UNIVERSITI PUTRA MALAYSIA

DETECTION OF MICROCALCIFICATIONS USING WAVELET TECHNIQUES IN MAMMOGRAM DIGITAL IMAGES AND DEVELOPMENT OF A SOFTWARE FOR EVALUATION OF RADIOLOGIST FINDINGS

MAJDI TAYSIR HASAN AL-QDAH.

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By

MAJDI TAYSIR HASAN AL-QDAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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To my family

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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January 2006

Chairman: Associate Professor Abd Rahman Ramli, PhD

Faculty: Engineering

This thesis describes a method of using wavelets in the detection comparison of breast cancer among the three main races in Malaysia: Chinese, Malays, and Indians followed by a system that records and evaluates the radiologist's findings over a period of time to gauge the radiologist's findings in confirming breast cancer cases. A comparison was carried out among few different wavelets to find out the best filter for detection for all three Malaysian races' mammograms. The detection of three filters was presented to three expert radiologists to confirm the best filter detector. As a result, the db4 wavelet was utilized to detect microcalcifications in mammogram digital images obtained from a Malaysian women sample. The wavelet filter's detection evaluation was done by visual inspection to confirm the detection results of those pixels that corresponded to microcalcifications. Detection

was counted if the wavelet detected pixels corresponded to the radiologically identified microcalcification pixels. The findings suggest that no one race mammograms are easier for wavelets' detections of microcalcifications and for the radiologist confirmation. After the radiologist's detection confirmation a new client-server radiologist recording and evaluation system is designed to evaluate the findings of the radiologist over some period of cancer detection working time. It is a system that records the findings of the Malaysian radiologist for the presence of breast cancer in Malaysian patients and provides a way of registering the progress of detecting breast cancer of the radiologist by tracking certain metric values such as the sensitivity, specificity, and Receiver Operator Curve (ROC).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah.

PENGENALPASTIAN KALSIFIKASI MIKRO MENGGUNAKAN TEKNIK WAVELET DI DALAM MAMMOGRAPHY DIGITAL DAN PEMBANGUNAN PERISIAN UNTUK PENILAIAN PENEMUAN PAKAR RADIOLOGI

Oleh

MAJDI TAYSIR HASAN AL-QDAH

Januari 2006

Pengerusi : Profesor Madya Abd Rahman Ramli, PhD

Fakulti : Kejuruteraan

Tesis ini menerangkan kaedah menggunakan wavelet di dalam pengenalpastian perbandingan kanser payu dara di kalangan tiga bangsa utama di Malaysia : Cina, Melayu dan India disusuli dengan sistem yang merekod dan menilai penemuan pakar radiologi dalam suatu jangkamasa tertentu yang boleh membuat penilaian dan mengesahkan kes-kes kanser payu dara. Perbandingan dibuat di antara beberapa wavelet berbeza untuk mengetahui penapis terbaik untuk pengenalpastian mammogram ketiga-tiga bangsa di Malaysia. Pengesanan tiga penapis dipersembahkan kepada tiga orang pakar radiologi untuk mengenalpasti pengesan penapis yang terbaik. Keputusannya, wavelet db4 digunakan untuk mengesan kalsifikasi mikro dalam imej-imej digital mammogram yang diperolehi dari sampel wanita

Malaysia. Penilaian pengesanan penapis wavelet dijalankan menggunakan pemeriksaan visual untuk memastikan keputusan penilaian piksel yang berpadanan dengan kalsifikasi mikro. Pengesanan diambilkira jika piksel yang dikesan menggunakan wavelet berpadanan dengan piksel kalsifikasi mikro yang telah dikenalpasti secara logik-radiologi. Penemuan mencadangkan kemudahan untuk mengesan wavelet bagi kalsifikasi mikro dan pemastian dari pakar radiologi pada mammogram tidak dipengaruhi oleh ketiga-tiga bangsa. Selepas pemastian pengesanan dari pakar radiologi, suatu sistem baru pelanggan-pelayan yang berfungsi merekod dan menilai direkabentuk bagi membuat penilaian penemuan-penemuan radiologi dalam suatu jangkamasa kerja pengesanan kanser. Sistem ini merekod penemuan pakar radiologi di Malaysia bagi pesakit-pesakit kanser payu dara di Malaysia dan menyediakan satu cara meregister progres dalam pengesanan kanser payu dara oleh pakar radiologi dengan memerhatikan nilai metrik tertentu seperti kepekaan, keperincian dan lengkok penerima operator.

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I certify that an Examination Committee has met on 27 February, 2006 to conduct the final examination of Majdi Taysir Hasan Al-Qdah on his Doctor of Philosophy thesis entitled "Detection of Microcalcifications Using Wavelet Techniques in Mammogram Digital Images and Development of a Software for Evaluation of Radiologist Findings" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

Majdi

(MAJDI TAYSIR AL-QDAH)

Date: 15APR2006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RMI	Remote Method Invocation
NCR	National Cancer Center
BIRADS	Breast Imaging Reporting and Data System
ACR	American College of Radiology
ROC	Receiver Operator Curve
ROI	Region of Interest
ATMTN	Asynchronous Transfer Mode Telemammography Network
CAD/DSP	Diagnosis-Detection/Digital Signal Processing
DICOM	Digital Imaging and Communications in Medicine
GUI	Graphical User Interface
MRRES	Malaysian Radiologist Records and Evaluation System

