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DEVELOPMENT OF TECHNIQUES FOR THE DETECTION OF TUMOURS IN BREAST MAGNETIC RESONANCE IMAGING

ALI QUSAY ZAHROON AL-FARIS

UNIVERSITI SAINS MALAYSIA
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DEVELOPMENT OF TECHNIQUES FOR THE DETECTION OF TUMOURS IN BREAST MAGNETIC RESONANCE IMAGING

by

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Thesis submitted in fulfilment of the requirements
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LIST OF ABBREVIATIONS

ANN	Artificial Neural Networks
ANOVA	Analysis of Variance
AUC	Area Under the Curve
BMRI-MASRG	Breast Magnetic Resonance Imaging Tumour using Modified Automatic Seeded Region Growing
BMRI-SRGPSOC	Breast Magnetic Resonance Imaging Tumour using Hybrid Automatic Method of Seeded Region Growing and Particle Swarm Optimization Image Clustering
CAD	Computer Aided Detection
CCL	Connected Component Labelling
EM	Expectation Maximization
FCM	Fuzzy C-Means
FNF	False Negative Fraction
FPF	False Positive Fraction
GT	Ground Truth
IARC	International Agency for Research on Cancer
ICM	Iterative Conditional Mode
IMPST	Improved Self-Training
KNN	K-Nearest Neighbours
LSAC	Level Set Active Contour
Maxp	Maximum Possible Pixel
MCET	Minimum Cross Entropy Thresholding
MCR	Misclassification Rate
MMRT	Mean Maximum Raw Thresholding

MRI	Magnetic Resonance Imaging
MSE	Mean Square Error
PSNR	Peak Signal to Noise Ratio
PSO	Particle Swarm Optimization
RIDER	Reference Image Database to Evaluate Therapy Response
ROC	Receiver Operating Characteristic
ROI	Region Of Interest
SR	Main Suspected Region
SRG	Seeded Region Growing
SRGFE	Seeded Region Growing Feature Extraction
STVF	Sum of True Volume Fraction
SVM	Support Vector Machine
SYNERACT	Synergistic Automatic Clustering Technique
TNF	True Negative Fraction
TPF	True Positive Fraction
WMMR	Window Mean Maximum Raw

LIST OF PUBLICATIONS

International Journals

1- Al-Faris, A. Q., Ngah, U. K., Mat Isa, N. A. & Shuaib, I. L., (2014). Computer-Aided Segmentation System for Breast MRI Tumour using Modified Automatic Seeded Region Growing (BMRI-MASRG). *Journal of Digital Imaging.* Springer: 27(1): 133-144.

2- Al-Faris, A. Q., Ngah, U. K., Mat Isa, N. A. & Shuaib, I. L., (2012). MRI Breast Skin-line Segmentation and Removal using Integration Method of Level Set Active Contour and Morphological Thinning Algorithms. *Journal of Medical Sciences* 12(8): 286-291.

Chapter in Book

1- Al-Faris, A. Q., Ngah, U. K., Mat Isa, N. A. & Shuaib, I. L., (2014). Breast MRI Tumour Segmentation Using Modified Automatic Seeded Region Growing Based on Particle Swarm Optimization Image Clustering. *Soft Computing in Industrial Applications.* Springer: 223(5): 49-60.

International Conferences

1- Al-Faris, A. Q., Ngah, U. K., Mat Isa, N. A. & Shuaib, I. L., (2012). Breast MRI Tumour Segmentation using Modified Automatic Seeded Region Growing Based on PSO Image Clustering. *17th Online World Conference on Soft Computing in Industrial Applications (WSC17)*. Technical University of Ostrava, Czech Republic.

2- Al-Faris, A. Q., Ngah, U. K., Mat Isa, N. A. & Shuaib, I. L., (2015). Automatic Exclusion of Skin Border Regions from Breast MRI Using Proposed Combined Approach. *2nd International Conference on Biomedical Engineering (ICoBE 2015)*. Penang, Malaysia (IEEE xplore).

