**INTRODUCTION**

In the human body, brain is the biggest and most complex organ. It generates all thoughts, action, remembrance, sense and understanding of the complete world. The complication of the connectivity among the brain cells is extremely complex. Every neuron can keep in touch with thousands or even tens of thousands of others, by means of small configurations known as synapses. The brain forms a million new associations for each second of human life. The outline and power of the associations is continuously varying and no two brains are identical. It is in these varying associations that memories are accumulated, habits learned and personalities shaped, through reinforcing certain patterns of brain activity, and losing others. The brain, nerves and spinal cord together form fraction of the nervous system. The brain of humans includes gray matter, white matter and cerebrospinal fluid. The gray matter encloses the nerve cells. Nerve cells and chemicals, known as neurotransmitters, assist several parts of the body communication. Tumors, seizures, headaches and further complications can influence the functioning of brain. Epilepsy is a brain disorder in which a person has repeated seizures over time. Seizures indicate the episodes of distressed brain activity that lead to changes in concentration or activities. Figures 1.1 to 1.3 demonstrate the structure of human brain, structure of the cortex and the nervous system of the brain respectively.

![Figure 1.1: Structure of the Human Brain](image-url)
Magnetic Resonance Imaging (MRI) scan is an analysis that generates extremely clear pictures, or images of the human body with the use of X-rays. In case someone is affected by epilepsy, a scan might help to find out the cause. Image contrast can be produced in a range of methods that emphasize various characteristics of these nuclei (e.g., their association with electromagnetic fields, their density, their chemical atmosphere or their diffusion or flow), averaged over small volume constituents of the brain, characteristically with a resolution of 1 cubic millimeter (mm). Most of the morphometric tools employed and developed were optimized for data obtained. The cerebral cortex is an extremely folded sheet of Gray Matter (GM) that exists within the Cerebro Spinal Fluid (CSF) and encloses a core of White Matter (WM). In order to examine cortical configurations, it is essential to eliminate non-brain tissue and categorize the remaining tissue into GM, WM and CSF. This premature processing of structural MRI data is called tissue segmentation. During segmentation, discovery of internal structure in brain MRI is extensively employed to diagnose numerous brain diseases, like multiple sclerosis, epilepsy, schizophrenia and alcoholism. Conventionally, segmentation of MRI is done manually with qualified radiologists.

Among other brain associated diseases, there are nearly 10 million persons affected by epilepsy in India. In view of the fact that the neurons communicate with one another by means of firing small electrical signals that pass from cell to cell, the firing pattern of these electrical signals imitates how active the brain is at any moment, and the position of the signals points out what the brain is doing, like seeing, thinking, hearing, feeling and controlling the movement of muscles. Epilepsy is a brain disorder that takes place when the electrical signals in the brain are interrupted. Interruption takes place when
the firing pattern of the brain's electrical signals happens to be irregular and strong, either in an isolated region of the brain or all the way through the brain. To be specific, epilepsy is a situation that involves having repetitive seizures. Two or more seizures must take place before a person can be diagnosed as having epilepsy. Epilepsy is a kind of seizure disease that results from anomalous action in the brain. In order to realize why seizures take place and why they induce a variety of physical symptoms, it is significant to recognize typical brain function, in addition to what causes cells in the brain to function strangely. Epilepsy is a severe disorder that not only influences the brain but also limits the activity one can perform. As a result, there is a requirement of automated localization of epileptic seizures in MRI images.

1.1. OVERVIEW OF THE RESEARCH TOPIC

Image segmentation is the complicated task of dividing an image into significant components, typically consisting of an object and background. At the same time, as a vital element of several imaging applications, e.g. tracking of moving cars, people and face recognition etc, it is of common interest to design tough and fast segmentation algorithms. On the other hand, it is well recognized that there is no common technique for solving the entire segmentation setbacks. Instead, the algorithms have to be exceedingly adjusted to the application with the intention of achieving better performance. The requirement for precise segmentation tools in medical applications is motivated by the increased capacity of the imaging devices. Universal modalities like CT and MRI generated images which basically cannot be inspected manually, because of high resolutions and a large number of image slices. In addition, it is extremely complicated to visualize complex structures of the brain image without cutting away huge portions of possibly significant data. In particular, detecting and segmenting brain MRI images is a significant but time consuming task executed by medical experts. Automating this practice is a challenging process because of the often high degree of intensity and textural similarity among normal and abnormal areas.

This research work concentrates on optimal segmentation procedure from MRI brain images for the localization of epileptic seizures. In order to successfully completed
this research work, the steps carried out on noisy and denoised images are: Preprocessing, Segmentation using Clustering Techniques, Segmentation using Optimized Clustering Techniques and Segmentation using Random based Optimized Clustering Techniques. During the first phase, for the purpose of removing non-cerebral tissues from MRI brain images, skull stripping is done with the help of noisy and denoised images. Original MRI is considered for skull removal by means of mathematical morphological operations. Denoising algorithm with Particle Swarm Optimization (PSO) is proposed for the purpose of removing the unnecessary (noise) information which exists in the original MRI. Mathematical morphological operations are executed for skull removal from denoised MRI. The effect of both the original and denoised skull removal images will assist segmentation in subsequent phases. During the second phase, segmentation by means of clustering approaches like K-Means and Fuzzy C Means (FCM) are done, using noisy and denoised MRI skull stripped images for segmentation of cerebral tissues like GM, WM and CSF.

