Introduction to MRI process and review on fMRI analysis

Shiju Samuel, Rohini S. Ochawar, M.S.S.Rukmini

ABSTRACT--- Magnetic Resonance Imaging (MRI) and functional magnetic resonance imaging (fMRI) has attracted a large number of researchers and many of them have contributed significant work regarding brain function mapping. The fMRI experiments are used to identify the abnormal functional connectivity (AFC) and dynamic functional connectivity (DFC). Many abnormalities are also detected by blood oxygen level dependent BOLD-fMRI. MRI and fMRI are two different sides of a coin. Both these techniques shall be helpful for the diagnosis if corresponding images elucidate the significant facts. Visualization of particular structure obtained in MRI and fMRI in order to analyze the abnormality, can be enhanced by proper image processing techniques. Hence, researchers have developed various technique and algorithms so as to yield perfect conclusion with regard to MRI and fMRI scan. The detailed review of the analysis of fMRI in order to understand and analyze fMRI scans are explored in this research paper.

Keywords— AFC, BOLD, MRI, fMRI

INTRODUCTION

MRI- From the beginning of the 1970s magnetic resonance imaging (MRI) has manifested to be highly adaptable imaging technique. MRI is most prominently used in diagnostic medicine and biomedical research. MRI is a method that uses a magnetic field and pulses of radio wave energy to create an impression of organs and composition inside the body. The differences of unusual tissues to normal tissues are fulfilled with MRI than other imaging techniques such as X-ray, CT & Ultrasound [1]. Magnetic Resonance Imaging was innovated by Paul C. Lauterbur in September 1971 [2]. He has published the related theory in March 1973 [3]. MRI shares discrete data about various compositions inside the human body which can also be visualized with x-rays, ultrasound or computer tomography (CT). MRI is a medical imaging technique and that utilizes Magnetic field, radio waves and computer to construct resemblance to the body structure. The MRI scanner is a tube enclosed by a colossus circular Magnet. It is extensively used by medical institutions and hospitals around the world. MRI procedure requires a vigorous magnetic field and radio waves to generate comprehensive images of the organs and tissues inside the body. The process uses Nuclear Magnetic Resonance (NMR) principle to get an image. The time span of the MRI procedure differs according to the need of application but the average time is 45 minutes to one hour. During MRI scanning, a person is required to remain unmoved. On both sides of the person, the high power magnets are permanently kept opened. MRI imaging creates a loud fragmentary banging noise. The MRI of the cervical spine needs at least 20-35 minutes and the MRI of upper limb requires 20-45 minutes [4]. Depending on which part of the body is being scanned, the patient is needed to wear a hospital gown. It is required to avoid metal zip buttons, belts, buckles and other ornaments during scanning. There may be risk and aches associated with MRI scan. MRI is most commonly used in hospitals and clinics for determining the diseases or ill condition and explains person's symptoms without exposing the body to ionizing radiation.

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Shiju Samuel, Research Scholar, Department of Electronics & Communication Engineering Vignan's Foundation for Science, Technology & Research Vadlamudi, Guntur Dist. Andhra Pradesh, India. (E-mail: ssamuel@stvincentngp.edu.in)

Dr. Rohini S. Ochawar, Associate Professor, Department of Electronics Engineering Shri Ramdeobaba College of Engineering & Management Nagpur, Maharashtra, India. (E-mail: ochawarrs@rknec.edu)

Dr. M.S.S.Rukmini, Professor, Department of Electronics & Communication Engineering Vignan's Foundation for Science, Technology & Research Vadlamudi, Guntur Dist. Andhra Pradesh, India. (E-mail: mssrukmini@gmail.com)

I. MRI PROCEDURE

MRI process is a non-invasive method of mapping the internal structure of the body by producing images by the virtue of gyromagnetic property of protons, with the greatest advantage of not using ionizing radiation for imaging. It portrays the distribution of hydrogen nuclei and parameters relating to their motion in water and lipids. In absence of the magnetic field, the hydrogen atoms corresponding to the water molecules/lipid in human body shows their random behaviour. When a strong magnetic field is applied during MRI process, the hydrogen atoms get aligned in some specific direction. After additional application of RF wave, these hydrogen atoms get once again realigned. Removal of RF signal resulted in returning to the original position and thereby releasing energy in the form of electrical signal. Due to large procedural time, MRI should be used only when the necessary information cannot be obtained by other less expensive and invasive means.

