UNIVERSITI PUTRA MALAYSIA

SEGMENTATION OF MRI BRAIN IMAGES USING STATISTICAL APPROACHES

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By

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

SEGMENTATION OF MRI BRAIN IMAGES USING STATISTICAL APPROACHES

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March 2011

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The segmentation of brain MRI images is a challenging and complex task, due to noise and inhomogeneity. The Gaussian Mixture Model (GMM) is a clustering algorithm that is commonly used for brain MRI segmentation. Usually, the Markov Random Field (MRF) model is used to capture neighbourhood information to make GMM more robust against noise, which is time-consuming and can be improved.

Noise is one of the obstacles for brain MRI segmentation. The non-Local means (NL-means) algorithm is a state-of-the art neighbourhood-based noise-reduction method which is time-consuming and its accuracy can be improved. Intensity inhomogeneity (where pixels belonging to the same tissue have different intensities) is another obstacle for brain MRI segmentation. Filter-based methods are commonly used for inhomogeneity correction which is very

simple and fast; but in general, inhomogeneity correction algorithms produce an estimation of inhomogeneity field. Therefore, these algorithms can be improved upon.

A neighbourhood-based noise-reduction algorithm which uses the edges of an image is proposed. A sample in the neighbourhood of a pixel does not contribute in the grey level estimation if an edge exists between the sample and the pixel. Also, a filter-based image inhomogeneity-correction algorithm is proposed which uses the maximum filter for inhomogeneity field estimation. Moreover, three improvements of EM for brain MRI segmentation are proposed, which incorporate neighbourhood information in a new manner in the clustering process. In addition, two algorithms for the post-processing of clustering results using user-interaction and the re-evaluation of boundary data in each cluster are presented.

The Dice similarity index for the proposed noise-reduction algorithm on 9% noise level was obtained about 0.918 with considerable improvement compared to NL-means. The Dice similarity index for the proposed inhomogeneity-correction algorithm on 40% inhomogeneity level was 0.933 and for real images 0.7627 with considerable improvement compared to recent methods. The Dice similarity index for one of the proposed improvements which yields the best results was: without post-processing equals to 0.8211, with re-evaluation of boundary data equals to 0.848 and with user-interaction equals to 0.8415. The proposed improvements with post-processing yield

higher similarity index than several state-of-the-art neighbourhood-based extensions for EM and Fuzzy C-Mean (FCM). One of the proposed improvements yields higher similarity index than other competing methods even without post-processing.

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

SEGMENTATION OF MRI BRAIN IMAGES USING STATISTICAL APPROACHES

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Pengerusi: Profesor Madya Abdul Rahman Ramli, PhD

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Segmentasi imej-imej MRI otak adalah tugas yang mencabar dan kompleks kerana hingar dan ketidakhomogenan. Model Campuran Gaussian (GMM) adalah algoritma pengelasan yang biasa digunakan untuk segmentasi MRI otak. Biasanya, Bidang Rawak Markov (MRF) digunakan untuk menangkap maklumat kejiranan untuk menjadikan GMM lebih teguh menentang hingar, tetapi ini memakan masa dan perlu diperbaiki.

Hingar adalah salah satu halangan untuk segmentasi MRI otak. *NL-means* adalah kaedah terkini pengurangan hingar berasaskan kejiranan yang memakan masa serta ketepatannya boleh ditingkatkan. Ketidakhomogenan intensiti (piksel-piksel kepunyaan tisu yang sama mempunyai intensiti yang berbeza) adalah satu lagi halangan untuk segmentasi MRI otak. Kaedah-

kaedah yang berdasarkan tapisan biasa digunakan untuk pembetulan ketidakhomogenan yang mana sangat mudah dah cepat; tetapi secara keseluruhannya, algoritma-algoritma pembetulan ketidakhomogenan menghasilkan suatu anggaran ketidakhomogenan dalam satu lapangan, bukannya ketidakhomogenan nyata. Maka, algoritma-algoritma ini boleh ditingkatkan.

Satu algoritma pengurangan hingar berdasarkan kejiranan yang menggunakan tepian imej dicadangkan. Satu sampel didalam kejiranan satu piksel, tidak menyumbang kepada penganggaran tahap warna kelabu seandainya satu tepian wujud antara piksel dan sampel tersebut. Satu algoritma pembetulan ketidakhomogenan berdasarkan tapisan juga dicadangkan yang mana menggunakan tapisan maksimum untuk penganggaran ketidakhomogenan lapangan. Tambahan lagi, tiga peningkatan baru EM untuk segmentasi MRI otak dicadangkan, yang menggabungkan maklumat kejiranan dengan cara baru dalam proses pengelasan. Tambahan pula, dua algoritma untuk pasca-pemprosesan bagi keputusan pengelasan menggunakan interaksi dan penilaian semula data sempadan dalam setiap kluster dibentangkan.

Indeks kesamaan Dice untuk algoritma pengurangan hingar yang dicadangkan pada peringkat hingar 9% diperolehi sekitar 0.918 dengan peningkatan yang cukup besar berbanding dengan *NL-means*. Indeks kesamaan Dice untuk algoritma pembetulan ketidakhomogenan yang dicadangkan pada 40% pada

tahap-ketidakhomogenan adalah 0.933 dan indeks kesamaan Dice yang dihasilkan adalah 0.7627 untuk gambar yang nyata dengan peningkatan yang cukup besar berbanding dengan kaedah semasa. Indeks kesamaan Dice bagi salah satu pembaikan yang dicadangkan yang menghasilkan keputusan yang terbaik adalah: tanpa pemprosesan pasca sama dengan 0.8211, dengan penilaian semula sempadan data sama dengan 0.848 dan interaksi dengan pengguna adalah 0.8415. Pembaikan yang dicadangkan dengan pasca-pemprosesan menghasilkan indeks kesamaan yang lebih tinggi berbanding dengan beberapa pembaikan berasaskan kejiranan untuk EM dan Fuzzy C-Mean (FCM). Salah satu pembaikan yang dicadangkan menghasilkan indeks kesamaan lebih tinggi daripada kaedah yang lain walaupun tanpa pasca pemprosesan.

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I certify that a Thesis Examination Committee has met on (14/03/2011) to conduct the final examination of Mohammad Ali Balafar on his thesis entitled "**SEGMENTATION OF MRI BRAIN IMAGES USING STATISTICAL APPROACHES**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctoral of Philosophy.

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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.

MOHAMMAD ALI BALAFAR

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