Volume 6, Issue 6, June 2016 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

A Survey on MRI Reconstruction

Sameer S. Sonawane*
ME Student(Dept. of E&TC)
GES R.H Sapat College of Engineering,
Nashik-5, Maharashtra, India

Santosh P. Agnihotri
Assistant Professor(Dept. of E&TC)
GES R.H Sapat College of Engineering,
Nashik-5, Maharashtra, India

Abstract— Image Reconstruction is the way of achieving an image of an object from the signal taken by scanning machine. The main aim of reconstruction action is to inspect the brain images precisely in order to completely analysis the problem of patient. Magnetic resonance imaging (MRI) is a non-invasive imaging scanning method that is proficient of giving high contrast image of soft tissues of the patient body. MRI is working on principle of nuclear magnetic resonance (NMR) and the data gather by MRI scanning machine is called as k-space data. For reconstructing an image from k-space data, there are various algorithms All the characteristics of k-space data and MRI data collection technique are explained in deep way. The methods used for image reconstruction discussed in detail along with their advantages and disadvantages. Different recent magnetic resonance imaging techniques as functional MRI, diffusion MRI have also been explained. This paper present overview of different methods for MRI reconstruction.

Keywords— MRI, NMR, Modern MRI, k-Space, Phase Error, PET, MRS.

I. INTRODUCTION

There are many scanners which help to inspect the patient's whole body or part of it, after inspecting, they give high quality images which have precise information about the scanned part [1]. Name of scanners are MRI, CT, PET (Positron Emission Tomography. They differ in the on which application, technology and working for in obtaining the images. Over the last two decades, the price for these devices is reduced and easily affordable to hospitals and diagnostic centres. MRI is used to generate precise and explanatory images of the tissues and organs in the patient body with the used of radio waves and magnetic field [2]. It benefit doctor to identify the different medical aspect of the scanned part of patient body in deep and clear with the help Nuclear Magnetic Response (NMR) signals, invented by Bloch and Purcell who got the Nobel prize in physics for this invention in 1952 [3]. MRI is a non-invasive scanning technique, Non-invasive refers to the analysis of the diseases in human body without injecting any instrument inside the body [4]. It does not use ionizing radiations that are harmful to human body and hence it is preferred over Computed Tomography (CT) scan for examining soft tissues [5]. MRI gives clear images of soft tissues compared to CT.MRI makes use of NMR of hydrogen atom. After the getting of NMR signals, they are elected to plan k-space data with the aid of Radio Frequency genrating Coil. MRI scanning machine has hardware components like Magnets, Gradient Coils, RF Coils, RF Detector as main part and computer system, and safety tool box as secondary part.

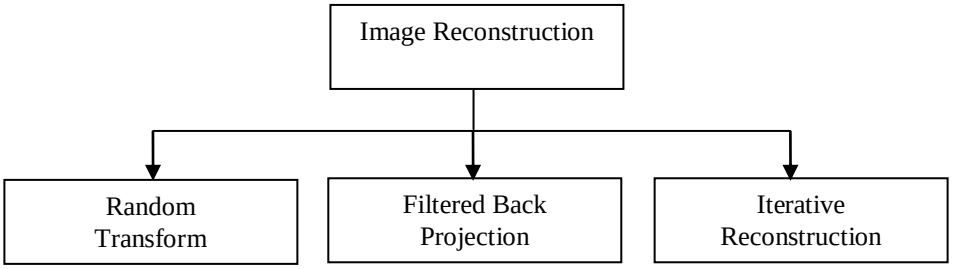

Fig.1. Image Reconstruction Branches

The raw data getting from scanning devices bank on the type of scanning device. K-space data is getting from MRI and Projection data set is getting from CT scan devices [9]. The raw data (k-space data) can have some missing entries because of incorrect scanning or due to travelling in medium (air or vacuum) or due to some other causes. The nature of raw data impact the aspect of final reconstructed images in all the scanning machine. The main obstacle in MRI is the reconstruction of an image from the incomplete (partial k-space) data form by the MRI scanner. It is very hard to have a scanning machine which can give complete k-space data [10]. The problem of missing or noisy k-space data is conqured by devising computational way that can correct the data ahead employing reconstruction algorithms. Hence, the problem of reconstruction of an image from k-space is a challenging one. The random function computes projections of an image matrix along a specified direction, The filtered back projection is commonly used in tomo graphic reconstruction of data obtained from clinic. And work on the principle of reconstruction from multiple projections. In iterative method image reconstructed in iterative fashion and used to reconstruct two dimensional and three dimensional images.

