CHAPTER 1
INTRODUCTION

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1.1. HEALTHCARE SYSTEMS

"Health is wealth," a golden proverb says. Human society spends more on health related aspects. The expenditure is either on maintaining good health or to recover from the illness. Health aspects of human beings do not differ in any country in the world. In the meantime, every level of the society whether poor or rich is ready to sacrifice any amount of money to save human life. It is a paradox that there is an increase in health disorders with the increase of technology advancement. It is a great challenge for Doctors, Nurses, Medical Supporting Staff, Technicians, Patients and the Information Technology who are the stake holders in the field of healthcare to fight back with the health issues.

One of the major factors to heal a disease is a proper diagnosis. In the process of diagnosis, doctors select one disease over another to narrow down to identify one of the doubted diseases with the support of a person's symptoms. Symptoms appeared and expressed by a person in the early course of a disease are often more unclear and undistinguishable than those that arise as the disease progresses. In such crucial initial stage, it is a tedious process to make an accurate diagnosis. The past health record, risk factors for certain diseases, and a recent exposure to disease, symptoms existing for a long time will lead to a path of right diagnosis.

At the same time, diagnosis includes various other evidences such as patient's physical attributes, expressions of distress and the results out of

the laboratory tests, X-Ray, CT and MRI procedures. Radiography and Imaging plays a vital role in the diagnosis of certain sicknesses. After receiving all the results and outcomes of the various tests, by applying the method of differential diagnosis, possible diagnoses chart can be prepared. With the help of the chart, additional information can be identified and doctors can prescribe further tests to narrow the chart to identify the disease and fix the root cause of the disease.

There are numerous ways the diagnosis is carried out as mentioned earlier. Medical Imaging is one of the important procedure to diagnose a disease in the patient. Russ and Woods (1995) have mentioned that Medical Imaging and Medical Image Processing (MIP) are dynamic areas in the field of healthcare. There is a huge volume of research going on in MIP with the goal of achieving 100% accuracy to support the doctors with the accurate results for the right and best treatment.

Medical Imaging started with radiography after the invention of x-rays by a German physics professor, Wilhelm (1895). Therapeutic contrast agents were used to visualizing organs and blood vessels in the years between 1906 and 1912. It was considered as a milestone in radiography. Because of these contrast agents having no harm, patients could be administered for the first time with either oral or vascular injections to envision gastrointestinal systems, gall bladder, blood vessels and bile ducts. Later by 1960's medical imaging process was used to visualize the inside of blood vessels, organs mainly into the heart chambers and arteries. This radiological application of penetrating through veins and visualizing the heart chambers for diagnosis is called as angiography.

The ultrasound scanners came in use in 1960's using the principals of sonar. The scanners used for diagnostic imaging radiate high frequency sound waves into a body using an electronic device called transducer. The invention of Computed Tomography (CT) by Hounsfield and Cormack (Wells, 2005) is another milestone in the field of medical imaging. Inventors were awarded Nobel Prize in 1970's for their contribution to the field of medical imaging. CT imaging could give better visualization into the pathogenesis of the body. It was an initiate by Raymond, 1971 encouraging scientists to use MRI and since then it took 20 years to reach the developed MRI by the contribution of various scientists. The images produced by MRI are very much useful in diagnosis and has conquered a major place in image processing.

1.2. IMPACT OF MRI IN DIAGNOSIS

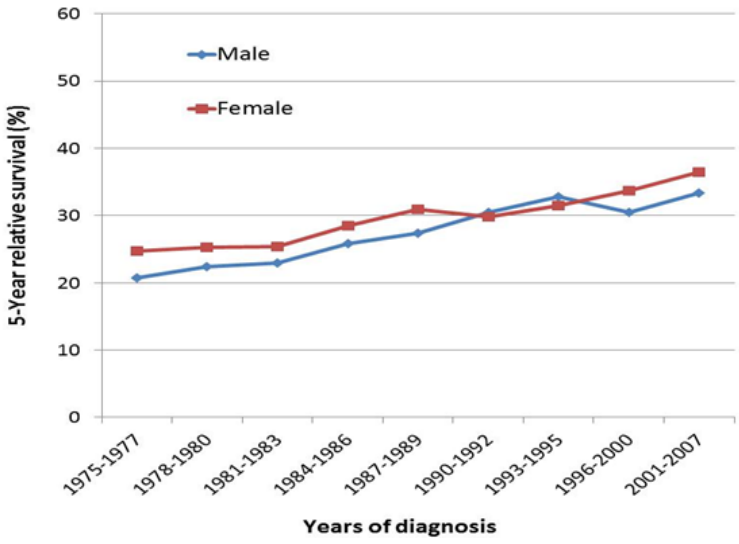

Figure 1.1 Impact of MIP on survival of 5-Year old brain tumour patients over years

