International Journal of Computer Networks and Communications Security

VOL. 3, NO. 4, APRIL 2015, 130–137
Available online at: www.ijcncs.org
E-ISSN 2308-9830 (Online) / ISSN 2410-0595 (Print)

A REVIEW: Applications of Brain image (FMRI)

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ABSTRACT

FMRI is one of the newest tools in neuroimaging. In recent decades there has been widespread use of fMRI images in various applications. fMRI is still in progress. fMRI is a diagnostic method of detecting how a healthy, ill, or damaged brain works neurology. In addition, it is useful for determine the amount of risk types of surgery and neurology. Doctors use fMRI to examine issues such as anatomy and to determine exactly which parts of the brain have critical positions, such as thinking, speaking, moving, and feeling via a procedure called brain mapping. fMRI can also help to determine the after-effects of stroke and brain injuries. Monitoring the growth of brain tumors, surgery schedule, etc. are other applications of the fMRI images. In this study, a number of articles on the fMRI images were reviewed, and some of the applications of these images were presented. Functional areas of fMRI images are the detection of brain activities and brain tumors, and brain mapping. Reviewing the valuable, albeit limited, papers undertaken on this subject in this field, has enabled to present some of the applications of this imaging tool in this study.

Keywords: *Machine learning, FMRI, Brain Tumors Detection, Application of fMRI, Brain Activity Prediction.*

1 INTRODUCTION

Functional magnetic resonance imaging or functional MRI (fMRI) is a functional neuroimaging procedure using MRI technology that measures brain activity by detecting associated changes in blood flow [1]. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled. When an area of the brain is in use, blood flow to that region also increases.

Noninvasive functional brain imaging has become an important tool used by neurophysiologists, cognitive psychologists, cognitive scientists, and other researchers interested in brain function. In the last five decades, the technology of noninvasive functional imaging has flowered, and researchers today can choose from EEG, MEG, positron emission tomography (PET), single-photon computed tomography (SPECT), magnetic resonance imaging (MRI), and fMRI. Each method has its own strengths and weaknesses, and no single method is best suited for all experimental or clinical conditions. Because of the inadequacies of individual techniques, there is increased interest in finding ways to combine existing techniques in order to synthesize the strengths inherent in each [2]. This paper presents an investigation on the applications of brain images (fMRI).

Thus, the purpose of this article is to provide a summary of the functional applications of these images, and to the way they can be used in the identification of brain tumors using machine learning algorithms. By examining numerous articles on fMRI applications, nine papers have been selected. Table 1 reports each article in great detail.

This paper structured is follows. In Section 2, we observe the background of the fMRI and its applications, and a brief description of machine learning algorithms. In Section 3, the studies in fMRI are presented.

2 BACKGROUND

In this section, the background of fMRI and its applications, and a brief description of machine learning algorithms are presented.

2.1 Fmri

The fMRI concept builds on the earlier MRI scanning technology and the discovery of properties of oxygen-rich blood. MRI brain scans use a strong, permanent, static magnetic field to align nuclei in the brain region being studied [1]. Since the 1890s it has been known that changes in blood flow and blood oxygenation in the brain (collectively known as hemodynamics) are closely linked to neural activity [1]. When neurons become active, local blood flow to those brain regions increases, and oxygen-rich (oxygenated) blood displaces oxygen-depleted (deoxygenated) blood around 2 seconds later. This rises to a peak over 4–6 seconds, before falling back to the original level (and typically undershooting slightly). Oxygen is carried by the hemoglobin molecule in red blood cells. Deoxygenated hemoglobin (dHb) is more magnetic (paramagnetic) than oxygenated hemoglobin (Hb), which is virtually resistant to magnetism (diamagnetic). This difference leads to an improved MR signal since the diamagnetic blood interferes with the magnetic MR signal less. This improvement can be mapped to show which neurons are active at a time [1].