During the third phase, segmentation by means of optimized clustering approaches like Genetic Algorithm (GA) and Firefly Algorithm (FA) are incorporated into FCM for the purpose of segmentation of cerebral tissues. During the fourth phase, random based optimized clustering approaches like Chaotic with Firefly Algorithm (CFA) and Levy Flights with Firefly Algorithm (LFFA) incorporated into FCM is proposed for segmenting the cerebral tissues. At last, with the intention of testing the efficiency of optimization and random based optimization schemes, the classical Benchmark Test Functions were utilized. It is noticed that the proposed scheme LFFA-FCM accomplishes the global minimum value in most of the test functions when compared against other optimization schemes. Based on the performance evaluation, it is confirmed that LFFA-FCM considerably diminishes the over segmentation rate, incorrect segmentation rate and under segmentation rate in GM, WM and CSF tissues from denoised images.

The foremost objective of this research work is to optimize the segmentation process with better accuracy rate for separating MRI brain cerebral tissues with the help of computational intelligence with support of image processing schemes. Prior to segmentation process, image denoising by means of computational intelligence based filtering scheme is also primarily focused, with the aim of removing the Additive White
Gaussian Noise (AWGN). The intention of the proposed research work is to obtain cerebral tissues for the purpose of segmenting the human brain images. The subsequent sections clearly analyze in detail the MRI and image segmentation process. The need for MRI segmentation and the automated segmentation of MRI images is discussed in detail. This chapter also entails the research motivation and objective of MRI brain image segmentation.

1.2. MAGNETIC RESONANCE IMAGING

Ever since the primary successful Nuclear Magnetic Resonance (NMR) experiments were conducted in 1946, numerous scientists, over the next more than a half-century, formulated MRI into the technology that is known currently. MRI has progressively become more preferred imaging modalities in currently to observe the structures within the body, which allows physicians to visualize dissimilarities among soft tissue with unbelievable acuity (Yuchou et al., 2012). MRI offers an imaging scheme, which is basically non-invasive and without any ionizing radiation. With regard to other imaging modalities like X-ray, ultrasound, or CT scan, MRI offers more details regarding structures within the body in several cases. Dissimilar to other imaging schemes, MRI makes use of a strong magnetic field and radio waves to produce computerized images of the body, that comprise head, chest, blood vessels, bones, pelvis, spine, joints, abdomen and so forth. It is utilized to recognize problems like tumors, injury, bleeding, blood vessel diseases or illness. In addition, contrast agents might be utilized at some stage in MRI to show anomalous tissue more evidently. It is also extensively utilized in research to measure brain structure and function.

During an MRI procedure, the patient lies within a massive hollow cylindrical magnet and is exposed to a strong stable magnetic field, as illustrated in Figure 1.4. Several atoms in the parts of the body being scanned, resonate to various frequencies of magnetic fields. MRI is employed mainly to sense the oscillations of hydrogen atoms, which enclose a proton nucleus that spins, and as a result can be thought of as holding a small magnetic field. In the MRI scenario, a background magnetic field lines up the entire hydrogen atoms in the tissue being imaged. Another magnetic field, oriented in a different way from the
background field, is switched on and off several times per second; at particular pulse rates, the hydrogen atoms resonate and line up with this second field. If the second field is switched off, the atoms that were lined up with it, swing back to arrange in a line with the background field. At the same time, when they swing back, they generate a signal that can be picked up and transformed into an image.

Figure 1.4: MRI Scanner

MRI is a kind of non-invasive scheme for imaging internal tissues and organs. The benefits of MRI, over other diagnostic imaging capabilities, are its high spatial resolution and outstanding discrimination in case of soft tissues. The application of MRI has developed quickly, in view of the fact that the scientific improvement in the early 1980 for diagnosis of a variety of diseases. One of the least reachable and most complicated organs, the human brain is the prime beneficiary of this new medical imaging scheme. MRI is a strong imaging approach for the purpose of studying brain disorders like multiple sclerosis, alzheimers disease, schizophrenia, epilepsy, brain tumor, etc. The brain includes three main soft tissue classes, which are white matter, gray matter and cerebrospinal fluid. It is essential to segment the quantity of GM, WM and CSF, in addition to their spatial distribution and temporal transformations for diagnosis of several brain illnesses. The tissue classes of the brain are given in Figure 1.5. 2D Brain MRI can be viewed in two different planes like axial plane and coronal plane, as illustrated in Figure 1.6.
Hybrid Fuzzy Clustering Technique using Random based Optimization for Segmenting MRI Brain Images

(a) Cerebral Tissues  (b) Non-Cerebral Tissues

Figure 1.5: MRI Brain Image showing Cerebral and Non-Cerebral Tissues

(a) Axial view  (b) Coronal view

Figure 1.6: 2D Brain MRI viewed from Two Directions

The major benefits of MRI system are as follows:

- It has an outstanding potential for managing soft tissue imaging,
- It has an extremely high resolution of the range of 1mm cubic voxels,
- It has better signal to noise ratio, and
- Multi channel images with uneven contrast can be accomplished with the help of different pulse sequences; this can be further exploited for segmenting and categorizing different structures.