Magnetic Resonance Imaging and its branches as Diffusion Tensor Imaging, and Functional MRI are mostly used in both research and diagnosis in Medical Imaging. Different methods gives different facent of the scanned part. For while, in neurology the T1, T2 images present high-resolution picture of the structural aspects of the brain [11]. They play as very useful diagnostic way to pinpoint the tumors and other structural deformity and prepare exact detection of the of the irregularity [12]. This is of good help in surgical removal of them, as it requires perfect separations of the limits. Diffusion Tensor Imaging (DTI) captures the structural inter connections in the brain by inspecting neural fibers . DTI primly provide a clear considerate of white matter. DTI works by calculating the principal path of water diffusion at each position, by scheming sequence of application of the magnetic gradients. The reconstruction method is disparate from that used in normal MRI and is beyond the capacity of the paper. In research area, MRI has been a modern tool in neuroscience research It has lead to many leaps in brain connectivity analysis which studies the functional connectivity in between different regions in the brain which could be structurally wired together. It helps to getting the teamwork that exists between different functional regions of the brain in carrying out different responses [13].

II. PRINCIPLE OF MRI

MRI uses the fundamental of nuclear magnetic resonance. Spatial Information is given by the spatial gradient of the activated magnetic field. The sampling trajectory in the k-space is calculated by the time craving of the applied magnetic field gradient. The engineering form of MRI lies in properly designing the way the magnetic field is applied to conjure nuclear magnetic resonance to capture the spatial distribution of hydrogen protons in the body of patient. There are three main of magnetic fields in the MRI scan machine: (i) B_0-main magnetic field, (ii) B_1-secondary magnetic obtained by Gradient coil, (iii) Radio frequency pulse. Primary magnetic field adjust hydrogen atom in parallel direction that is known as longitudinal magnetization as presented in Fig. 2. Gradient coils give secondary magnetic field; three gradient coils along x, y and z direction. It grand MRI to produce magnetic field directionally along x, y, and z axes. It also grand spatial encoding for MRI images in the x, y and z axes that is known as localization. An object is placed in the main magnetic field as a result net magnetization is formed by gradient magnetic field along x, y, z axes [14].

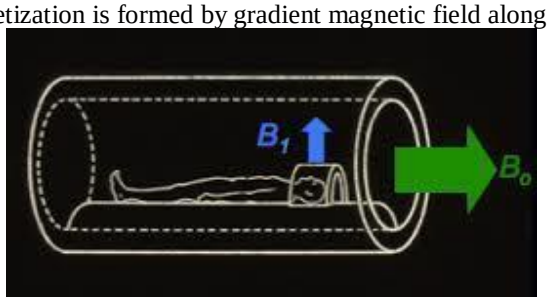

Fig. 2 Magnetization in MRI[20]

Net magnetic moment can be given as [14]:

$$B(r) = B_0 + G_r.r \tag{1}$$

Radio frequency coils is used for transmitting RF pulse and receiving signals in MRI, it also agitate alignment of protons. Few low energy protons spin to a high energy state by shortening magnetization in longitudinal direction. A proton continuous to its normal state in the main magnetic field is called as Relaxation. Relaxation in longitudinal axis is described as T1 relaxation as it is align parallel to B0, and relaxation in transverse axis is termed as T2 relaxation as perpendicular to B0. After applying the RF pulse, the various protons get flicked back to low energy state from high energy state that is parallel to B_0. This release in energy is achieve in the form of NMR signals. RF coils take these signals. The computer system work on this the analog data from RF coils and do analog to digital conversion of data. The digitized version of the body part which will get stored in momentary image space also called the k-space, the Fourier transform of the image. K-space stored digitized NMR signals during data acquisition phase. It shows the spatial position enclosed by frequency and its phase data obtained by MRI scan. K-Space data is sent to image processor where some reconstruction algorithm is applied to reconstruct an image [15].

The physical principle of NMR signals is the main bank of Nuclear Spin. NMR signals are obtained when the protons come back to low energy from higher energy. Nuclear spin is an essential form of angular momentum (μ) borned by atomic nuclei and other necessary particles Here, in MRI, It is an belief that Hydrogen atom proton nuclei gets aligned in parallel direction towards prime magnetic field.

