UNIVERSITI PUTRA MALAYSIA

ULTRA WIDEBAND TECHNIQUE FOR BREAST CANCER DETECTION USING MULTI-LAYER FEED-FORWARD NEURAL NETWORKS

SALEH ALI ALSHEHRI

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By

SALEH ALI ALSHEHRI

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

June 2011

DEDICATION

To my Parents,

My Wife,

My Sons and Daughters

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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Chairman : Assoc. Prof. Adznan Bin Jantan, PhD

Faculty : Engineering

Breast cancer is one of the main causes of women's death. Early detection of tumors increases the chances of overcoming this disease. There are several diagnostic methods for detecting tumors, each of which has its own limitations. Recently, Ultra Wideband (UWB) imaging has gained wide acceptance for several good features such as its specificity and lack of ionizing radiation. The confocal method has been the dominant technique in this area based on homogeneous breast tissues and prior knowledge of tissue permittivity. Hence it is impractical and difficult to be implemented clinically.

This thesis has focused on development of a complete non-confocal system for breast tumor detection using Neural Network (NN)-based Ultra Wideband (UWB) imaging considering both homogeneous and heterogeneous tissues. The work has been done in two phases: i) Simulation and ii) Experiment.

At the simulation stage, a feed-forward NN model was developed to identify the existence, size, and location of tumors in a breast model. Spherical tumors were created and placed at arbitrary locations in a hemispherical breast model using the Computer Simulation Technology (CST) software as an Electromagnetic (EM) simulator. The UWB signals were transmitted and received through breast phantoms. The transmitter and receiver were rotated 360° to detect tumor existence, size, and location in a two-dimensional breast slice using the best-complement rule. A modified Principle Feature Analysis (PFA) method was implemented to reduce the feature vector size and extract the most informative features. We have found that the most informative features occur at the maxima and minima of the signals. The extracted features from the received UWB signals were fed into the NN model to train, validate, and test it first and then to detect the presence, size, and location of possible breast tumors.

After simulation proof, a system was developed for experimental tumor detection. The system consisted of commercial UWB transceivers, a developed NN model, and breast phantoms for homogenous and heterogeneous tissues. The breast phantoms and tumor were constructed using available low cost materials and their mixtures with minimal effort. The materials and their mixtures were chosen according to the ratio of the dielectric properties of the breast tissues. A Discrete Cosine Transform (DCT) of the received signals was used to construct the feature vector to train the NN model. Finally, the system was trained to distinguish between malignant and benign tumors.

Tumors as small as 0.1 mm and 0.5 mm (diameter) have been successfully detected through simulation and experimental investigation respectively. The tumor existence, size, and location detection rate are about (i) 100%, 93%, and 93.3% and (ii) 100%, 95.8%, and 94.3% through simulation and experimental system respectively. Possible differentiation between malignant and benign tumor was also achieved. The method utilizes the power of neural networks and demonstrates a new direction in this field. This gives assurance of breast tumor detection and the practical usefulness of the developed system in the near future.

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

TEKNIK JALUR ULTRA LEBAR (UWB) UNTUK PENGESANAN KANSER PAYUDARA MENGGUNAKAN PELBAGAI-LAPISAN MASUKAN-KEHADAPAN RANGKAIAN NEURAL

Oleh

SALEH ALI ALSHEHRI

Jun 2011

Pegerusi : Profesor Madya Adznan Bin Jantan, PhD

Fakulti : Kejuruteraan

Kanser payudara merupakan salah satu punca utama kematian wanita. Pengesanan tumor meningkatkan peluang untuk mengatasi penyakit ini. Terdapat beberapa kaedah diagnostik untuk mengesan tumor, namun begitu masing-masing mempunyai kekurangannya sendiri. Baru-baru ini, pengimejan Jalur Lebar Ultra (UWB) semakin diterima berdasarkan beberapa cirinya yang baik, seperti kekhususan dan kekurangan sinaran pengionannya. Kaedah konfokal merupakan teknik yang paling kerap digunakan dalam bidang ini, berasaskan tisu payudara homogen dan maklumat terdahulu mengenai ketelusan tisu. Dengan itu, ia tidak praktikal dan sukar untuk dilaksanakan secara klinikal.

