Computer-aided Diagnosis in Brain MR Imaging- A Step Towards Automatic Lesion Interpretation

Rupali Kamathe[#1], Kalyani Joshi[#2]

[#]*Department of Electronics and Telecommunication, PES's Modern College of Engineering, Pune-5.*

[1]rupalikamathe@gmail.com [2]krjpune@gmail.com

Abstract- *The ever-increasing stream of images and other information makes heavy demands on the radiologists. Magnetic Resonance Imaging (MRI), because of its superior soft tissue differentiation characteristics along with high spatial resolution and contrast is proved to be an important tool in the clinical and surgical environment. In this patient is not exposed to any harmful ionizing radiations. Brain MRIs may be used to assess disorders such as HIV infection of the brain, stroke, head injury, coma, Alzheimer disease, tumors and multiple sclerosis. Radiologists examine the Brain MR Images and based on visual interpretation of the films along with pathological reports, identify the presence of lesions. The large volume of MRI data to be analyzed with limited number of radiologists is labor intensive and costly task which may lead to inaccuracy in interpretation when the number of cases is more. This demands a need for automated systems for analysis and classification of different medical images. Computer assistance has already proved its value and will undoubtedly play a greater role in the future.*

Keywords : *Magnetic Resonance Imaging (MRI), Computer-aided Diagnosis (CAD).*

I. INTRODUCTION

Medical imaging has contributed significantly to progress in medicine since the discovery of x-rays in 1895 by W C Roentgen. The imaging modalities like Ultrasonography, Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Digital Radiography have been developed since then. Over the period of last 50 years tremendous growth has been seen in the field of diagnostic imaging [1].

Medical images obtained from different modalities are presented to a radiologist for interpretation and a diagnosis of a medical condition of a patient with proper correlation with pathological test reports. The diagnosis heavily depends on the knowledge and experience of the radiologist in medical field. From a physician's standpoint, image interpretation and decision making have been considered as the most important processes in diagnostic radiology. Recently, breast mammographic images are analyzed with the help of computer to assist the interpretation by radiologist in abnormalities related to breast lesions. [1], White Matter Lesions (WMLs) in Brain MRI [4]; this is generally known as computer-aided diagnosis (CAD).

During last 20 years large growth has been seen in use of CAD in diagnostic radiology. The CAD system aims to improve the accuracy of diagnosis of different diseases and image interpretation consistency of a radiologist who uses the computer output as a 'second opinion' [2]. Computer by pointing to a restrained lesion may remind to the radiologist to consider carefully to the lesion which would otherwise be missed. Development of various CAD systems needs to employ image processing techniques for quantitative analysis of images. The understanding of the medically relevant content of the images on the basis of features which can quantitatively measure the particular image parameter is of utmost importance. For example, in computerized systems it will be useful to imitate the approaches similar to those practiced by Radiologists during clinical diagnosis process of lesions. Radiologist's involvement in differentiating between normal and abnormal images (or between benign and malignant lesions), also the way they quantify the different features for clinical diagnosis of the particular disease may be very useful.

CAD is a relatively young interdisciplinary technology combining elements of artificial intelligence and digital image processing with radiological image processing. A typical application is the detection of a tumor. CAD has has emerged as one of the major research subjects in medical imaging and diagnostic radiology. The basic concept of CAD is to provide a computer output as a second opinion [2] to assist radiologists' image interpretation by improving the accuracy and consistency of radiological diagnosis and also by reducing the image reading time.

The general approach for CAD is to find the location of a lesion and also to determine an estimate of the probability of a disease. The principle aim of the CAD system is to characterize suspicious objects efficiently and automatically, and that can help radiologists make reliable diagnostic decisions.

Both detection and characterization processes in interpretation and diagnosis heavily depend on the radiologists' knowledge, experience, memory and intuitions. So, there are chances for errors and the human interpretation of clinical images can vary person to person [2].

The CAD system for Brain MRI can provide the valuable and accurate details of brain tumors in MR images [5], detection of atrophy in Brain for Multiple Cognitive Impairments (MCI) [6], classifying normal and Multiple Sclerosis [8] cases etc. Typical CAD system consists of different phases like- Image Acquisition and pre-processing, Enhancement, Segmentation and Classification.

The MRI systems are the best medical imaging modalities to represent the human brain components, but still variations on the contrast of the same tissue are found in an image due to RF noise or shading effects due to magnetic field variations, resulting in tissue misclassification later on. Abnormality detection in Magnetic Resonance (MR) brain images is a challenging task. The difficulty in brain image analysis is mainly due to the requirement of detection techniques with high accuracy within quick convergence time. The detection process of any abnormalities in the brain images is a two-step process. Initially, the abnormal MR brain images are classified into different categories (image classification) as the treatment planning varies based on types of abnormalities.

