IDENTIFICATION OF MYOCARDIAL INFARCTION TISSUE BASED ON TEXTURE ANALYSIS FROM ULTRASOUND IMAGES

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To my parents, my beloved wife and sons, Rimico, Septiadi and Madani for their supports and understandings

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ABSTRACT

Texture is an important characteristic that can be used for identification and/or detection for surface defects or abnormalities. This research has developed an algorithm for identifying heart with suspected myocardial infarction problem based on texture analysis applied on echocardiography images. A hybrid technique of wavelet extension transform with gray level co-occurrence matrix is proposed. In this work wavelet extension transform is used to form an image approximation with higher resolution. The gray level co-occurrence matrices computed for each sub-band are used to extract four feature vectors: entropy, contrast, energy (angular second moment) and homogeneity (inverse difference moment). The classifier used in this work is the Mahalanobis distance classifier. The method is tested with clinical data from echocardiography images of 30 patients. For each patient, tissue samples are taken from suspected infarcted area as well as from non infarcted (normal) area. For each patient, 10 image frames separated by some time interval are used and for each image frame 5 normal regions and 5 suspected myocardial infarction regions of 16x16 pixel size are analyzed. The proposed method has achieved 91.67% performance accuracy in classifying between normal and infarcted hearts. Thus, the proposed technique may be used as a computerized second opinion for determining whether a person is suffering from a myocardial infarction heart or not.

ABSTRAK

Tekstur adalah ciri penting yang dapat digunakan untuk mengenalpasti dan/atau pengesanan permukaan untuk kerosakan atau keanehan. Penyelidikan ini telah membangunkan sebuah algoritma untuk mengenalpasti jantung yang disyaki mengalami infarksi miokardium berdasarkan menganalisa tekstur dengan menggunakan imej daripada ekokardiografi. Di sini campuran daripada teknik jelmaan wavelet tambahan dan teknik matrik se-kejadian tahap kelabu adalah dicadangkan. Di dalam penyelidikan ini jelmaan wavelet tambahan digunakan untuk menghasilkan sebuah imej hampiran yang mempunyai resolusi yang lebih besar. Matrik se-kejadian tahap kelabu yang dihitung untuk setiap sub-jalur digunakan untuk mencirikan empat sifat vektor: entropi, kontras, tenaga (sudut momen kedua) dan kehomogenan (momen bezaan songsang). Pengklasifikasian yang digunakan di dalam penyelidikan ini adalah pengklasifikasian jarak Mahalanobis. Kaedah yang telah dicadangkan diuji dengan data klinikal daripada imej ekokardiografi untuk 30 orang pesakit. Untuk setiap pesakit, contoh tisu diambil daripada kawasan yang disyaki infark dan kawasan bukan infark (normal). Untuk setiap pesakit, 10 bingkai imej yang dipisahkan oleh sela waktu tertentu di mana 5 kawasan normal dan 5 kawasan disyaki infarksi miokardium berukuran 16x16 piksel akan dianalisa. Kaedah yang dicadangkan ini telah mencapai prestasi ketepatan sebanyak 91.67% dalam mengkelaskan antara jantung yang normal dan yang infark. Justeru itu, teknik yang dicadangkan ini boleh digunakan sebagai pandangan kedua yang dikomputerkan bagi menentukan sama ada seseorang itu mengalami infarksi miokardium atau tidak.

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LIST OF ABBREVIATIONS AND SYMBOLS

c_j	-	Space of approximation
ϕ	-	Scaling function
d_j	-	Space of detail
$\uparrow 2$	-	Up sampling
$\downarrow 2$	-	Down sampling
$1\uparrow 2$	-	Up sample rows: insert zeros at odd-indexed rows
$1\downarrow 2$	-	Down sample rows: keep the even indexed rows
$2\uparrow 1$	-	Up sample columns: insert zeros at odd-indexed columns
$2\downarrow 1$	-	Down sample columns: keep the even indexed columns
ASM	-	Angular second moment
C	-	Covariance matrix
d	-	Distance measure
dc	-	Displacement in columns
dr	-	Displacement in rows
DWT	-	Discrete wavelet transform
E	-	Energy
FIR	-	Finite impulse response
g(-m)	-	Decomposition high pass filter
GLCM	-	Gray level co-occurrence matrix
h(-m)	-	Decomposition low pass filter
HH	-	High frequency (diagonal edges)
HL	-	Vertical high frequency (horizontal edges)
IDM	-	Inverse difference moment
LH	-	Horizontal high frequency (vertical edges)
LL	-	Low pass filter (low frequency component)
ROI	-	Region of interest

