Scientific Computing Department
Faculty of Computer & Information Sciences
Ain Shams University

3D Medical Image Segmentation

A thesis submitted to the department of Scientific Computing,
in partial fulfillment of the requirements for the degree of Master of Science in Scientific Computing.

By

Marwa Ibrahim Shams

Teaching Assistant at Scientific Computing Department,
Faculty of Computer and Information Sciences,
Ain Shams University

Under Supervision of

Prof. Dr. Howida A. Shedeed
Professor in Scientific Computing Department
Vice Dean of Graduate Studies and Research
Faculty of Computer and Information Sciences
Ain Shams University

Dr. Safwat H. Hamad
Associate Professor in Scientific Computing Department
Faculty of Computer and Information Sciences
Ain Shams University

Dr. Mohammed A.-Megeed Salem
Associate Professor in Scientific Computing Department
Faculty of Computer and Information Sciences
Ain Shams University

Cairo 2017

Acknowledgements

First of all, I would like to thank Allah for giving me opportunity, determination and providing me the blessings to complete this work. This thesis could not have been done without his help and generosity.

...

I would like to thank Prof. Dr. Howida A. Shedeed for her patience, guidance and dedicating much of her time to help me.

...

I would like to express my sincere appreciation and gratitude to Dr. Safwat H. Hamad and Dr. Mohammed A.-M. Salem who always believed in me and never hesitate to provide me support and motivation. I appreciate all their ideas, efforts, and the time that they have devoted to support and assist me through my thesis.

...

Many thanks to my parents, my whole family, and my friends for their endless prayers and love.

...

Abstract

Recently, automated analysis of medical images becomes important for easier and faster clinical diagnosis. Identifying human organs is the key component for such analysis, i.e., segmentation of the anatomical structures from medical images.

Coronary arteries segmentation in three-dimensional (3D) images has gained wide interest in old and recent scientific research and is regarded as a fundamental step in evaluating the degree of Coronary Artery Disease (CAD) in cardiac clinical diagnosis and surgical planning. Thus, various methods have been developed for segmenting coronaries from different cardiac imaging modalities.

Previously developed segmentation methods were designed in a way that can address the challenging task of coronary arteries. The challenges of coronary segmentation can be summarised in four points: the small size of coronaries, structures attached to coronaries has similar intensity and intensity, shape variations along the vessels and presence of calcifications.

The research problem of coronary segmentation was divided into three parts. First, enhancing the 3D input images using vessel enhancement techniques which make it easier to detect and extract coronary vessel regions in next steps. Second, recognizing and segmenting coronaries using a proper segmentation method that can handle the changes in intensity and geometry along coronaries. Third, using the resulted coronary vessel tree for detecting and quantifying stenoses (narrowness).

A framework for a coronary segmentation, stenoses detection and quantification system is proposed along with a comprehensive overview of the state-of-art coronary segmentation algorithms.

The proposed coronary segmentation framework was divided into three main parts: enhancement and preprocessing, coronary segmentation, and stenoses detection and

quantification. In enhancement, input CTA images are enhanced by removing calcifications using thresholding, making coronary regions more obvious using histogram equalization and enhancing vessel regions using Hessian based analysis. Input centerlines are also resampled for better accuracy of segmentation results and such resampled centerlines are used in a volumetric wrapping step. The resulted wrapped volume is then used in the segmentation step that recognizes and segments coronary vessels using Otsu thresholding technique. Finally, the segmented coronaries are then used in a further step to detect and quantify vessel stenoses. This was done by analysing the area of vessel cross-sections along the whole coronary tree to detect stenoses and apply linear regression to these calculated areas to quantify the degree of (stenoses) narrowing.

The proposed system was tested and evaluated on 48 Computed Tomography Angiography (CTA) standard datasets of coronary patients at different levels of severity. The evaluation uses three metrics for comparing obtained segmentation results with the manual segmentation annotated by three experienced observers. Stenoses detection and quantification results are also quantitatively evaluated using two evaluation metrics for each step by comparing obtained results to detection and quantification previously defined by physicians. Furthermore the results were compared with other state-of-art algorithms showing the strengths and weaknesses of the proposed system.

Contents

List of Figures

List of Tables

List of Abbreviations

3D Three Dimensional

AHA American Heart Association

CAD Coronary Artery Disease

CCA Conventional Coronary Angiography

CCS Coronary Calcium Score

CCTA Coronary Computed Tomography Angiography

CHD Coronary Heart Disease

CMP Curved Multi-planer

CP Calcified Plaques

CT Computed Tomography

CTA Computed Tomography Angiography

CVDs Cardiovascular Diseases

HU Hounsfield Unit

ICA Invasive Coronary Angiography

IVUS Intra Vascular Ultra Sound

LAD Left Anterior Descending

LCA Left Coronary Artery

LCX Left Circumflex

LM Left Main

MaxD Maximum Distance / Hausdorff Distance

MP Mixed Plaques

MR Magnetic Resonance

MSD Mean Squared Distance

NCP Non-Calcified soft Plaques

PET Positron Emission Tomography

PPV Positive Prediction Value

QCA Quantitative Coronary Angiography

RCA Right Coronary Artery

RPD Right Posterior Descending

XRA X-ray Angiography