I J C T A, 9(9), 2016, pp. 3935-3944

Magnetic Resonance Imaging (MRI) Technique based on ROC in Medical Image Processing

R. Kalpana[1] and P. Chandrasekar[2]

ABSTRACT

Biomedical image processing is a technique used to create visual representation of interior body for clinical analysis. Which is further used to diagnose the body parts which are invisible, as well as to treat disease. It is an ocean in biomedical field. It also covers the processing of image formation, signal collecting, processing of picture, and displaying of images to analysis based on features derived from images. With the development of high technology various image processing system has been introduced. The core objective of this paper is to provide the basic concepts and techniques used in medical image processing.

Index Terms: Magnetic Resonance Imaging, ROC, DFT, Sampling theorem, Image segmentation and Medical image process

1. INTRODUCTION

Magnetic Resonance Imaging (MRI) scan images are used to analyze the interior body structure and find the various types of diseases present in human body [1, 2]. Also how does the proton works and spins when the magnetic fields are applied on it [3]. This process is explained derivatively by using Fourier transforms and its inverse [4]. There are many applications which used Fourier fundamentals. Here we have discussed convolution theorem based on DTFT, theory based on sampling process, DFT [5, 6, 7]. With the help of Fourier transform and sampling theory we collect few problems that executed in MR technique [8]. Basics of Gibbs oscillation phenomenon, Aliasing artifacts, Motion artifacts are described here [9, 10]. In computer aided diagnostic processing, Medical Image Processing covered so many topics [11]. Some deals with general application theory and some with specific applications. Here we focused on image segmentation and multi-spectral analysis [12, 13]. Finally we are validating the algorithm using receiver operating characteristics (roc) analysis [14, 15, 16].

MRI scan is a system that uses strong magnetic fields, RF waves and a computer to generate the detailed image of the body structure. MRI scanner is a large tube that has powerful circular magnets. The patient is placed inside the tube during this scan process. Very strong powerful magnet is used in this technique which arranges the atom nuclei in a proper position. The human body and the magnetic field arrange cause the atom to resonate. This method is called as nuclear magnetic resonance. The scanner detects as well as creates an image with the help of nuclei that produce rotating magnetic fields by its own.

Human body consists of major part of water. This water molecule (H_2O) contains hydrogen nuclei which is the proton, get aligned in the magnetic field. When the scanner applies strong magnetic field, the proton get spins. Radio frequency also produced by this scanner by varying magnetic field. With this variable field, the energy is absorbed by proton, it flip their spins. This process is known as precession.

[1] Research Scholar / ECE, School of Electrical & Computing, Vel Tech University, *Email: kalpsprabha@gmail.com*

[2] Professor & Head / EEE, Vel Tech University, Avadi, Chennai, *Email: drchandrasekar@veltechuniv.edu.in*