α	-	Threshold value
θ	-	Angle
μ	-	Mean vector
ψ	-	Mother wavelet

LIST OF TERMINOLOGY

Algorithm: A set of instruction, especially ones that can be implemented on a computer, for a procedure that can manipulate data.

Asynergy: Lack of coordination among various muscle groups during the performance of complex movements, resulting in loss of skill and speed.

Coronary Artery: The vessels that supply the heart muscle with blood rich in oxygen

Echocardiography: A diagnostic test which uses ultrasound waves to form images of the heart chambers, valves and surrounding structures. It can measure cardiac output and is a sensitive test for inflammation around the heart (pericarditis). It can also be used to detect abnormal anatomy or infections of the heart valves.

Infarction: Death of tissue from lack of oxygen.

Myocardial Infarction: Also called heart attacks occur when one or more of the coronary arteries that supply blood to the heart completely blocked and blood to the heart muscle is cut off

Myocardial refers to heart's muscle mass.

Region-of-interest: A selected portion of the image whose individual or average pixels value can be displayed numerically

Thrombosis: Formation or presence of a thrombus clotting within a blood vessel which may cause infarction of tissue supplied to the vessel.

Tissue: A group of similar cells united to perform a specific function.

Ultrasound: A type of imaging technique which uses high-frequency sound waves.

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CHAPTER 1

INTRODUCTION

1.1. Background

Textures provide important role for automatic visual inspection. Their analysis is fundamental to many applications such as industrial monitoring of product quality control, remote sensing of earth resources, and medical diagnosis. Much research work has been done on texture, such as classification, compression, retrieval and segmentation for last three decades. Despite the effort, texture analysis is still considered an interesting but difficult problem in image processing. Texture analysis can be defined as an attribute representing the spatial arrangement of the gray levels of the pixels in a region (Chang and Kuo*,* 1993).

Echocardiography is a diagnostic test that uses ultrasound waves to create an image of the heart muscle. Echocardiography can provide a wealth of helpful information, including the size and shape of the heart, its pumping strength, and the location and extent of any damage of its tissue. It is especially useful for assessing diseases of the heart valves. It not only allows doctors to evaluate the heart valves, but it can detect abnormalities in the pattern of blood flow, such as the backward flow of blood through partly closed heart valves, known as regurgitation. Echocardiography can also help to detect the thickness of the heart's wall in an attempt to compensate for heart muscle weakness. Another advantage to echocardiography is that it is noninvasive and has no known risks or side effects (Bianco, 2003).

Smith (2004) has presented that a normal echocardiogram shows a normal heart structure and the normal flow of blood through the heart chambers and heart valves. However, a normal echocardiogram does not rule out the possibility of the heart disease. An echocardiogram may show a number of abnormalities in the structure and function of the heart, such as:

- Thickening of the wall of the heart muscle (especially the left ventricle).
- Abnormal motion of the heart muscle.
- Blood leaking backward through the heart valves (regurgitation).
- Decrease blood flow through a heart valve.

Early detection and quantitative assessment of tissue alteration in a disease is a challenge for noninvasive imaging techniques. Direct histologic assessment is limited by a requirement for obtaining tissue for examination. Therefore, to better characterize the onset and progression of myocardial infarction, a noninvasive imaging technique for distinguishing normal from abnormal tissue would be of particular importance (Kerut *et al.*, 2003). Myocardial infarction is also called heart attacks occur when one or more of the coronary arteries that supply blood to the heart completely blocked and blood to the heart muscle is cut off (Smith, 2004).