1.3. History of Epilepsy

Epilepsy is one of the most ordinary neurological disorders. India is the mostly affected, since it has about 10 million people suffering from epilepsy (prevalence of about 1%), (Sridharan and Murthy, 1999). It is higher in the rural (1.9%) as compared against the urban (0.6%). In case of Canada, approximately 15,000 people are diagnosed with epilepsy every year. However, in Australia, almost 400,000 people are living with epilepsy and it is
over 500,000 people in the UK. Epilepsy has an effect on about 2.3 million adults and 467,711 children of 0-17 years in the United States. The number of epileptologists and neurologists is extremely inadequate for providing services to epilepsy patients in India (Leonardi and Ustun, 2002; Pahl and de Boer, 2005). The burden of epilepsy as estimated by the Disability-Adjusted Life Years (DALYs) ranges to 1% of the overall burden of disease in the world. The social stigma and isolation, that People With Epilepsy (PWE) in India face, paves way for increase of the disease burden (Jain and Satishchandra, 1998). Epilepsy is not benign, in particular if not treated. Injury and death can result from inadequately treated or untreated epilepsy. Status epilepticus is a severe and potentially life-threatening impediment of epilepsy. The amount of epilepsy patients in the metropolis like Delhi and New Delhi is in the range of 130,000 (an approximated population of 13 million) and in the entire India it is in the range of 10 million (in an approximated population of 1.0 billion). More vital is that about 0.5 to 1 million new cases are included every year to the previously existing large numbers in India – rising the societal burden as a result of epilepsy. A report of World Health Organization (WHO) states that skull damage is a common source of epilepsy worldwide.

Defining Epilepsy

Epilepsy is a kind of chronic disorder characterized by recurrent unprovoked seizures:

- An epileptic seizure indicates transient occurrence of indications and/or symptoms because of peculiarly excessive or synchronous neuronal activity in the brain. The epileptic seizure might be characterized by means of sensory, motor or autonomic phenomena with or without loss of consciousness, and

- All PWE encompass seizures. However, all those who have seizures do not have epilepsy. Seizures taking place in a setting of an acute illness or medical condition like high fever, hypoglycemia, etc, are categorized as acute symptomatic seizures.

Epilepsy is a kind of central nervous system disorder (neurological malfunction) in which nerve cell action in the brain becomes interrupted, causing seizures or periods of
strange activities and sensations, and may lead to loss of consciousness. Seizure indications can differ extensively. Some people with epilepsy just stare blankly for a few seconds at some point in a seizure. At the same time, others repeatedly twitch their arms or legs. In the range of 1 in 26, people in the United States develop a seizure disorder. Almost 10% of individuals might have a single unprovoked seizure. On the other hand, a single seizure does not signify a epilepsy, as a minimum two unprovoked seizures are normally necessary for an epilepsy diagnosis. Even gentle seizures might necessitate treatment, since they can be hazardous during activities like driving or swimming. Treatment with medications or sometimes surgery can control seizures for about 80% of people with epilepsy. Some children with epilepsy might also outgrow their condition with age.

Seizure and Epilepsy

Seizures (irregular movements or behavior because of unusual electrical activity in the brain) are an indication of epilepsy. However, not all people who appear to have seizures have epilepsy; epilepsy is a collection of associated disorders characterized by a tendency for persistent seizures.

Non-epileptic seizures (known as pseudoseizures) are not accompanied by anomalous electrical activity in the brain and may perhaps be caused through psychological issues or stress. On the other hand, non-epileptic seizures look like proper seizures, which make diagnosis more complicated. Normal EEG readings and lack of reaction to epileptic drugs are two indications which are not factual epileptic seizures. These categories of seizure could be treated with psychiatric medications.

Provoked seizures are a kind of single seizures that might take place due to trauma, low blood sugar (hypoglycemia), high fever, low blood sodium or alcohol or drug exploitation. Fever-associated (or febrile) seizures might happen at some point in infancy. However, it is typically outgrown by the age of 6. Subsequent to a cautious evaluation to approximate the risk of recurrence, patients who undergo a single seizure might not require treatment. Some people with epilepsy just stare blankly for a few seconds at some point in a seizure. Others repeatedly twitch their arms or legs.

Causes of Epilepsy

Epilepsy happens on account of irregular electrical activity originating in the brain. Brain cells keep in touch by means of sending electrical signals in an organized
pattern. In case of epilepsy, these electrical signals turn out to be irregular, giving rise to an "electrical storm" that generates seizures. These storms might be inside a particular part of the brain or be generalized, in accordance with the category of epilepsy. In several cases, a cause cannot be recognized; on the other hand, factors that are related include brain trauma, strokes, brain cancer and drug and alcohol misuse, among others. Epilepsy happens when permanent changes in brain tissue cause the brain to be too emotional or nervous. The brain transmits irregular signals. This results in constant, irregular seizures. Symptoms differ from person to person. Some people might have uncomplicated staring spells, and others have violent shaking and loss of alertness. The seizure is related to the part of the brain affected and is the reason for epilepsy. Figure 1.7 illustrates the electrical activity that is passed through the axon where the receptor cells are triggered.

