ALZHEIMER DETECTION USING GAUSSIAN MAP DESCRIPTORS

By

Shereen Ekhlas Mohammed Ibrahim

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Biomedical Engineering and Systems

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Summary:
Alzheimer's disease (AD) is a considered one of the common elderly disease that causes changes in behavioral and memory loss because of the death of brain cells. There are three stages for Alzheimer disease named: Alzheimer's Disease patient (AD), Mild cognitive impairment (MCI) and Early stage. In this work, we purpose the use of the Gaussian map descriptors to distinguish between AD, MCI and normal (N) subjects, by analyzing the hippocampus and amygdala. Based on Gaussian maps, several features were extracted such as the Gaussian curvatures, the mean curvature and Gaussian shape operator, which are then fed to the Support Vector Machine (SVM) in order to employ the classification task. The proposed workflow consists of seven main steps: Eddy current correction, Brain extraction, registration, segmentation, Gaussian map features calculations, and evaluation and validation of results. This thesis gives a detailed implementation for each mentioned steps.

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List of Symbols, abbreviations, and Nomenclature

AAL	Automated Anatomical Labeling
AD	Alzheimer’s disease
ADNI	Alzheimer's disease Neuroimaging Initiative
ANN	Artificial Neural Network classifier
AUC	Area Under Curve
BOVW	Bag-of-Visual-Words
CT	Computed Tomography
CSF	Cerebrospinal Fluid
DTI	Diffusion Tensor Imaging
EM	Expectations and Maximization
FDA	Food and Drug Administration
FMRI	Functional MRI
FSL	FMRIB Software Library
IR	Inversion Recovery sequence
GR	Gradient Echo sequence
K-NN	K-nearest neighbor classifier
Libsvm	Library of Support Vector Machine
MCI	Mild cognitive impairment
MLE	Maximum likelihood estimate
MRI	Magnetic Resonance Imaging
NIA	National Institute on Aging
NIBIB	National Institute of Biomedical Imaging and Bioengineering
NMR	Nuclear Magnetic Resonance
NTI	Normalized Thickness Index
PCA	Principle component analysis
PCC	Posterior cingulate cortex
PD	Proton Density
PET	Positron emission tomography
RBF	Radial Basis Function
RF	Radio frequency
ROC	Receiver Operating Curve
ROI	Region of interest (ROI)
TE	Echo Time
TI	Inversion Time
TIV	Total Intracranial Volume
TR	Repetition Time
SE	Spin Echo sequence
SPHARM	Spherical harmonics
SPHARM-PDM	Spherical Harmonics-Point Distribution Model
SPM	Statistical Parametric Mapping
S_p	Gaussian shape operator
SVM	Support vector machine
SVM-RFE	SVM Recursive Feature Elimination

VBM	Voxel-based Morphometric
VolBrain	Volume of Brain

Abstract

Alzheimer's disease (AD**)** is a considered one of the common elderly diseases. It is a type of dementia that causes changes in behavior in addition to memory loss because of the death of brain cells. It is considered a chronic neurodegenerative disease which gets worse over time. Its symptoms are progressive as it starts with forgetting some common words or places, developing over time to forgetting the patient's own identity. Early stage in which people may perform their usual activities as they still drive, work and deal with other people but with less efficiency. There are two stages for AD, named: Mild cognitive impairment (MCI) which is also known as moderate Alzheimer's disease and considered the longest stage and may last for many years. AD, which is severe stage or late stage, which ends with the patient death.

The Hippocampus and Amygdala regions, sub-regions of the limbic system, are responsible of the memory storage. These two regions are very good indicators for the presence of AD and considered as the most affected part in terms of shape by the Alzheimer deterioration.