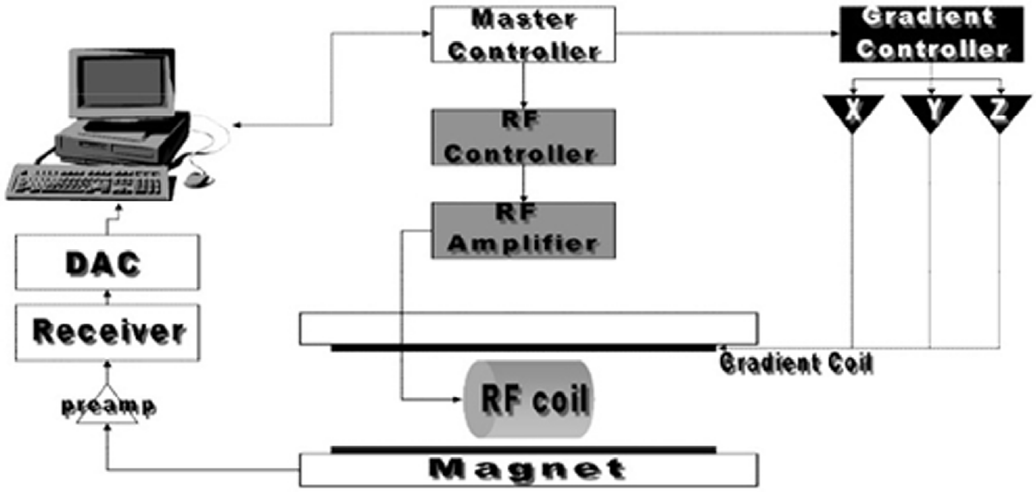

Figure 1: Basic instrumentation of MRI

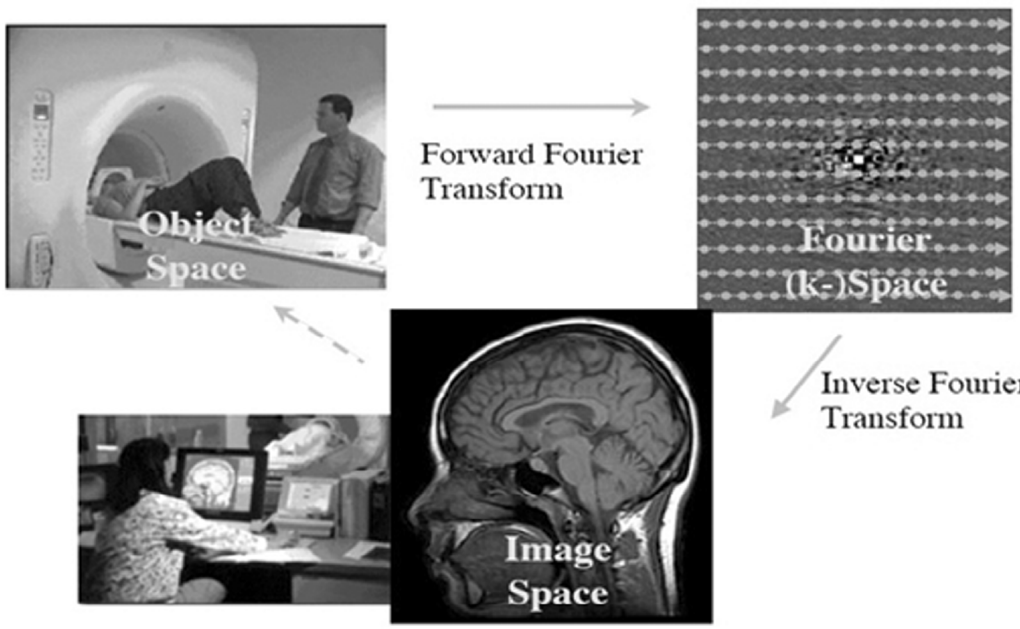

Figure 2: Forward and inverse Fourier transforms MR Imaging

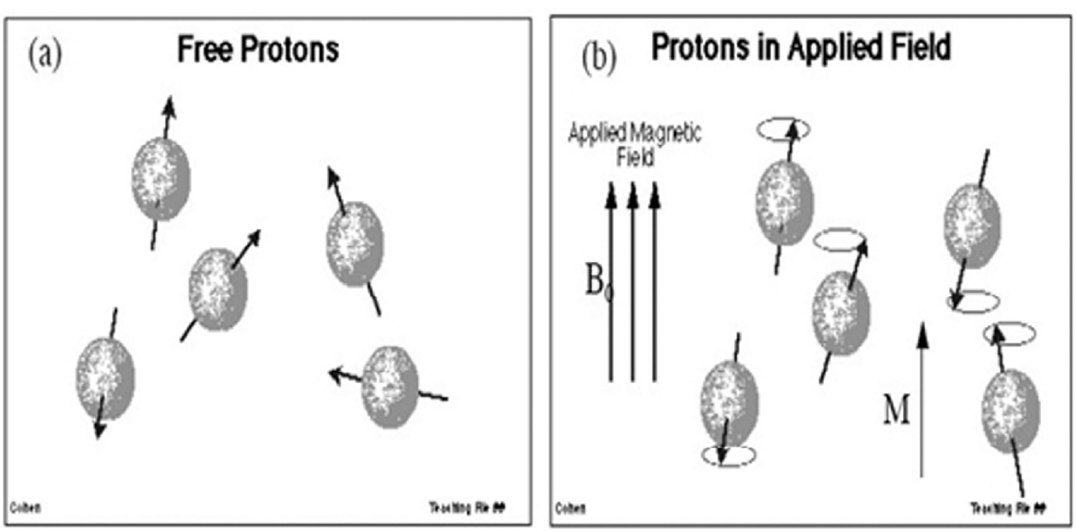

Figure 3: Nuclear magnetic moment vectors (a) free protons and (b) protons in applied magnetic field

When it returns, the scanner measures the radio signal. Due to spinning of protons, nuclear magnetic moment takes place. Here is the diagrammatic representation of free protons and in applied magnetic field.

2. BASIC OF FOURIER TRANSFORM

Here, we have discussed Fourier theory and its fundamentals to better understanding the MRI artifacts and image processing. Here we have focused some essential concepts: Convolution theorem based on FT, theory based on sampling process, DFT.

$$f(x) \rightarrow F(U) = \int_{-\infty}^{\infty} f(x) \exp(-j2\pi ux)\,dx$$

Conversely, the Fourier response is given as $F(u)$, $f(x)$ is the inverse Fourier transformation.

