FINGERPRINT IMAGE SEGMENTATION USING HIERARCHICAL TECHNIQUE

WAN AEZWANI BT WAN ABU BAKAR

This thesis is submitted as a partial fulfilment of the requirements for the degree of Master of Science (Computer Science)

Faculty of Computer Science and Information System
Universiti Teknologi Malaysia

MAY 2000

SPECIAL TRIBUTES AND DEDICATIONS

My Family...

We, arwah cik, tok wan, brothers and sisters especially Pok Jih, Abang Har, Abang Lee, Kak Ina, Kak Ini, Ajea, Da and Aliza that my eternal grateful thanks and full gratitude goes to all of you that always neverendingly being there for me.

My seniors, juniors and colleagues...

Especially for Azmi Kamis and Masrina Sulong for welcoming me in the world of graphics fingerprint image. Also for my roommate Kak Shidah, my colleagues Kak Rad, Kak Teni, Kak Ana and Kak Lili for your support and encouragement.

My proof readers...

Especially for Hazinah Kutty Mummy, thanks for everything.

My fiancé...

Especially for Abang Mus, I will never be able to produce this report if not for the effort of him with his productive comments and cross every T's and dots every I's.

And lastly...

To all who helps me in everything.

ACKNOWLEDGEMENT

A special recognition goes to my project supervisor, Prof. Dr. Ghazali Sulong for his superb ideas and smart guidance that given me much effort to complete this project. Without his guidance, I don't think I can further my knowledge and experience in developing the project.

A special thanks to all administration staffs of Faculty Of Computer Science and Information System, that from time to time always incorporates me with the management stuff and administration procedure and also to the technical staffs for maintaining the technical support.

A profound thanks also goes to School of Graduate Studies, University of Technology Malaysia for providing me a chance to further my study in the esteemed educational organisation.

ABSTRACT

Fingerprints are the ridge and furrow patterns on the tip of the finger and its verification is an important biometric technique for personal identification. The quality of the fingerprint image is the most significant factor in a reliable matching process. Thus, any pre-processing algorithm should aim to enhance the quality of the existing features without creating false features. This scenario brings the idea of the research. The research focus on the segmentation approach. The purpose of the study is to identify a segmentation approach of fingerprint image by considering several approaches namely Hierarchical technique and Region growing by pixel aggregation technique. The process is vital when to apply next pre-processing stages i.e. thinning, identifying between true and false minutiae and minutiae extraction process. The research is supported by 50 samples of data that is collected through an available fingerprint device. The development of this research is by using Delphi 3.0.

ABSTRAK

Cap jari merupakan corak batas dan galur yang terdapat pada jari manusia dimana pengesahan pada setiap cap jari merupakan teknik biometrik yang penting untuk pengenalan seseorang individu. Tahap kualiti pada imej cap jari merupakan faktor yang signifikan untuk menjalani proses pemadanan yang boleh dipercayai. Oleh sebab itu, setiap algoritma yang melibatkan peringkat pra-pemprosesan perlu menekankan kepada peningkatan tahap kualiti ciri-ciri yang ada pada imej cap jari tanpa mewujudkan ciri-ciri yang salah. Senario sebegini memberi idea kepada kajian untuk meneroka dan menumpukan kepada teknik segmentasi di dalam peringkat pra-pemprosesan imej. Tujuan kajian dibuat adalah untuk mengenalpasti pendekatan yang ada dalam proses segmentasi. Antara pendekatan yang diambilkira ialah *Teknik Hirarki* dan juga *Teknik Region growing by pixel aggregation*. Proses segmentasi penting untuk pengendalian proses yang seterusnya seperti penipisan, penentuan antara minutiae yang benar atau yang salah dan juga proses pengekstrakan *minutiae*. Kajian ini dibantu oleh 50 sampel data yang dikumpul melalui peranti imej cap jari yang disediakan. Kajian ini dibangunkan dengan menggunakan perisian Delphi 3.0.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Dpi	Dot per inch
FAR	False Acceptance Ratio
FP	Fingerprint Image
FRR	False Rejection Ratio
FTIR	Frustrated Total Internal Reflection
HB1	High Boost 1 filtering
HP	Hewlett Packard
HP1	High Pass 1 filtering
ID	Identification
Med 3x3	Median 3x3
QC	Quality control check
RG	Region growing
ROI	Region of Interest

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Introduction

1.1.1 History of fingerprint

The beginning of the fingerprint is not known. But for certain, there are definite periods in its history. The first period started when human beings become aware of fingerprint that such fingerprint is used as a mean of individual signature. The second period then started with the development of fingerprint coding and filing system and technique of searching for latent prints (Alobaidi, 1998).

Ancient Chinese and Babylon had been using fingerprints on clay tablets for business transactions. Later, in 14^{th} Persia century, various official government papers had fingerprints until a doctor of one government officer observed that no two fingerprints were exactly the same (Alobaidi, 1998).

In 1686, a professor of anatomy, Marcello Malphigi has noted the ridge, spiral and loop which were the nature of fingerprint, but unfortunately he didn't mentioned about its value as tools for individual identification (Alobaidi, 1998).

Credit for early scientific contributions in fingerprinting is given to many people especially Dr. Henry Faulds (1843 - 1930), Harris Wilder (1864 - 1928) and Henrich Poll (1877 - 1939). The first scientific contribution was made by Francis Galton (1822 - 1916). It was he who established the fact that no two fingerprints are the same. He had established the individuality and permanence of fingerprints and produced the first fingerprint classification system while in the mean time he identified the unique characteristics of fingerprint, whereby it's known as *Galton's Details*. He classified the patterns into three major types for filing purposes (Hughes, 1991).

A more advanced classification of fingerprints was made by Edward Henry (1850 - 1931). Henry's classification as it becomes known, is the basis for all of today's fingerprint classification schemes. The four major types in the Henry classification are : arches, loops, whorls and composites (Hughes, 1991).

In 1923, a professor of anatomy, John Evangelist Purkinji discussed about 9 fingerprint patterns but he too made no attempt of the value of fingerprint for personal identification.

Starting on 1960s, Federal Bureau of Investigation (FBI) and Paris Police Department had made a big investment to support the development of Automated Fingerprint Identification System (AFIS) which is the system to identify the fingerprint matching. Their effort were so successful that a large number of AFIS's are currently installed and in operation at law-enforcement agencies world-wide. These systems have greatly improved the operational productivity of these agencies and reduced the cost of hiring and training human fingerprint experts for manual fingerprint identification. Automatic fingerprint identification rapidly grew beyond law enforcement into civilian application. In fact, fingerprint-based biometric systems are so popular that they have almost become the synonym of biometric systems. Refer to **Figure 1.1** to denote a schematic block diagram of an AFIS (Kasaei, et al., 1997).