Three studies in 1992 were the first to explore using the BOLD contrast in humans. Kwong and colleagues used a gradient-echo Echo Planar Imaging (EPI) sequence at a magnetic field strength of 1.5 T to study activation in the visual cortex. Ogawa and others conducted the study using a higher field (4.0 T) and showed that the BOLD signal depended on T2* loss of magnetization. T2* decay is caused by magnetized nuclei in a volume of space losing magnetic coherence (transverse magnetization) from both bumping into one another and from intentional differences in applied magnetic field strength across locations (field inhomogeneity from a spatial gradient).

Bandettini and colleagues used EPI at 1.5 T to show activation in the primary motor cortex, a brain area at the last stage of the circuitry controlling voluntary movements. The magnetic fields, pulse sequences and procedures and techniques used by these early studies are still used in current-day fMRI studies. But today researchers typically collect data from more slices (using stronger magnetic gradients), and preprocess and analyze data using statistical techniques [1].

In order to delve into the brain functions via fMRI, it is require to take images of the brain intermittently, while the subject is stimulated or required to perform a task.

2.2 Applications Of FMRI

The fMRI data and images can be used to examine the different areas which require the investigation of the brain functions. These images are highly regarded in the field of neuroscience, and mainly they are used for the exploration and detection of the way a cognitive activity affects the brain. In addition, they have attracted numerous attentions due to being useful in modeling of cognitive activities and diagnosing some cognitive and neural diseases. However, in diagnostic and clinical fields, fMRI are often used. The following present some examples of its applications.

- The mapping of the areas involved in speech before the surgery.
- The evaluation of the plasticity after the brain injury.
- The assessment of the patients with consciousness disorders (coma, the vegetative state, the minimal consciousness state, and looked-in syndrome)
- Some of the fMRI applications for research are as follows:
- The mapping of complex activities (such as emotions, motor control, and language-specific functions, etc.) in the normal and the disease states
- The monitoring of the therapeutic responses
- nervous notations
- Lie detection, etc.

In the early decades of fMRI's emergence, in neuroimaging, this method has a profound impact on the method adopted by neuroscientists for studying brain functions.

Today, a number of these works have entered the clinical arena. It seems that this transition occurs more rapidly in the next decade. Indubitably, before the clinical fMRI with all its potential can be known and used, many issues should be resolved in order to be able to find the precise signals of the electrical activities. However, owing to the probability of the detection and treatment of diseases and its utility, the researchers endeavor to modify and utilize the fMRI as a clinical tool.

2.3 Machine Learning

Machine learning is a scientific discipline that deals with the construction and study of algorithms that can learn from data [3]. Such algorithms operate by building a model based on inputs [4] and using that to make predictions or decisions, rather than following only explicitly programmed instructions. Machine learning can be considered a subfield of computer science and statistics. It has strong ties to artificial intelligence and optimization, which deliver methods, theory and application domains to the field. Machine learning is employed in a range of computing tasks where designing and programming explicit, rule-based algorithms is infeasible.

Machine learning algorithms can be used in various applications of the FMRI images. A summary of some of these algorithms are described in the following.

2.3.1 Support vector machines

Support vector machines (SVMs) are a set of related supervised learning methods used for classification and regression. Given a set of training examples, each marked as belonging to one of two categories, an SVM training algorithm builds a model that predicts whether a new example falls into one category or the other [5].

2.3.2 Bayesian networks

A Bayesian network, belief network or directed acyclic graphical model is a probabilistic graphical model that represents a set of random variables and their conditional independencies via a directed acyclic graph (DAG) [5].

2.3.3 Artificial neural networks

An artificial neural network (ANN) learning algorithm, usually called "neural network" (NN), is a learning algorithm that is inspired by the structure and functional aspects of biological neural networks. Computations are structured in terms of an interconnected group of artificial neurons, processing information using a connectionist approach to computation. Modern neural networks are non-linear statistical data modeling tools. They are usually used to model complex relationships between inputs and outputs, to find patterns in data, or to capture the statistical structure in an unknown joint probability distribution between observed variables [5].

In papers [6] and [7], the types of machine learning are discussed for the purpose of diagnosis and identification of diseases using the fMRI images.