Symposium Papers

1- Al-Faris, A. Q., Ngah, U. K., Mat Isa, N. A. & Shuaib, I. L., (2011). MRI Breast Tumour Segmentation and Classification using a Modified Seeded Region Growing Method, *School of Electrical and Electronic 3rd Postgraduate Colloquium (EEPC 2011)*. USM, Pahang. Malaysia.

2- Al-Faris, A. Q., Ngah, U. K., Mat Isa, N. A. & Shuaib, I. L., (2013). Combined Method for Skin-Line Segmentation and Removal of Breast MRI, *School of Electrical and Electronic 4th Postgraduate Colloquium (EEPC 2013)*. USM, Perak. Malaysia.

PEMBANGUNAN TEKNIK-TEKNIK UNTUK PENGESANAN TUMOR DALAM PENGIMEJAN RESONANS MAGNETIK PAYUDARA

ABSTRAK

Kanser payudara ialah penyebab utama kematian di kalangan pesakit kanser yang melanda wanita dan kanser kedua paling lazim di seluruh dunia. Pengimejan Resonans Magnetik (MRI) adalah salah satu daripada alat-alat radiologi yang paling berkesan untuk menyaring kanser payudara. Bagaimanapun, teknik-teknik pemprosesan imej diperlukan bagi membantu pakar radiologi dalam mentafsir imej dan memisahkan wilayah tumor bagi mengurangkan jumlah positif yang palsu. Dalam kajian ini, pendekatan segmentasi dengan ciri-ciri automatik dibangunkan untuk tumor MRI payudara. Kaedah bermula dengan pemerolehan data diikuti oleh proses prapemprosesan. Ini diikuti dengan proses pengecualian garis kulit payudara menggunakan kaedah bersepadu *Level Set Active Contour* and *Morphological Thinning*. Berikutnya, kesan penting dikesan menggunakan kaedah Mean Maximum Raw Thresholding (MMRT) dicadangkan. Kemudian, pada fasa segmentasi tumor, dua kaedah diubahsuai *Seeded Region Growing* (SRG) dicadangkan; iaitu *Breast MRI Tumour* menggunakan Modified Automatic SRG (BMRI-MASRG) dan *Breast MRI Tumour* menggunakan SRG berdasarkan Particle Swarm Optimization Image Clustering (BMRI-SRGPSOC). Data set MRI payudara RIDER digunakan untuk penilaian dan keputusan dibandingkan dengan data set sebenar (*ground truth*). Daripada analisis keputusan, dapat diperhatikan bahawa pendekatan yang

dicadangkan mencatat hasil-hasil hasilan yang tinggi menerusi pelbagai langkah. Keputusan pengecualian garis kulit mencatat purata prestasi yang tinggi bagi kedua-dua peringkat peringkat segmentasi sempadan (kepekaan = 0.81 dan ketentuan = 0.94 dan peringkat penyingkiran kawasan kulit (kepekaan = 0.86 dan ketentuan = 0.97). Penilaian kualiti MMRT menunjuk keputusan lebih jitu dengan purata PSNR = 69.97 dan MSE = 0.01. Dalam fasa segmentasi tumor, keputusan-keputusan kepekaan untuk dua kaedah yang dicadangkan; BMRI-MASRG dan BMRI-SRGPSOC, menunjukkan hasil segmentasi yang lebih tepat dengan purata masing-masingnya 0.82 dan 0.84. Begitu juga, hasil ketentuan mencatat prestasi lebih baik berbanding dengan cara sebelumnya. Purata BMRI-MASRG dan BMRI-SRGPSOC adalah masing-masingnya 0.90 dan 0.91.