The statistics show that the accuracy enhancement in findings from the MIP has led to better treatment, in turn, the survival rate has enriched. The above placed figure 1.1 (Brain Tumor Research, 2014) shows how the development of imaging and diagnosis tools have increased the survival rates of 5-year old patients over the past three decades.

1.3. GROWTH OF MRI USAGE

There is a rapid growth in performing MRI scans. In the meantime, the number of MRI machines also increases due to high need. According to the Siemens sources (Swati, 2013) the KGS Scan Centre in the South Indian city of Madurai performs over 100 MRI scans per day at its two sites. Patients come here from 50 neighbouring communities. The two Madurai centres have achieved a record of performing over 100 MRI scans in a day. Even on a Sunday, MRI examinations can amount to 80. On January 15th, 2013, the centres reported 138 MRI examinations.

The following figure 1.2 OECD (2014) with statistics shows that the increase in a number of MRI exams per 1000 patients in a year.

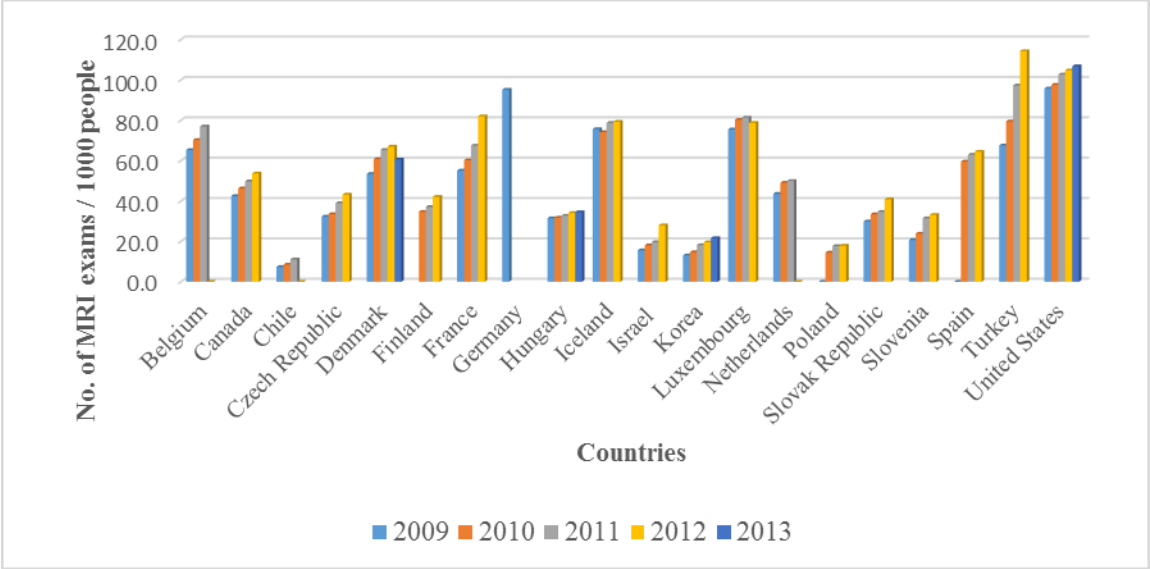

Figure 1.2 Magnetic resonance imaging (MRI) exams, total per 1000 population.

All the above statistics show that there is an extreme increase in the usage of MRI for diagnosis. The following statistics helps us to concentrate more on the organs on which MRI are performed more.

1.4. MRI EXAMINATIONS ON ORGANS IN PERCENT

The following table shows that the percentage of MRI scans performed on each organ of the human body.

Table 1.1 Percentage of MRI taken in human organs.