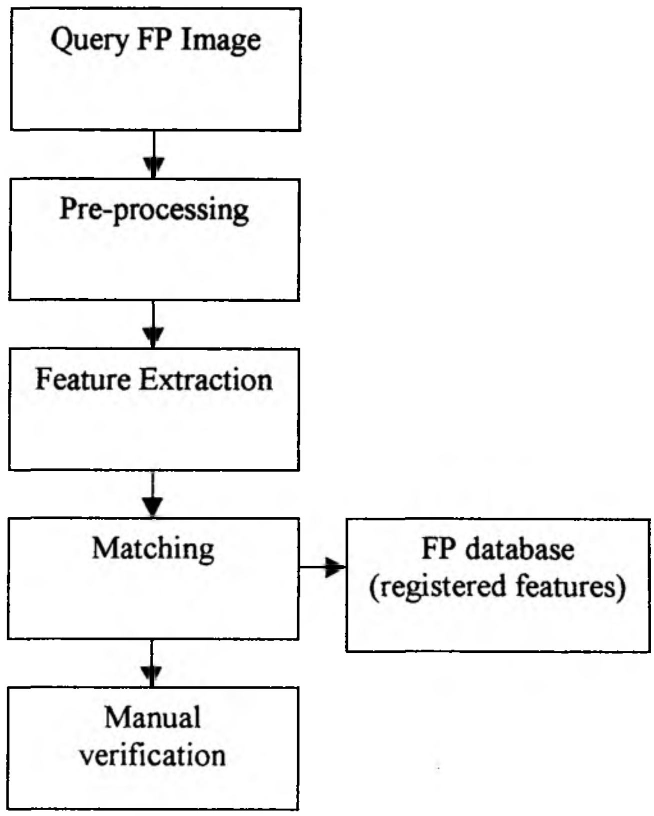


Figure 1.1 : Schematic Block Diagram of an AFIS

1.1.2 The nature of fingerprint

The fingerprint will remain unchanged during an individual's lifetime. The skin is composed of layers of cells by which those near the surface make up the outer portion of skin is called *epidermis* and the inner skin is called *dermis*. By looking at a cross section of the skin, a boundary of cells separating the epidermis is noted and it is made up of *dermal pipilae* that determines the form and pattern of ridges on the skin surface. Once the dermal pipilae developed in human fetus, ridge pattern remain unchanged except to enlarge during growth (Alobaidi, 1998).

1.1.3 Biometric Overview

Any human physiological or behavioural characteristic can be used to make a personal identification as long as it satisfies following requirements (Jain, et al., 1997) :

- Universality means that every person should have the characterisation.
- Uniqueness indicates that no two person should be the same in terms of characteristics.
- Permanence means that characteristics should be invariant with time.
- Collectability indicates that the characteristics can be measured quantitatively.

In practice, there are some other important requirements namely :

- Performance that refers to the achievable identification accuracy, the resource requirements to achieve an acceptable identification accuracy and the working or environmental factors that affect the identification accuracy.
- Acceptability that indicates to what extent people is willing to accept biometric system.
- Circumvention that refers to how easy it is to fool system by fraudulent techniques.

Biometrics is a rapidly evolving technology that has been widely used in forensics such as criminal identification and person security and has the potential to be widely adopted in a very broad range of civilian applications as in **Figure 1.2** :

- Banking security such as electronic fund transfers, ATM security, check cashing, and credit card transaction.
- Physical access control such as airport access control.
- Information system security such as access to databases via login privileges.
- Government benefits distribution such as welfare disbursement programs.

- Customs and immigration such as the Immigration and Naturalisation Service Passenger Accelerated Service System (INSPASS) which permits faster immigration procedures based on hand geometry.
- National ID system which provide a unique ID to the citizens and integrate different government services.
- Voter and driver registration providing registration facilities for voters and drivers.

Table 1. Biometric applications		
Forensic	**Civilian**	**Commercial**
Criminal investigation	National ID	ATM
Corpse identification	Driver's license	Credit card
Parenthood determination	Welfare disbursement	Cellular phone
	Border crossing	Access control

Figure 1.2 : Biometric Applications

Currently, there are nine biometric technology (Jain, et al., 1997) include fingerprint, face, hand geometry, hand vein, retinal pattern, iris, signature, voice print and also facial thermograms. Of the nine technology, nevertheless not many of them are acceptable as indisputable evidence of identity i.e. extensive studies have been conducted on automatic face recognition and number of face recognition system available, yet it has not been proved that face can be used reliably to establish identity. Moreover, although signatures also are legally acceptable biometric, they rank a distant second to fingerprints due to the issues involved with accuracy, forgery and behavioural variability.

For the recent time, the only legally accepted, readily automated and mature biometric techniques is the AFIS which has been used and accepted in forensics since the early 1970s.

1.2 Background of the problem

The local ridge characteristics and their relationships exclusively determine the uniqueness of a fingerprint. On top of that, it is widely used as a personal identification for automated systems.

One of the main problems in extracting structural features is the presence of noise (unwanted information that can result from the image acquisition process) in the fingerprint image. Commonly used method for taking fingerprint impressions involved applying a uniform layer of ink on the finger and rolling the finger on paper. These events cause the following types of problems (Ratha, et al., 1996) :

- Over-inked areas of the finger create smudgy areas in the image.
- Breaks in ridges are created by under-inked areas.
- The skin being elastic in nature can change the positional characteristics of fingerprint features depending upon the pressure being applied on the fingers.

But then although inkless methods for taking fingerprint impressions are now available, these methods still suffer from the positional shifting caused also by skin elasticity. Poor quality fingerprint images pose important problems in minutiae extraction, causing the disappearance of real ones and/or the presence of spurious (false) i.e. true bifurcations very often disappear due to insufficient pressure of the finger. On the other hand, true endings disappear when the finger is pressed too hard producing false ridge continuity.

In designing of a fingerprint-verification system, imaging systems presents a number of peculiar and challenging situations which due to these following scenario (Jain, et al., 1997) :

- *Inconsistent contact* : the act of sensing distorts the finger. Determined by the pressure and contact of the finger on the glass platen, 3-dimensional shape of the finger gets mapped onto the 2-dimensional surface of the glass platen. This mapping function is uncontrolled and results in different inconsistently mapped fingerprint images across the impressions.

- *Nonuniform contact* : Ridge structure of a finger would be completely captured if ridges of the part of the finger being imaged are in complete optical contact with the glass platen. However, the dryness of the skin, skin disease, sweat, dirt and humidity in the air all confound the situation, resulting in nonideal contact situation : some part of the ridges may not come in complete contact with the platen, and regions representing some valleys may come in contact with the glass platen. This results in 'noisy' low-contrast images, leading to either spurious minutiae or missing minutiae.

- *Irreproducible contact* : Manual work, accidents, inflict injuries to the finger, thereby changing the ridge structure of the finger either permanently or semipermanently. This may introduce additional spurious minutiae.

- *Sensing act* : the act of sensing itself adds noise to the image. For example, residues are leftover from the previous fingerprint capture. A typical finger-imaging system distorts the image of the object being sensed due to imperfect imaging conditions. In the image acquisition stage i.e. FTIR sensing scheme, there is a geometric distortion because the image plane is not parallel to the glass platen.

1.3 Statement of the problem

Fingerprint recognition remains as one of the most prominent biometric identification methods. The quality of the fingerprint image is the most significant factor in a reliable matching process. Any pre-processing algorithm should aim to enhance the quality of the existing features without creating false features. The whole scenario is presented by the main research question :
How to improve the quality of fingerprint features through the pre-processing steps in order to ease the process of forwarding steps in fingerprint image processing ?