DEVELOPMENT OF TECHNIQUES FOR THE DETECTION OF TUMOURS IN BREAST MAGNETIC RESONANCE IMAGING

ABSTRACT

Breast cancer is the leading cause of death amongst cancer patients afflicting women and the second most common cancer around the world. Magnetic Resonance Imaging (MRI) is one of the most effective radiology tools to screen breast cancer. However, image processing techniques are needed to help radiologists in interpreting the images and segmenting tumours regions to reduce the number of false-positive. In this study, a segmentation approach with automatic features is developed for breast MRI tumours. The methodology starts with data acquisition followed by pre-processing. This is then followed with breast skin-line exclusion using integrated method of Level Set Active Contour and Morphological Thinning. Next, regions of interests are detected using proposed Mean Maximum Raw Thresholding method (MMRT). In the tumour segmentation phase, two modified Seeded Region Growing (SRG) methods are proposed; i.e. Breast MRI Tumour using Modified Automatic SRG (BMRI-MASRG) and Breast MRI Tumour using SRG based on Particle Swarm Optimization Image Clustering (BMRI-SRGPSOC). The RIDER breast MRI dataset was used for evaluation and the results are compared with the ground truth of the dataset. From analysing the evaluation results, it can be noticed that the proposed approaches scored high results using various measures comparing to previous methods. The results of skin-line exclusion scored high average performance in both

stages; border segmentation stage (sensitivity = 0.81 and specificity = 0.94) and removal stage (sensitivity = 0.86 and specificity = 0.97). The quality evaluation of MMRT showed improved results with average of PSNR = 69.97 and MSE = 0.01. In the tumour segmentation phase, the sensitivity results of the two proposed methods; BMRI-MASRG and BMRI-SRGPSOC showed more accurate segmentation with averages of 0.82 and 0.84 respectively. Similarly, the specificity results also scored better performance compared to previous methods. The averages of BMRI-MASRG and BMRI-SRGPSOC are 0.90 and 0.91 respectively.

CHAPTER 1

INTRODUCTION

1.1 Background

Breast cancer is the second most common cancer in the world and is the leading cancer amongst women. According to a study conducted by the International Agency for Research on Cancer (IARC) (an intergovernmental agency forming part of the World Health Organization of the United Nations), an estimation of 1.677 million new breast cancer cases have been diagnosed in 2012 (794,000 in developed countries and 883,000 cases in the third world countries), making 25.2 % of total new cancer cases in the world. Figure 1.1 shows the ten most commonly diagnosed cancers in the world, the figure estimates total number and percentage of new cases diagnosed per year. Similarly, the death rates among breast cancer patients are the most amongst cancer cases, as shown in Figure 1.2 (Ferlay *et al.*, 2013).

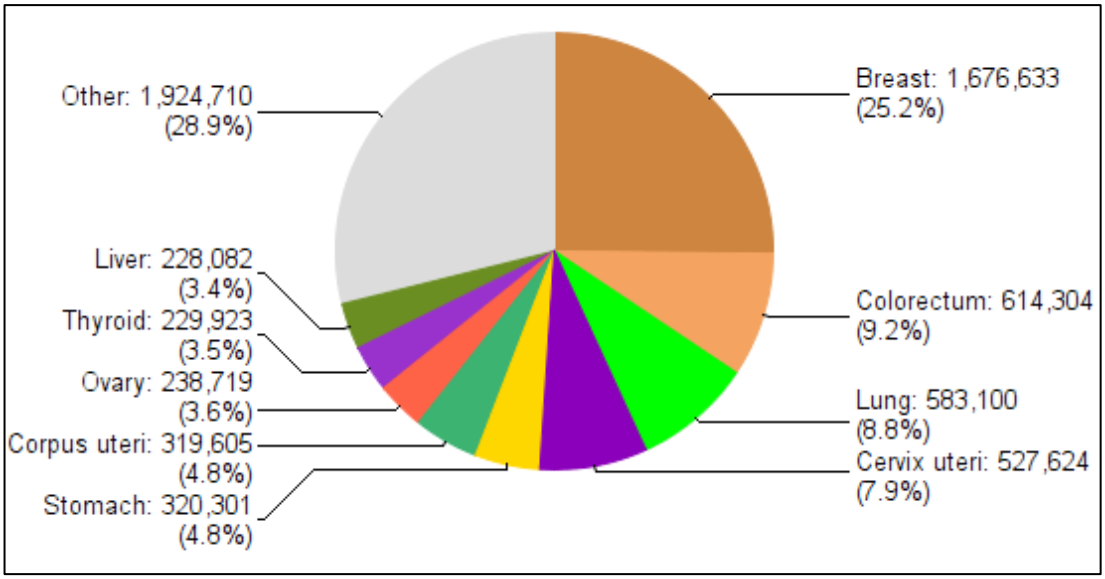

Figure 1.1 Estimated number of cancer diagnosed cases in the world based on IARC study (Ferlay *et al.*, 2013).