![Image of electrical activity in neurons](image_url)

**Figure 1.7: Electrical Activity in Neurons causing Epilepsy**

**Types of Epilepsy and Seizures**

Patients with epilepsy might experience over one seizure category. This is due to the reason that seizures are simply symptoms. As a result, it is vital that neurologist diagnose the type of epilepsy, not just the type(s) of seizure that patients have. Epilepsies are largely categorized in accordance with the seizure category, age of onset and possible etiology:
• Localization-related epilepsies are characterized by means of seizures that include a focal or partial onset, and generalized epilepsies are characterized by generalized commencement of seizures,
• Idiopathic epilepsies are those that are inherited or happen without particular pathologic cause,
• Symptomatic epilepsies are those related with a known or suspected brain disease or lesion, and
• Epilepsy syndromes are age reliant and might begin during infancy, childhood or adolescence.

The seizures can be split into two main categories, namely, Generalized and Partial (Focal). The Generalized seizures are characterized by features of involvement of both the halves of the brain (cerebral hemispheres) at the same time, from the commencement of attack. They might be tonic-clonic (grand mal), brief absences (petit mal) or even unexpected, brief jerks of limbs (myoclonic). Partial (Focal) seizures begin in one cerebral hemisphere and the electrical action does not extend to the other side of the brain. As a result, the term “Partial Seizure” indicates that only a certain portion of the brain is engaged. In certain partial seizures, consciousness might be retained at first. Subsequently, the fit might become secondarily generalized and the patient will become unconscious and have a major convulsion. The features of a partial seizure reflect the portion of the brain engaged, and an extensive variety of symptoms will possibly occur. Partial seizures are segregated into two main categories:

• Simple partial seizures, in which there is no change of consciousness, and the patient might have jerking of hand or foot or face. Less frequently, there might be tingling or numbness in the concerned parts, and
• Complex partial seizures (temporal lobe), in which consciousness is missing or damaged, is often followed by complex automatisms. At some stage in this period, the patient might stop all activities, look blank, stare ahead and might be engaged in automatic chewing or swallowing actions, cyclic utterances, wandering actions, fumbling with dresses or other semi-purposeful motor actions. As has been indicated earlier, the partial seizure
that might be simple or complex, may perhaps spread within a short time to become a generalized seizure. In certain scenarios, the features of partial seizures might be remembered as the “aura” (warning). The generalized seizure is normally a tonic-clonic convulsion.

The 'fits' or 'seizures' can lead to loss of alertness or consciousness and interruptions of movement, sensation (together with vision, hearing and taste), autonomic function, mood and mental function. Anyone can be attacked by seizures at any age.

Birth injuries, infections including worm infestations, vascular disease, tumors and subtle developmental abnormalities of the brain are the important causes of epilepsy. Many patients have epilepsy without any detectable brain disease. In most such cases epilepsy is thought to be due to hereditary factors. Though epilepsy need not be feared more than diabetes or hypertension, there is social stigma as well as myths attached to it. These baseless apprehensions stem from the widespread ignorance about epilepsy. However, the truth is that epilepsy can be treated. Some people affected by epilepsy disease in India and US are shown in Figure 1.8.

Figure 1.8: People affected by Epilepsy in India and US

Epilepsy is almost always treated by using anti-epileptic drugs (AEDs). As per WHO, 3 out of 4 people in the world with epilepsy do not receive treatment at all, mainly due to economic and social reasons. Epilepsy is a unique disorder, which, if not treated, can profoundly influence people's ability to participate fully in society. With proper treatment,
patients of epilepsy can also lead a normal, healthy life and actively contribute to the society.

Various studies have shown that about 60-70% of newly diagnosed children and adults with epilepsy can be successfully treated with one simple anti-epileptic drug. About 15-20% patients can be helped by the use of more than one drug and some new anti-epileptic drugs that are slightly expensive. The seizures are poorly controlled in about 5-10% of patients who need to be investigated for possible surgical treatment for epilepsy. Epilepsy surgery in carefully selected patients can even cure epilepsy. With a correct treatment approach, most patients with epilepsy can enjoy life as much as any healthy person can. The development of automatically and accurately performing patient specific brain segmentation method could be used, for finding the location epileptic seizures, that could be useful for the clinical diagnosis.

1.4. NEED FOR HUMAN BRAIN MAGNETIC RESONANCE IMAGING SEGMENTATION

The segmentation of GM, WM and CSF tissues on MRI images is important in both research and clinical diagnosis with epilepsy disease. In future, it is important that segmentation method helps to find the location of epileptic tissue. Although manual segmentation by qualified professionals remains superior in quality to automatic methods, it has two drawbacks. The first drawback is that, producing manual segmentations or semi-automatic segmentations, is extremely time-consuming, with higher accuracies on more finely detailed volumes, demanding increased time from medical experts. The second problem with manual and semiautomatic segmentations, is that the segmentation is subject to variations both between observers and within the same observer. The manual segmentation has no confidence in tracking the epilepsy tissue during the patient follow-up process, and the automatic methods, that could achieve a sufficient level of accuracy, would be highly desirable for their ability to perform high-throughput segmentation.