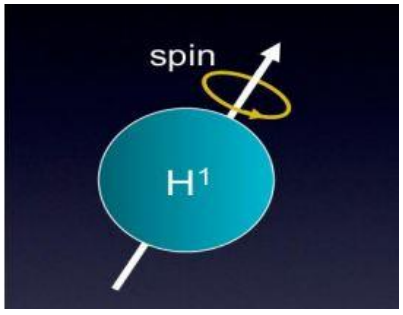

Fig. 3 Hydrogen Atom Spinning [11]

The human Body is poised of primarily with water and carbohydrates. The water and carbohydrates has lots of hydrogen atoms. In normal human body, percentage of water is more than 60%. When the gradient magnetic field fall on the body, the hydrogen atom of the body get stimulated to spin in one direction. This spin happens because Hydrogen Atom has only one proton and it may be aligned effectively in the MRI magnet. The proton possesses the property of spin which is causes nucleus to generate an NMR signals that further picked by the radio frequency coils to generate k-space. Since, bones are not having any water; it does not produce any data for image. Bones retain blank area in images that is why MRI scanners are better than other for scanning soft tissues. The Radio Frequency coils detect the NMR signals obtained by the nuclear spin. Both phase and frequency data are assigned in the form of matrix, of complex numbers, whose central region has low frequency. This is essentially referred as k-space data. [16]

III. DIFFERENT MRI TECHNIQUES

A. Functional MRI

The Functional MRI was developed almost the end of 20th century. As name suggest it is used to explain functional movement of body part with respect to brain. It measure brain activity by measuring changes related to blood flow.This technique based on the fact that blood flow and neuronal activation are link to each other. It supplement a new way to the research by permissive the observation of functional variations of the neural processes that palpable as subjective capabilities of individuals. fMRI has also dealt as a basic diagnostic tool by helping the recognition of functional oddity that impair the normal functioning of the brain. Neurological processes are essentially electrochemical signals, which are the truthful indicators of brain activity which is tough to inspect. Therefore measurable stand-in indicators had to be matured to trace neural movement and their derivations from equilibrium state.When an part of the brain is in use, blood flow to that part also raise. An raise in the volume of blood flow account a small variation in the MR signal to a turn in the concentration of oxygenated hemoglobin. This variation in MRI signal can be gives to change in the level of neural activity [17].

It measures the magnetic differences in blood when it is in oxygenated and deoxygenated state. Naturally haemoglobin in the blood turn into paramagnetic when it is in de-oxygenated state, it gives bigger Magnetic Resonance signal than in oxygenated state. It analyse multiple images at various time. While scanning, it enlarge nerves to work rapid and pursue BOLD (Blood Oxygen Level Dependent) effect, which is used for inspecting organs that are working as brain tissues. Assume if portion of brain has to be removed because of tumor or any other cause, fMRI helps to inspect the side effects after removing that area from the brain.

B. Diffusion MRI

It is fact on how water molecules diffuse through body tissues. This way bank on the Brownian motion of water molecules. Water lean to diffuse more along the fibers and therefore it may be used to identify structural detailed of neural network. It work on principle of Diffusion tensor imaging (DTI), The principal direction of diffusion is taken from the Eigen vectors of the diffusion tensor have at that points. When the magnetic field gets agitated a dephasing gradient magnetic field is activated. This produces the magnetic dipoles at different locations to precess at various angular velocities. Dephasing magnetic field rattle phase alignment and the signal observed is weaken therefore. If there is no changes of water molecules then rephasing gradient could realign the magnetic dipoles. This realignment as the enhance of the signal captured. But the water diffuses during the rephasing process, the pulse decline to refocus all the magnetic dipoles as a result in a signal loss. The signal loss is a action of the diffusion effects of the tissue [18].

C. Interventional MRI

Interventional MRI was mainly made for the interventional radiology. It does not cause any harm effect to the patient at the time of scanning. It has no magnets, but, it has quasi static fields and strong magnetic radio frequency fields that are generated from the scanner. Its degree of invasiveness is quite huge as compared to other MRI imaging techniques.

D. Real Time MRI

Real Time MRI scanning machine continuously observed the objects in real time. Its inspection is based on radial iterative reconstruction and FLASH (Fast Low Angle Shot). FLASH is a basic principle for obtaining the k-space data that is obtained from scanning device. It is applied to study cardiac movement of the nerves and obtain cardiovascular imaging. It obtaining the heart beat imaging that is up to 50 frames per second. Apart from cardiac functionality it is also used for studying the joint kinetics.