3 STUDIES IN FMRI

Much research in various areas such as brain activity detection and brain tumor diagnosis has been performed. The review of all studies conducted is outside the scope of this article, So, just several cases in this area are presented. In this section, the focus is on those tasks undertaken for brain activity detection and tumor diagnosis, and other tasks pertaining to the application of these images.

In the present study, initially, the studies done in the field of brain activity identification are presented. Then, the studies on tumor diagnosis are reviewed. Finally, other applications of the fMRI images are discussed.

3.1 Related Studies On The Identification Of The Active Areas Of The Brain

There has always been the question of how the human brain is able to understand a lot of things. This question and its probable answers have been discussed in many articles. In the paper [8], the computational method has been proposed to predict brain activity against various nouns using the fMRI images and a data set of 60 nouns. This method consists of two stages. In the first stage, the coordination between the noun and 25 semantic features (verbs) is calculated. In the second stage, the brain activity is predicted. The second approach provided in this research is to use the semantic feature signature (25 verbs) in order to identify the areas that have the greatest activity against verbs, and to predict the brain activity against different nouns.

Enormous stimuli are used to identify of the brain activity, including the auditory stimuli. In the paper [9], the reaction of the people’s brain when they hear the 5 sets of pairs of stimuli was reported. These stimuli were (1) listening to melodic tonal stimuli or listening to nonsense speech, (2) listening to an auditory stimulus or mentally rehearsing the stimulus, (3) listening to melody, speech or rehearsing, (4) listening to a pure tone or a band-passed noise burst, and (5) listening to a low-frequency tone or a high-frequency tone. To predict the Instantaneous Cognitive States, the experiments were performed on two pairs of stimuli 3 and 4 using the classification method . The effective features used for classification were selected from the fMRI images. After the training of the proposed system, it can be used for future prediction.

3.2 Related Studies On The Brain Tumor Diagnosis

Patients with brain tumors are exponentially increasing day by day. The brain tumor is an abnormal and uncontrolled growth of cells in the brain. In the paper [10], a new method is proposed for extracting amounts of metabolites (NAA, Creatine, Choline, Cr2) to identify the type of tumors. This method is based on decision tree algorithms. In this way, instead of storing the fMRI images, metabolite values are stored, which reduces the memory requirements and image processing tasks. The FMRI images enter as inputs to the system and metabolite values are extracted from the images. Then, using clustering and classification methods, the type of tumors are identified. Three methods are used in the diagnosis of brain tumors. The first method, which is a type of unsupervised learning method, is the weighted Kmeans and Z-score. The second method is application trees and can be conducted via weka software and the logistic regression function. The third method is a decision tree J48 graft. The second and third methods are supervised methods. The third method has been used in this paper which can yield better results (94.73%) in comparison with the other methods.

In the paper [11], because of the difficulty of identifying all the voxel data, Rajamani and Mohanraj proposed a method for the segmentation of the fMRI images and the identification of the voxels in order to be able to identify the type of the brain tumor. In this method, initially, the fMRI images are logged in the system. Then, via the SRM method, which is used for the segmentation of the images, the segmentation is performed considering the intensity of light, texture, brightness, and contrast. Using these areas, the metabolites values are extracted. These values are filtered, and in order to access the tumor type, the association rules are used. After that, the rules are constructed and evaluated in terms of accuracy. In this way, the tumor type is determined.

3.3 Related Studies On The Other Applications Of The Fmri

Several stages can be done during the observation of the word in order to find that word. These stages involve the processing of the visual perception, the number of letters in words, bigram and words communication frequency. Referring to these issues, Alexandre Gramfort and colleagues, in Article [12], attempted to predict the visual perception of the words (stimuli) using the fMRI images. In this paper, in order to solve this problem, a set of word binary characteristics is proposed to describe that word. So, the letters are marked by a series of lines; then, each independent binary variable is predicted. A method of Logistic Loss is used for predicting the class with the probabilistic prediction. This process makes it possible to rank the candidate words. To determine the correlation among the different features, a two-step process is used via logistic regression. To collect the brain images, a set of words with 46 words including 6 verbs is used. Each word is shown for 3 seconds, and then black screen is displayed for 5 seconds. To predict the visual perception, supervised learning is run via the standard GLM on the coefficients obtained using 28-second cutting frequency. A t-test was run to detect the effect of each voxel before the decoding. The allocation of the p_value to each voxel made it possible to map each voxel to a feature. The proposed method was performed on the data obtained from the 3 persons and the results are 95%, 92% and 93%.