Organs	**Percentage of MRI**
Spine	26%
Brain	25%
Head and Neck	6%

Upper Extremities	11%
Lower Extremities	9%
Abdomen and Pelvis	8%
Chest	2%
Breast (MRM)	2%
Cardiac	1%
Angiography (MRA)	9%
Other	1%

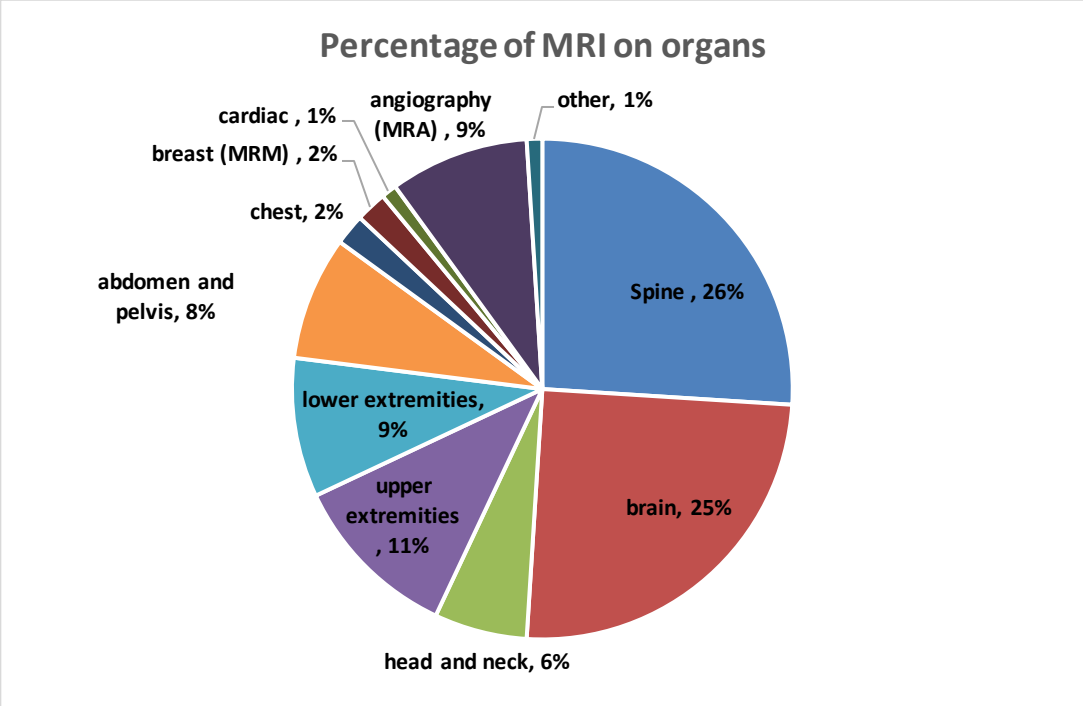

Figure 1.3 Percentage of MRI scans on different organs

According to the information given in the Siemens magazine (Medical Solutions, 2015) it is evident that the number of MRI performed on Spine and Brain are more than any other organs as illustrated in the figure 1.3. It shows the need of analysis more on the specific organs. The research has taken the path for analysing the brain MRI for getting better results to support the healthcare professionals and the patients.

More than any other cancer, brain tumors can have lasting and life-altering physical, cognitive, and psychological impacts on a patient's life. This means that malignant brain tumors can often be described as equal parts neurological disease and deadly cancer. Even benign brain tumors can be deadly if they interfere with portions of the brain responsible for vital bodily functions. There are more than 120 different types of brain tumors, many of their own multitude of subtypes. (National Brain Tumor Society, USA).

1.5. MRI PROCESSING

Magnetic Resonance Imaging (MRI) is a scanning procedure done on the human body to reveal the characteristics of an organ. MRI uses a solid magnetic field and non-ionizing radiation in the radio frequency waves to produce an image of a human body. It can be thought of more sophisticated tool to diagnose a disease. During MRI scanning, magnetic field elevates the state of hydrogen nuclei of water molecules in the body (Geraldine B and Carol, 2012). In such elevated state, MRI learns the state of the organ. In the MRI procedure, the patient is temporarily exposed to a burst of radio-frequency energy in the presence of a magnetic field which makes the hydrogen nuclei in a raised up energy state. During this elevated state,

molecules experience their regular, microscopic tumbling and they shed this energy into their surroundings. This process is known as relaxation. The difference in relaxation rates in various tissues are captured as images. This procedure was at first branded as Nuclear Magnetic Resonance (NMR) but the term "nuclear" was detached to dodge any connection with nuclear radiation.

