UNIVERSITI PUTRA MALAYSIA

ESTIMATION OF GESTATIONAL AGE FROM ULTRASOUND IMAGES USING DIRECT LEAST SQUARES FITTING OF ELLIPSES

RAKEEB SAEED KAID

ESTIMATION OF GESTATIONAL AGE FROM ULTRASOUND IMAGES USING DIRECT LEAST SQUARES FITTING OF ELLIPSES

By

RAKEEB SAEED KAID

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2007

DEDICATION

To my family

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

ESTIMATION OF GESTATIONAL AGE FROM ULTRASOUND IMAGES USING DIRECT LEAST SQUARES FITTING OF ELLIPSES

By

RAEEB SAEED KAID

September 2007

Chairman: Mohammad Hamiruce Marhaban, PhD

Faculty: Engineering

Ultrasound imaging or echography is a very important and competitive medical diagnostic tool, due to its low cost, short acquisition time, and non-invasive nature. However, ultrasound images are inherently difficult to analyze due to their echo texture, speckle noise, low contrast and weak edges.

Measurement of the fetal head biparietal diameter (BPD) and head circumference (HC) is crucial for estimation of fetal age. Due to the noisy nature of ultrasound images and variation in image acquisition and measurement techniques, manual measurements of these parameters are subject to inter and intra-observer variability.

The aim of this work is to develop a fully automated technique for efficient and accurate detection and estimation of the gestational age of a fetus by measuring the biparietal diameter of the head. The head was assumed to have an elliptical shape. No user input or

size range of the head was required. The proposed technique based on a method called direct least squares fitting of an ellipse. This method combines several advantages: It is ellipse-specific so that even bad data will always return an ellipse, it can be solved naturally by a generalized eigensystem, and it is extremely robust, efficient and easy to implement.

The process goes through three steps: image preprocessing (contrast enhancement, smoothing, and intensity enhancement), object extraction (sharpening, morphological reconstruction and skeletoning) and fitting an ellipse to the resultant shape and measuring its parameters.

The proposed fully automatic technique was tested and evaluated on about 20 images of fetal heads. The images had a combination of noise and low contrast. Excellent linear correlation r = 0.997 between manual and automatic measurement was obtained, which verifies the reliability of the proposed automatic approach.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENGANGGARAN USIA KANDUNGAN DARI IMEJ ULTRABUNYI MENGGUNAKAN PENYESUAIAN ELIPS KUASA DUA KECIL LANGSUNG

Oleh

RAKEEB SAEED KAID

September 2007

Pengerusi: **Mohammad Hamiruce Marhaban, PhD**

Fakulti: **Kejuruteraan**

Pengimejan ultrabunyi atau ekografi adalah peralatan perubatan yang berdaya saing dan sangat penting memandangkan ianya murah, pengambilan imej yang pantas, dan tidak menyusahkan. Walaubagaimanapun, imej-imej ultrabunyi kadang kala susah untuk dianalisa disebabkan tekstur gema, hingar berbintik, kontras rendah kadar ketajaman dan bucu yang tidak jelas.

Pengukuran kepala kandungan iaitu diameter “biparietal” (BPD) dan lilitan kepala (HC) adalah penting dalam penganggaran usia kandungan. Disebabkan hingar yang terdapat pada imej-imej ultrabunyi dan pelbagai variasi dalam pengambilan imej dan teknik-teknik pengukuran, pengukuran secara manual parameter-parameter ini adalah bergantung kepada perbezaan luaran dan dalaman pemerhati.

Matlamat penyelidikan ini adalah untuk membangunkan teknik automatik sepenuhnya untuk mengesan dan menganggarkan perkembangan usia kandugan secara efisyen dan

tepat dengan mengukur diameter “biparietal” kepala janin. Kepala janin adalah dianggap berbentuk elips. Tiada sebarang input atau anggaran saiz kepala diperlukan dari pemerhati. Teknik yang dicadangkan adalah berdasarkan satu teknik yang dipanggil penyesuai kuasa dua terkecil langsung untuk elips. Teknik ini menggabungkan beberapa kebaikan: ia adalah khas untuk elips di mana walaupun data yang diterima kurang sempurna, ia tetap akan menghasilkan elips; ia boleh diselesaikan secara semulajadi dengan sistem eigen umum; dan ia sangat stabil, efisyen dan mudah digunakan.

Proses ini melalui tiga tahap:pra-pemprosesan imej (penambahbaikan kontras, perataan, dan penambahbaikan kecerahan), pengekstrakan objek (pembaikan morfologi, penghasilan rangka) dan penyesuaian elips kepada bentuk yang terhasil dan pengukuran parameter-parameter.

Teknik automatik sepenuhnya yang dicadangkan ini telah diuji dan dinilai dengan menggunakan 20 imej-imej wanita mengandung. Imej-imej ini mengandungi kombinasi hingar dan kontras rendah. Salingkaitan lelurus r = 0.997 yang sangat baik antara pengukuran manual dan automatik telah dihasilkan, yang membuktikan kestabilan system automatik yang dicadangkan ini.