On the other hand, automatic methods would be advantageous since they are not subject to this variation, and thus the significance of changes in Gray Matter tissue could be more easily assessed. In addition to localization of epileptic sources within the brain, accurate automatic segmentation methods additionally have the potential to reduce the
variability, and increase the standardization of other measurements and protocols, including the quantification of edema or necrosis. Also, automatic segmentation could lead to new applications, including effective content based image retrieval in large medical databases. This could allow clinicians to find similar images in historical data, based on epileptic tissue location, grade, size, enhancement, and extent of edema, similar patterns of growth or a variety of other factors.

This information could help clinicians in making decisions, in addition to being a useful research tool for exploring patterns in the historical data. In a similar way, accurate segmentation method could be used in combination with relevant features and machine learning methods to improve epilepsy detection. Due to the above advantages of the automatic segmentation, it becomes a necessary issue for clinicians. This automatic segmentation can be more efficient with MRI other than PET and CT images. MRI is one of the most common diagnostic tests used for patients for epilepsy prediction. Shortage of radiologists and the large volume of MRI scan images that need to be analyzed may lead to labour intensive, expensive and inaccurate prediction. Hence, there is a need to generate an efficient prediction model for making the correct diagnosis of epilepsy and accurate prediction of its type.

1.5. AUTOMATED SEGMENTATION FOR HUMAN BRAIN MRI

Automated segmentation system for epilepsy through MRI is highly needed to segment the epileptic tissue more accurately. In general, preprocessing and segmentation work is done for MRI images to segment tissues. This research work primarily focuses on segmentation with the help of preprocessing task. Initially, preprocessing techniques are applied to improve the image quality and remove noises for the accurate separation of undesired regions in MRI. Through preprocessing, the segmentation is used to segment cerebral tissues from MRI brain images. Here, the appearance of segmented tissues has some information, which will be useful in further detection of epilepsy surgery.

1.5.1. Preprocessing

Preprocessing mainly involves those operations that are necessarily prior to the main goal analysis and extraction of the desired information and normally geometric corrections of the original actual image. These improvements include correcting the data...
for irregularities and unwanted atmospheric noise, removal of non-brain element image and converting the data correctly reflected in the original image. Segmentation is the process of partitioning an image to several segments but the main difficulties in segmenting an image are

i) Noise,
ii) Blur low contrast,
iii) Bias field (the occurrence of smoothly varying intensities within tissues), and
iv) Partial volume effect (a voxel contributes in multiple tissue types).

Image filtering and enhancement stage is the most obvious part of medical image processing. The filtering approach has been proved to be the best when the image is corrupted with various noises. Normal filters may work efficiently if the noise level is low, but if the noise level is high, normal filters would not be able to work efficiently. In such a case, combinations of filters are required to be done to enhance the quality of the image. This pre-processing stage is used for reducing image noise, highlighting important portions or displaying obvious portions of digital images. Some more techniques can employ medical image processing of coherent echo signals prior to image generation, and some of the images are hanging from clip, and hence they may produce noise. The enhancement stage includes resolution enhancement and contrast enhancement. These are used to suppress noise and imaging of spectral parameters. After this stage, the medical image is converted into standard image without noise, film artifacts and labels. Numerous techniques were applied in the studies of noise removal, but still the removal of irrelevant background parts becomes difficult. This problem is solved by using the skull stripping mainly for the image enhancement; most common are region growing and mathematical morphology.

1.5.2. Significance of Denoising in MRI Segmentation

Image denoising is a common preprocessing step in many Magnetic Resonance (MR) image processing and analysis tasks, such as segmentation (Shattuck et al., 2001), registration (Ashburner and Friston, 1997) or parametric image synthesis (Kosior et al., 2007). Noise may be produced because of imperfect instrument used during processing,
interference and compression (Devanand, 2012). Image noise in large measures contributes to high hazards faced by human (Olawuyi, 2011). Many filtering methods use the signal averaging principle, which is based on the natural spatial pattern redundancy in the images.

Modern wavelet based filters have also been applied to MR image denoising (Nowak, 1999; Wood and Johnson, 1999). Such filters, although effective, are prone to introduce characteristic artifacts (small spots) that can hamper the image analysis process. In the context of wavelet thresholding, a new denoising technique for multi-component images, exploiting inter-scale and inter-component correlations was proposed (Scheunders and Backer, 2007). This technique was demonstrated to outperform similar single and multi-component wavelet thresholding techniques.

On the other hand, a partial volume modelling based approach has been proposed (Thacker and Pokric, 2004), where the filtering was performed, using multidimensional data and a partial volume data density model. This approach abandons altogether local smoothness constraints, and achieves noise reduction, by enforcing agreement between measured data, using underlying tissue proportions, computed from a physics based image formation model. In the digital images like MRI, noises are low as well as high frequency components. Removing high frequency components is very easy as comparatively with low frequency components as real signal and low frequency noise cannot be distinguished easily (Devanand, 2012).