Introduction to fMRI

Functional Magnetic Resonance Imaging (fMRI) measures signal changes in the brain that are triggered because of changing neural activity by identifying changes in blood flow. This method is based on the fact that, the cerebral blood flow and neuronal activation is integrated. The blood flow increases when an expanse of the brain is working. The primary form of functional MRI (fMRI) uses the BOLD contrast discovered by "Seji

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Ogawa" [5]. It is actually the brain and body scan for measuring neural activity in the brain or spinal cord of humans by imaging the difference in the flow of blood (Hemodynamic response) connected to energy use by brain cell. From the beginning of 1990s, fMRI is used to monitor brain image investigation, as it is not needed for people to encounter surgery or to be bare to ionizing radiation. FMRI is used both in the research world and fairly in the clinical world. This is further merged and supplemented with other assessment of brain physiology for example electroencephalography (EEG) etc. for analysis. The newly discovered procedures which enhance both space and time intent are being examined and these mainly utilize naturally occurring phenomenon other than BOLD. Based on fMRI technique, various industries have also developed the various commercial products such as "Lie detector" etc. [6].

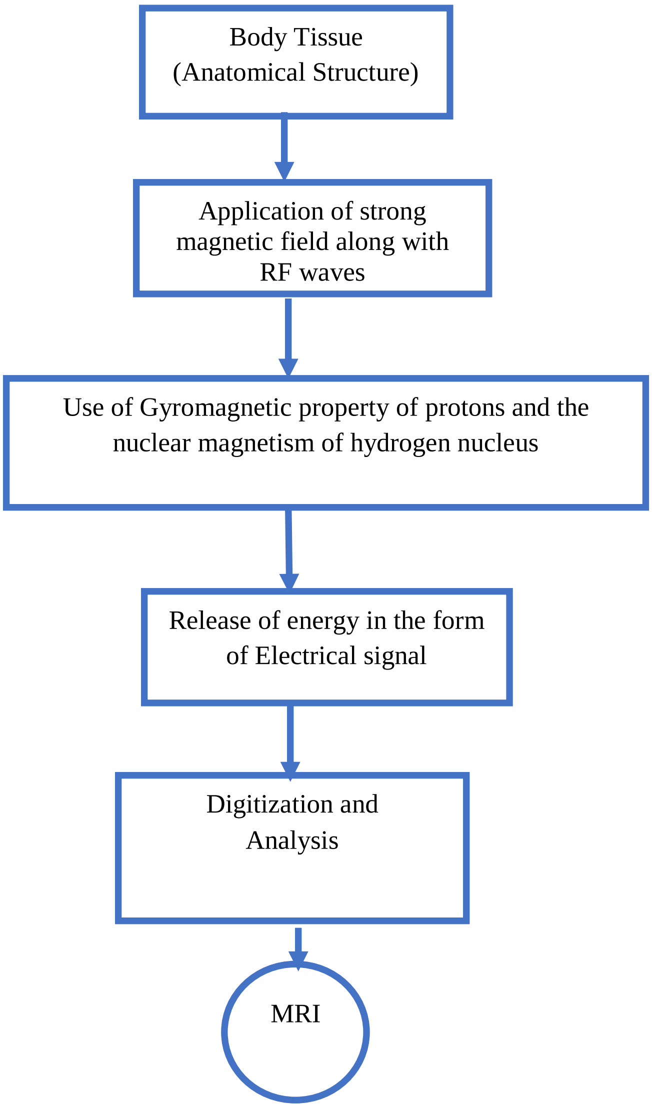

Figure 1: MRI Process

Figure 1 mentioned herewith completely describes change in any body tissue undergoing MRI process. Application of strong magnetic field along with radio frequency waves affects the magnetic property of hydrogen nucleus in body tissue. Change in magnetic property yields release of energy which is digitized and available as MRI [27].