Tesis ini memberi tumpuan pada perkembangan sistem bukan konfokal lengkap bagi

pengesanan tumor payudara pada peringkat dengan menggunakan pengimejan Jalur Lebar Ultra (UWB) berasaskan Rangkaian Neural (NN) yang mengambil kira kedua-dua tisu homogen dan heterogen. Tugas ini dilakukan dalam dua fasa: i) Simulasi dan ii) Uji Kaji.

Pada peringkat simulasi, model NN suap depan telah dibangunkan untuk mengenal pasti kewujudan, saiz dan lokasi tumor di dalam model payudara. Tumor berbentuk sfera diwujudkan dan diletakkan di lokasi secara rambang di dalam model payudara hemisfera dengan menggunakan simulator (Computer Simulation Technology CST) Elektromagnet (EM). Isyarat UWB dipancarkan dan diterima melalui fantom payudara. Pemancar dan penerima diputarkan 360° untuk mengesan kewujudan, saiz dan lokasi tumor dalam hirisan payudara dua dimensi dengan menggunakan peraturan pelengkap terbaik (*best-complement rule*). Kaedah Analisis Ciri Prinsip (PFA- *Principle Feature Analysis*) telah digunakan untuk mengurangkan saiz vektor khusus dan mengekstrak ciri paling informatik. Kami telah mendapati bahawa nilai ciri paling informatik berlaku pada isyarat maksimum dan minimum. Ciri yang diekstrak daripada isyarat UWB dimasukkan ke dalam model NN untuk membiasakan, mengesahkan dan mengujinya terlebih dahulu dan kemudian untuk mengesan kewujudan, saiz dan lokasi tumor payudara yang mungkin ada.

Setelah memperoleh keputusan ujian simulasi, satu sistem dibangunkan untuk mengesan tumor secara eksperimen. Sistem ini merangkumi penghantar-terima UWB komersil, model NN yang dibangunkan, serta fantom payudara bagi tisu homogen dan heterogen. Fantom payudara dan tumor dibina menggunakan bahan dan campuran yang sedia ada yang berkos rendah dengan usaha yang minimum.

Bahan dan campurannya dipilih menurut nisbah sifat dielektrik tisu payudara. Pengubah Kosinus Diskret (DCT) isyarat yang diterima telah digunakan untuk membina vektor khusus untuk membiasakan model NN ini. Akhir sekali, sistem ini dilatih untuk membezakan antara tumor malignan dan benigna.

Tumor sekecil 0.1 mm dan 0.5 mm (diameter) masing-masing telah berjaya dikesan melalui simulasi dan perlaksanaan eksperimen. Kadar pengesanan kewujudan, saiz dan lokasi tumor ialah sekitar (i) 100%, 93%, dan 93.3% dan (ii) 100%, 95.8%, dan 94.3% masing-masing melalui simulasi dan sistem eksperimen. Kemungkinan pembezaan antara tumor malignan dan benigna juga turut dicapai. Kaedah ini menggunakan kuasa rangkaian neural dan mempamerkan hala tuju baharu dalam bidang ini. Ini menjamin pengesanan tumor payudara pada peringkat dan kegunaan praktikal bagi sistem yang bakal dibangunkan dalam jangka masa terdekat ini.

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I feel that I am lucky to be given the chance to study at UPM, Faculty of Engineering. The support from the Department of Computer and Communication System Engineering is much appreciated.

I certify that a Thesis Examination Committee has met on 15th June 2011 to conduct the final examination of Saleh Ali Alshehri on his thesis entitled "**Ultra Wideband Technique For Breast Cancer Detection Using Multi-Layer Feed-Forward Neural Networks**" in accordance with the Universities and University Collages Act 1971 and Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctor of Philosophy.

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

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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.

SALEH ALI ALSHEHRI

Date: 15 June 2011

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