The following 3 major issues are taken into account to answer the main research question stated above.

1. Why choose fingerprint instead of face, hand-written or speech ?

- *What is the science of fingerprint ?*
- *How many patterns are there ?*

2. How can fingerprint images are recognised ?

- *What techniques did previous authors use ?*
- *What are the distinct steps involved in pre-processing ?*
- *What is done in segmentation process ?*
- *What is the significance of the process if it's going to be done ?*

3. What are the algorithms available in segmentation stage ?

- *What algorithm available here based on tool constraint ?*
- *What algorithm is going to be considered ?*
- *Does it have a future value ?*

4. What is the difference between segmentation and filtering technique?

- *How does it differ ?*
- *What is the significance between those two ?*

1.4 Purpose / Objective of the study

The purpose of the study is to identify a robust segmentation approach of fingerprint image by experimenting several approaches. Segmentation is the process of isolating between the foreground and the background of the fingerprint image with the purpose to identify the ridge line. This process is vital when to apply the thinning, identifying between true and false minutiae, minutiae extraction and other pre-processing stages in the field of image processing. Supporting by 50 of sample data, the research project is a complete and comprehensive for recognition system that accurately supported the fingerprint matching or classification. The main objectives of this research proposal are :

- To identify techniques involved in segmentation process that is to be applied in fingerprint images.
- To evaluate and analyse the robust segmentation techniques which is to be used in fingerprint recognition methodology.

1.5 Theoretical framework

To propose a technique for fingerprint image segmentation, the author has taken into a great consideration about the field in image processing and pattern recognition area. The theoretical framework of this research is shown in **Figure 1.3.** The dotted line indicates the focus area of the research.

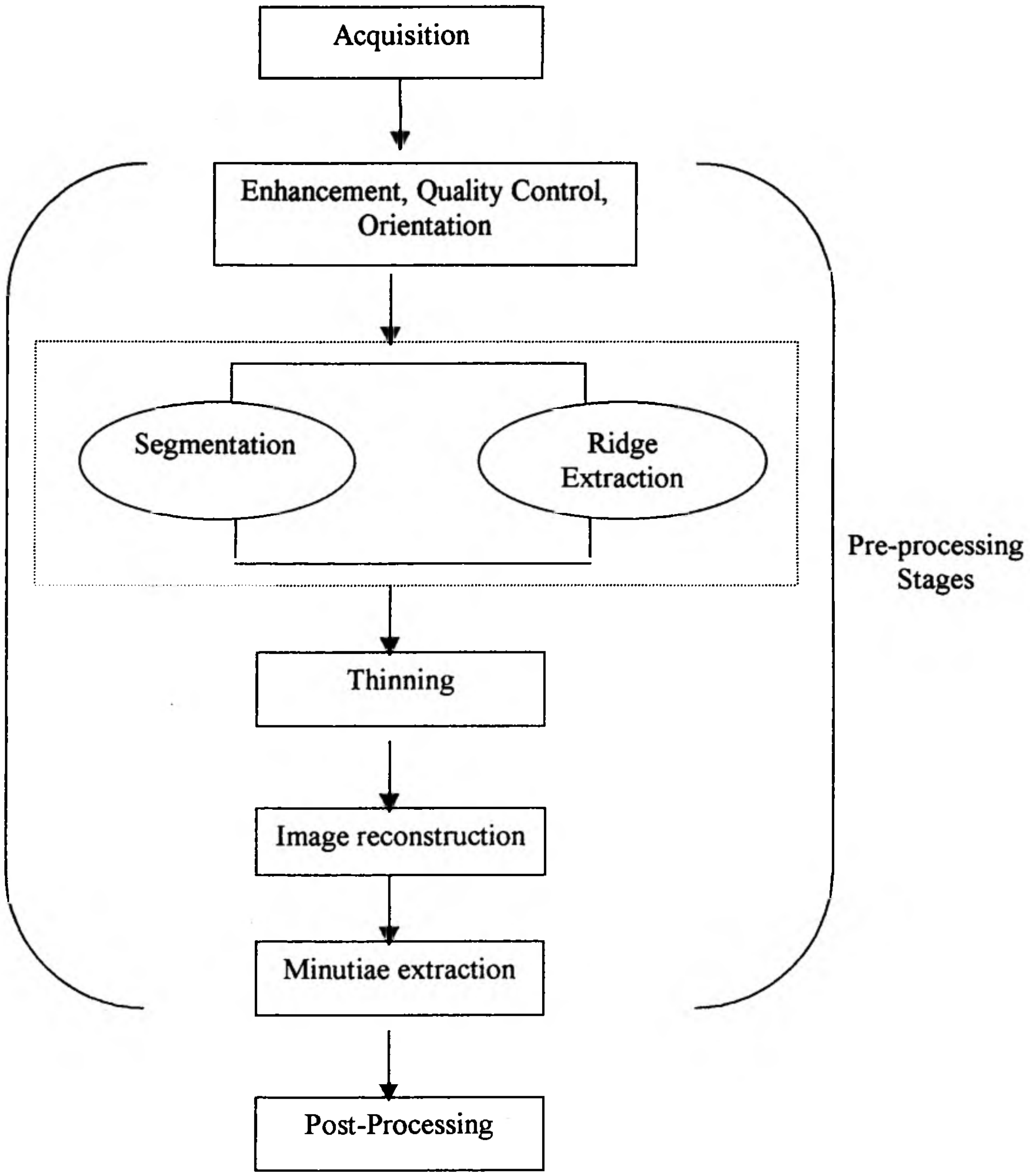


Figure 1.3 : Schematic Block diagram of fingerprint image processing

1.6 Importance of the study

Although the fingerprint image is scanned through Biometric Scanner-Veridicom Passprint, not all the images are in a good quality. Skin elasticity or dirt on the scanner screen may effect in a bad quality and hence introduce noise or distortion to fingerprint image. And if the rolled fingerprint is to be used, the problem is the intensity level of the ink on the rolled fingerprint also may occur. Thus, the development of a fast, accurate and robust recognition system in the pre-processing stage is very important with the goal to create an effective database for fingerprint matching and retrieving. Focus area of the research is on the segmentation and ridge extraction process. This process is done after image enhancement, quality control and image orientation process (Azmi, 2000) and before the next stages i.e. thinning, minutiae extraction and post-processing can be undertaken.

1.7 Scope of the study

Main focus area of this research project is on the segmentation process. But to end up with the process, the fingerprint image must be pre-processed through the following steps :

i. Fingerprint image is live-scanned through a biometric device and manual scanned which restricted to 50 images in TIFF (Tagged Image File Format).
ii. The quality of image is then enhanced by conducting the process of noise removal using Median Filtering 3x3 technique and also through the process of image sharpening using High Boost1 filtering (Azmi, 2000) and High Pass1 filtering.
iii. Histogram is then plotted and thereafter, the process of quality control is done to attain a good image.
iv. Image orientation estimation is now undertaken.

v. Then, segmentation is done by considering two techniques which are *Hierarchical* technique by (Jain, et al., 1997) and *Region Growing by pixel aggregation* technique by (Alobaidi, 1998).