It is stated that the radiation during MRI is harmless with respect to the current medical advancements. Especially in the brain and spinal cord scans, MRI can yield much better results while working with soft tissues compared to X-rays. functional MRI (fMRI) is an advancement of MRI that quantifies progressive variations. Detection of neural activity which is done through fMRI can be a suitable example for the usage of fMRI. Another MRI called diffusion MRI that measures the diffusion of water molecules in anisotropic tissues like white matter in the brain.

The images captured from MRI are also naturally not away from the limitations which are part of the images received from other imaging modalities. There are various factors causing these imperfections. For example, metallic implants in the body will cause imaging artifacts in MRI. Some of the imperfections are:

1. Poor resolution (in the spatial and spectral domains).
2. More noise.
3. Insufficient contrast.
4. Linear distortions.
5. Presence of imaging artifacts.

As it is discussed earlier, there are various key imaging modalities with its certain benefits and drawbacks. At the same time, algorithms pitched to one instrument may not work as well on another instrument. Adopting a suitable algorithm for an instrument can be achieved by understanding the basic physics of the given modality.

There are various processing techniques applied on the MR images to get the essential attributes for further analysis. As it is illustrated earlier, MR images come out with different shortcomings due to different reasons. In such situation, it is very crucial to opt a best suitable image processing algorithm to process the image and give extremely accurate results. The researchers are working with the same zeal to achieve maximum accuracy in processing MR images.

1.6. NEED FOR THE STUDY

Medical Image Processing is bottomless as well as the broader level of research area that keeps the researcher especially those in the same domain always to bring out new findings to enhance the efficiency of medical image diagnostics (Netto et al., 2008). Even though there are new researches coming out every day on MIP, there is no end to say one has achieved 100% accuracy of results. There are more hidden parameters yet to be brought out to reach the desired accuracy. When a parameter causing a problem for attaining efficiency is addressed, other parameters emerge to be addressed. At the sametime, the working pattern of algorithms, the direct and indirect variables, a combination of algorithms, the input produced by various machines, the number of inputs and the technology used are having a great impact in the preciseness of the output.

Image Processing is a wider and deeper area where the researchers have more to identify and it is a continuous process (PA, 2016). Especially when it comes to Medical Image Processing, it demands more expertise to help the medical professionals to diagnose the disease for further investigations and treatment procedure. Medical Image Processing (MIP) starts with the acquisition of the medical image, improvement, investigation, visualization, and communication as well as the medical imaging applications (Wu et al., 2012). MIP is an unceasing process in research and development and it demands the researcher to get better and better results.

The core purpose of image processing applications being developed is to extract significant characteristics from the derived image of the human organ, from which an eloquent, informative and clarity of understanding can be achieved. There are various factors hindering the quality process of segmentation of brain MR image. One of the critical problem in segmentation is time consumption. Accordingly, the research combs the basics of various brain segmentation algorithms employed with different methodologies by researchers. The different approaches like thresholding, region growing, clustering, neural network and genetic algorithms for segmentation are considered to find the optimum solution.

For any MIP algorithm to succeed in achieving efficiency, three critical mechanisms need to be fulfilled. The first is the focus and problem identification at the grassroots level. The second is ensuring coverage, quality, relevance and reliability of data so that the information existing through MIP is effectively used for attaining the optimum result. The third

is investigation, timely dissemination and feedback on the information available through the system.

Keeping these three key factors in mind, one could identify that there is a continuous need for improving the efficiency of the MRI processing to achieve maximum accuracy to reach the right diagnosis. There are various algorithms and methodologies used for processing MR images. Each algorithm shows improvement in efficiency in different conditions.

In the current days, there are various tools and methods to analyze the medical images and to extract the required and necessary information. Even though it is evident that the research over the past century has taken us to the advancement in MIP, one can accept that there is a need to enhance the MIP with better tools and involvement of cutting edge software. Following are the concerns even to obtain the imaging which is the first step of MIP.

1.6.1. Correctness and Accuracy

MIP is not working directly with the region of interest as a doctor goes to the affected region of the human body and manually checks with invasive procedures. So imaging may not give precise results as the human procedure gives the reality. Sometimes the area of interest that looks fine, may be malignant and which looks to be malignant may be totally normal.

1.6.2. Cost and Size

The cost of medical imaging devices is hundreds of thousands of dollars. Additionally, the devices may need exceptional operating procedures and costs associated with running them, such as liquid nitrogen to keep them cool or isotopes for imaging purposes. Moreover, the infrastructure

necessitated by the devices is also highly comfortable with respect to size and setup.

