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Computer-aided automated discrimination of Alzheimer's disease and its clinical progression in magnetic resonance images using hybrid clustering and game theory-based classification strategies☆

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ABSTRACT

Early detection and identification of morphological differences in the brain is crucial for the pre-surgical planning of Alzheimer's disease treatment. Magnetic resonance imaging (MRI) can detect Alzheimer's disease as well as its severity levels in patients. An automatic segmentation of the grey matter, white matter, cerebrospinal fluid and hippocampus is required to obtain accurate volume of various brain matters. In this study, an effective segmentation and classification techniques are proposed to accurately distinguish the progress of Alzheimer's disease, mild cognitive impairment and normal control subjects. A hybrid segmentation technique is formulated with *K*-means clustering and graph-cut methods to perform segmentation. The clustered regions are assigned labels according to their features for the classification analysis. They are further classified as normal cognitive impaired, stable mild cognitive impaired, progressive mild cognitive impaired or Alzheimer's disease using the game theory classifier. The proposed method achieves an accuracy of about 85.5 %.

1. Introduction

The most common cause of memory loss is Alzheimer's Disease (AD). It is very difficult to identify it in its early stages, and it requires a very accurate diagnosis process. During the early stages, the hippocampus, a grey matter (GM) structure of the temporal lobe, is affected [1]. Hence, by analysing hippocampus volume using magnetic resonance imaging (MRI), the

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disease level can be detected. Measuring hippocampus volume requires a great deal of time and is not feasible for manual segmentation. Automatic segmentation is required to bypass these restrictions and obtain the AD biomarkers [2]. Because the boundaries of the hippocampus region obtained from MRI scans are imperfect, knowledge of prior data is essential for obtaining accurate markers. Prior data can be obtained using the statistical information of shape deformations or by using the registration process with a single-object atlas template [3,4]. MRI is widely preferred for obtaining exhaustive structural brain images in three dimensions (3-D). In this imaging technique, in vivo voxel dimensions of certain structures influenced by disease progressions can be obtained. Structural MRI is broadly accessible, provides better accuracy of diagnosis and has reasonable costs. Furthermore, MRIs indicate higher associations with the progression of mild cognitive impairments (MCI) to AD [5]. However, the dissimilarities between progressive MCI (pMCI) and stable MCI (sMCI) are too minute to be discovered via MRI. This refined dissimilarity has emerged from huge inter-subject inconsistencies and age-linked deviations. Hence, predicting MCI-to-AD conversion by MRI scanning is an arduous task. In the current comprehensive literature [6], particle swarm optimization based fuzzy c-means technique have been appraised for segmenting the brain region, and limited number of validation parameters were used to validate the segmentation accuracy. Consequently, it is crucial that we develop more innovative approaches for detecting MCI-to-AD conversion. Accurate segmentation of the hippocampus region via 3-D MR imaging requires eminent expertise to manually represent the organisation of each MRI slice. In many diagnoses, especially that of AD, the measurement of volumes on a single MR image is not enough. We also must measure change over time [7]. Change data can rule-out several vital biological discrepancies and help monitor the progression of the disease. The large inter-subject variability can be decreased with the help of spatial registration on a mutual plot for evaluation [8]. Various registration methods have been presented in literature for sorting anatomies at various levels. Affine registration was utilised in [9], and some other perfect non-rigid registrations were exploited. Via precise registration techniques, they effectively arranged anatomical formations of various matters for assessment, learning that the disease variation between subjects may be relatively detached. However, when the registration process was not implemented, inter-subject uncertainty and disease deviations among subjects were well-maintained. Still, if the inter-subject variability increases, the perceptive pathological disparities may be veiled, and the classification analysis of MCI controls could be encumbered. In some instances where the registration process is nearly perfect, inter-subject uncertainty and morphological difference are eliminated [10]. The author [11] validated that age is a key aspect in either distinguishing AD or identifying the progression of MCI to AD. Thus, it is advantageous to eliminate the consequences of normal ageing from MRI data before training classifiers. The exclusion of ageing effects has been noted to enhance the classification performance in varying amounts, contingent upon the applied features and classification algorithms. With the consequences of registration and normal ageing, the exploitation of training data from various subject categories can also impact the prediction of MCI-to-AD transformation. Rigid-body registration of serial MRI have been utilised to identify overall brain alterations in AD and quantifications [12]. These schemes are not robust when the structures are tiny and are not completely outlined with cerebrospinal fluid (CSF) regions of brain margins. However, high accuracy can be notionally attained with an appropriate technique for the quantification of hippocampus variation, because the alterations in serial MRI with hippocampus deterioration is quite less, compared to variations among people. Nonlinear registration ascertains a suffering field, which encapsulates anatomical disparities between persons and structural variations over time. This work [13] focused on spider web based segmentation was employed to define a group of nonlinear warping methods based on physical structure of a compressible viscous fluids. Structural variations of neurodegenerative brain disorders were steady and constant, implying that fluid registration could offer an acceptable model for atrophy in this vital analytical association. The authors [14] have implemented fluid registration to renovate an anatomical atlas of the brain with the help of a potential homoeomorphic transformation. Furthermore, this registration technique was applied to trace the development of lesions and to observe brain atrophy in a few subjects. Automatic contests of GM and CSF from a whole 2-dimensional brain image was performed; a 3-D template was employed to label the hippocampus.

In this paper, the white matter (WM), GM, and CSF regions are segmented from a 3-D MRI of the brain. To apply a preprocessing strategy to the image, techniques such as registration, skull stripping and histogram normalisation are employed. During the feature extraction process, only the essential features are selected and applied to train the classifier. Hybrid clustering is employed for the segmentation of WM, GM, and CSF regions from the MR input image. Then NC, MCI, and AD subjects are labelled using hybrid clustering and the game theory classifier. The performance of the proposed work is estimated using the baseline scans of the OASIS dataset (https://www.oasis-brains.org/.)

Section 2 provides a clear illustration of the various pre-processing methods which are used to remove artefacts from the input images. Section 3 deals with the segmentation approach using K-means and graph-cut strategies. Section 4 describes the classification analysis of AD using game theory, followed by Section 5, which describes the efficacy of the proposed method using extensive investigational results. The manuscript ends with Section 6, which provides a conclusion and future work of this research work.

2. Materials and methods

MRI T1-weighted images data have been accessed from the OASIS and Brain Web databases (http://www.bic.mni.mcgill.ca/brainweb/) for this research. The brain images are first pre-processed, where registration, skull stripping and histogram normalisation are performed. Then, feature extraction and selection processes follow. WM, GM, CSF and hippocampus re-