1.8 Definition of terms

Arch	The pattern in which the ridges enter on one side, rise in the middle and flow out from the other side
Biometric	Biometric refers to unique physical traits of an individual such as a fingerprint, retina, or palm print. At this time, the fingerprint is the biometric identifier of choice.
Central point/core	Approximately the centre of loop fingerprint located within or on innermost recurve
Delta	The point of spreading apart of two parallel ridges. The ridges must surround the pattern area and converge at the other side of the pattern
Feature extraction	Converts the original data to a suitable form (feature vectors) for use as input to the decision processor for classification
Filtering	The process of removing the undesired noise to preserve the true ridge/valley structure
Image processing	The refinement of a picture or photo to improve the clarity.

	It is used in image recognition and computer vision.
Left loop	The pattern in which a ridge recurve (loop) to the left angle, touching a line drawn from the delta to the central point (same as right loop except to the left)
Minutiae	Specified term for ridge ending and ridge bifurcation
Pattern recognition	Consist of basically 3 phases which are data acquisition, data pre-processing and decision classification
Ridge bifurcation	The point where a ridge forks or diverges into branch ridges.
Ridge ending	The end point of a ridge or the point where a ridge end abruptly
Ridges/valleys	Furrows on the surface of a fingertips
Right loop	The pattern in which a ridge recurve (loop) to the right angle, touching a line drawn from the delta to the central point. There is exactly one delta in the pattern
Segmenting	The process of isolating between the foreground and the background of the fingerprint image with the purpose to identify the ridge line.
Tented arch	The pattern in which like the plain arch (normal arch), except from that the ridges form a sharp angle (e.g. like a tent) at the centre. There is no delta structure in arch and tented arch

Thinning	The process to extract and apply additional constraints on the pixel elements that are to be preserved so that linear structure of the input image will be recaptured without destroying its connectivity.
Whorl	The pattern in which contains at least two deltas and one recurving ridge such as a spiral or a variation of a circle

1.9 Summary

Chapter II explains the review of literature about what have been done by the previous authors considering fingerprint recognition and conclude about the desired approaches of segmentation, which is applied in the research. In terms of certain algorithm to extract features, pre-processing stage is undertaken.

BIBLIOGRAPHY

Alobaidi, B. M. K. (1998) "Fingerprint Image Enhancement." Faculty of Computer Science & Information System, University Of Technology Malaysia (UTM) : Thesis MSc.

Amengual, J.C., Juan, A., Perez, J.C., Prat, F., Saez, S., and Vilar, J.M., 1997. "Real-time Minutiae Extraction in Fingerprint Images" 6th International Conference on Publication, Vol. 2, pp. 871 - 875.

Azmi, Kamis. (2000) "Pengecaman Cap Jari : Peningkatan Kualiti Imej" Faculty of Computer Science & Information System, University Of Technology Malaysia (UTM) : Thesis BSc.

Bowen, J. D. 1992. "Automatic Fingerprint Pattern Classification Using Neural Networks." IEE Colloquium on Neural Network for Image Processing Applications (Digest No. 186).

Dzulkifli, Mohamad. (1997) "The Identification of Trademark Symbols based on Modeling Techniques" Faculty of Computer Science & Information System, University Of Technology Malaysia (UTM) : Thesis Phd.

Halici, U., and Ongun, G. 1996. "Fingerprint Classification Through Self Organizing Feature Map Modified to Treat Uncertainties." Proceedings of the IEEE 84, no. 10, pp. 1497 – 1512.

Hughes, P. A., and Green, A. D. P. 1991. "The Use Of Neural Networks For Fingerprint Classification." IEEE 2nd International Conference on Artificial Neural Networks pp. 79 -81.

Hussain, Z. (1991) "Digital Image Processing : Practical Applications of Parallel Processing Techniques." Ellis Horwood Limited, USA.

Jain, A. K., Hong, L., Pankanti, S., and Bolle, R. 1997. "An Identity – Authentication System Using Fingerprint." Proceedings of the IEEE. Vol. 85, No. 9, pp. 1365 – 1388.

Kamijo, M. 1993. "Classifying Fingerprint Images Using Neural Network : Deriving the Classification State." IEEE International Conference of Neural Network 3, pp. 1932 – 1937.

Kasaei, S., Deriche, M., and Boashash, B. 1997. "Fingerprint Feature Extraction Using Block-Direction On Reconstructed Images." IEEE Tencon of Speech Technologies for Computing & Telecommunication, pp. 303 – 306.

Kasaei, S., Deriche, M., and Boashash, B. 1997. "Fingerprint Feature Enhancement Using Block-Direction On Reconstructed Images." 1st IEEE International Conference on Communication & Signal Processing, ICICS '97, pp. 721 – 725.

Maio, D., and Maltoni, D. 1996. "A Structural Approach to Fingerprint Classification." Proceedings of 13th International Conference on Pattern Recognition, Vol. 3, pp. 578 – 585.

Moscinska, K., and Tyma, G. 1993. "Neural Network Based Fingerprint Classification." Proc. Of IEE 3rd International Conference On Neural Network, pp. 229 - 232.

Myler, Harler, R., and Weeks, Arthur, R. (1993) "The Pocket Handbook Of Image processing Algorithms In C." Prentice Hall : Englewood Cliffs, New Jersey.

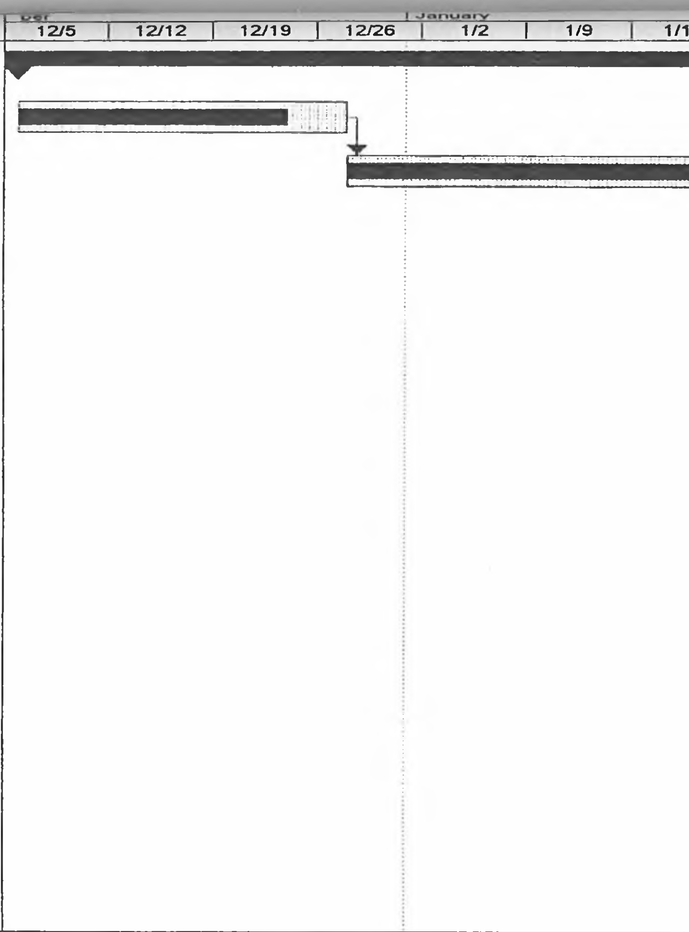
Ratha, N. K., Karu, K., Chen, S., and Jain, A. K. 1996. "A Real-Time Matching System For Large Fingerprint Databases." IEEE Transactions on Pattern Analysis and Machine Intelligence 18, no. 8, pp. 799 – 813.