The analysis of the fMRI images are done to identify how the brain responses to feelings or other activities. An application of the fMRI images is the clinical diagnosis. For example, in paper [13], a method is proposed for the classification of the healthy persons and addicts. In this paper, several classification methods have been investigated:

A) PCA and classification (KNN, GNB, SVM)

B) the voxel-based feature selection and classifier (KNN, GNB, SVM)

C) (Adaboost). The data was collected based on the loss of the nerve sensitivity to the protrusion of paper money in cocaine users. The proposed method consists of Boosting algorithm with side information to select the effective features in the data sets. The FMRI images are used as inputs. Side information is added with the adjustment of the classification and the update of weights. Thus, drug addicts can be detected using their fMRI images.

Anouk den Braber and colleagues, in paper [14], examine the neural changes in the discordant monozygotic twins using their fMRI images. As the results of this study show, the level of the behavioral disorder in the OCS twins reduces the brain activity in the dorsolateral prefrontal cortex, thalamus pulvinar, and inferior parietal cortex. Evidence shows that environmental and genetic factors have a significant impact on the neurobiological changes. The twins were selected using a questionnaire. The OCS factors included anxiety, discomfort, repetitive behaviors, Czech, washing, counting successive, etc.. To conduct the experiments, the two-sample test was performed on the Tower of London (TOL). In the first and second experiments, the number of bead movements towards the objective, and the number of yellow and blue beads were considered respectively.

The investigation of the active areas of the brain via the fMRI images used throughout the TOL experiment indicated that the neurological changes were related to the environmental conditions. The results show a decrease in the brain activity in high levels of OCS and an increase in the metabolism due to the disorders. The Neurobiological changes in discordant twins were just due to environmental stressors.

This question has always been why after the trauma some of the intrusive memories come to mind while others do not return? Intrusive memories are the key treatment for stress disorders in post-traumatic condition, and finding their cause is of paramount importance. The key feature of intrusive memories is their involuntary. In paper [15], a method is proposed based on the multivariate pattern analysis (MVPA) and classification algorithms to predict the intrusive memories of the traumatic film footage using the fMRI images. For this purpose, the fMRI images of people who were watching the traumatic film were used. The results show that the brain activity increases during the observation of the traumatic scenes. The main objective of this study was to identify the potential and flash back scenes and to predict the intrusive memories of the brain. For the pre-processing of the fMRI raw data, the ICA technique was used to identify the level of the brain activity. To do this, the brain was divided into 8 weighted parts considering the activity level, so, 5 regions participated. The place and time of the activation in the brain were very important. The system input was a sequence of flash back and potential scenes obtained from the fMRI data collected from the people watching the movie. Therefore, it can be stated that the voxel activity levels are considered as input while the movie was being watched. The proposed system had a result of 68%. The tests on the two-sample data set were repeated. In this system, the proper features of the scenes were selected using MVPA, and the SVM classifier provided the answer to the question of whether these scenes return or not.

Lie detection has become an important issue. Courts and the law are interested in the use of lie detection system; however, the uncertainty about it hinders its widespread use. In paper [16], a method is presented for distinguishing truth from lies. In this paper, deception is defined as a deliberate attempt at the false induction of the purpose. To extract the truth from the lies, the fMRI images were used. While the participants were lying, their front and parietal regions of brain are more active. 5 stimuli were used to obtain these images: ((1) Lie (5 of clubs or 7 of spades); (2) Truth (5 of clubs or 7 of spades); (3) recurrent distracter (2 of hearts); (4) variant distracter (remaining cards 2–10, all suits); and (5) null (back of a card)). Using these images, the regional brain activity was analyzed. Thus, at first, the pattern of the brain activity was examined when the participants were lying. Using four patterns, the voxel activity levels in the brain regions were investigated, and the logistic regression and classification and regression trees (CART) were used to detect the truth from the lies. The accuracy of the system was equal to 85%.