1.6.3. Limitations of Resources

Many devices need isotopes to function. Yet, there is only a certain amount of isotopes freely available at one time and scarcities can cause long wait-times for analysis and imaging.

Once the imaging is done, during the MIP, researchers have biggest challenges in front of them.

1. The size of medical image datasets go into gigabytes and sometimes terabytes in the case of 3D images.
2. In order to analyze 3D images of huge size, researchers need high computational power to work on with. They can take help of GPUs cost very high. Either the research labs can invest for GPUs by purchasing the hardware or an individual can run a simulation on servers of companies like Amazon.

Researchers are working in various viewpoints to improve the efficiency of MIP by increasing the quality of machines with less cost, improving algorithms more and more efficient to reach the optimum results and adopting new technologies in processing.

1.7. CLOUD SERVICES TO ENHANCE HEALTHCARE SYSTEM

There is an unceasing advancement in information technology to support human life and make the things easier and reducing cost. In this order of

advancements, cloud computing is one of the major outburst makes the applications simpler by providing different services and available anywhere. Cloud computing is now a mandatory concept being used in the IT industry which changes the style of programming in a way to provide faster and cost-effective solutions to different applications. To enjoy the benefits of the cloud services, many applications move towards the cloud and ultimately every stakeholder of an application is benefited directly or indirectly. In this scenario, the healthcare industry is to be modernized consistently since information technology has become the bloodstream of healthcare applications Since healthcare industry moves in the direction of an information-centric care delivery model, it is very sure that cloud computing can play a vital role in the revolution of healthcare applications.

In the current trends, the healthcare system is one of the different applications (Soman, 2011) being explored, redesigned and made available for various needs of different levels of people from the medical practitioners to a patient. If these applications are transferred to the cloud environment, surely it will benefit the human life in different ways like money and time.

It is noted that the human beings spend more money on health in one's life. Statistics shows that compare to the expense on healthcare by developed countries, Americans spend over twice as much per capita. As per the statistics, the Indian healthcare industry grows at a swift pace and is expected to become a 280 billion $ (OECD, 2015) industry by 2020.

From these statistics, it is evident that every human needs to spend a major part of their income for healthcare. In such scenario, hospitals, clinics,

laboratories, insurance firms, and research labs can get high-end computing resources at lower initial principal costs through services from cloud computing. Besides, cloud environments can pave a way for novelties in healthcare systems and their applications to take them to the up-to-date implementation of high-end technologies.

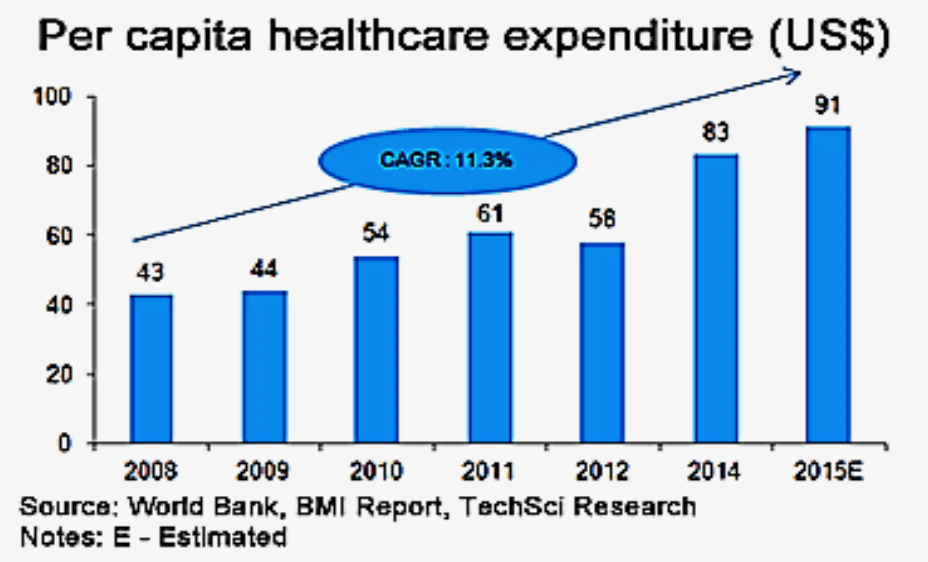

Figure 1.4. Rise in per capita healthcare expenditure in India.