ACKNOWLEDGEMENTS

I would like to take this opportunity and thank my supervisor, Dr Mohammad Hamiruce Marhaban, for his support, guidance and understanding. Through the course of my master's studies I have had the great fortune to get to know and interact with him. His comments and suggestions for further development as well as his assistance during writing this thesis are invaluable to me. His talent, diverse background, interest, teaching and research style have provided for me an exceptional opportunity to learn and made be become a better student.

I would also like to thank Dr Samsul Bahari Mohd Noor my co-supervisor for his help and valuable suggestions.

I would also like to thank Sana'a Community College (SCC) for their financial support during my study.

Finally, I would like to thank my family and friends, without whose support I would never have managed to complete this project.

APPROVAL

I certify that an Examination Committee has met on **10/9/2007** to conduct the final examination of **Rakeeb Saeed Kaid** on his **Master** thesis entitled "Estimation of Gestational Age in Ultrasound Images Using Direct Least Squares Fitting of Ellipses" 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:

Ishak B. Aris, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Iqbal B. Saripan, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Syed Javaid Iqbal, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd fua'ad Hj.Rahmat, PhD
Associate Professor
Faculty of Electrical Engineering
Universiti Technology Malaysia
(External Examiner)

HASANAH MOHD CHAZALI, PhD
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Mohammad Hamiruce Marhaban, PhD
Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Samsul Bahari B. Mohd. Noor, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 22 January 2008

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution**.**

RAKEEB SAEED KAID

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS/NOTATIONS/GLOSSARY OF TERMS

2D	Two Dimensions
3D	Three Dimensions
4D	Four Dimensions
AC	Abdominal Circumference
BHPF	Butterworth Highpass
BPD	Biparietal Diameter
c	Constant
cm	Centimeter
CRL	Crown-Rump Length
CT	Computed Tomography
f	Input Image
FL	Femur Length
g	Output Image
GA	Gestational Age
GLPF	Gaussian Lowpass Filter
HC	Head Circumference
HPF	Highpass Filter
Hz	Hertz
KHz	Kilohertz
log	Natural Logarithm
LPF	Lowpass Filter

MHz	Megahertz
MM	Mathematical Morphology
MRI	Magnetic Resonance Imaging
NMR	Nuclear Magnetic Resonance
PET	Positron Emission Tomography
UBM	Ultrasound Biomicroscopy
US	Ultrasound
η	Any real number does not equal zero
λ	Eigenvalue
σ	Standard Deviation
σ^2	Variance
$\oplus$	Dilation
φ	Empty set
$\boldsymbol{\theta}$	Erosion

CHAPTER 1

INTRODUCTION

1.1 Background

Ultrasound imaging or echography is a very important medical diagnostic auxiliary tool. Its relatively low cost, short acquisition time and non invasive nature makes echography a very competitive method. This fact has stimulated a great amount of research aimed at increasing its diagnostic potential [1]. The use of ultrasound during pregnancy has become an important obstetric tool for assessing a wide area of internal organs. There are two types of obstetric examination namely, the common or basic examination and the targeted examination. Examples of the basic examination include determination of gestational age, fetal number, viability, lie, placental location and grade, and volume of amniotic fluid. Examples of the targeted examination include detection of a fetus suspected of anatomic and functional defects [2].

Several parameters are used as age and development indicators, the most important of which are: biparietal diameter (BPD), head circumference (HC), femur length (FL), crown-rump length (CRL), and abdominal circumference (AC). Each of these parameters provides, through a specific mathematical expression, estimates of the gestational age (GA), given in weeks (w) and days (d) [3] consistency and reliability of measurements are thus a very important issue.

1.2 Problem Statement

Manual extraction of head contours in medical ultrasound images requires an expert knowledge and it is a tedious and time-consuming task. Factors contributing to the subjectivity of biparietal measurements include the noisy nature of ultrasound images, the varying experience level of sonographers, and the common presence of artifacts extending from the boundary of the fetal head. In addition, manual contour extraction is influenced by the variability of the human observer which limits its reliability and reproducibility. The development of automatic techniques for extraction of contours of fetal anatomic structures can in principle eliminate the variability introduced by the human operator, contributing to reliable and reproducible measurements [4-7]. An automatic system for fetal head detection, recognition and measurement in ultrasound images could promote the standardization of fetal head measurements, resulting in more reliable age estimates.

1.3 Aims and Objectives

- To identify the key problems with manual estimation of the gestational age.
- To develop a fully automatic, fast and accurate technique for detection a fetal head and estimation the gestational age by measuring the biparietal diameter of the head.
- To develop an algorithm to overcome the problems of echo texture, speckle noise, low contrast and weak edges of ultrasound images.

- To evaluate the advantages of direct least squares fitting of ellipses method.

1.4 Contribution

This research develops a new technique to detect features in ultrasound images, which shows a very good performance in detection and estimation gestational age in ultrasound images. The developed method makes use of major image processing methods and fundamentals. The developed technique has some great advantages, it is fast, accurate, reliable and easy to implement. The ultrasound images of a fetal head are very noisy, weak edge delineation and low contrast, which required the development of a three-step method to overcome these challenges, image preprocessing, object extraction and object detection and measurement.