$$f(x) = \int_{-\infty}^{\infty} F(u) \exp(j2\pi ux)\,du \leftarrow F(u)$$

FT properties is given below for analysis of MRI image and for future references

a) Uniqueness: $f_1(x) = f_2(x) \leftrightarrow F_1(u) = F_2(u)$

b) Linearity: $af_1(x) + bf_2(x) \leftrightarrow aF_1(u) + bF_2(u)$

c) Shifting theorem:

$$f(x - x_0) \leftrightarrow F(u) e^{-j2\pi u x_0}$$

$$e^{-j2\pi u_0 x} f(x) \leftrightarrow F(u - u_0)$$

d) Conjugate symmetry: $f^*(x) \leftrightarrow F^*(-u)$. Specifically, if $f(x)$ is a real-valued function, then $f(x) \leftrightarrow F(u) = F^*(-u)$

e) Scaling property: $f(ax) \leftrightarrow \frac{1}{|a|} F\left(\frac{u}{a}\right)$

f) Parseval's formula: the energy is conserved in both the space and frequency domains, i.e.,

$$\int_{-\infty}^{+\infty} |f(x)|^2 dx = \int_{-\infty}^{+\infty} |F(u)|^2 du$$

g) Derivative property:

$$(-j2\pi x)^n f(x) \leftrightarrow \frac{d^n F(u)}{du^n}$$

$$\frac{d^n f(x)}{dx^n} \leftrightarrow (j2\pi u)^n F(u)$$

h) Convolution theorem:

$$f_1(x) \otimes f_2(x) \leftrightarrow F_1(u) F_2(u)$$

$$f_1(x) f_2(x) \leftrightarrow F_1(u) \otimes F_2(u)$$

2.1. Fourier Convolution Theorem

The essential concept in image process is explained with help of convolution process. Its function is defined as,

$$f(x) \otimes g(x) = \int_{-\infty}^{+\infty} f(\alpha) g(x-\alpha) d\alpha$$

2.2. Sampling Theory

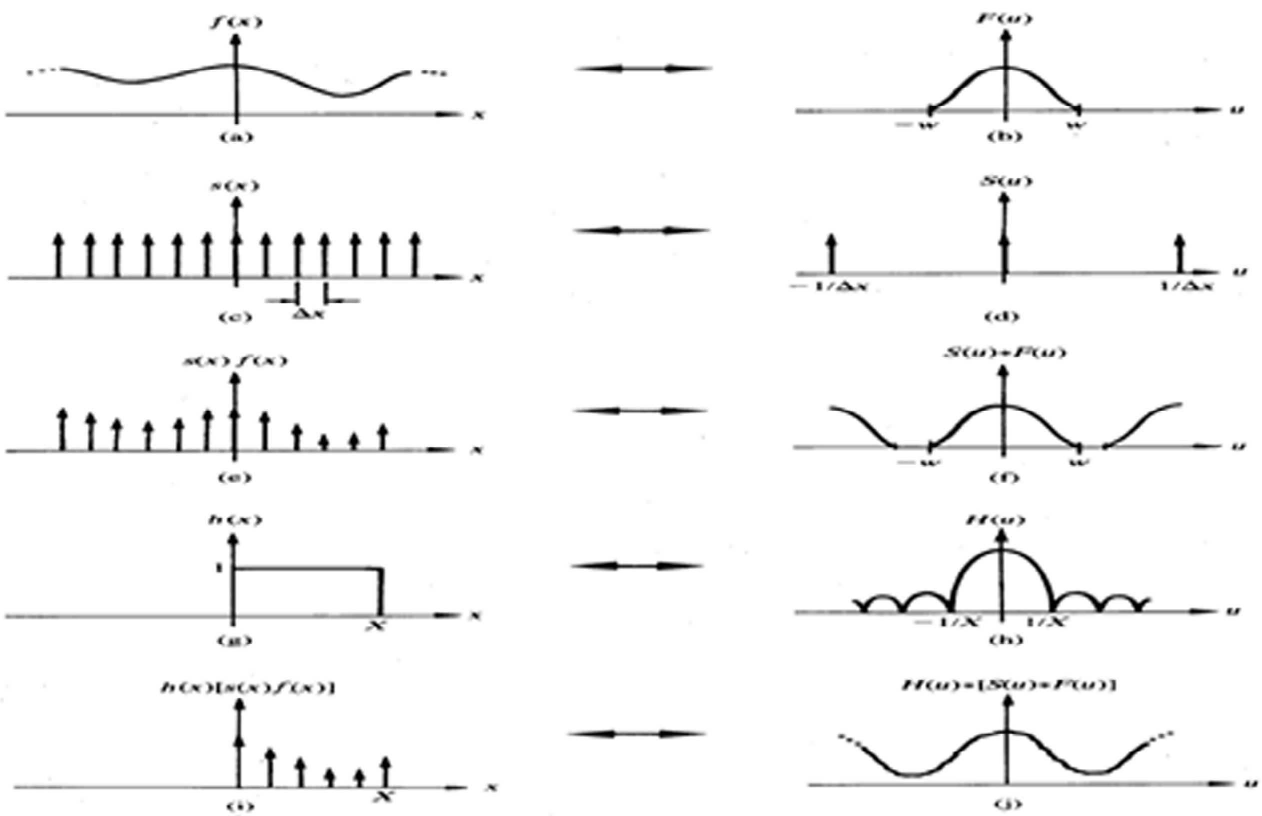

Figure 4: Finite-sampling concepts

Many applications in common is processed with sampling time. But MRI system is processed with sampling in frequency domain

Band-limited function spacing is, Δx, satisfies $\Delta x \leq 1/2W$. This is known *Sampling Process*. The replications overlap when the sampling rate is too low, this condition known as "*aliasing*". "*Sampling rate*" is the minimum sampling rate in order to avoid aliasing problem and is equal to the twice of the maximum of message frequency $f(x)$, i.e., 2W.