II. FMRI PROCEDURE

fMRI analyzes the metabolic changes that takes place within the brain. It can be applied to evaluate the brain's anatomy, regulate the region of the brain that are holding adverse functions, assess the cause of stroke, to guide brain treatment. fMRI is one of the imaging technique which can easily detect the abnormality inside the brain. fMRI helps to identify the confined changes in flow of blood and blood oxygenation in the brain due to neural activity. FMRI uses the physical phenomena of Nuclear Magnetic resonance (NMR) and magnetic resonance imaging to understand the confined differences in hemodynamic that is activated by local neural scheme [26].

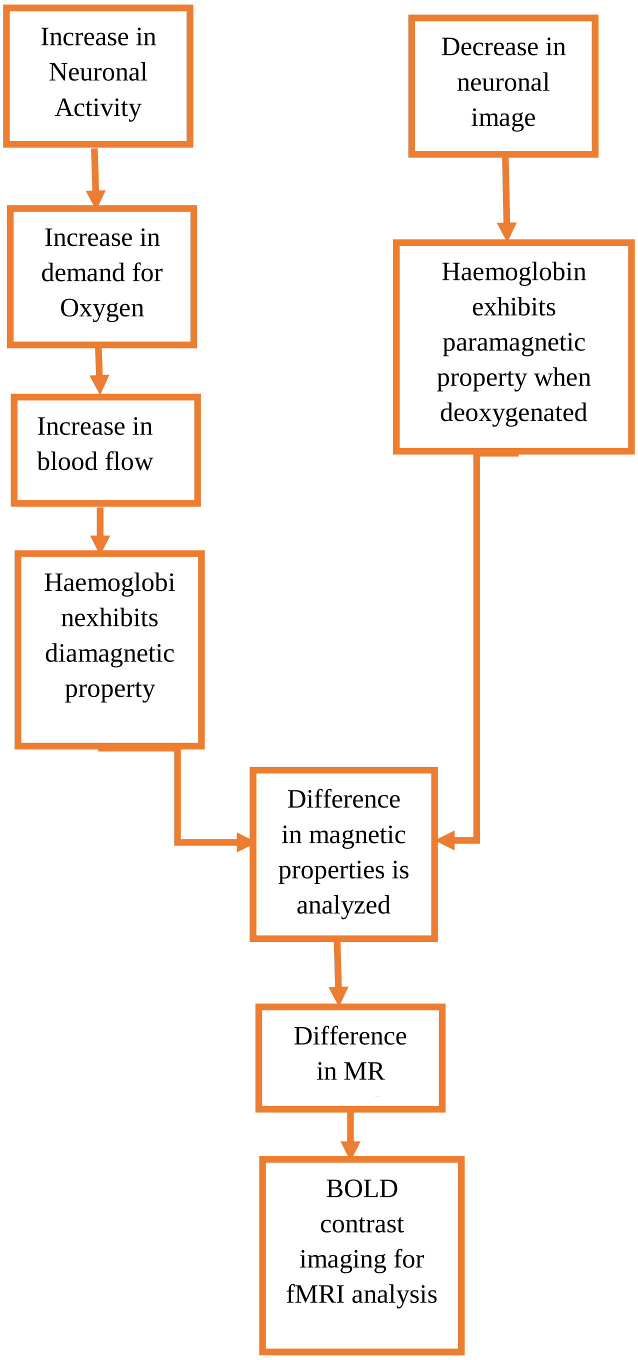

Figure 2: fMRI Process

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Introduction to BOLD

In fMRI, contrast imaging technique is used to observe various parts of the brain or other organs of the human body which are found to be active at any given time. Seiji Ogawa and colleagues in 1960's invented the concept of BOLD contrast imaging. Study of BOLD contrast is based on the fact that when neuronal activity becomes high in one part of the brain, then there is also an increased amount of cerebral blood flow for the preservation of neurons, astrocytes and other cells of the brain. An experiment was carried out by him in regard to change of blood oxygenation level which could be detected with MRI. The other famous explorer of BOLD fMRI includes "Kenneth Kwong" and his colleagues, who first use this technique in the human brain in 1992 [7]. To a great extent, fMRI researchers use BOLD contrast imaging as a method to identify which parts of the brain is most active as shown in figure 2. Neural activity directly assess the oxygen extraction fraction in the part of the brain which assesses how much of the oxyhaemoglobin in the blood has been converted to deoxyhaemoglobin

