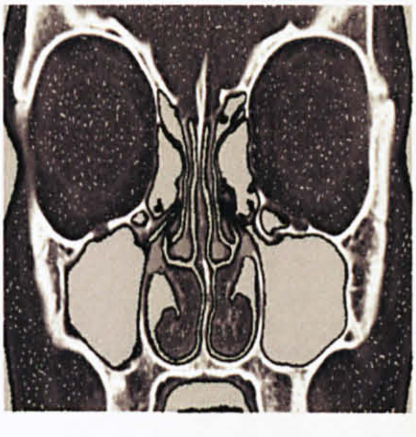


Figure 13.5: Image of healthy sinuses after Contourlet enhancement and waterhed segmentation using Algorithm 1

Figure 13.6: Image of healthy sinuses after Contourlet enhancement and waterhed segmentation using Algorithm 2

The output images show that using the Algorithm 2 for segmentation is better that Algorithm 1. This can be proved using Human Vision System at the output image of sinus with sinusitis. As method of segmentation is decided, those methods had been run for ten more images of sinuses.

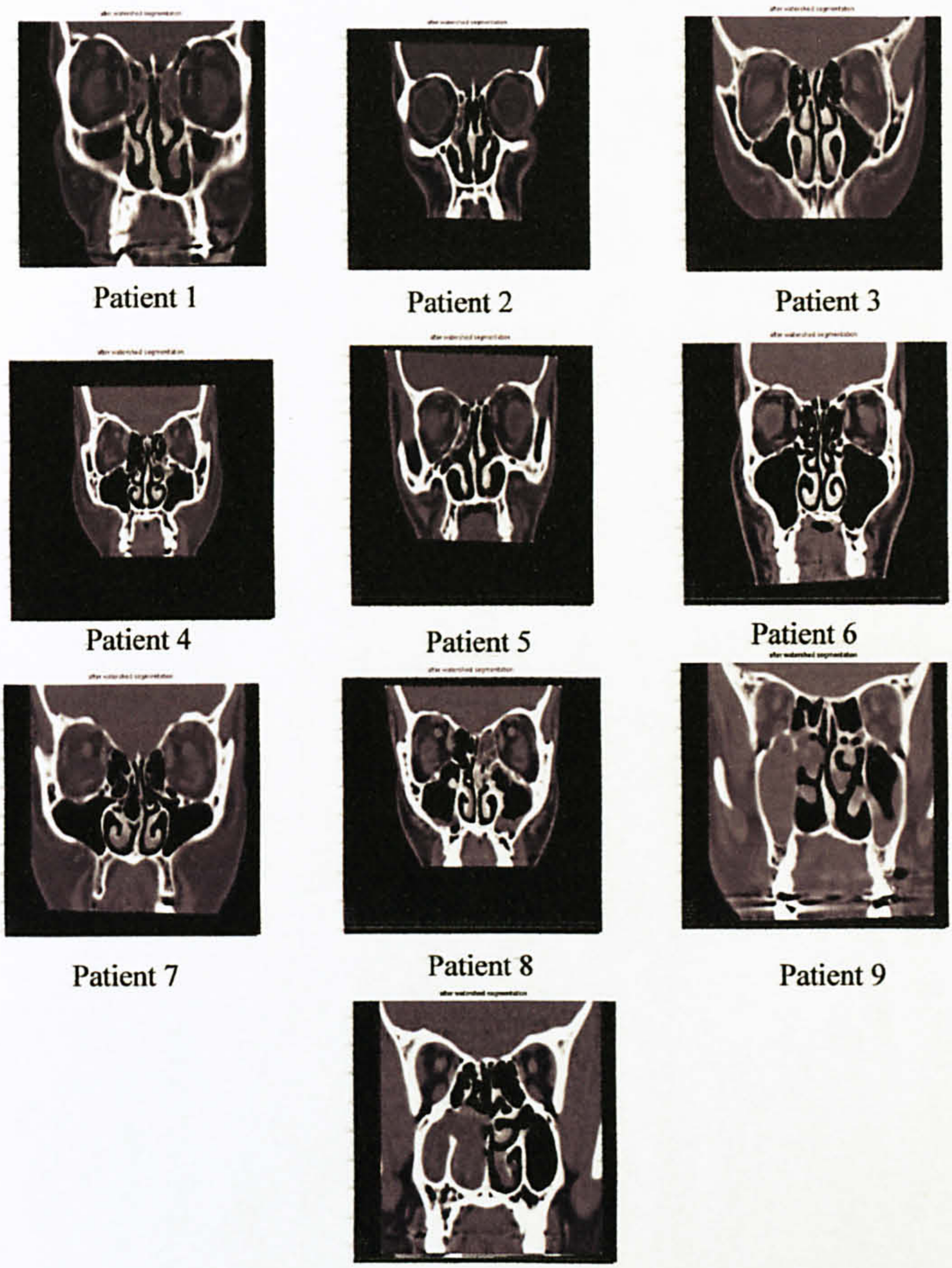


Figure 14: Sinuses images of ten patients

4.1.2 Grading of Sinusitis

The grading was performed on both image of healthy sinuses and sinuses with sinusitis. The calculated severity factor for the healthy sinuses is 0 as there are no mucous areas in sinuses while for the sinuses with sinusitis is 0.91, indicating serious sinusitis. The calculation matched the diagnosis of both the healthy sinuses and the sinuses with sinusitis. Besides the calculated severity factor, the binary output images of this process show very clearly the mucous and hollow areas of sinuses. The grading was performed on ten more images of sinusitis. This analysis will help doctors in diagnosis of the sinusitis.

Image	Severity Factor
Patient 1	0.10
Patient 2	0.15
Patient 3	0.25
Patient 4	0.34
Patient 5	0.31
Patient 6	0.19
Patient 7	0.01
Patient 8	0.42
Patient 9	0.73
Patient 10	0.84

Table 1: Severity Factor

4.2 Discussions

The CT scan images of sinus containing random noise have been de-noised and enhanced using Contourlet transforms. The comparison had been done using Pixel Signal Noise Ratio (PSNR). The PSNR is the most commonly used as a measure of quality of reconstruction in image de-noising. The PSNR for both noisy and de-noised images were identified using the following formulae:

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \qquad \text{.......................... (3)}$$

Mean Square Error (MSE) which requires two *m x n* grayscale images I and K where one of the images is considered as a noisy approximation of the other is defined as:

The PSNR is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\|I(i,j) - K(i,j)\|^2$$

.... (4)

Here, MAX_I is the maximum pixel value of the image.

The efficiency of segmentation can be ensured by testing the algorithm with more input images. So, from this matter, we can choose the algorithm that is suitable to do the segmentation. Afterwards, the grading of sinusitis will be evaluated after the algorithm for segmentation has been determined.