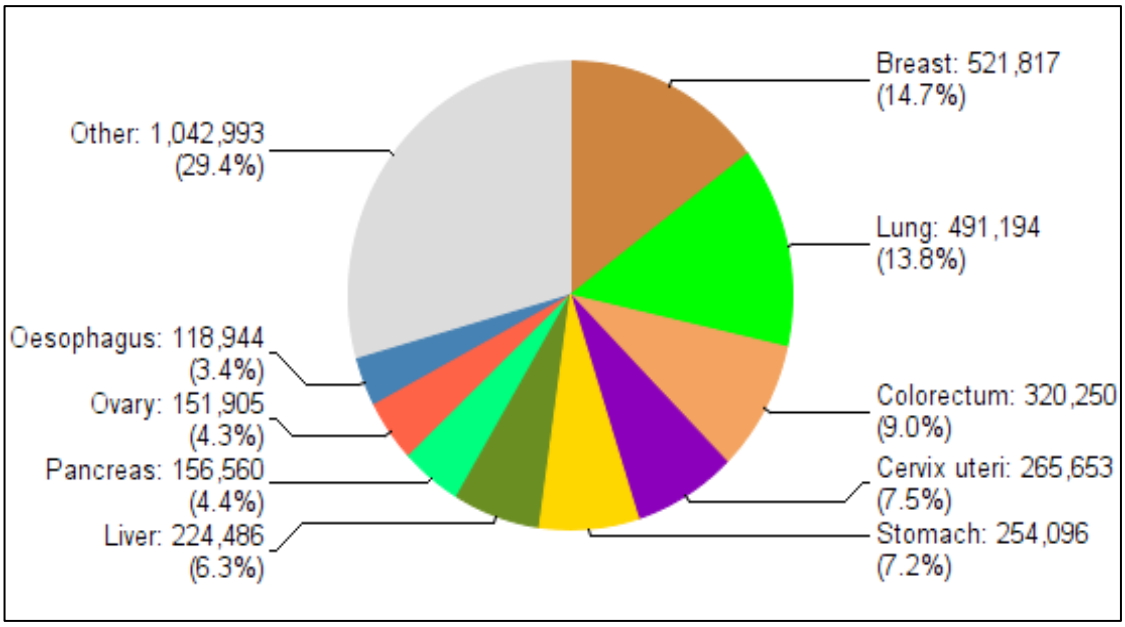

Figure 1.2 Estimated number of cancer deaths in the world based on IARC study (Ferlay *et al.*, 2013).

In Malaysia, breast cancer is the leading diagnosed cancer among women where the estimated number of this disease is around 38.74 per 100,000 populations. Close to 5,410 new cases are reported annually, making 28.0 % of total new cancer cases for women in Malaysia. Figure 1.3 shows the estimated number of cancer diagnosed cases in Malaysia based on IARC study (Ferlay *et al.*, 2013). Breast cancer is also the first common cause of death between women cancer patients with 2,572 death cases per year, making 24.7 % of total cancer death cases in Malaysia. Figure 1.4 shows estimated number of cancer deaths in Malaysia based on IARC study (Alias *et al.*, 2008).