Following are the important demands of healthcare systems from information technology met by cloud computing:

- Cloud Computing facilitates access to the high-end processing resources and enormous storage amenities.
- Since healthcare involves huge data sets of electronic health records and medical images from different modalities, cloud computing supports analytics of such huge data called Big Data.

- Cloud computing can simplify the sharing of health information of patients among authorized doctors and hospitals located in any parts of the globe.
- Cloud computing can provide instant access to life-saving data and avoid duplicate tests on patients.
- Importantly, in the process of diagnosis cloud computing helps the doctors and technicians by enhancing the ability to examine and track information of treatments, expenses, responses from patients instantaneously and work with future plans of treatment.

As cloud computing offers different service models like Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS), it will be more beneficial if healthcare professionals choose the best one or combination which meets their occupational needs.

For small health clinics, it would be a more attractive economic option to use SaaS, by means of its pay-per-use business model. Because SaaS reduces the cost on round-the-clock IT staff in consort with capital investments on licensed software, hardware, and different operating systems. Bigger hospitals equipped with the resources to construct their own cloud based solutions, PaaS can be considered as a right choice. IaaS can be a superior option for healthcare organizations looking for a more scalable infrastructure since IaaS can provide an economical solution which caters to security, elasticity, built-in backup, and data safety. For the meantime cloud computing delivers functionality for handling data in a distributed, global and persistent means supporting a number of platforms, systems, and applications.

At the same time, depends on the healthcare applications, the decision can be made by the healthcare professionals to move the applications to the cloud. In general, healthcare applications can be classified as clinical and non-clinical whereas clinical applications consist of patients' health records, doctors' plan of treatment and procedure and image processing applications. The non-clinical applications consist of automated in-patient and out-patient billing, hospital employee management, hospital accounts management and decision support systems. The selection of an application to be incorporated into a particular cloud model like private, public or hybrid can also contribute more to the security and privacy of data.

When cloud computing provides various advantages for healthcare systems, it needs to work for data security, privacy, accessibility to authorized users, access from different people of different locations, data originality, and long lasting preservation. It is a concern of cloud service providers who are accountable for all these while in compliance with government and industry guidelines.

Implementation of cloud computing in healthcare has taken place at a slow pace due to some sceptical questions like how healthcare can benefit from cloud contributions and how much of their processes they can afford to transfer to the cloud. Still there are few areas like electronic health records, data analytics and imaging systems in which different sectors of healthcare institutions succeeded greatly with cloud setting out.

1.8. ADVANTAGES OF CLOUD MEDICAL IMAGING

Quality of Service (QoS) represents the performance level, reliability, and availability presented by a specific application and by a platform or infrastructure which enables the application to run. QoS is essential with respect to cloud users, to give the expected level of excellent features, and for the cloud providers, to get the optimum trade-offs between QoS levels and functioning expenses. QoS can be achieved for the proposed medical application in cloud setup by considering the following advantages of Cloud Medical Imaging.

1.8.1. Connectivity from Anywhere at Anytime

Cloud services can make medical images accessible from anywhere and on different devices. This flexibility simplifies the process of connectivity. While upholding appropriate security measures, a cloud imaging system can provide access to data without any additional network complexities.

1.8.2. System Elasticity

Whether storage space needs to double or triple, an IT team can scale their storage and other resources with only a few clicks when operating in the cloud. This eliminates the need for any major hardware expenses and offers a faster turnaround time to an adjustment period.

1.8.3. Data Protection and Redundancy

Medical imaging data is typically larger in size compared to other health data sets. It means that the backups and disaster recovery (DR) systems must have enough capacity to keep copies of the data in case of system failure and data corruption. With the cloud alternative, healthcare entities are putting the DR burden directly on the service provider. Most service

providers offer data redundancy across multiple data centers, as well as additional retention capabilities to ensure the data is protected in case it ever must be restored.

1.8.4. Payment Flexibility

Another desirable feature of cloud products is that that client only pay for what they use. This is especially helpful in the radiology space since images are not frequently accessed after initial readings and interpretations. This means the primary costs of the system are the result of the initial data or image load, which helps lower costs for healthcare groups.