Rician noise (Hossein, 2009) affects the image, in both quantitative and qualitative manner, and thus it hinders image analysis, interpretation and feature detection. The great challenge of image denoising is preserving the edges and all fine details of an image while suppressing noise. It still remains a challenge for researchers as noise removal introduces artifacts and causes blurring of the images (Rupinderpal and Rajneet, 2013). Many of these methods use the information of a single image, without taking into consideration the intrinsic multi-component nature of MRI. In order to avoid this problem, many edge preserving filters have been proposed. However, such method usually erases small features, and transforms image statistics, due to its edge enhancement effect resulting in unnatural images. So, it is necessary to develop an efficient denoising technique to avoid such data corruption.
1.5.3. **Significance of Skull Stripping in MRI Segmentation**

Skull stripping is the process of segmenting brain from non-brain tissues (e.g. skull, scalp, eyes and neck) in whole-head MRI images. Skull stripping is one of the preprocessing phases in image processing of brain for detection of brain diseases. Skull stripping, an important part in neuro image study, is a difficult task due to various problems like shape of brain, intensity of the MR images and similarity of intensity values in brain and non-brain tissues. The brain portion must be extracted from the skull before the application of segmentation, classification and registration processing algorithms.

Skull stripping isolates brain from the non-brain tissues. It is highly significant in medical and image processing fields. Nevertheless, the manual process of skull stripping is challenging due to the complexity of images and time consumption and being prone to human errors. Thus, skull stripping uses an effective method. Studies of brain anatomy and pathology are most commonly based on magnetic resonance imaging (MRI), due to its good soft tissue separation. Here, T1-weighted protocols, which belong to the fastest MRI protocols available, are often preferred, since they offer a good contrast between gray (GM) and white cerebral matter (WM) as well as between GM and cerebrospinal fluid (CSF).

Whole brain segmentation is often regarded as an essential step in a neurological image processing pipeline, either because the whole brain is the region of interest, such as in studies of Morbus Alzheimer, or because the subsequently performed steps benefit from the fact that only a small set of well known tissue types is left over (i.e. WM, GM, CSF and possibly lesions), such as statistical brain tissue segmentation methods. Later, it offers a good basis for volumetric or morphometric examinations like cortex reconstructions, and yield promising results in accounting for intensity non-uniformity. However, their convergence is distorted by the presence of non-brain tissue. For brain warping techniques, that are used to perform inter-subject studies, it is as well desirable to exclude all non-brain tissues from the matching process. However, in MRI images, an automatic skull stripping based on mathematical morphology is strongly recommended, as those would improve the quality of the segmentations for MRI images.
1.5.4 Segmentation

Images may be acquired in the continuous domain such as on X-ray film, or in discrete space as in MRI. In 2-D discrete images, the location of each measurement is called a pixel. If the domain of the image is given by ‘I’, then the segmentation problem is to determine the sets \( S_k \subseteq I \) whose union is the entire image I. Thus, the sets that make up segmentation must satisfy \( I = \bigcup_{k=1}^{K} S_k \) where \( S_k \cap S_j \) for \( k \neq j \), and each \( S_k \) is connected. Ideally, a segmentation method finds those sets that correspond to distinct anatomical structures or regions of interest in the image. When the constraint that regions be connected is removed, then determining the sets is called pixel classification and the sets themselves are called classes. Pixel classification, rather than classical segmentation, is often a desirable goal in medical images, particularly when disconnected regions belonging to the same tissue class need to be identified. There are several types of segmentations possible to find localization of epileptic seizures from MRI of brain. Those segmentations have several advantages and disadvantages. There is no such algorithms which always produce very good results for all types of MRI of brain images. Thus, accurate segmentation over full field of view is another acute problem, but during the segmentation procedure, verification of results is another source of difficulty.

1.5.5 Significance of Clustering in MRI Segmentation

Medical Image Segmentation is the process of automatic or semi-automatic detection of boundaries within a 2D or 3D image. A major difficulty of medical image segmentation is the high variability in medical images. First and foremost, the human anatomy itself shows major modes of variation. Furthermore, different modalities (X-ray, CT, MRI, microscopy, PET, SPECT, Endoscopy, OCT and many more) are used to create medical images. The result of the segmentation can then be used to obtain further diagnostic insights. Possible applications are, automatic measurement of organs, cell counting, or simulations based on the extracted boundary information. In particular, an automatic MR image segmentation is a difficult mission, because MR images are difficult in nature for linear features. MR image segmentation performance is affected by many issues such as Partial Volume Effects (PVE) which means a pixel contains more than one
tissue. This leads to misclassification as a result of blurred boundary between tissues. Intensity nonuniformity means that the artifact intensities of the same tissue are not constant over the image spatial domain and geometric deformations (Rogowska, 2009; Angenent et al., 2006).