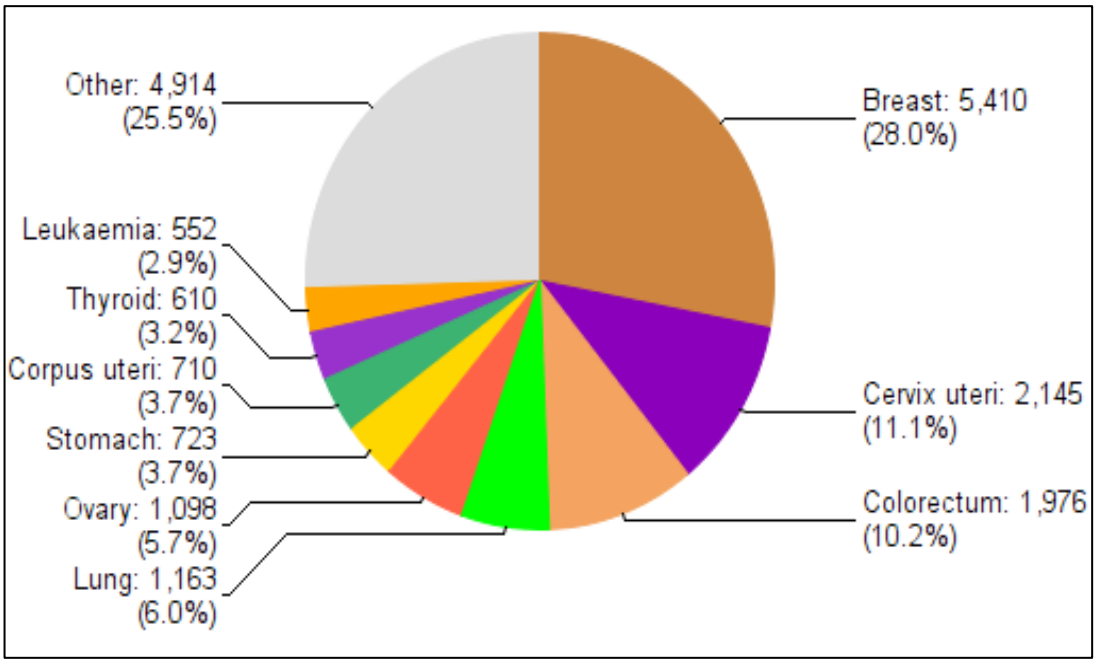

Figure 1.3 Estimated number of cancer diagnosed cases in Malaysia based on IARC study (Ferlay *et al.*, 2013).

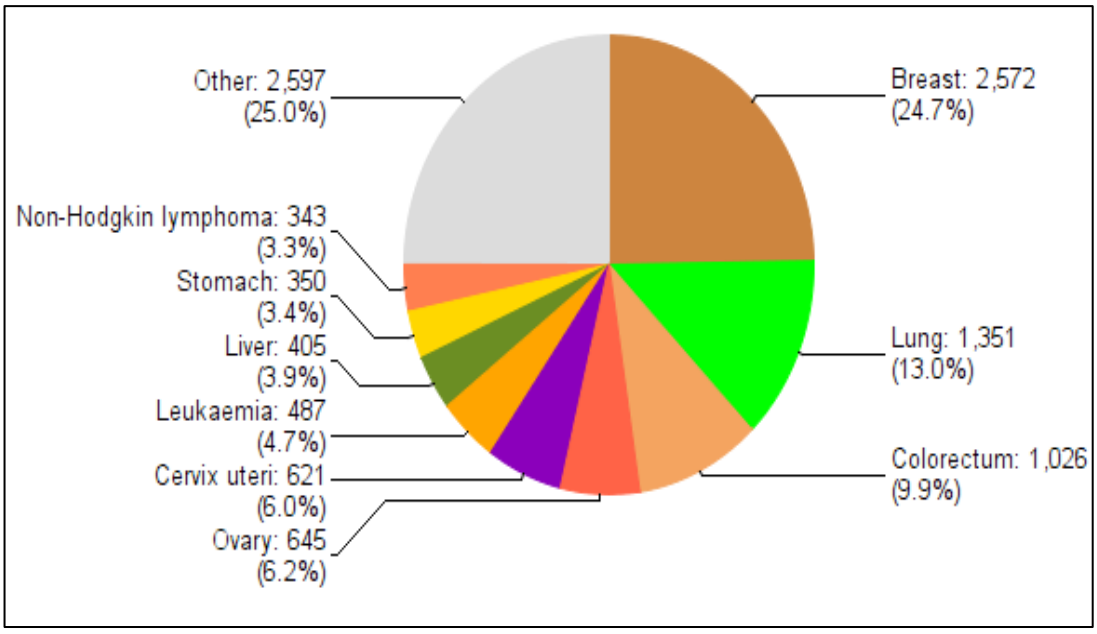

Figure 1.4 Estimated number of cancer deaths in Malaysia based on IARC study (Ferlay *et al.*, 2013).