The standard for grading is divided by into six parts; mild, slightly mild, moderate, highly moderate, severe and very severe. The range of those standards operations is as below:

Standards of operations	**Range of severity factor**
Mild	0.01 ~ 0.31
Slightly Mild	0.31 ~ 0.40
Moderate	0.41 ~ 0.50
Highly Moderate	0.51 ~ 0.64
Severe	0.65 ~ 0.74
Very Severe	0.75 ~ 1.00

Table 2: Standards of operations

So, based on Table 3, the ten images from ten patients can be graded for severity of sinusitis.

Image	**Standards of operations**
Patient 1	Mild
Patient 2	Mild
Patient 3	Mild
Patient 4	Highly Mild
Patient 5	Mild
Patient 6	Mild
Patient 7	Mild
Patient 8	Moderate
Patient 9	Severe
Patient 10	Highly Severe

Table 3: Standards of operations for ten patients

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

As conclusions, the image preprocessing techniques applied on the images were able to increase the efficiency for the next process which is segmentation of the sinus images. The advantages using this Contourlet transform is this method also reduce the noise in the images. The watershed segmentation is automatic segmentation of the images and the time was taken is fast. Last but not least from the standards of grading was created to help doctors to diagnose the sinusitis.

5.2 Recommendations

Another method for denoising and enhancement images need to add in this project for comparison with the Contourlet transforms and to prove that the Contourlet transforms is a better method to improve the image before images segmentation.

More segmentation approaches need to be tested for sinusitis images which may give the better results. By applying more segmentation methods; the comparison can be made to find the suitable method to give the better result. This project can be continued further to perform the 3-D reconstruction where are used the results of images segmentation.

REFERENCES

[1] Radio Society of North America. (2009, June 22). CT of Sinuses. Retrieved August 3, 2009, from the World Wide Web: http://www.radiologyinfo.org/en/pdf/sinusct.pdf

[2] D.L. Donoho and I.M. Johnstone," Ideal spatial adaptation via wavelet shrinkage," *Biometrika*, 81, pp.425-455, 1994.

[3] T.T. Cai and B.W. Silverman," Incorporating information on neighbouring coefficients into wavelet estimation," *Sankhya, Ser. B*, 63(2), pp.127-148, 2001.

[4] G.Y.Chen, T.D. Bui and A. Krzyzak," Image denoising with neighbor dependency and customized wavelet and threshold," Pattern *Recognition 38*, pp. 115-124, 2005.