There are different classifications of medical image segmentation techniques. There are no standard classifications of techniques. The most commonly used segmentation techniques can be classified into two broad categories viz., Region based segmentation techniques that look for regions satisfying a given homogeneity criterion, and Edge-based segmentation techniques that look for edges between regions with different characteristics (Rogowska, 2009). Region based techniques depend on partitioning an image into regions according to common image properties. These properties can be intensity values, a texture pattern, a gradient, a colour, brightness, geometric properties and homogeneity properties, based on similarity criterion (Fiorentini et al., 2010). Region based techniques divide into Split and Merge and Region Growing (Chuang et al., 2006; Sikka et al., 2009).

With regard to Split and Merge based on quad quadrant tree representation, the Split process will be repeated until each region contains only homogeneous pixels (Fiorentini et al., 2010; Sikka et al., 2009). This lacks the sensitivity to image semantics (Jan, 2006). Region Growing depends on bottom up technique, and starts with n pixels as seeds. Each seed is treated as a region, and then each region grows by adding its neighbour pixels with similar properties. Its drawbacks are, difficulty to detect edges, its seed pixels generally require manual input for each region to be segmented and being affected by partial volume leads to holes or disconnection (Feng, 2005; Wirjadi, 2007).

Edge-based Segmentation depends on applying gradient operator edges in the image. Its algorithms have two main steps, namely, edge detection and edge linking (Sikka et al., 2009; Morra et al., 2006). Level Set Method is a counter evolution method which is based on the shape of the contour and driven force field (Sijbers et al., 1997; Chen, 2009). It is able to handle the topological change of the regions, but it cannot maintain information of shape. Deformable models idea depends on a boundary of an object such as a parameter for a curve or a surface. A good detection of an object contour is achieved on using a
suitable initialization. Deformable model techniques are robust to noise, but they require initialization of a contour that is close to object boundary, which helps to detect true boundary. Also, it is hard to handle a deformable model (Goldszal and Pham, 2000; Luo, 2006).

Clustering is one of the most usable or utilizable techniques in MRI segmentation, where it classifies pixels into classes, without knowing previous information or training. It classifies pixels with highest probability into the same class. It may find unclassified pixels which do not belong to any class probability. Clustering techniques training is done by using pixel features with properties of each class (Pham et al., 2000; Wang et al., 2008). Clustering is suitable in biomedical image segmentation when the number of clusters is known for particular clustering of human anatomy. Lot of research has been performed for the segmentation of MR brain images to find the localization of epileptic seizures from MRI images. Some work regarding MRI segmentation of tissues using clustering and other methods can be found (Sarbani and Monisha, 2011; Roy and Samir, 2012).

According to Theodore pilot study, in United States of America, approximately two million adults and 500,000 children have been diagnosed with epilepsy. 600,000 people have seizures that are not controlled by antiepileptic drugs. When drugs fail to control epilepsy, brain surgery is often the only remaining remedial option. But localizing the epileptic focus is a more complicated one. Therefore, there is a strong need to have efficient computer based system, that accurately examines the location of epileptic, along with less interaction of user interface.

1.6. MOTIVATION OF THE RESEARCH

Sudden Unexpected Death in EPilepsy (SUDEP) is the sudden, unexpected death of someone with epilepsy and who was otherwise healthy. No other cause of death is found when an autopsy is done. Autopsy plays the core role in determining the diagnosis of SUDEP. Autopsy, per its definition, fails to reveal the underlying cause of death; however, several autopsy reports confirm the following findings in the brain, lungs, heart and liver of patients with SUDEP. Each year, more than 1 out of 1,000 people with epilepsy die from
SUDEP. If seizures are uncontrolled, the risk of SUDEP increases to more than 1 out of 150. These sudden deaths are rare in children, but are the leading cause of death in young adults with uncontrolled seizures. The person with epilepsy is often found dead in bed and does not appear to have had a convulsive seizure.

About a third of them do show evidence of a seizure close to the time of death. They are often found lying face down. No one is sure about the cause of death in SUDEP. Some researchers think that a seizure causes irregular heart rhythm. More recent studies have suggested that the person may suffocate from impaired breathing and fluid in the lungs, and being face down on the bedding. Approximately, 50,000 people die each year from prolonged seizures, SUDEP and other seizure-related causes of brain. The SUDEP accounts for 8-17% of deaths in adults and 34% of deaths in children with epilepsy. Successful epilepsy surgery may reduce the risk of SUDEP, but this depends on the outcome in terms of seizure control. In many patients with epilepsy, antiepileptic drug treatment is unable to control the seizures.

The diagnosis of epilepsy and the localization of epileptic focus are made using the criteria weighted by clinical manifestations, electrical patterns identified on the Electroencephalogram (EEG), structural abnormalities on Magnetic Resonance Image (MRI) and functional changes on Positron Emission Tomography (PET) studies. Using MRI, it is possible to detect an epileptogenic lesion in 80 percent of the patients. Resection of these lesions can lead to seizure freedom in many patients.