2.3. Discrete Fourier Transform

The DFT concept easily understands with help of periodicity property. This Periodicity property explains help of sampling theory. It is graphically shown below.

3. COMMON MR IMAGE ARTIFACTS

MR Imaging process can be good to know well with the help of the Fourier transform and the sampling theory. Gibbs ringing artifacts, aliasing and motion artifacts are discussed here.

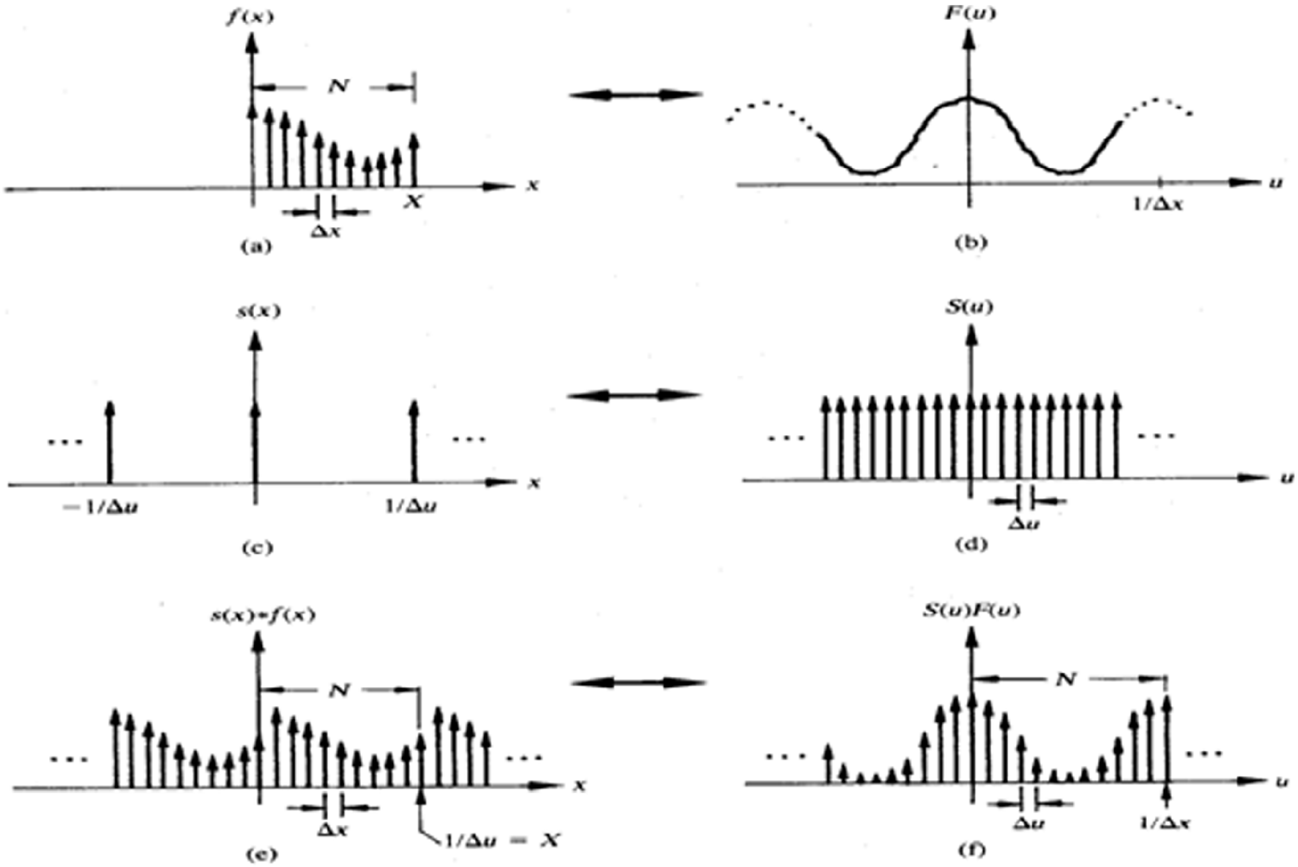

Figure 5: Discrete Fourier transform shown in graph

3.1. Gibbs Ringing Artifacts

Gibbs artifacts mostly appear as a multiple fine parallel lines. It uses Fourier transforms to reconstruct MR signals into images.

3.2. Aliasing Artifacts

An Aliasing artifact defines the signal which is different from the original continuous signal from the samples.

3.3. Motion Artifacts

Motion artifacts lead the image to blurring due to inconsistencies in amplitude and phase.

4. COMPUTER AIDED DIAGNOSTIC PROCESSING

There are many topics in image processing. How Image segmentation and multi-spectral analysis used in medical processing image is discussed here.

4.1. Image Segmentation

Image Segmentation is the process of making an image into multiple parts. There are different methods to execute the performance of segmentation based on different techniques like, thresholding method, Transform method and texture methods.