[5] Zhou Dengwen and Shen Xiaoliu. (2008).*Image Denoising Using Block Thresholding.* Retrieved September 1, 2009, from the World Wide Web: http://www.mathworks.com/matlabcentral/fileexchange/24430

[6] IMAGE SEGMENTATION AND MATHEMATICAL MORPHOLOGY Retrieved April 28, 2010, from the World Wide Web: http://cmm.ensmp.fr/~beucher/wtshed.html

[7] X.Zong, A. F. Laine, E. A. Geiser, D.C. Wilson, " Denoising and Contrast enhancement via wavelet shrinkage and nonlinear adaptive gain", Proc. of SPIE, vol. 276, pp.566-574, Orlando, April 1996.

[8]Liang Li, Yingxia Fu, Peirui Bai;Wenjie Mao, "Medical Ultrasound Image Segmentation Based on Improved Watershed Scheme", Bioinformatics and Biomedical Engineering , 2009. ICBBE 2009. 3rd International Conference,Page(s): 1-4,2009.

[9] Ng, H.P.,Ong, S.H., Foong, K.W.C., Goh, P.S., Nowinski, W.L.," Medical Image Segmentation Using K-Means Clustering and Improved Watershed Algorithm", Image Analysis and Interpretation, 2006 IEEE Southwest Symposium on , Page(s): 61 – 65,2006.

[10]Iznita I.L., Vijanth, S.A., Venkatachalam P.A., Lee S.N., Computerized segmentation of sinus images",Innovative Technologies in Intelligent Systems and Industrial Applications, 2009. CITISIA 2009, Page(s): 125 – 128, 2009.

[11] Peng-Yeng, Ling-Hwei Chen. (1994). A New Method for Multilevel Thresholding using Symmetry and Duality of Histogram. *1994, International Symposium on Speech, Image Processing and Neural Networks,13-16 April 1994, Hong kong.*

[12] Hamed Shah-Hosseini, Reza Safabakhsh (2002). Automatic Multilevel Thresholding for Image Segmentation by Growing Time Adaptive Self-Organizing Map. *IEE Transaction on Pattern Analysis and Machine Intelligence, Vol.2, No. 10, October 2002*

[13] L.Cao,Z.K.Shi and E.K.W. Cheng. (2002). Fast Automatic Multilevel Thresholding Method. IEE 2002. *Electronic Letters, 1st August 2002,Vol.38, No.16.*

[14]Arthur L.da Cunha, Jianping Zhou and Minh N. Do. (2006, October). Retrieved September 1, 2009, from the World Wide Web: http://www.ifp.illinois.edu/~minhdo/publications/nsct.pdf

[15] Yuqian ZhaoJianxin Liu, Huifen Li, Guiyuan Li,"Improved watershed algorithm for dowels image segmentation'', Intelligent Control and Automation, 2008. WCICA 2008. 7th World Congress , Page(s): 7644 – 7648,2008.

[16] Hieu Tat Nguyen, Worring, M., van den Boomgaard, R.," Watersnakes: energy-driven watershedsegmentation" Pattern Analysis and Machine Intelligence, IEEE Transactions Volume: 25 , Issue: 3 Page(s): 330 – 342,2003.

[17] Zhengmao Ye, Mohamadian, H., Yongmao Ye, "Analyzing contrast enhancement and watershedsegmentation using quantitative information measuring ",Intelligent Control and Automation, 2008. WCICA 2008. 7th World Congress, Page(s): 248 – 253, 2008.

[18] Shuang Wang, Xiuli Ma, Xiangrong Zhang, Licheng Jiao, "Watershed-based textural image segmentation", Intelligent Signal Processing and Communication Systems, 2007. ISPACS 2007. International Symposium, Page(s): 312 – 315, 2007.

[19] Zhengmao Ye, Mohamadian, H., Yongmao Ye, "Gray level image processing using contrast enhancement and watershed segmentation with quantitative evaluation", Content-Based Multimedia Indexing, 2008. CBMI 2008. International Workshop, Page(s): 470 – 475, 2008.