1.5 Scope of Work

The scope of this research is to detect the fetal head and estimate the gestational age from ultrasound images. The ultrasound images used in this study have the same resolution and were collected from the same ultrasound machine. During scanning the images, resolution must be kept constant for all images to keep the dimensions of the images constant.

This research develops a fully-automatic algorithm for detection and estimation the gestational age using biparietal diameter only, however, the algorithm can be extended to estimate other measurements like head circumference and abdominal circumference. Because the head contour is assumed to have an elliptical shape, automatic ellipse detection is used to detect the head contour.

1.6 Thesis Organization

This chapter provides an introduction to the research project described in this thesis and describes how the thesis is organized.

Chapter Two is a literature review of medical imaging history and types of medical imaging. The major algorithms and concepts related to ellipse detection are presented and discussed. Related work and its limitations are also presented.

Chapter Three presents the methodology, which includes the algorithm design used to extract the area of interest from the ultrasound image and estimate the gestational age. Also it presents the direct least squares fitting of ellipses method, with a description of each step and how it works and how it was implemented.

Chapter Four continues by showing the results of the automatic estimation of gestational age method for various ultrasound images and comparing between the manual and the automatic method. Discussion is also presented in that chapter.

Chapter Five summaries and concludes the work presented in the previous chapters and the future work is discussed.

CHAPTER 2

LITERATURE REVIEW AND BACKGROUN INFORMATION

2.1 Medical Imaging Modalities

Medical imaging is the process by which physicians evaluate an area of the subject's body that is not externally visible. Various imaging are available for acquiring complementary for different aspects of anatomy. Examples are ultrasound (US), magnetic resonance imaging (MRI), X-rays including computed tomography (CT), and positron emission tomography (PET). Medical imaging may be "clinical", seeking to diagnose and examine disease in specific human patients (pathology). Alternatively, it may be research-motivated, attempting to understand processes in humans or animal models. Many of the techniques developed for medical imaging also have scientific and industrial applications.

2.1.1 X-rays Imaging

X-rays are a type of electromagnetic radiation with wavelengths of around 10-0.01 nanometers. The X-ray photographic plate or film is used in hospitals to produce images of the internal organs and bones of a patient. The part of the patient to be X-rayed is placed between the X-rays source and the photographic receptor to produce what is a shadow of all the internal structure of that particular part of the body being X-rayed. The

X-rays are blocked by dense tissues such as bone and pass through soft tissues. Those areas where the X-rays strike the photographic receptor turn black when it is developed. So where the X-rays pass through "soft" parts of the body such as organs, muscle, and skin, the plate or film turns black. Contrast compounds containing barium or iodine, which are radiopaque, can be injected in the artery of a particular organ, or given intravenously. The contrast compounds essentially block the X-rays and hence the circulation of the organ can be more readily seen.

X-rays are especially useful in the detection of pathology of the skeletal system, but are also useful for detecting some disease processes in soft tissue. Some notable examples are the very common chest X-rays, which can be used to identify lung diseases such as pneumonia, lung cancer or pulmonary edema, and the abdominal X-ray, which can detect ileus (blockage of the intestine), free air (from visceral perforations) and free fluid (in ascites). In some cases, the use of X-rays is debatable, such as gallstones (which are rarely radiopaque) or kidney stones (which are often visible, but not always). Also, traditional plain X-rays pose very little use in the imaging of soft tissues such as the brain or muscle.

2.1.2 Computed Tomography

Computed tomography, known as CT or CAT scanning, was introduced into clinical practice in Britain in the early 1970s. Scanners were developed to study the brain in cross section, but other applications soon became apparent and today computed tomography of the chest, abdomen, and pelvis is common place. The information acquired by computed tomography is stored on a computer as digital raw data and an image can be displayed on a video monitor or printed on to the X-ray film.

Conventional radiographs depict a three dimensional object as a two dimensional image. Their main limitation is that overlying tissues are superimposed on the image. Computed tomography overcomes this problem by scanning thin slices of the body with a narrow X-ray beam which rotates around the body, producing an image of each slice as a cross section of the body and showing each of the tissues in a 10 mm slice (Figure 2.1).

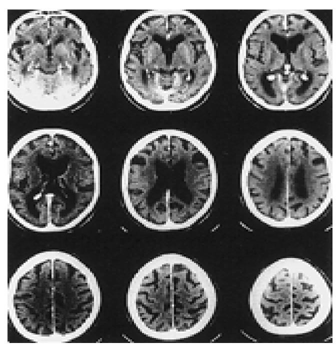

Figure 2.1: An Example of a Multi-slice Computed Tomography Image

Another limitation of the conventional radiograph is its inability to distinguish between two tissues with similar density, such as soft tissue and fluid. Computed tomography can differentiate between tissues of similar density because of the narrow X- ray beam. The benefits of computed tomography do not come without a price. Firstly, computed tomography is considerably more expensive than conventional radiography. Secondly,