III. REVIEW ON FMRI ANALYSIS

Electroencephalography (EEG) and fMRI are two supportive modalities representing a combination of various underlying neural sources as proposed by Borbala Hunyadi, et. al., 2016 [8]. They have revealed the EEG-fMRI fusion which provides a detailed spatiotemporal characterization of an EEG-fMRI dataset in epileptic patients, controlling new insights in epilepsy research. An electric current in magnetic resonance (MR) compatible stimulator at variable amplitude and frequency elicit tactile skin receptors (mechanoreceptors) as proposed by Hartwig, et. al., 2006 [9]. The intention is to suggest specific tactile sensations with the help of an electric current in place of mechanical stimulant. They also proposed the device which is drafted using safety standards in sequence to follow with the threshold of voltage and current. The high-resolution fMRI (hi-res fMRI) technique bridges the gap among the macro and the micro view of brain as proposed by Nikolaus kriegeskorte & peter bandettini, 2006 [10]. Hi-res fMRI is achievable in human studies using 3-Tesla scanners. The small receive coil has several benefits over a single (example birdcage) coil. With a formation of small receive coils, image signal to noise ratio (SNR) can be effective and the image evaluation method can be effective by use of parallel imaging (PI) methods as introduced by Jacco A de Zwart, et. al., 2006 [11]. The three benefits of Parallel Imaging (PI) –fMRI have been enlisted as- (i) the depletion of artifacts in one shot order both geometrical twist and communication loss caused by off resonance effects. (ii) the potential for growth in spatial and temporal resolution. (iii) the curtailment of gradient loud noise in sequence to decreased reciprocal action amongst the scanner and the fMRI experiment. Yiheng Tu, et.al., 2015 [12] have suggested a supervised dimension reduction technique named Principal Component Sliced Inverse Regression (PC-SIR) for analyzing high- dimensional fMRI data. Its stimulation and fMRI pain reduction outcome showed that PC-SIR provided better performance in (i) recognizing activation patterns from the entire brain fMRI data, (ii) prophesying pain opinion after dimension reduction. Standard quality biomarkers are discovered to treat the people who are undergoing from traumatic brain injury (TBI). TBI affects human being's thinking, memory, personality and behaviour. The "Resting-state functional network connectivity (rsFNC)" derived from fMRI as a possible biomarker and their results agree with reported connectivity growth in the cerebellum and the Supplementary Motor Area (SMA) as investigated by Victor M. Vergara, et. al., 2015 [13]. The fMRI pattern and motor function recovery of a pretentious limb is associated in between an early stage of striatocapsular infarction (SCI) as investigated by Long-Jiang Zhou, et. al., 2017 [14]. Striatocapsular infarction is a certain shape of profound hemispheric cerebral infarction in the region of middle cerebral artery that result in a compound constellation of subcortical and cortical signs and symptoms [15]. Unsupervised clustering and independent component analysis (ICA) are investigative data-driven procedures that are considered to be the hypothesis-generating method. A new paradigm in ICA has come out discovering "clusters" of dependent components. Anke Meyer-Base, et. al., 2004 [16] have experimentally measured four standard independent component analysis (ICA) algorithms which are chosen in the fMRI literature with two new algorithms, (i) tree-dependent and (ii) topographic ICA. fMRI brings together the model of merging two solid analytic data analysis skill, ICA and unsupervised clustering process. They determined the good condition and reliability of withdrawing task-related operative maps and time courses from fMRI data sets. The outcome of ICA technique is rooted on the factor that the space sharing of brain region activated by task performance must be spatially maveric of the distributions of region influenced by artifacts.