In this work, we purpose the use of the Gaussian map descriptors to distinguish between AD, MCI and normal (N) subjects, by analyzing the Hippocampus and Amygdala. Based on Gaussian maps, several features were extracted such as the Gaussian curvatures, the mean curvature and the Gaussian shape operator, which are then fed to the Support Vector Machine (SVM) in order to employ the classification task. Gaussian map features are computed for Hippocampus region, Amygdala region, doing feature level fusion which means merging between hippocampus region features and Amygdala region features and finally doing region level fusion which means adding Hippocampus region to Amygdala region.

Alzheimer's Disease Neuroimaging Initiative (ADNI) Dataset formed of forty five, fifty five and sixty five T_1 -weighted MRI volumes for AD, MCI and normal subjects respectively. ADNI dataset is a global research effort that actively supports the investigation and development of treatments that slow or stop the progression of AD. ADNI is publically available dataset for free to authorized investigators through the Image Data Archive (IDA).

Different Preprocessing steps should be performed in order to prepare the data for analytics. FSL software was used to carry out the preprocessing operations such as the eddy current correction, brain extraction, registration and segmentation of hippocampus and amygdala regions.

Gaussian map features which are Gaussian curvature, mean curvature and Gaussian shape operator are calculated for the segmented ROI. Fisher score was used for dimensionality reduction purposes in order to overcome the overfitting problem followed by SVM classifier for the classification between Normal and Abnormal subjects and between AD and MCI subjects. 10 folds cross validation was used in the whole study to study the system robustness based on the accuracy as well as the area under the curve for the ROC curve.

The results of the system shows that Gaussian curvature feature is competitive to classify between Normal people and abnormal as well as the AD and MCI for all regions. For Hippocampus region accuracies of the system based on Gaussian curvature for normal and abnormal classification and for AD and MCI classification are 69.5%, 98.3% respectively. Doing feature level merging improve accuracy of the system slightly as accuracies reaches 70.4% for normal and abnormal classification and 96.2% for AD and MCI classification. Region level fusion boosted the performance of the classifier especially in AD and MCI classification to reach 100% accuracy and reaches 72.2% for normal and abnormal classification.

Chapter 1: Introduction

Alzheimer's disease (AD) is a neurological disorder in which the death of brain cells causes problems with memory, thinking and behavior. It is a general term for memory loss and other intellectual abilities serious enough to interfere with daily life. Alzheimer's disease accounts for 60 to 80 percent of dementia cases.

AD is not considered a normal deterioration of the health with aging, although it is considered as the most known risk factor increasing with aging. Moreover, the majority of patients suffering from AD are of 65 years and older. Nevertheless, Up to 5 percent of the patients have an early onset AD (also known as younger onset), which often appears their 40s or 50s years old. In early stages of AD, the memory loss is mild, whereas, in late stage of AD, individuals lose the ability to carry out a conversation and respond to their environment [1].

AD is a type of dementia that involves the death of the brain cells and though causing behavioral changes, unstable thinking and memory loss. Its symptoms are slowly developed with the progression of the disease. There are different factors that effect on the progression of AD such as age, family history, and the education level. It is considered as one of the common elderly disease that occurs at the age 60 and older. Nevertheless, Up to 5 % of the patients suffering from AD are of 40 to 50 years old which is mostly considered due to some family history [1].

On Anatomical basis, AD, caused by brain cell death, is considered as a neurodegenerative disease, which means there is progressive brain cell death that is increasing with time. Though, the total brain size shrinks with AD. At the late stages, the brain tissue has progressively fewer nerve cells and connections [1].

AD worsen over time, although the rate at which the disease progresses varies. On average, a person with AD lives ranges from four to eight years after diagnosis, nevertheless, in some cases, they can reaches 20 years after diagnosis. This period variation is mainly based on several factors such as the early diagnosis and treatment, high level of education, the family history as well as multiple genetic and environmental factors [2].

In this study, we employ new shape based features to distinguish between AD, MCI and normal subjects based on T_1-weighted MRI dataset. The proposed features are based on Gaussian map descriptors, which are distinguishing the change in shape of the regions affected during Alzheimer for the different categories. Several modules have been used for the data preparation, analysis and performance evaluation, which will be explained in details later within the thesis.