4 CONCLUSIONS

In this article, various applications of the fMRI images were discussed. A brief description of the use of these images was provided to achieve our goals by using various techniques such as machine learning algorithms. The fMRI imaging tool has a wide application in the brain mapping and the identification of the brain activity and tumor detection. The fMRI plays a key role in determining the location and type of tumors.

Table 1: Overview of the 9 fMRI studies

Article Name		Author (s)	Publish	Year	Pages	Data Sets	Method
Identification of the brain active areas	Meanings of Nouns Predicting Human Brain Activity Associated with theMeanings of Nouns	Tom M. Mitchell,Svetlana V. Shinkareva, Andrew Carlson, Kai-Min Chang, Vicente L. Malave, Robert A. Mason, Marcel Adam Just	Science(AAAS)	2008	1191-1195	9subject with 60 word and 25 verbs (Semantic Features)	
	A Machine Learning Approach to Detecting Instantaneous Cognitive States from fMRI Data	Rafael Ramirez, Montserrat Puiggros	Springer-Verlag Berlin Heidelberg	2007	248-259	Experiment 3 including 6 person(3 femal-3 men), Experiment 4 including 12 person	SVM, ANN, KNN, Ranking , DT
The brain tumor detection	Detection of Brain Tumor by Mining fMRI Images	Meghana Nagori, Shivaji Mutkule, Praful Sonarkar	International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE)	2013	1718-1722	76 instance (21 Benign,22 Mild, 19 Malignant,14 Infection)	C4.5 algorith m
	Brain Imaging Techniques For Brain Tumor Classification Using ARM And SRM Technique	Ms.M.Rajamani , Mr.M.Mohanraj	International Journal Of Research In Computer Applications And Robotic (IJRCAR)	2014	174-180	159 instance (45 Benign,48 Mild, 49 Malignant,17 Infection)	SRM , Associa tion Rule Mining
Other usage fMRI	Decoding Visual Percepts Induced by Word Reading with fMRI	Alexandre Gramfort ,Gael Varoquaux, Bertrand Thirion, Christophe Pallier	Pattern Recognition in NeuroImaging (PRNI)	2012	13-16	3subject with 46 word including 6 verbs	logis tic regre ssion GLM
	Machine Learning for Clinical Diagnosis from Functional Magnetic Resonance Imaging	Lei Zhang, Dimitris Samaras, Dardo Tomasi, Nora Volkow, Rita Goldstein	IEEE	2005	1-7	16 cocaine dependent,13 non-drug-using	Boostin g with side informa tion
	An fMRI study in monozygotic twins discordant for obsessive–compulsive symptoms	Anouk den Braber , Dennis van ’t Ent, Gabrie¨lla A.M. Blokland , Danie¨l S. van Grootheest, Danielle C. Cath , Dick J. Veltman , Michiel B. de Ruiter , Dorret I. Boomsma	Biological Psychology(Science direct)	2008	91-103	12MZtwin pairs discordant for OCS (14 females and 10 males) were recruited from the Netherlands	
	First steps in using machine learning on fMRI data to predict intrusive	Ian A. Clark, Katherine E. Niehaus Eugene P. Duff, Martina C. Di Simplicio, Gari D. Clifford,	Behaviour Research and Therapy (ELSEVIER)	2014	37-46	22 participants took part in Bourne et al. (2013; mean age= 22 years,	Multiva riate Pattern Analysi s (MVPA

	memories of traumatic film footage	Stephen M. Smith, Clare E. Mackay, Mark W. Woolrich, Emily A. Holmes				17 female), and 35 in Clark et al. (submitted for publication; mean age =22.43 years, 29 female).	) , SVM
	Telling Truth From Lie in Individual Subjects With Fast Event-Related fMRI	Daniel D. Langleben, James W. Loughead, Warren B. Bilker, Kosha Ruparel, Anna Rose Childress, Samantha I. Busch, and Ruben C. Gur	Human Brain Mapping	2005	262–272	26 right-handed male	logistic regression with classification and regression trees (CART)

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