Modern radiation therapy is used to cure tumours. These methods are surprisingly workable in the displacement of transmitting energy quantity on an aimed volume. Supply of quantity should be distributed accurately, in order that the tumour is uncovered to an excessive quantity and it will be helpful to save the nearby healthy structures. This modern method can be utilized by regulating the required quantity in that area, so that it equalize the difference in transmitting energy signal in the tumour. It indicates dose painting. For productive dose painting, fMRI methods are necessary to spot an area in a tumour that needs a higher measure. Magnetic resonance imaging (MRI) into outer radiotherapy progress of working propelled along high-level soft tissue contradistinction is much better contrasted to Computed tomography (CT) as proposed by Uulke A van der Heide, et. al., 2012 [17]. They have labeled various matters and narrated clinical growth in

MRI guided dose painting in order to better clarity in delivery in radiation therapy (RT), benefits of merging functional MR and positron emission tomography (PET), MRI guided radiotherapy (MR-linacs, MR-guided brachytherapy, MR for proton therapy) and dose painting trials. The statistical substructure of instrument training supplication in fMRI are described by Elia Formisano, et. al., 2008 [18]. They concentrated on two techniques SVM and appropriate vector machine, which are individually appropriate for the categorization and regression of fMRI motif. They have used the motif remembrance skill in functional MRI data inspection and also illustrated the use of support vector machine (SVM). Entire brain supplication of these methods create an applicable methodological summons in terms of most favorable feature selection. The origin of low-frequency alteration in fMRI signal, utilizing both power and time spectral analyses on tissue-section fMRI and cardiorespiratory (to supply oxygen to skeletal muscles during sustained physical activity) data as investigated by Mehrdad Razavi, et. al., 2008 [19]. They have described a methodological analysis of fMRI signal and presented the summary of their work as follows: (i) fMRI data were divided into five reciprocal and complete tissue composition (grey & white matter, cerebrospinal fluid (CSF), a tubular structure caring blood, and extra cerebral portion). (ii) All the individual voxel of all tissue form were analyzed separately and calculated for that entire tissue structure, so that there was no known process in choosing a “seed” voxel or area of interest to indicate a specific tissue form. (iii) Face analysis in a stage wise manner was carried out permitting the research of the temporal link between the distinct frequency element of fMRI signal across the distinct tissue form, and (iv) comprehensively differing sampling rates made sure that fMRI signal variations were resolved lacking temporal aliasing problems relating to the action of heart & lungs.

Thus, huge image dataset obtained during MRI & fMRI scans needs to be handled by certain techniques. Many researchers have preferred the clustering technique to handle this huge database. Nicola Morelli et. al., 2008 [20] have examined the cerebral process occur in middle of four patients with series of cluster headache (CH) with fMRI, the patients goes inside the MRI machine for checking abnormalities in the body and functional data asset without symptom. Vajarala Ashikh, et. al., 2015 [21] have proposed the important method of clustering for systemizing a structured set of data into categories, ordering points to recognize clustering structure (OPTICS) algorithm has been cast-off to execute clustering of fMRI data. They analyzed the implementation and determined the purpose rate of OPTICS. Michael de-Ridder, et.al., 2015 [22] have narrated in progress investigation on fMRI visualization and consider the prospective for virtual reality (VR) and augmented reality (AR) combined with signal based inputs to generate an immersive domain for visualizing fMRI data. They suggested that VR/AR can possibly control the recognized challenging by permitting for a depletion in visual clutter. Their suggestion is based on the compound interplay of visualizing important functional correlated ideas. Hiroyuki Akama, et. al., 2015 [23] have presented multivariate pattern analysis (MVPA) skill using one of two easy and computationally affordable splitting methods, joint ranking feature selection (JRFS) and disjoint feature selection (DJFS). Xinpei Ma, et. al., 2016 [24] discussed the testing of high parameter voxel carefully by solving problem in multi-voxel pattern analysis (MVPA) in neuroscience by combining Hierarchical heterogeneous particle swarm optimization (HHPSO) and Support vector machine (SVM). They have compared the categorization outcome acquired by four more basic algorithms, counting without feature selection (WFS), sequential forward feature (SFF), sequential backward feature (SBF), and particle swarm optimization (PSO). The proposed HHPSO–SMV claims for two advantages: (1) it clears the unwanted features rapidly, and (2) It chooses algorithm better than other algorithms in terms of accuracy. Gopikrishna Deshpande, et. al.,2015 [25] have demonstrated the value of fully connected cascade (FCC) artificial neural network (ANN) architecture for classifying subjects with giving attention to deficit hyperactivity disorder (ADHD) related cases. It resulted in improved classifier design and discriminative connectivity based features for detailed analysis of hyperactivity disorder (ADHD).