Technically it is classified using structural and statistical methods. Image properties such as edges and regions are explained in structural method. Here the images are divided into small regions, it is measured

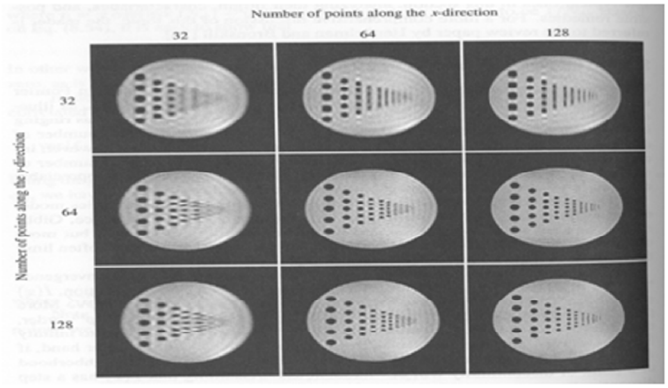

Figure 6: Ringing pattern used in Gibbs ringing artifacts in Fourier reconstructions

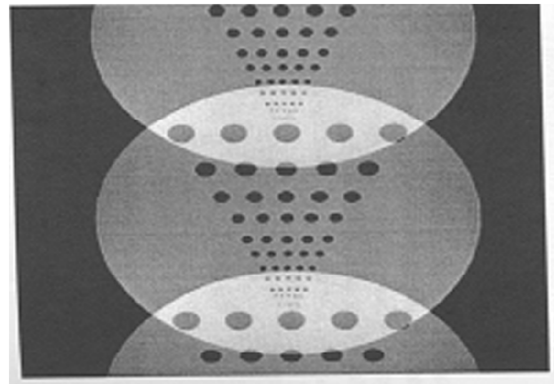

Figure 7: Aliasing artifacts-vertical direction

Figure 8: Motion artifacts of lower abdomen

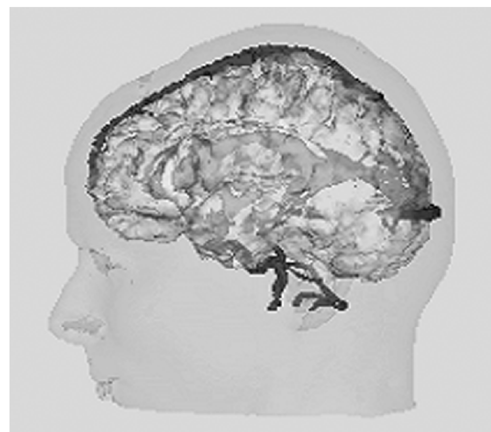

Figure 9: MRI 3D Segmentation

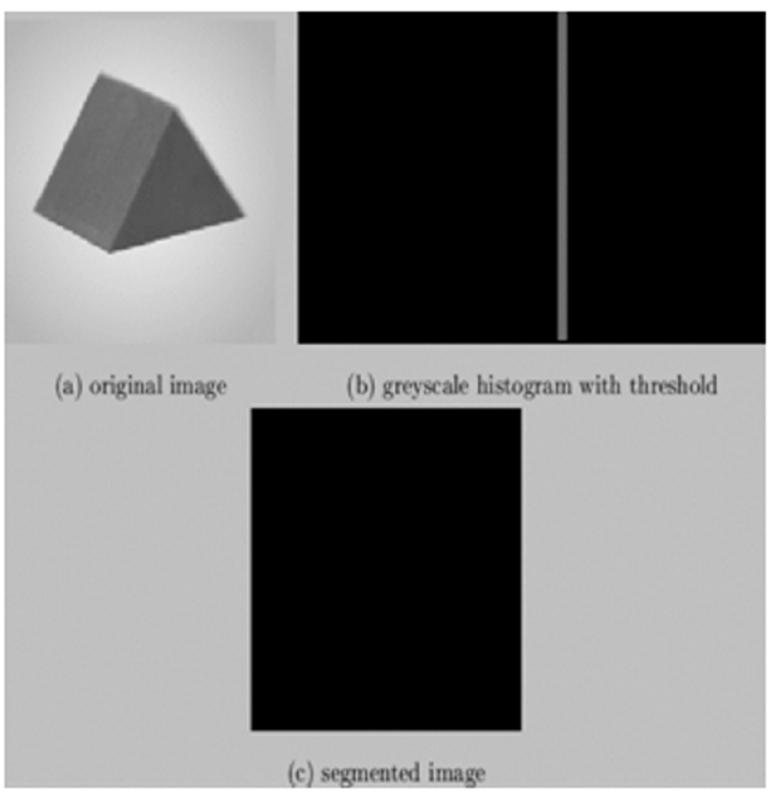

Figure 10: Single threshold of segmentation

as seeds. The boundaries are investigated, the strong are kept and the weak ones are rejected. According to probability values, Statistical method label pixels, which are given based on the distribution of intensity of the image.