MRI scan clearly depicts high resolution of brain anatomy than PET and CT. MRI scans can be used to look at the structure of the person’s brain (how their brain is made up). In people with epilepsy, it can be used to see if there is an obvious reason (structural cause) for their seizures. This might be a scar or lesion on their brain that can be seen on the image. A variety of MRI image segmentation approaches in brain have proposed to find the location of epilepsy. However, the irrelevant regions (non-cerebral tissue) and unwanted background segmentation may lead to confusions for region predictions. Hence, there is a need to generate an efficient segmentation model for making a correct and accurate prediction of epilepsy and its type.
1.7. **RESEARCH OBJECTIVES**

The objective of this thesis is to develop segmentation methods for medical imaging applications, using swarm based clustering approaches. The main aim is to propose a brain epileptic segmentation system suited for MRI processing. The purpose is to easily segment epilepsy in MRI with reproducible results. Cluster analysis identifies groups of similar objects and therefore helps in discovering distribution of patterns in large data sets. Clustering is most widely used for real world applications. However, accuracy of these algorithms for abnormal brains with edema, tumor, epilepsy, etc is not efficient because of limitation in initialization of this algorithm. In this research work, swarm based techniques have been proposed to improve the efficiency of clustering approaches.

The main focus of the work, based on human MRI brain image, is to optimize the segmentation process with higher accuracy rate, for finding the epileptic tissues of the brain, by using computational intelligence and image processing techniques. The following are the research goals set for segmentation of MRI brain cerebral tissues:

- To remove the noise from MRI brain images using filtering techniques,
- To analyze the effect of optimized noise removal techniques over the segmentation process,
- To segment cerebral tissues from MRI brain images using clustering techniques,
- To improve the segmentation rate of WM, GM and CSF tissues from MRI brain images using optimized clustering techniques and random based optimized clustering techniques, and
- Evaluation of optimization algorithms using standard test functions.

The work flow diagram for the overall research work is illustrated in Figure1.9.
Hybrid Fuzzy Clustering Technique using Random based Optimization for Segmenting MRI Brain Images
Figure 1.9: Work Flow Diagram of the Overall Research Work
1.8. LAYOUT OF THE CHAPTERS

Chapter 2 analyses the existing preprocessing methods using image denoising techniques, Preprocessing methods using Skull Stripping, Segmentation using clustering techniques, Segmentation using optimized clustering techniques and Segmentation using random based optimized clustering techniques. This chapter examines the characteristics of existing methods and major issues of the existing methods in the literature. The inference from the existing techniques is also discussed in this chapter.

Chapter 3 explains the details of the methodology and presents the research methodology of the entire work and steps carried out in proposed methods for segmentation of MRI brain image through clustering and computation intelligence.

Chapter 4 explains the proposed methodology of Preprocessing methods using Skull Stripping with Noisy images, Preprocessing methods using Filtering techniques and Preprocessing methods using Skull Stripping with Denoised images. This chapter focuses on the noise reduction problem to enhance the segmentation accuracy for MRI images.

Chapter 5 explains the proposed methodology of Segmentation of Noisy MRI brain images and Segmentation of Denoised MRI brain images. K-Means and Fuzzy C Means (FCM) clustering methods are used for segmentation. Results from preprocessing step shows that it exhibits great improvement in extraction of brain cerebral regions. Then, the results obtained from clustering segmentation with different tissues are separated. FCM technique is easily trapped into the local minimum and does not take into consideration the spatial contextual information. So, there is an increasing need for optimizing the cluster centers in FCM segmentation.

Chapter 6 discusses the proposed methodology of Optimized Segmentation of Noisy MRI brain images and Optimized Segmentation of Denoised MRI brain images. Image preprocessing is done initially, followed by Optimized clustering techniques such as Genetic Algorithm and Firefly Algorithm (FA) implemented into FCM for segmenting the MRI brain cerebral tissues like GM, WM and CSF regions. In this chapter, the behavior of attraction co-efficient and randomization co-efficient in firefly can be tuned to find the
global search mobility for which random based metaheuristic optimization techniques can be proposed further.

Chapter 7 discusses the proposed methodology of Random based Optimized Segmentation of Noisy MRI brain images and Random based Optimized Segmentation of Denoised MRI brain images. The Random based optimized clustering techniques such as Chaotic Map and Levy Flights are implemented into FA for finding the global cluster centers as the initial cluster value of FCM. Finally, FCM is used for segmenting the MRI brain cerebral tissues like GM, WM and CSF regions. The Chebyshev Chaotic map and Levy distribution is used for optimizing the attraction co-efficient and randomization co-efficient of firefly algorithm. Then, the results obtained from random based optimized clustering segmentation with different tissues are segmented separately.

Chapter 8 shows the experimental results with the comparison of previous approaches. This chapter concludes the thesis with the findings for MRI image segmentation on various performance parametric standards, which covers a summary of this thesis, including the conclusions drawn from the research.

The findings of the current study are summarized along with future research directions in Chapter 9, Summary and Conclusion.

1.9. SUMMARY

This chapter provided the overall analysis of the basics of MRI image segmentation. Need of the MRI image segmentation system and problems of the MRI image segmentation are also discussed. The major objective of the work and layout of the entire chapters are also discussed at the end of the chapter. Review of the existing segmentation methods and their issues will be summarized in the next chapter, Review of Literature (Chapter 2).