Number of classification methods is available, that allow an individual class prediction. Among them, machine- learning techniques are widely used to distinguish magnetic resonance (MR) images from two groups of subjects (e.g., patients vs. healthy subjects). All these techniques require a training population, i.e., well characterized subjects (for instance healthy subjects and patients with known diagnosis), in order to categorize new subjects, who belong to the so-called test population, into one of the classes the subjects of the training population belong to. They also require one or more feature parameters to differentiate the two groups under study.

Accurate feature extraction leads to accurate automatic classification of brain diseases. Approaches used for classification falls into two categories: Supervised learning technique such as Artificial Neural Network (ANN), Support Vector Machine (SVM) and K-Nearest Neighbor (KNN) which are used for classification purposes. And K-means Clustering, Self Organizing Map (SOM)s etc which come under the other category known as unsupervised learning for data clustering.

II. RATIONALE

Ability of humans to detect lesions is greatly affected in presence of noise in images. Also, the image data to be scanned is usually vast making the detection of potential disease a burdensome task leading to cause oversight errors. Another problem is that some of the abnormal and normal lesions appear to show similar characteristics in image form and hence may cause interpretational errors. CAD system development for medical image interpretation has shown the potential for computers to provide a 'second opinion' in image interpretation.

III. BRAIN MRI

Brain MR images are of different types depending on repetition and echo time (TR & TE resp.) required. It also depends on image intensities of water content, fat content and fluids.

T1-weighted:

- Short TR and short TE.
- Fluids – Dark (1500-2000 msec.)
- Water-based tissues – mid-grey (400-1200 msec.)
- Fat-based tissues-very bright (100-150 msec.)
- TR increases, signal intensity increases.

T2-weighted:

- Long TR and long TE
- Fluids – bright (700-1200 msec.)
- Water-based tissues-mid-grey (40-200 msec.)
- Fat-based tissues – mid-grey (10-100 msec.)
- TE increases signal intensity decreases.

PD-weighted:

- Long TR and short TE
- No lot of contrast difference between grey and white matter.
- CSF – dark
- Fat – bright

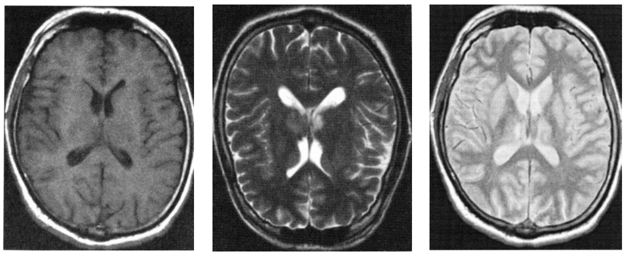

Fig. 1

Types of MRI: T1-weighted, T2-weighted, PD-weighted

Brain MRI is always observed by 3 views viz. axial, coronal and saggital. By observing all three views, radiologists make exact conclusion.

- Axial is cross-sectional view which is also called as transverse.
- Coronal is horizontal section perpendicular to y-axis.
- Saggital is vertical section perpendicular to x-axis.

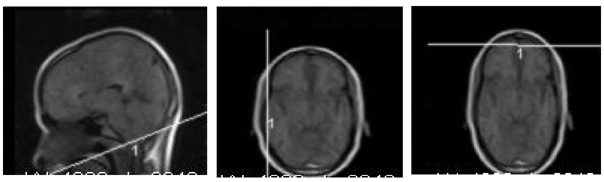

Fig. 2 Views of MRI: Axial, Coronal, Saggital

Fully automatic brain tissue classification from MRI is of great importance for research and clinical studies of the normal and diseased human brain. Operator-assisted classification methods are non-reproducible, and also are impractical for the large amounts of data required for a meaningful statistical analysis. Tissue classification plays a vital role in diagnosis of various diseases. The tissues are labeled as gray matter, white matter, and CSF (cerebro-spinal fluid).

Fig. 3:

Brain Tissue Classes: White Matter, Gray Matter, CSF

IV. COMPUTERIZED DIAGNOSIS OF LESIONS

With current radiographic techniques, considerable variability occurs in the interpretation of lesions by radiologists is seen although general rules for the differentiation between malignant and benign lesions exist. Hence CAD also aims to extract and analyze the characteristics of benign and malignant lesions that are seen on MRI in an objective manner to aid the radiologist by increasing diagnostic accuracy, thereby reducing the number of false diagnoses of malignancies. This in turn may decrease the number of surgical biopsies performed and their associated complications [2]. With same intentions authors have developed CAD system for Brain Tumor diagnosis. The work has been extended for Alzheimer's disease progression stages and Multiple Sclerosis.

A. CAD FOR BRAIN TUMOR DIAGNOSIS

A brain tumor or intracranial neoplasm occurs when abnormal cells form within the brain. There are two main types of tumors: malignant or cancerous tumors and benign tumors. Cancerous tumors can be divided into primary tumors that started within the brain and those that spread from somewhere else known as brain metastasis (secondary) tumors.