[20] Ng, H.P., Huang, S., Ong, S.H., Foong, K.W.C., Goh, P.S., Nowinski, W.L.,"Medical image segmentation using watershedsegmentation with texture-based region merging", Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE, Page(s): 4039 – 4042, 2008

APPENDICES

APENDDIX A: GANTT CHART OF STUDY

No.	Detail/ Month	Aug 2009	Sep 2009	Oct 2009	Nov 2009	Dec 2009	Jan 2010	Feb 2010	Mar 2010	Apr 2010	Mei 2010	Jun 2010
1	Literature review											
2	Noise reduction and Image enhancement											
3	Segmentation											
4	Grading Image											
5	Gathering Material (sinus images)											

APENDDIX B: WATERSHED SEGMENTATION ALGORITHM 1

```
clear all
close all

c=5;b=1.8;t=0.8;

image = imread('IMAGE.JPG');

image_greyscale = rgb2gray(image);
image_greyscale = imresize(image_greyscale,[512 512]);

%Contourlet enhancement
level_con= [0,0,4,5,5];
y2=pdfbdec(double(image_greyscale),'9-7','pkva',level_con);
for s=2:(length(level_con)+1)
  for k=1:length(y2{s})
       y2{s}{k}=ne_en_fu(y2{s}{k},t,b,c);
   end
end

image_grayscale = pdfbrec(y2,'9-7','pkva');
figure,imshow(image_greyscale);
title ('contourlet enhancement');

%Watershed Segmentation
h=fspecial('sobel');
fd=double(image_greyscale);
g=sqrt(imfilter(fd,h,'replicate').^2);

im=imextendedmin(image_greyscale,2);
fim=image_greyscale;
fim(im)=175;
figure,imshow(fim);
title ('After watershed segmentation');
```

Note: function 'pdfbdec' is in the contourlet toolbox

```
function y=ne_en_fu(u,t,b,c)
%u is the coefficient amplitude in transform domain
%M is the magnitude of the maximum coefficient amplitude
%t*M is a threshold which show that the coefficients larger than
this
%threshold will be linearly amplified
%b and c together determine the gain needed in each amplitude
interval
M=max(u(:));
v=2.5*u/(t*M);
y=u.*sign(u).*tanh(b*v).*(1+c*exp(-v.^2))
```

APENDDIX C: WATERSHED SEGMENTATION ALGORITHM 2

```
clear all
close all
c=5;b=1.8;t=0.8;
image_greyscale=imread('patient_10a.jpg');


image_greyscale = rgb2gray(image_greyscale);
image_greyscale = imresize(image_greyscale,[512 512]);

%contourlet enhancement

level_con= [0,0,4,5,5];

y2=pdfbdec(double(image_greyscale),'9-7','pkva',level_con);
for s=2:(length(level_con)+1)
  for k=1:length(y2{s})
      y2{s}{k}=ne_en_fu(y2{s}{k},t,b,c);
   end
end
image_grayscale = pdfbrec(y2,'9-7','pkva');

%watershed segmentation
se = strel('disk', 15);
Itop = imtophat(image_greyscale, se);
Ibot = imbothat(image_greyscale, se);

Ienhance = imsubtract(imadd(Itop, image_greyscale), Ibot);
figure, imshow(Ienhance);title('after watershed segmentation');
```

APPENDIX D: GRADING THE SINUSITIS

```
image = imread ('contour_algor2.jpg');
segmented = double(image_greyscale);
segmented = rgb2gray(segmented);
segmented = watershed_segmentation(image);
figure,imshow(segmented);


[rows cols] = size (segmented);

reply = input('Any mucous in sinuses? Y/N : ', 's');
if (reply == 'Y')
   mucous = rg(segmented,20);
   mucous_counter = 0;
   for r = 1:rows
      for c = 1:cols
      if (mucous(r,c) == 1)
         mucous_counter = mucous_counter + 1;
      end
   end
end
else
   mucous = zeros (size (segmented));
   mucous_counter = 0;
end

reply = input ('Any unaffected area in sinuses? Y/N :', 's');
if (reply == 'Y')
      hollow = rg(segmented,20);
      hollow_counter = 0;
      for r = 1:rows
         for c = 1:cols
            if (hollow(r,c) == 1)
               h0llow_counter = hollow_counter + 1;
            end
         end
      end
   else
      hollow = zeros (size (segmented));
      hollow_counter = 0;
   end

   total = hollow + mucous;

   total_counter = 0;
   for r = 1:rows
```

```
        for c = 1:cols
            if (total(r,c) ~= 0)
                total_counter = total_counter + 1;
            end
        end
    end

    percentage_hollow = hollow_counter / total_counter * 100;
    percentage_mucous = mucous_counter / total_counter * 100;


fprintf ( '\nPercentage of unaffected area in sinuses: %3.2f;',percentage_hollow);
fprintf ( '\nPercentage of mucous area in sinuses: %3.2f;',percentage_mucous);
fprintf ('\n\n');

    figure, imshow (hollow);
    figure, imshow (mucous);
    figure, imshow (total);
```