Texture analysis of echocardiography images in this research are used for diagnosis of myocardial infarction tissue. The approach is to characterize tissue based on the spatial distribution of ultrasound amplitude signal within a region of interest (ROI). Skorton *et al*., (1983) defined echocardiography image texture as: Two-dimensional spatial distribution of echocardiography amplitudes or gray levels.

Most of the texture defect detection applications are on textile, paper, steel and wood inspection. There have been a number of applications of texture processing for inspection problem. Many of these approaches have provided goods results in different fields of application, but a large number of them have shown very low classification rate or could not be implemented at all when texture sample are of small dimensions. However texture characterization of 2-D echocardiography image is not an easy task to perform, because it is well known that ultrasound images have very poor quality (Mojssilovié *et al.*, 1997).

(a)


(b)

Figure 1.1: (a) echocardiography image, a typical ultrasound image of a human heart (b) example of natural texture collection.

Figure 1.1 gives some example of natural texture (Fig.1.1b) and a typical ultrasound image of a human heart (Fig.1.1a). In most cases, they are degraded by speckle noise, acoustic shadowing, and system distortions present in all instrumentation. The main disadvantage of 2-D echocardiography for the purpose of texture description and classification in this application is caused by the structure of the heart muscle.

1.2. Objectives

The objectives of this research are:

- To design and develop an algorithm for identifying myocardial infarction tissue using texture analysis techniques.

- To evaluate the relationship between texture properties of myocardial infarction using quantitative computer analysis on 2-dimensional echocardiogram based on texture analysis techniques.

1.3. Scopes

The main focus of this research is based on texture analysis for identification of myocardial infarction tissue. Some limitations are applied to the research activity in order to keep the observation on its track. To achieve this goal, the scope of the current research has been defined as follows:

- The medical images are captured directly from the echocardiography machine using PC via frame grabber card. Block diagram of the data acquisition system is shown in Figure 1.2. All ultrasound images are captured from a HP SONOS 5500 imaging system with a 3.5 MHz transducer probe with a depth setting of 16 cm. Images were digitized with 512 x 512 pixels and 256 gray level resolutions.

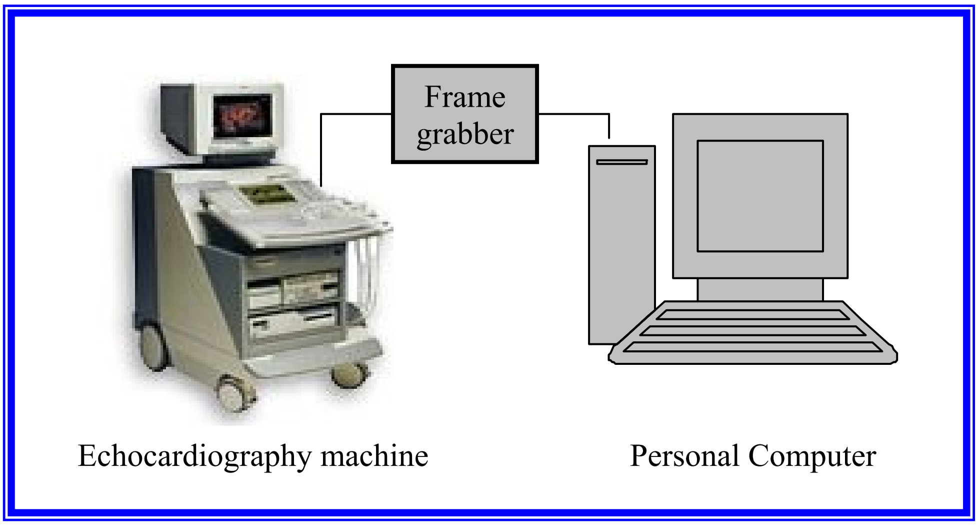
- Region of Interest (ROI) used for distinguishing a textural normal area and infarcted area is set to 16x16 pixels. The sample data were taken by supervised technician who is an experienced echocardiographer. The white square corresponds to texture sample of Region of interest (ROI) and the red square is the coronary artery region. Illustration of a typical ultrasound image of human heart and 16x16 ROI is shown in Figure 1.3.

- Sample images are from adult Malaysian males and females.