4.2. Multi Spectral Analysis

By nature, the acquisition process of MRI data depends on their contrast and different parameters, because of this reason MRI data are called as multi spectral components.

5. EVALUATION OF ALGORITHM

ROC investigation is used to compare accuracy, precision and efficiency of various algorithms. ROC analysis is used to differentiate patients with the disease from that non disease. This algorithm is used to differentiate abnormal tissue from normal tissues. Figure 12 explains the investigation of ROC for diseased population

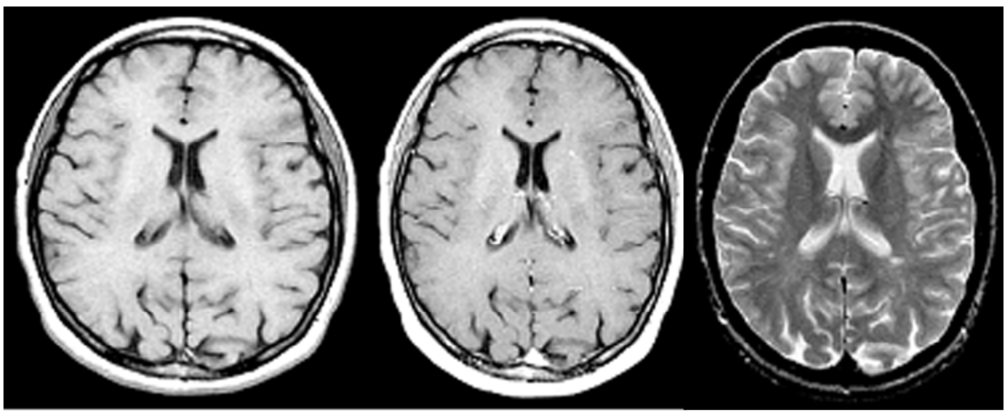

Figure 11: MRI Multi Spectral Components

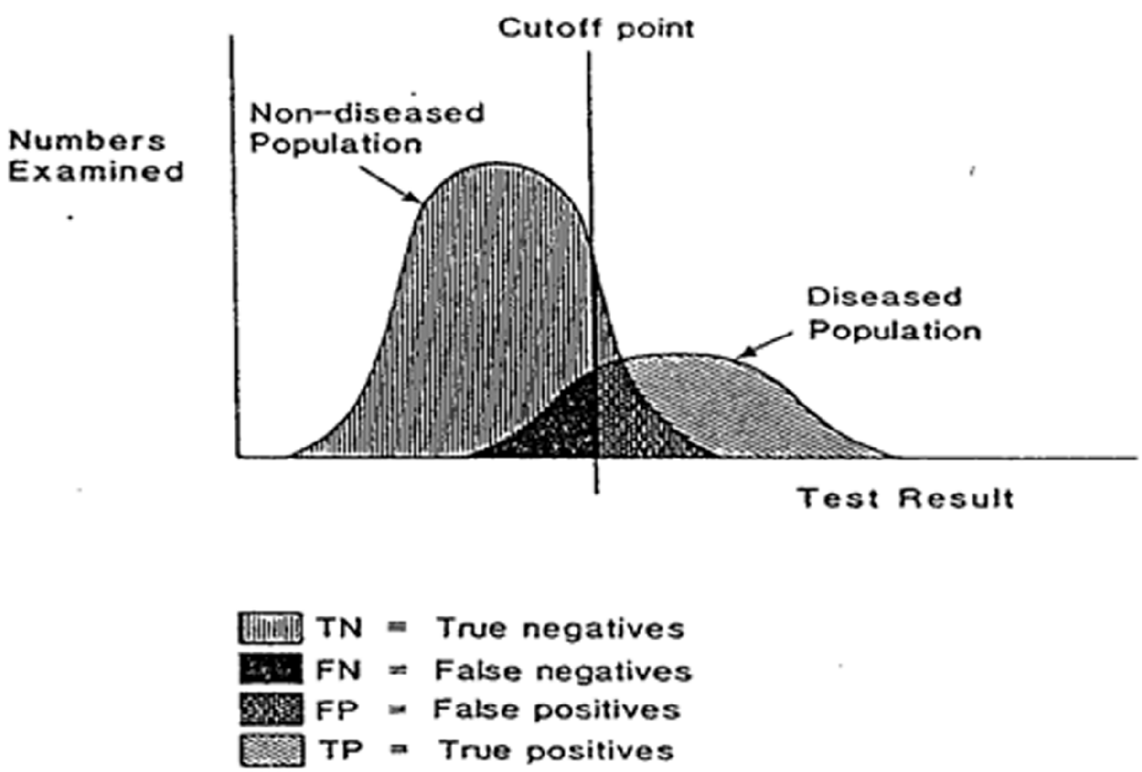

Figure 12: The overlap bar of FP and FN

Two by two matrix is investigated from with diseases and non diseased population.