Despite the appeal of the cloud, there can be some challenges associated with its implementations. Installing cloud products require appropriate planning and a strong understanding of what is being offered by the cloud providers. Knowing the correct storage plans, connectivity requirements, available data protections, compliance certifications, and support are a few areas that must be thoroughly evaluated before making an investment in cloud services. It is also important to identify any initiatives in which images are shared with other groups, such as health information exchanges, as those transactions can affect overall costs. The upside of cloud services can be quickly eclipsed by the burden of data download fees if sufficient planning is not done ahead of transitioning to the cloud.

1.9. MOTIVATION

Even though the quantity of medical image of patients is swiftly increasing, much of that evidence is not being used to its full potential to achieve

enhanced results with the diagnosis. There is a challenge for medical professionals nowadays to integrate an increasingly multifaceted and massive quantity of data and images in order to deliver consistent and cost-effective healthcare. The use of electronic medical records for a patient visit, test, and drug data is increasing. Any medical professional can affirm that there are numerous data hidden in an image needs to be integrated into these medical records for the better diagnosis which leads to the best treatment.

Since technology has entered into every area of a human's life and the busy life style has enforced the time constraint, there is a need for remote diagnostics also which can help to solve the issues.

By looking into the challenges, there is a need to study the software to work with humungous datasets of medical images and to increase the efficiency of the algorithm to operate on them. Since the Big Data of Medical Images need highly precise processing, huge storage and in depth analysis, it is essential to contribute to the research of MIP to advance it to the next generation health care system.

This results in both lower costs and greater flexibility which are among the key benefits offered by cloud computing. In such environment, the benefit is enjoyed by the software provider, the doctor and by the patients. Using the cloud for other applications such as X-ray image processing means that customers no longer have to purchase an expensive data processing infrastructure but instead, only pay each time they need a patient diagnosis. Cloud solutions are also flexible.

Meanwhile, there are challenges placed before the researchers of medical imaging and various techniques and technologies being tried to achieve the accuracy maximum to reach the right diagnosis and save the human life at the very best level. Keeping all these in mind, since the research has concentrated on brain MR images, it is focused on the algorithms working well with brain image segmentation.

With the supporting literature survey and considering the needs, the research has incorporated the architecture of Parallel Genetic Algorithm (PGA) for brain MR image segmentation. The incorporated PGA are analyzed with the different working factors to improve the efficiency.

Since the research is intended to help the healthcare professionals as well as the patients to get the analyzed data and extracting useful information from the existing brain MRI Big Data, Hadoop and Spark are used for executing algorithms in different environments in the cloud.

The research works on the segmentation of brain MR images to find the tumors. The research concentrates on enhancing the efficiency of Parallel Genetic Algorithm for brain MRI segmentation. Since the medical image databases are growing rapidly in every minute, keeping their volume and the necessity for the next generation technologies in mind, Hadoop and Spark have been adopted in the cloud environment and the performance of the algorithm is evaluated to support the future system.

The proposed framework is named LISA with the meaning for each alphabet.

L stands for Lacis which means network. The network is the life stream of entire research done here.

I stands for Iatraliptic which means the curing of diseases by means of unguents. One of the objectives of the research is to provide efficiently segmented brain image for better treatment.

S stands for Subnubilar which means under clouds. The research is mainly using next generation software technologies used in cloud computing.

A stands for Architecture where the research proposes a framework using next generation technologies to enhance the performance of the algorithm.

1.10. ORGANIZATION OF THE THESIS

The thesis will be divided into five chapters. Chapter 1 will provide an introduction to the Medical Image Processing, development in its understanding, main components such as MR images and theme of the thesis. The effect of these components on observations and how they change the medical image diagnostics will also be discussed. There will also be brief explain about the need for this study in this chapter.

Chapter 2 will be on the review of the literature, covering some of the most important studies over the years which made significant contributions in this field. The limitations of these studies will also be discussed and the attempts made to overcome those limitations in the proposed methodology will be noted. Chapter 3 deals with the data collection and the methodology used to acquisition of data.

Chapter 4 will portray the research work carried out, implementation of the proposed algorithm in a different number of clusters using Apache Hadoop and Spark. In the first part of the chapter efficiency of proposed algorithm is described with the achieved results. The second part gives the complete overview of the performance of the proposed PGA algorithm in Hadoop and Spark with the analysis. Finally, the results are projected and discussions are made on the results. Chapter 5 will give the summary, future extension of work based on the achieved results, mobile application development for the future expert system "LISA" with the derived conclusions. At the end list of publications and conference proceedings resulted from our work will be noted down.