- **Benign Tumor**

A benign brain tumor grows slowly, has distinct boundaries and spreads rarely. Benign brain tumors have a homogeneous structure and do not contain cancer cells.

- **Malignant tumor**

Malignant brain tumors have a heterogeneous structure and contain cancer cells. This can be further classified into different types as:

1. Glioma grade-I,II or III, IV
2. Meningioma etc.

Authors have developed CAD system which can automatically classify input MRI either as Normal, Benign, Glioma or Meningioma based on training samples.

B. CAD FOR ALZHEIMER'S DISEASE DIAGNOSIS

Dementia is becoming an important issue among the elderly. Alzheimer‘s disease (AD) is a common cause of dementia. With almost 26.6 million people lived with Alzheimer‘s disease in the world in 2006, it is estimated that the prevalence would increase to 100 million by 2050 [6]. One obvious symptom of Alzheimer‘s disease is that people suffering from Alzheimer‘s disease loses some part of memory and forgets things much more frequently than normal aging people. As the disease progresses, the patients lose the ability of thinking, reasoning and language skills. Mild cognitive impairment (MCI) is a transitional state between Alzheimer‘s disease and normal aging. MCI is mostly associated with memory loss and not as severe as AD. The rate of converting to AD in MCI patients is much higher than the incidence in general population. Therefore, it will be very helpful to predict the disease development among MCI patients.AD patients are not only suffering from the disease but also relying on daily health care to live on a normal life. Almost 43% of patients [6] need high-level care provided by nursing homes. The daily health care is a huge burden to the society. If patients or potential patients could get treatment as soon as possible, the need for health care would be reduced. Recently, Alzheimer‘s disease has been a hot research topic. Lots of funding and resources have been invested in this area not only for detecting the disease in patients but also for predicating disease development to let patients get treatment as soon as possible.

Authors have developed classification technique that will classify the MRI images into NC (Normal Controls), MCI, and AD images.

C. CAD FOR MULTIPLE SCLEROSIS DIAGNOSIS

Multiple sclerosis (MS) is an inflammatory disease in which the insulating covers of nerve cells in the brain and spinal cord are damaged. This damage disrupts the ability of parts of the nervous system to communicate, resulting in a wide range of signs and symptoms, including physical, mental and sometimes psychiatric problems [8].

The estimated number of people with MS has increased from 2.1 million in 2008 to 2.3 million in 2013. [9]

Authors have developed CAD System which can automatically classify input MRI scan as Normal Controls (NC) or suspected MS lesion.

IV. CONCLUSIONS

Brain MRI CAD systems classify lesions similarly to expert radiologists. In future, with the success of computerized classification of lesions tested with big varied image data base with more case studies, the integration of detection and classification methods into more clinical prototypes can be planned. It is important to note that current computer analysis schemes are used as 'second readers' and not as primary readers. CAD methods might be used to bring to the notice of the radiologists the missed lesions if any during routine screening procedure performed on the patient

REFERENCES

1] Kunio Doi, "Diagnostic imaging over the last 50 years: research - and development in medical imaging science and Technology" MPhys. Med. Biol. 51 (2006) R5–R27.

[2] Maryellen L Giger, "Computer-aided Diagnosis in Medical Imaging – A New Era in Image Interpretation", BUINESS BRIEFING: NEXT–GENERATION HEALTH CARE.

[3] G. Newstead, L. Arbash Meinel, "Computer-aided visualization and Analysis (CAVA) research system for breast cancer detection and diagnosis", MEDICAMUNDI 52/1 2008/07.

[4] Renske de Boer, Henri A. Vrooman, Fedde van der Lijn, Meike W. Vernooij, M. Arfan Ikram, Aad van der Lugt, Monique M.B. Breteler, Wiro J. Niessen, "White matter lesion extension to automatic brain tissue segmentation on MRI", NeuroImage 45 (2009) 1151–1161.

[5] P. Georgiadis et al. "Enhancing the discrimination accuracy between etastases, gliomas and meningiomas on brain MRI by volumetric extural features and ensemble pattern recognition methods" ELSEVIER, Magnetic Resonance Imaging, Volume 27 ,pp. 120–130, 2009.

[6] R. Kirsi Juottonen, Mikko P. Laakso, Kaarina Partanen, and Hilkkan Soininen,"Comparative MR Analysis of the Entorhinal Cortex and Hippocampus in Diagnosing Alzheimer Disease'', Neuroradiology 20:139–144, January 1999.

[7] Multiple Sclerosis International Federation 2013, "Atlas of MS 2013, Mapping Multiple sclerosis around the world" (2002).

[8] Ayelet Akselrod-Ballin,"Automatic Segmentation and Classification of Multiple Sclerosis in Multichannel MRI" IEEE transactions on biomedical engineering, vol. 56, no. 10, October 2009.

[9] Multiple Sclerosis International Federation 2013, "Atlas of MS 2013, Mapping Multiple sclerosis around the world".