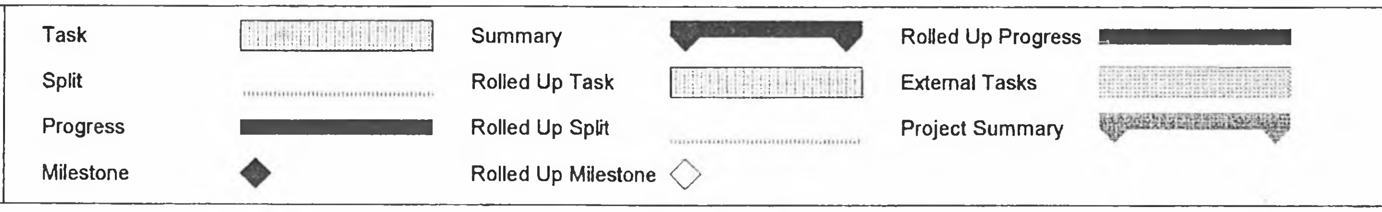
Uchida, K., Kamei, T., Mizoguchi, M., and Temma, T. 1998. "Fingerprint Card Classification with Statistical feature Integration." Proceedings 14th International Conference Pattern recognition 2, pp. 1833 – 1839.

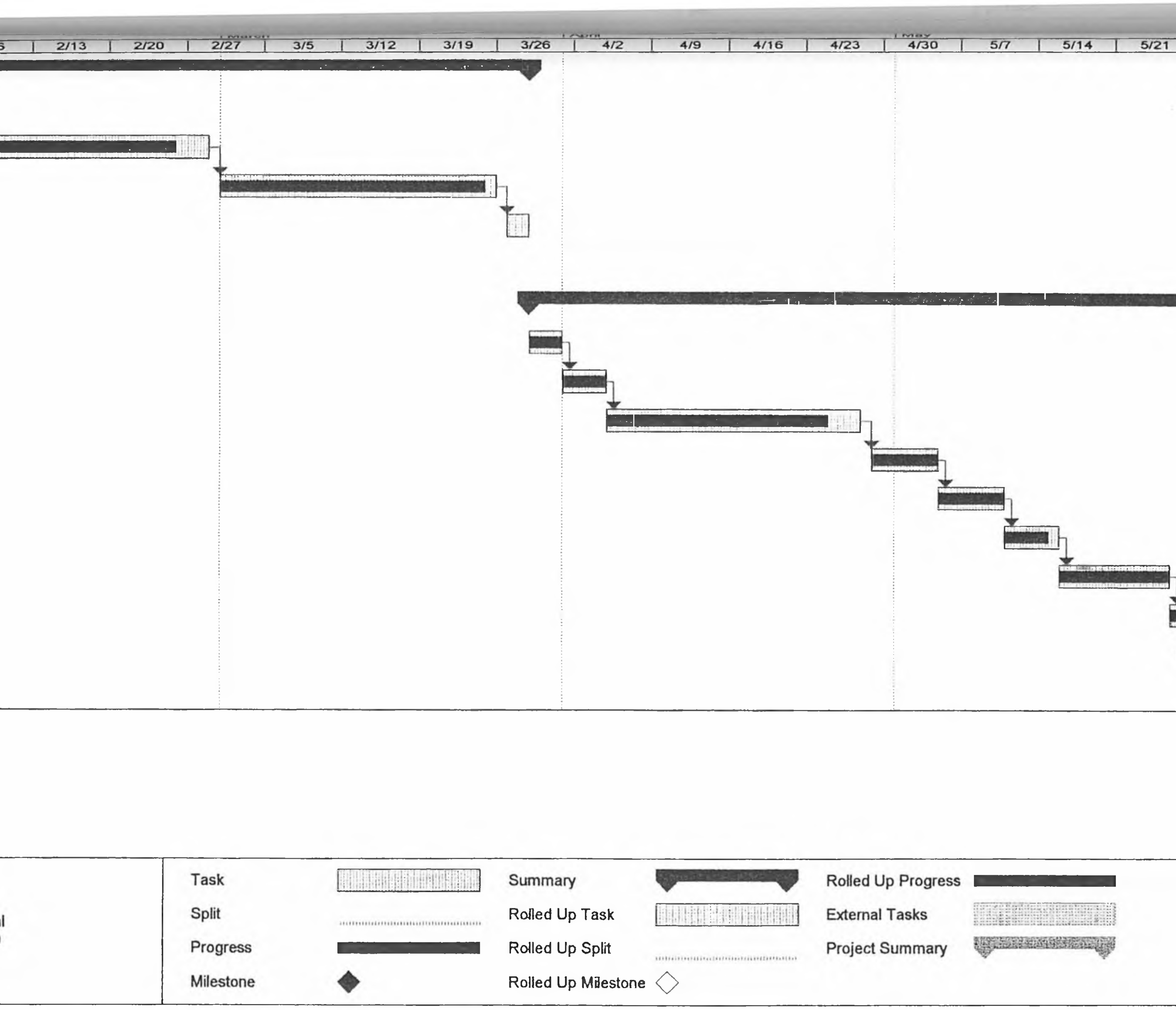
Umbaugh, Scott, E. (1998) "Computer Vision and Image Processing : A Practical Approach Using CVIPtools (International Edition)." Prentice-Hall International, Inc., USA.

Xiao, Q., and Raafat, H., 1990. "A Combined Statistical and Structural Approach For Fingerprint Image Postprocessing". IEEE Transaction, pp. 331 – 335.