CHAPTER I

INTRODUCTION

1.1 Introduction

Breast cancer is one of the most common cancers for women in different countries and Malaysia is no exception. Different women across the world have variations in breast cancer tissue depending on the body size, diet, reproductive characteristics such as age of menarche, number of children, and age of menopause. Also, existence rates vary from one race to another; higher rates of breast cancer have been reported in white women more than in black women [1]. A study done by University Malaya Medical Center in Kuala Lumpur (HUKL) in the year 2000 has shown that 60% of 952 cancer patients admitted to the UHKL in the years 1993 to 2000 were Chinese patients. It was concluded that the incidence of breast cancer in Chinese appears to be higher than the other two races, namely Malays and Indians [1]. It was also shown that 30-40% of all patients were in the late stages of the cancer. After comparing the data with Caucasians' data in the United States and Europe it was suggested that Malaysian women tend to get the disease at an early age with smaller tumor sizes. Also the findings suggest that breast cancer in Malaysians is more aggressive type than Caucasians. Furthermore, it can be said that women self-examination has sometimes shown shortcomings in that it allowed the cancer to grow to dangerous points before detection is made especially in

Malaysian women. This makes it clear that a method that makes an earlier detection of breast cancer possible is always needed. Nowadays this method is through screening with mammography.

Regarding computer methods in mammography, it is a difficult task to design methods of automatic computer detection because of the nature of mammograms. The mammograms are images of high resolution and low contrast with a great variation in the grayscales of different mammograms. When designing a computer system for analysis of mammograms, it is necessary to find methods suitable for locating early signs of breast cancer, microcalcifications. In a mammogram, radiologists try to identify calcifications as indicators of early cancer. In some mammograms the calcifications are seen as white spots on a dark gray background while in other mammograms are visible as brighter gray spots on a slightly darker gray background. There may also be other bright regions not associated with calcifications, which makes straightforward methods applied to other medical images inappropriate for detection of early signs of cancer, microcalcifications, and there is a need to help radiologists obtain better diagnosis by providing special computer aided tools. One good tool for analysis of medical images is wavelets' analysis [2]. The wavelet transform is a useful mathematical tool that currently has been applied in different applications of image processing including the detection of cancers in mammograms.

1.2 Scope and Motivation of the Research

Since it has been reported by the Malaysian National Cancer Center (NCR) [1] that the incidence of breast cancer is lower in Malay women compared to Chinese and Indian women, the race factor in mammography has to be investigated; especially if the risk of cancer in Chinese women is related to the race factor or it is related to the lifestyle, reproductive practices, age, diet, genetics, which are factors that have been shown to influence the occurrence of cancer not only in the breast but also all over the body and among different races of the world. The question might be asked whether it is also difficult to diagnose breast cancer in one race of the Malaysian society more than other races. This work will concentrate on the study and comparison of the three Malaysian race's mammograms in relation to the detection of breast cancer. It uses the wavelet detection techniques to compare the easiness or difficulty of detecting early signs of cancer in Malaysian mammogram images. The work is not concerned with the study of pattern classification of the clustered shapes of calcifications within a mammogram image but more on the detection comparison of the wavelet filter for different Malaysian races' mammograms. Also, since the definite results of studying any factor related to cancer can only be obtained after a long period of time, real data by working radiologists has to be obtained and evaluated related to the race factor study or even related to other factors' studies that can be done by other researchers working in the field. Therefore, this work designs and implements a

separate evaluation system that allows radiologists to record and track their findings for a period of working time with system automatic evaluation at each period of the radiologist findings. The design of such system can act as a computer aid tool for radiologists and medical institutions since medical computer specialists currently are trying to develop complete medical information systems that all doctors being an orthopedics, pediatric, or a radiologist and other medical staff can use within a medical environment. This work will help design the radiologist component of the information system for use of medical institutions and for researchers' utilization to study certain factors' relation to breast cancer.

1.3 Problem Statement

Microcalcifications form the early signs of cancer and they appear as bright small white spots in a mammogram image; but they are not easily detected by radiologists which results in many missed diagnoses. Several techniques and methods have been proposed for enhancing and extracting microcalcification from mammogram images including neural networks and fuzzy techniques (Nagel et al. [40], Cheng et al. [39], and Verma and Zakos [72]); morphological operations (Betal [37], Pohlman et al. [55], Quadrates & Sacritan [34], and Smith et. al [35]); fractal methods (Sang & Jun [51] and Huai et. al [50]); and lastly wavelet based techniques (Liu et al. [61], Laine et al. [62], Chen et al. [63], Strickland and Hahn [64], Yoshida

et al. [65], Murat. et. al [67], and Werapon & Kosin [66]). Wavelets specifically have been used in many applications and in the use of identifying small features within a mammogram image as they can perform better in the detection of those fine features than other conventional methods such as unsharp masking, morphological operations, matched filters, and multi scale segmentation Murat et al. [67]. Wavelets have good filtering abilities since they use multiresolution property to analyze images that allows them to zoom on in details within an image at different subbands. But more work is needed to investigate the suitable wavelet filter(s) for the analysis and its performance by comparing wavelets from the same family and among different families; also more work is needed to investigate the breast tissue characteristics' variations among different races in cancer detection because of the intensity contrast values and their effects on the detection capabilities of the filters. Moreover, there is no method that can accomplish a 100% detection and positive presence of breast cancer especially if the microcalcifications are not clustered; therefore, the radiologist should be involved in the decision-making and the final results of identifying the presence of benign or malignant cancers in any detection system even though it is understood that malignant tumors could arise if the microcalcifications are usually clustered it is not necessarily true for all clustered cases; furthermore, the cluster size and shape is not clearly defined and could vary from few pixels to more number of pixels in order