E. Magnetic Resonance Spectroscopy

Magnetic Resonance Spectroscopy (MRS) is mostly used to obsereved the metabolism in the body tissues. Metabolism is the reactions that allow living beings to grow and reproduce. MRS generates resonance spectrum that is related to the variations of isotope that will energies to form raw data of the scanned object. Two or more elements are called isotope when they have same number of protons in their nuclei. It is used for diagnosing metabolic disorder. It is also used for obtaining biochemical reaction information of the tissue in the human body. The problem of missing or noisy k-space data is conquered by devising computational way that can correct the data ahead employing in this reconstruction method.

IV. MRI BRAIN IMAGE RECONSTRUCTION METHODS COMPARISON

Table I Methods Comparison

S. N	Reference	Advantages	Disadvantages
1	Reference[1]	The gridding method with density compensation factor is fast and effective	The gridding method works only when under-sampled data is available.
2	Reference[2]	The method gives better reconstruction accuracy and computational complexity of Reconstructed image than existing methods	Complex convex optimization mathematics used.
3	Reference[3]	MR reconstructed image easily obtained from only 20% of sampling.	For getting reconstructed image o ne has to solve the difficult problem of minimizing nonsmooth function on large data sets.
4	Reference[4]	A new way for situation in which the signal is compressible in wavelet basis.	A bit slower system.
5	Reference[5]	It achieves a maximum reduction in the number of diffusion measurement	Reconstruction accuracy is not good.
6	Reference[6]	Generalized Series is necessary for capturing missing information, and has less computational complexity.	Result has high frequency ringing and loss of resolution.
7	Reference[7]	It required less scanning time with better accuracy.	It is sensitive to noise.
8	Reference[8]	The LSQT method give renovation when a suitable parameter selected.	Recommended obly for high size images.
9	Reference[9]	Image quality is conserve	Used Complex data and and complex system
10	Reference[10]	It work on system which has less memory requirements	Factor measure of Performance remain same.
11	Reference[11]	Image resolution is somewhat enhanced	High computationally complex
12	Reference[12]	Removes motion artifacts from reconstructed process	A complex system
13	Reference[13]	A simple method reconstruction	Few artifacts are observed when image is reconstructed.
14	Reference[14]	Retain image view and resolution	The method is not practically implemented yet.
15	Reference[15]	The method give less noisy image	Computationally slower process
16	Reference[16]	The method not only preserved contrast but also removes noise	It required more memory for storage of sample.

V. CONCLUSIONS

In this survey paper, the essentials of MRI have been shortly studied. It is a correlated area involving physics, mathematics, computational sciences etc. All the methods for reconstruction come under the computational sciences. Various modern magnetic resonance imaging techniques like fMRI, diffusion MRI were also discussed. Magnetic resonance imaging (MRI) is a non-invasive imaging scanning method that is proficient of giving high contrast image of soft tissues of the patient body. We also described different methods for MRI reconstruction along with its advantages and disadvantages in a tabular form. It is observed from survey that lot of work has been done in this field but still has a opportunity for further work in future.

ACKNOWLEDGMENT

The authors are grateful to all teachers of the Department of Electronics and Telecommunication, Dr. Patil Hemprasad Y for deep guidence related project **.**Dr. P. C. Kulkarni, Principal, Mr. P. M. Deshpande, Project Director, Sir M. S. Gosavi, Director, and G.E.S. R.H.Sapat College of Engineering, Manangement Studies and Research Nashik, Maharashtra, India.

REFERENCES

[1] Je rey A. Fessler,IEEE Signal Process Mag. 2010 July 1; 27(4): 81–89. doi:10.1109 on"Model based image reconstruction for MRI "

[2] Junzhou Huang,Shaoting Zhang,Dimitris Metaxas,Department of Computer Science, 110 Frel-inghuysen Road Piscataway, NJ 08854-8019,elsevier, 2011 on "Efficient MR image reconstruction for compressed MR imaging".

[3] Shiqian Ma,Wotao Yin,Yin Zhang and Amit Chakraborty,IEEE 978-1-4244-2243-2/08, 2008 on "An Efficient Algorithm for Compressed MR Imaging using Total Variation and Wavelets".

[4] Seon Yeong Lee and Dympna Gallagher "Assessment methods in human body composition", Clinical nutrition and metabolic care 2008; 11(5):566-572. doi:10.1097/MCO.0b013e32830b5f23.