Task Name	Duration	Start	Finish
PROJECT I	**98 days**	**Mon 12/6/99**	**Tue 3/28/00**
Preliminary study	19 days	Mon 12/6/99	Mon 12/27/99
Literature review and data collection	54 days	Tue 12/28/99	Mon 2/28/00
Writing the proposal (Project I)	22 days	Wed 3/1/00	Sat 3/25/00
Presentation of the proposal	2 days	Mon 3/27/00	Tue 3/28/00
PROJECT II	**55 days**	**Wed 3/29/00**	**Wed 5/31/00**
Analyze possible segmentation technique a	3 days	Wed 3/29/00	Fri 3/31/00
Preparation of image samples	3 days	Sat 4/1/00	Tue 4/4/00
Design & Coding	20 days	Wed 4/5/00	Thu 4/27/00
Build a system prototype	5 days	Sat 4/29/00	Thu 5/4/00
Implementation - processing code with sam	5 days	Fri 5/5/00	Wed 5/10/00
Testing and evaluation	4 days	Thu 5/11/00	Mon 5/15/00
Write-up thesis draft	9 days	Tue 5/16/00	Thu 5/25/00
Presentation for Project II	1 day	Fri 5/26/00	Fri 5/26/00
Modification of the draft	3 days	Sat 5/27/00	Tue 5/30/00
Submit thesis	1 day	Wed 5/31/00	Wed 5/31/00



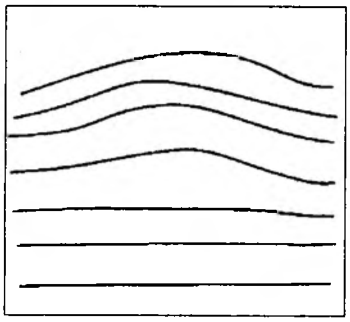




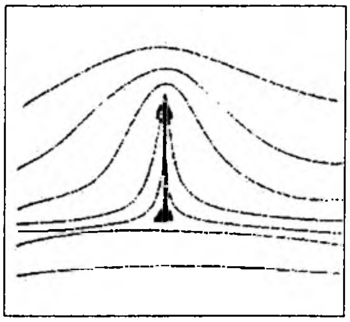
2/13
2/20
2/27
3/5
3/12
3/19
3/26
4/2
4/9
4/16
4/23
4/30
5/7
5/14
5/21
Task
Split
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Split
Rolled Up Milestone
Rolled Up Progress
External Tasks
Project Summary

APPENDIX B

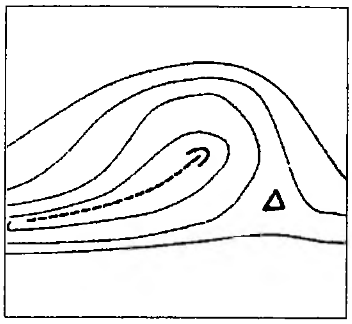
FINGERPRINT PATTERN TYPES



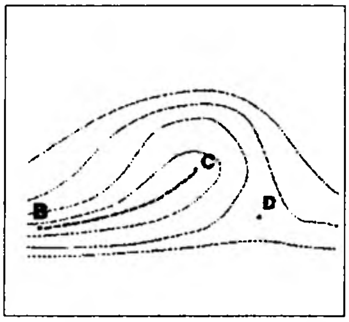
Arch



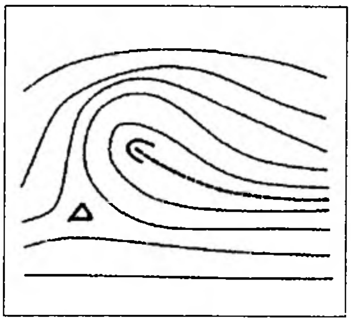
Tented Arch



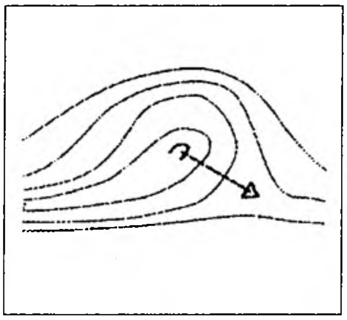
Left Loop



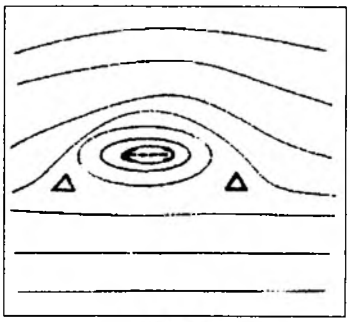
Left Loop



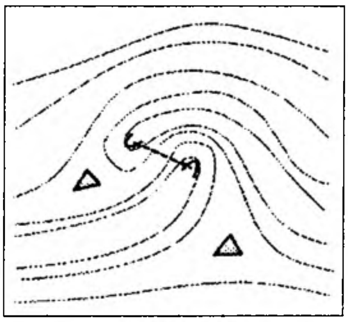
Right Loop



Loop



Whorl



Twin Loop

APPENDIX C

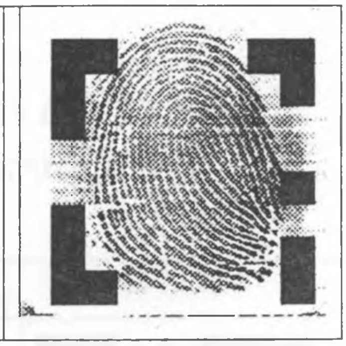
ORIGINAL SIZE OF FINGERPRINT IMAGE SCANNED THROUGH BIOMETRICS-SCANNER VERIDICOM PASSPRINT (300 x 300 PIXEL)

APPENDIX D

RESULT OF 10 SAMPLES OF IMAGE SEGMENTATION BY 4 X 4 AND 32 X 32 BLOCK WITH HIERARCHICAL TECHNIQUE

SAMPLE	ORIGINAL IMAGE	4X4	32 X 32
1(1X)			
2(1Y)			
3(2X)			
4(3X)			

5(3Y)			
6(4X)			
7(4Y)			
8(5X)			
9(6X)			

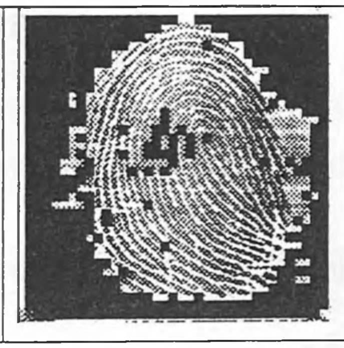
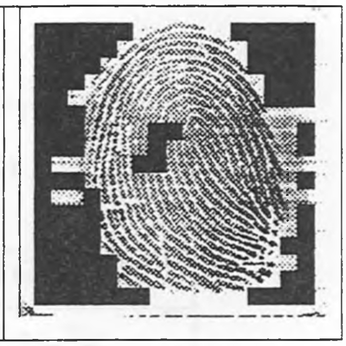
10(7X)			

APPENDIX E

RESULT OF 10 SAMPLES OF IMAGE SEGMENTATION BY 8 X 8 AND 16 X 16 BLOCK WITH HIERARCHICAL TECHNIQUE

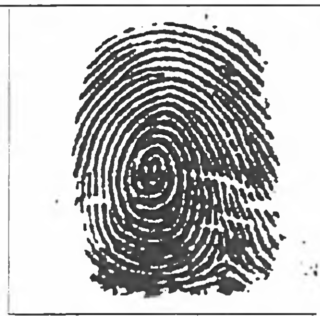
SAMPLE	ORIGINAL IMAGE	8 X 8	16 X 16
1(1X)			
2(1Y)			
3(2X)			
4(3X)			

5(3Y)			
6(4X)			
7(4Y)			
8(5X)			
9(6X)			

10(7X)			

APPENDIX F

RESULT OF 10 SAMPLES OF IMAGE SEGMENTATION WITH REGION GROWING TECHNIQUE

SAMPLE	ORIGINAL IMAGE	REGION GROWING
1(1X)		
2(1Y)		
3(2X)		
4(3X)		

5(3Y)		
6(4X)		
7(4Y)		
8(5X)		
9(6X)		