		TRUTH	
		P	N
TEST	P	TP	FP
	N	FN	TN

The test accuracy is defined as,

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \times 100\%$$

The sensitivity of a test is defined as “people proportion with disease, they will identify by test”,

$$\text{Sensitivity} = \frac{TP}{TP + FN} \times 100\%$$

The specificity of a test is defined as “people proportion without the disease they will authenticate by test, that is free of disease”,

$$\text{Precision} = \frac{TN}{TN + FP} \times 100\%$$

It is good if the sensitivity is high which helps in excluding the diseases, screening, associated with missing the diseases. Also it is good if the specificity is high which confirms the disease occurrence and if there is any hazard in treat the disease unnecessarily.

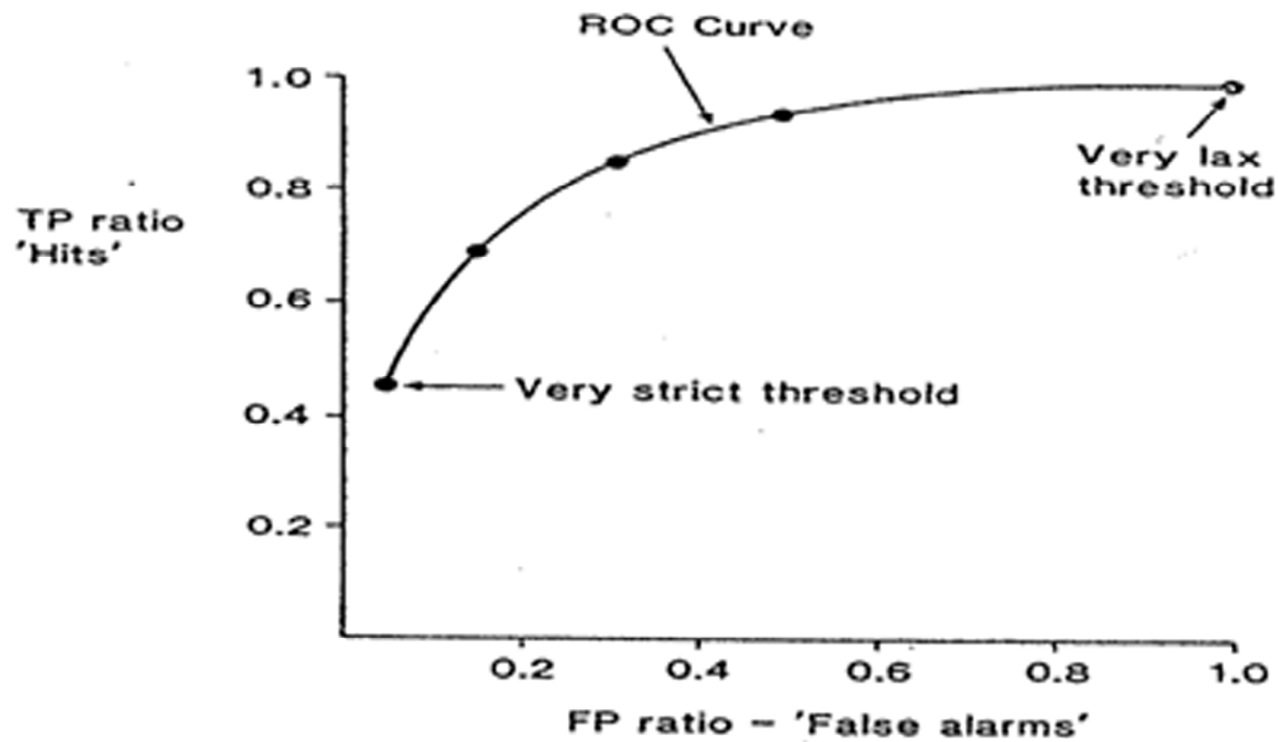

Figure 13: Five level diagnostic probability ROC curve

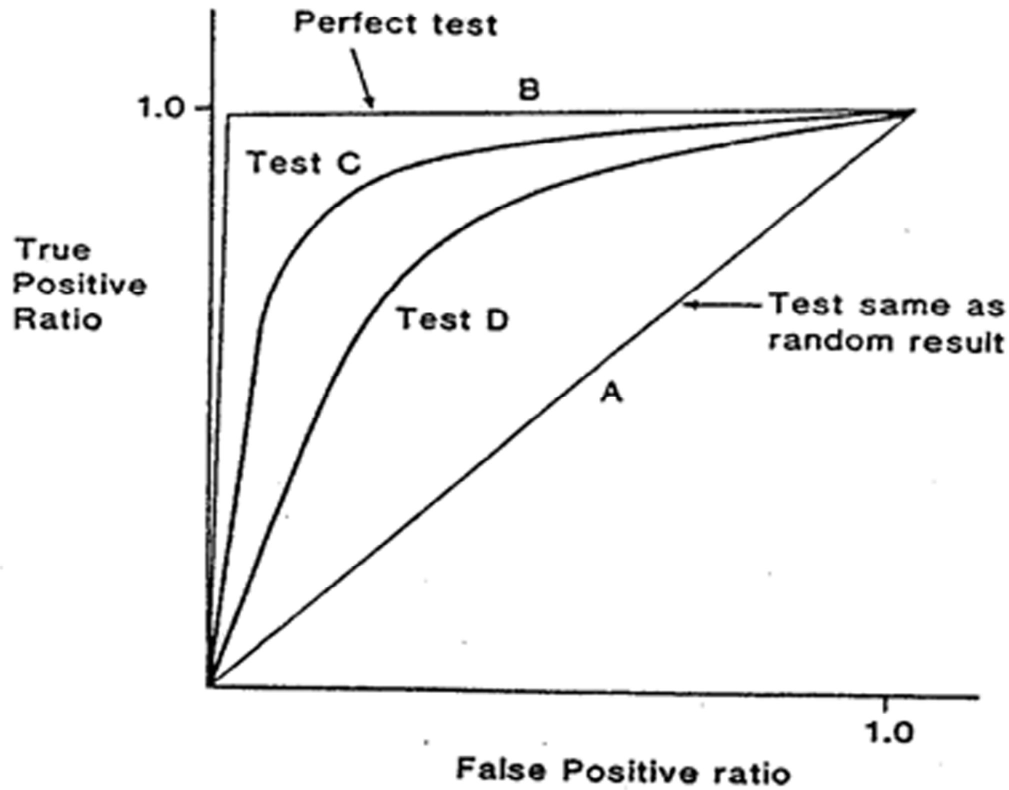

Figure 14: ROC curves

6. CONCLUSION

Medical Image Processing (MRI) helps us to know the internal body structure which is invisible. Also clinically it helps doctors to diagnose the exact problem and treat the diseased person. Then we get to know how Fourier and its inverse transform are used in medical image processing. It is explained using convolution theorem based on FT, theory based on sampling process and DFT. 3 types of artifacts and how it is used in medical image processing also discussed here. Computer aided diagnosis processing also helpful in segmenting the image in MR Imaging. Finally we are validating the accuracy, specificity and sensitivity of the diseased patient from those without the disease using algorithm. We assure that paper explain you to understand the basics of medical image processing, where and how it is used and its importance.

REFERENCES

[1] D. Canet, Nuclear Magnetic Resonance: Concepts and Methods, John Wiley & Sons, New York, 1996.

[2] Z.P. Liang and P.C. Lautenberg, Principles of Magnetic Resonance Imaging: a signal processing perspective, IEEE press series in biomedical engineering, 1999.