[5] O. Michailovich, Y. Rathi and S. Dolui, "Spatially Regularized Compressed Sensing for High Angular Resolution Di usion Imaging," in IEEE Transactions on Medical Imaging, vol. 30, no. 5, pp. 1100-1115, May 2011.doi: 10.1109/TMI.2011.2142189.

[6] H. M. Nguyen and G. H. Glover, ”A Modified Generalized Series Approach: Application to Sparsely Sampled fMRI,” in IEEE Transactions on Biomedical Engineering, vol. 60, no. 10, pp. 2867-2877, Oct. 2013. doi: 10.1109/TBME.2013.2265699

[7] N. Chau ert; P. Weiss; J. Kahn; P. Ciuciu, ”A projection algorithm for gradient waveforms design in Magnetic Resonance Imaging,” in IEEE Transactions on Medical Imaging , vol.PP, no.99, pp.1-1doi: 10.1109/TMI.2016.2544251.

[8] Dong Liang, E.Y. Lam and G.S.K. Fung, 2007. Direct Reconstruction of Spiral Mri Using Least Squares Quantization Table, Biomedical Imaging: From Nano to Macro, 2007. ISBI 2007 4th IEEE International Symposium on, pp: 105-108, 12-15 April2007 doi: 10.1109/ISBI.2007.356799

[9] Hui, Y. and M.R. Smith, 1995. MRI reconstruction from truncated data using a complex domain back propagation neural network, Communications, Computers and Signal Processing, 1995. IEEE Pacific Rim Conference pp; 513-516,17-19doi: 10.11 09/PACRIM.1995.519582

[10] Zhili Yang Jacob, M., 2009. Efficient NUFFT algorithm for non-Cartesian MRI reconstruction, Biomedical Imaging: From Nano to Macro, 2009. ISBI '09 IEEE International Symposium, 117-120, 07 August 2009

[11] ZhuoWeng, Guo-Xi Xie, Xin Liu1, Hai-Rong Zheng and Cheng-Yi Xiong, 2010. A New Method for Removing Motion Artifacts in Parallel MRI Reconstruction, 2010 3rd International Conference on Biomedical Engineering and Informatics (BMEI 2010)

[12] Donglai Huo, D.L. Wilson, K.A. Salem and H. Moriguchi, 2003. Evaluation of noise effects in spiral MRI image reconstruction using perceptual difference model (PDM), Engineering in Medicine and Biology Society, 2003. Proceedings of the 25th Annual International Conference of the IEEE, 1: 486-489 Vol.1

[13] Tieng, Q.M., P. Ullmann, G.J. Galloway, J. Hennig, G.J. Cowin and V. Vegh, 2008. An Approach of Deriving Relative Sensitivity Profiles for Image Reconstruction in MRI, Selected Topics in Signal Processing, IEEE Journal, 2(6): 817-827, Dec. 2008. doi: 10.1109/JSTSP.2008.2006719

[14] Carlson, J.W., 1989. MRI data acquisition and image reconstruction from multiple, non-interacting receiver coils, Engineering in Medicine and Biology Society, 1989. Images of the Twenty-First Century., Proceedings of the Annual International Conference of the IEEE Engineering in, pp: 607-608 vol.2

[15] Abche, A.B., F. Yaacoub, Y. Hamam and E. Karam, 2008. An MRI image reconstruction approach based on the minimization of a complex norm, Industrial Electronics, 2008. IECON 2008 34th Annual Conference of IEEE, pp; 1839-1844, 10-13 Nov. 2008. doi: 10.1109/IECON.2008.4758235

[16] Fitzsimmons, J.R., Rui Yan and D Erdogmus, 2005. MRI Image Reconstruction via Homomorphic Signal Processing, Acoustics, Speech and Signal Processing, 2005. Proceedings (ICASSP '05).IEEE International Conference:121-124/ICASSP.2005.1415356

[17] Shan Tong, A.M. Alessio and P.E. Kinahan, 2009. Evaluation of noise properties in PSF-based PET image reconstruction, Nuclear Science Symposium Conference Record (NSS/MIC), 2009 IEEE, pp: 3042-3047, Oct. 24 2009-Nov. 1 2009 doi: 10.1109/NSSMIC.2009.5401574

[18] Thomas E. Nichols, Jinyi Qi, Evren Asthma and Richard M. Leahy, 2002. Spatio temporal Reconstruction of List-Mode PET Data, IEEE Transactions on Medical Imaging, 21(4), APRIL 2002.