- Offline processing using Matlab programming language.

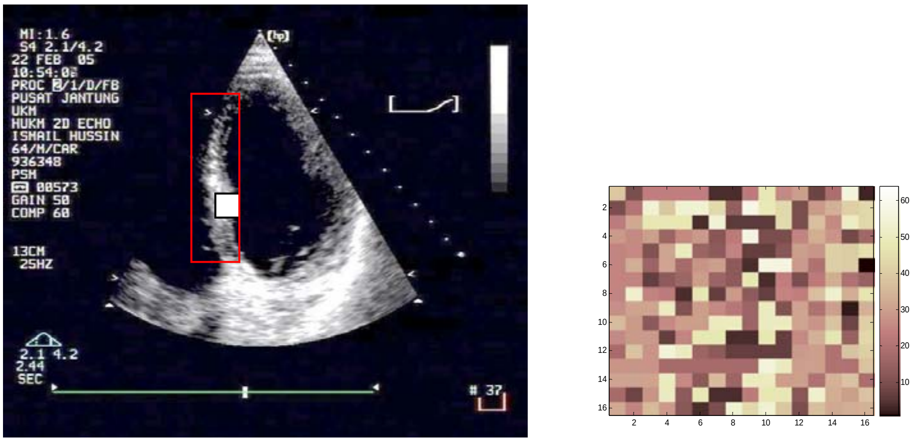
- Inspection area is confined to the coronary artery region. The area of coronary artery region is shown in red square Figure 1.3.a.

- This research does not intend to replace the function of heart specialist. The aim is to provide a secondary opinion.



(a) **(b)**

Figure 1.2: Block diagram of the data acquisition system: a) Echocardiography machine, b) Personal Computer (Data acquisition, storage, and display)



(a) **(b)**

Figure 1.3: a) A typical ultrasound image of a human heart with resolution 512x512 pixels. The white square corresponds to texture sample of Region of interest (ROI) and the red square is the coronary artery region, b) A 16 x 16 pixel of ROI has been extracted from the ultrasound image Figure a.

1.4. Hypothesis

The research undertaken in this thesis is based on the following hypotheses:

First, the characterization of tissues can be analyzed from their textures. In other words, dead tissues exhibits different texture and thus can be differentiated from normal tissues.

Second, based on the first hypothesis, a heart suffers from infarction (dead tissue) will have denser texture compare to normal tissue.

1.5. Contributions

The original contribution of this research is in the development of a method for identifying myocardial tissue using texture analysis applied onto echocardiography image. Much research work has been done on texture analysis for defect detection or similarity measured problem. Most of them used texture samples obtained from good quality and standard image size such as: textile, paper, steel, rock and wood inspection. The proposed technique in this research performed texture analysis based on poor quality images.

The proposed method is a hybrid between wavelet extension transform and gray level co-occurrence matrix (GLCM). The developed algorithm has been trained and tested with image data of size 16x16 pixels.

1.6. Organization of this Thesis

This thesis is divided into seven chapters. An overview for each chapter is given in this section.

Chapter 1: Introduction to problems and brief overview of applications, where objectives, scopes, contributions and structure of the thesis are explained.

Chapter 2: Literature review of previous works in texture analysis is discussed. In this chapter proposed method for this work is also discussed after considering several advantages and disadvantages of the existing techniques.

Chapter 3: This chapter describes a brief introduction to the wavelet transform and wavelet extension transform as they will be the basis techniques in texture analysis.

Chapter 4: The concept for gray level co-occurrence matrix (GLCM) is given in this chapter. This GLCM is used to perform feature extraction which is then used in the texture analysis problem.

Chapter 5: Development of the algorithm for identification of myocardial infarction tissue from echocardiography images is explained in this chapter. The processing are described step by step and the developed algorithm are illustrated in this chapter.

Chapter 6: Results obtained from experiments based on the proposed approach are given in this chapter. An application of texture analysis for medical image especially echocardiography image is demonstrated.

Chapter 7: Conclusions of the thesis are given in this chapter. A summary of the finding, followed by a list of area where further investigation may lead to improvement in the proposed texture analysis algorithms are also discussed.

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