[3] M. NessAiver, All You Really Need to Know about MRI Physics, Simply Physics, 5816 Narcissus Ave, Baltimore, MD, 1997.

[4] R.C. Gonzalez and P. Wintz, "Digital Image Processing", second edition, Addison-Wesley, 1987.

[5] R.J. Marks II, Advanced Topics in Shannon Sampling and Interpolation Theory, Springer-Verlag, New York, 1993.

[6] R.C. Gonzalez and RE Woods, "Digital Image Processing", third edition, Addison-Wesley, 1993.

[7] R.J. Marks II, Introduction to Shannon Sampling and Interpolation Theory, Springer-Verlag, New York, 1991.

[8] R.M. Henkelman and M.J. Bronskill, "Artifacts in magnetic resonance imaging", Rev. Magn. Reson. Med., vol 2, pp. 1-126, 1987.

[9] X. Zhou, Z.P. Liang, G.P. Cofer, C.F. Beaulieu, S.A. Suddarth, and G.A. Johnson, "Reduction of ringing and blurring artifacts in fast spin-echo imaging," J. Magn. Reson. Imag., vol 3, pp. 803-807, 1993.

[10] D Atkinson, DLG Hill, PN Stoyle, PE Summers, and SF Keevil, "Automatic correction of motion artifacts in magnetic resonance images using an entropy focus criterion," IEEE Trans. Med. Imag. vol 16, pp903-910, 1997.

[11] M. Bomans, K.H. Hohne, L.A. Kramer, and J.M. Fletcher, “3-D segmentation of MR images of the head for 3-D display,” IEEE Trans. Med. Imag., 18(1):25-34, 1990.

[12] C.A. Glasbey, “An analysis of histogram-based thresholding algorithms,” CVGIP—Graphics Models and Image Processing, vol. 55, pp. 532-537, 1993.

[13] L.P. Clarke, R.P. Velthuizen, M.A. Camacho, J.J. Heine, M. Vaidyanathan, L.O. Hall, R.W. Thatcher, M.L. Silbiger, “MRI segmentation: methods and applications”, Mag. Reson. Imag., vol 13, no. 3 pp. 343-368, 1995.

[14] C.E. Metz, “ROC methodology in radiologic imaging,” Investigative Radiology, vol. 21, pp. 720-733, 1986.

[15] J.A. Hanley, “Receiver operating characteristic (ROC) methodology: The state of the art,” Critical Reviews in Diagnostic Imaging, vol. 29, pp. 307-335, 1989

[16] C.E. Metz, “Basic principles of ROC analysis,” Seminars In Nuclear Medicine, vol. 8, pp. 283-98, 1978.