10(7X)		

APPENDIX G

SAMPLES OF 42 GOOD FINGERPRINT IMAGES

SAMPLE	IMAGE	SAMPLE	IMAGE
1		2	
3		4	
5		6	
7		8	

9		**10**	
11		**12**	
13		**14**	
15		**16**	
17		**18**	

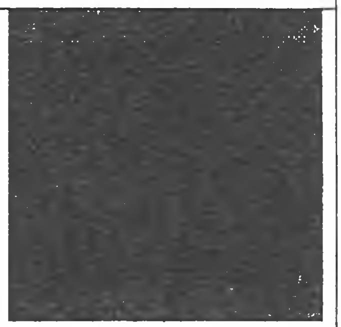
19		**20**	
21		**22**	
23		**24**	
25		**26**	
27		**28**	

29		**30**	
31		**32**	
33		**34**	
35		**36**	
37		**38**	

39		**40**	
41		**42**	

APPENDIX H

SAMPLES OF 8 POOR FINGERPRINT IMAGES

SAMPLE	IMAGE	SAMPLE	IMAGE
1		2	
3		4	
5		6	
7		8	

APPENDIX I

SOURCE CODE FOR SEGMENTATION BY HIERARCHICAL TECHNIQUE

```
unit orientation;

interface

uses  unit_tiff,vicwin, childwin,dialogs,sysutils,forms,graphics;

type
    Gxbuffer  = array[1..300, 1..300] of integer;
    Gybuffer = array[1..300, 1..300] of integer;
    ORbuffer = array[1..300, 1..300] of integer;

var
  Gxbuf : Gxbuffer;
  Gybuf : Gybuffer;
  ORbuf : ORbuffer;
  cl    : real;

procedure divBlock(x1,y1,x2,y2 :integer);
procedure Orient;
procedure correct;


implementation

uses hboost,thres,main;

procedure correct;
var
   m,n : integer;
   t:integer;
begin
     for n:= 1 to info.Length do
     begin
          for m:= 1 to info.Width do
          begin
               mnorder[n,m] := BoostOutBuf[m,n];
          end;
     end;

     for n:= 1 to info.Length do
     begin
          for m:= 1 to info.Width do
          begin
               BoostOutBuf[m,n] := mnorder[m,n]
          end;
     end;

     correctdone:=true;
end;


procedure divBlock(x1,y1,x2,y2 :integer);
```

```
var
   theta                 : real;
   deg,deg2, z           : real;
   m, n, gx, gy          : integer;
   u, v, x, y            : integer;
   count                 : integer;
   m1, m2, n1, n2        : integer;
   i,j                   : integer;
   vx,vy, ve             : real;
//   cl                   : real;

begin
     vx :=0;
     vy := 0;
     ve := 0;
     count :=1;
     m1 := x1;
     m2 := x2;
     n1 := y1;
     n2 := y2;

     i:=0;
     j:=0;

     for n := n1 to n2 do      //baca piksel 16x16
     begin
          j:=j+1;
          for m := m1 to m2 do
          {kira Gradient Gx dan Gy}
          begin
               i:=i+1;
               gx := (BoostOutBuf[m-1,n+1]) + 2*(BoostOutBuf[m,n+1])
+ (BoostOutBuf[m+1,n+1]);
               gx := gx - (BoostOutBuf[m-1,n-1] +
2*(BoostOutBuf[m,n-1]) + BoostOutBuf[m+1,n-1]);

               gy := (BoostOutBuf[m+1,n-1] + 2*(BoostOutBuf[m+1,n])
+ BoostOutBuf[m+1,n+1]);
               gy := gy - (BoostOutBuf[m-1,n-1] + 2*(BoostOutBuf[m-
1,n]) + BoostOutBuf[m-1,n+1]);

               GxBuf[i,j] := gx;
               GyBuf[i,j] := gy;
          end;
          i:=1;
     end;

     for v := 1 to blok do
     begin
          for u:= 1 to blok do
          begin
                vx := vx + (2 * gxbuf[u,v] * gybuf[u,v]);
                vy := vy + (sqr(gxbuf[u,v]) - sqr(gybuf[u,v]));

                ve := ve + (sqr(gxbuf[u,v]) + sqr(gybuf[u,v]));
          end;
     end;

     if ve<>0 then
     begin
          cl := sqrt ((sqr(vx) + sqr(vy))/(ve * blok * blok));
```

```
end
else
cl := 0;

{for n := n1 to n2 do
begin
     for m := m1 to m2 do
     begin
          if cl < thresholdvalue then
          begin
               BoostOutBuf[m,n] :=  255;

setpixelcolor(TMDIChild(MainForm.ActiveMDIChild).Vicimage,m,n,0);
          end;
     end;
end;
          }
//mainform.Memo1.Lines.Add(floattostr(cl));

if vy<>0 then
begin
     theta := 0.5 * arctan(vx/vy);
     deg := 180.0 / 3.142 * theta;
     if (deg < 0) and (deg >=-180) then
     begin
          deg := deg + 180;
     end;
end;

if vy=0 then
begin
     theta:=0;
end

else if vy > 0 then
begin
     theta := theta + 3.142;
end

else if vx > 0 then
begin
     theta := theta + (3.142/2);
end

else if vy < 0 then
begin
     theta := theta + (3.142/2);
end
else
     theta := theta;


with TMDIChild(MainForm.ActiveMDIChild).image6.Canvas do
     begin
          pen.Width:=2;
          pen.Color:=clred;
          x := trunc(hipo * cos(theta));
          y := trunc(hipo * sin(theta));
          moveto(m1+(blok div 2)+x,n1+(blok div 2)-y);
          lineto(m1+(blok div 2)-x,n1+(blok div 2)+y);
     end;
```

```
    with TMDIChild(MainForm.ActiveMDIChild).image5.Canvas do
        begin
            pen.Width:=2;
            pen.Color:=clred;
            x := trunc(hipo * cos(theta));
            y := trunc(hipo * sin(theta));
            moveto(m1+(blok div 2)+x,n1+(blok div 2)-y);
            lineto(m1+(blok div 2)-x,n1+(blok div 2)+y);
        end;
end;


procedure Orient;
var
   xblock, xbal, yblock, ybal :integer;
   xcount, ycount :integer;
   x1,y1 :integer;
begin
     yblock:=info.Length div blok;
     ybal:=info.Length mod blok;
     xblock:=info.width div blok;
     xbal:=info.width mod blok;

     //mainform.Memo1.Lines.Add ('length : '+inttostr(info.Length));
     //mainform.Memo1.Lines.Add ('width : '+inttostr(info.width));
     //mainform.Memo1.Lines.Add ('xblock : '+inttostr(xblock));
     //mainform.Memo1.Lines.Add ('xbal : '+inttostr(xbal));
     //mainform.Memo1.Lines.Add ('yblock : '+inttostr(yblock));
     //mainform.Memo1.Lines.Add ('ybal : '+inttostr(ybal));

     x1:=1;
     y1:=1;

     for ycount:=1 to yblock do
     begin
          for xcount:=1 to xblock do
          begin
               with TMDIChild(MainForm.ActiveMDIChild).image2.canvas
do
               begin
                    //pen.Color:=clblue;
                    //rectangle(x1,y1,x1+16,y1+16);
                    //pen.Color:=clblue;
                    //Pixels[x1+8,y1+8]:=clblue;
                    divBlock(x1,y1,x1+blok,y1+blok);
               end;
               x1:=blok*xcount;
          end;

          x1:=1;
          y1:=blok*ycount;
     end;

end;

end.
```