IV. RENAL FMRI

Jeff, Zhang, 2017 [26] have summarized recent advantages in fMRI; contrast enhanced and non-contrast in evaluating renal function. Contrast enhanced MRI is developed as a reliable tool as electrical signal is digitized and analyzed in a computer to produce MR image. MRI has the advantages of providing multilane images with fine anatomic detail and contrast resolution. Advantages of MRI are counterbalanced by high cost and extensive calculating several functional limit of the kidneys. The technique takes only a short dose of contrast and it can be included into clinical MRI rules of large number of renal diseases, such as tumor and “obstructive uropathy.” Non-contrast MRI methods are encouraging and calculating various phase set of renal physiology and its value assessed through renal allograft.

V. DISCUSSION

A typical fMRI scanning session continues for one to two hours and outcome is in the form of megabytes of data. The concept behind the theory and practicalities is combined with procedures that data are composite and developing. In order to understand and analyze, systematic detection of changes, a simple and statistical test can be used in fMRI data analysis for example t-test. The physical movement related issues of the patients and the concerned data obtained from MRI/fMRI machine needs to be pre-processed before analysis for the conclusions to be drawn by the radiologist. Motion correction algorithms need to be applied during data analysis because of head movements of the patients.

Scientific investigation using MRI/fMRI shall be correct if any only if the MRI/fMRI scan images are clear. But many a times, some distortions are naturally present in the scan images due to preparative or investigative procedure. These distortions are technically termed as artifacts. With these artifacts MRI/fMRI scan images may misguide radiologist. Hence, in order to avoid this, image processing algorithms are required to be applied on to these MRI/fMRI images so that artifacts shall be removed as in figure 3.

VI. CONCLUSION & FUTURE SCOPE

Thus, the conclusion herewith lies with the fact that, MRI/fMRI scan images shall undergo image processing algorithms to yield correct MRI/fMRI data to be available to the radiologist for correct diagnosis of the disease. Hence, a large amount of scope is still involved in correctly processing and interpreting the scanned data of MRI and fMRI using image processing algorithms.

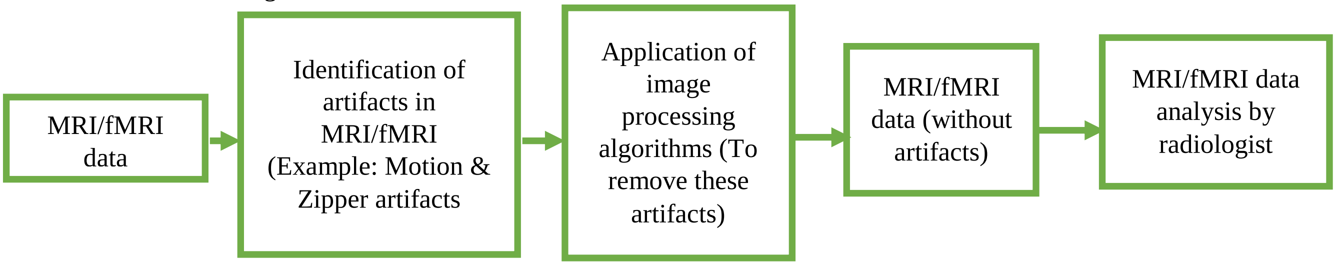

Figure 3: Artifacts removal process of fMRI/MRI signal

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