APPENDIX J

SOURCE CODE FOR SEGMENTATION BY REGION GROWING BY PIXEL AGGREGATION TECHNIQUE

```
unit region_grow;

interface

uses sysutils, unit_tiff, main, childwin, vicwin, math,
     Windows, Messages, Classes, Graphics, Controls, Forms, Dialogs,
     StdCtrls;

//uses sysutils, unit_tiff, main, childwin, vicwin, math;

const
 xseed = 30; yseed =  30;

type
inbuffer = array[1..600, 1..600] of integer;
outbuffer = array[1..600, 1..600] of integer;
GrayLevel = array[0..255] of integer;

procedure RegionGrowing(name : string);
procedure grow(x, y, threshold :integer);
procedure BacaImej(Vicimage : imgdes);
procedure BacaMedian(Vicimage : imgdes);
procedure BacaHPass(Vicimage : imgdes);
procedure BacaHBoost(Vicimage : imgdes);
procedure BacaAdaptive(Vicimage : imgdes);
procedure DisplaySegment;
function IntToBinary(value, digit:integer):integer;
procedure RGData;

var
  RGinbuf : inbuffer;
  RGoutbuf:  outbuffer;
  total, count : integer;
  N1, M1 : integer;
  N2, M2 : integer;
  GV : GrayLevel;
  fb : textfile;
  threshold : integer;
  threshvalue : integer;

implementation
//Region Growing

uses  median, hpass, hboost, adaptive, histo_grow;

procedure RegionGrowing(name : string);
var
  x, endx, y, endy : integer;
  thresInput : string;

begin
  N1 := 0;  M1 := 0;
```

```
  N2 := width; M2 := height;
  endx := N2-1; endy := M2-1;
//  xseed := 50; yseed :=  50;

//  thresInput := InputBox('Region Growing', 'Enter Threshold
Value', thresInput);
//  threshold := strtoint(thresInput);
  for y := 1 to endy do
    for x := 1 to endx do
     RGoutbuf[y][x] := 1;

  total := 0; count := 0;
  for y := yseed - 5 to yseed + 5 do
    for x := xseed - 5 to xseed + 5 do
      if ((x>1) and (y>1) and (x<endx) and (y<endy)) then
      begin
        count := count + 1;
        total := total + RGinbuf[y][x];
      end;
      grow (xseed, yseed, threshold);
  DisplaySegment;

end;

procedure grow (x, y, threshold  : integer);
var
  diff, mean :  real;

begin
    if RGoutbuf[y][x] = 1 then
    begin
       mean := total/count;
       diff := RGinbuf[y][x] - mean;
       if (diff < 0) then
         diff := -diff;

       if (diff < threshold) then
       begin
         total := total + RGinbuf[y][x];
         count := count + 1;
         RGoutbuf[y][x] := 0 ;


       if (x = 3) and (y = 1) then
       begin
         for y := M1+1 to M2-1 do
         begin
           for x := N1+1 to N2-1 do
           begin
             if RGoutbuf[y][x] = 1 then
             begin
               mean := total/count;
               diff := RGinbuf[y][x] - mean;

             if (diff < 0) then
               diff := -diff;
             if (diff < threshold) then
             begin
               total := total + RGinbuf[y][x];
               count := count + 1;
               RGoutbuf[y][x] := 0;
```

```
                mean := total/count;
              end;
            end; end;
          end;
          exit;
        end;

        if (x > 1) then
          grow(x-1, y, threshold);
        if (y > 1) then
          grow(x, y-1, threshold);

      end;
   end;
end;

procedure BacaImej(Vicimage : imgdes);
var
 i, j, y : integer;
begin
   for i := 1 to Info.Length do
       begin
         for j := 1 to Info.Width do
           begin
             y := TData[i]^[j] ;
             RGinbuf[i][j] := y;
           end;
       end;
end;

procedure BacaMedian(Vicimage : imgdes);
var
 i, j, y  : integer;
begin
     for i := 1 to Info.Length do
       begin
         for j := 1 to Info.Width do
           begin
             y := MedOutBuf[i][j]  ;
             RGinbuf[i][j]  := y;
           end;
       end;
end;

procedure BacaHPass(Vicimage : imgdes);
var
 i, j, y  : integer;
begin
     for i := 1 to Info.Length do
       begin
         for j := 1 to Info.Width do
           begin
             y := PassOutBuf[i][j]  ;
             RGinbuf[i][j]  := y;
           end;
       end;
end;

procedure BacaHBoost(Vicimage : imgdes);
var
 i, j, y  : integer;
```

```
begin
     for i := 1 to Info.Length do
       begin
         for j := 1 to Info.Width do
           begin
             y := BoostOutBuf[i][j] ;
             RGinbuf[i][j] := y;
           end;
       end;
end;

procedure BacaAdaptive(Vicimage : imgdes);
var
 i, j, y  : integer;
begin
     for i := 1 to Info.Length do
       begin
         for j := 1 to Info.Width do
           begin
             y := AdapOutBuf[i][j] ;
             RGinbuf[i][j] := y;
           end;
       end;
end;

procedure DisplaySegment;
var
  i, j : integer;
begin
  for i := 1 to Info.Length do
    begin
      for j := 1 to Info.Width do
        begin
          if RGoutbuf[i][j] = 0 then
            begin
              RGoutbuf[i][j] := 255;

setpixelcolor(TMDIChild(MainForm.ActiveMDIChild).Vicimage,j,i,255);
            end
          else
            if RGoutbuf[i][j] = 1 then
            begin
              RGoutbuf[i][j] := 0;

setpixelcolor(TMDIChild(MainForm.ActiveMDIChild).VicImage,j,i,0);
            end;
        end;
        TMDIChild(MainForm.ActiveMDIChild).image1.refresh;
    end;
    RGData;
end;

{ ************************** CHECK DATA **************************
}
procedure RGData;
var
   i, j, k : Integer;
begin
     AssignFile(fb, 'c:\RG_data.txt');
     Rewrite(fb);
```

```
      k:= 0;
      for i:= 1 to Info.Length do
      begin
             for j:= 1 to Info.Width do
             begin
                  if k = Info.Width then
                  begin
                       Writeln (fb, IntToBinary(RGOutBuf[i][j],1));
                       k:= 0;
                  end
                  else
                      Write (fb, IntToBinary(RGOutBuf[i][j],1));
                  k:= k + 1;
             end;
      end;
      Writeln(fb);
      Writeln(fb, 'End Of Text');
      CloseFile(fb);
end;

{ ************************* BINARY FUNCTION
********************************* }
function IntToBinary(value, digit:integer):integer;
begin
     case value of
          0 : IntToBinary := 1;
          255 : IntToBinary := 0;
     end;
end;

end.
```