USING REISSNER-NORDSTROM SOLUTION FOR MODELING EPILEPTIC SEIZURES

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To all muslim ummah… … …

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All praise is to Allah swt, the truth and the only God deserved of All Praise and Submissions. Peace and blessing to the blessed and chosen prophet, Muhammad saw, who is the messenger and the teacher of the truth.

A lot of work, time, effort and energy were place upon this research. Nonetheless, the journey going through the process of becoming learned and experienced individual, with more courage and perseverance was a very tough one. It was the journey of life itself, which changes me to become a better person mentally, physically and spiritually, with a very clear goal in this life and the next.

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ABSTRACT

Modeling of the brainstorm of epileptic seizure is to find and follow paths of clusters of charges carried by ions from epileptic foci to the scalp area of the brain. This will also estimate the location of the epileptic foci or onset of the seizures. The foci may be located in a small volume of brain tissue due to unusually large accumulation of ionic charges. As a seizure begins, the electrostatic repulsive force among these ions throws the ions outward in all directions along 100 billions neurons inside the brain. These charges of electric pulses arrive finally at the scalps, and are recorded as electroencephalography (EEG) voltage signals. Modeling this event poses challenges since seizures might start at other locations at the same instant. Hence, the mixture of paths from different foci is unavoidable which resulted in a very chaotic trace of EEG signals. Sporadic ionic burst of the epileptic brainstorm is very similar to the event of the Big Bang. The tremendous explosion originated from a point of singularity, threw all matters and space outwards, and started the expansion of the universe. The journey of the matters along with this expansion provides a good model for the journey of the charges to the scalp during brainstorm epileptic seizure. General relativity states that the fundamental force of gravitation can be described as a curved space-time caused by the presence of matter and energy. Thus, matters move along this curve space-time, during the expansion of the universe. Likewise, electrostatic field of charges curved space provides path for the charges' journey during epilepsy attack. Exact solution to the Einstein Field equation of fluid which describes the expansion of the universe may also give exact solution to Einstein field equation of electromagnetic field which describes the path of the ions during epilepsy attack. The electrovacuum solution of Reissner-Nordström metric of a charged, non-rotating black hole is suited to the variables of the model. Results obtained were then compared to another result that was obtained by using pixel image method of flat EEG. The percentage agreement is around 56.3% and was determined by the number of pixel dots that actually resides in the spherical domains of the charges' paths. Significantly and interestingly enough, 33% of the lengths of the paths are less than 4 mm while 67% are much deeper inside the brain. This value totally agrees with the percentage of folded cortex deep inside the brain and far from the scalp.

ABSTRAK

Memodelkan ribut otak semasa serangan sawan dalam kajian ini bertujuan untuk mengesan dan mengikuti perjalanan kelompok-kelompok cas yang dibawa oleh ion-ion dari lokasi bermulanya serangan hingga ke kawasan tengkorak kepala. Ini juga dapat menganggarkan lokasi titik bermulanya punca sawan bagi ribut otak tersebut. Titik ini dapat dikesan pada satu kawasan kecil tisu otak di mana terdapat pengumpulan cas-cas yang lebih banyak dari biasa. Apabila serangan bermula, daya tolakan elektrostatik di antara cas-cas ini menyebabkan ion-ion tertolak keluar ke semua arah dengan melalui lebih dari 100 billion neuron-neuron dalam otak. Cas-cas ini kemudiannya tiba di tengkorak kepala dan di kesan sebagai isyarat voltan EEG. Membangunkan model pegerakkan cas ion-ion ini merupakan cabaran yang besar. Serangan sawan boleh berlaku di beberapa lokasi yang lain pada ketika yang sama dan oleh itu, percampuran jejak cas-cas ini tidak dapat dielakkan lalu menghasilkan isyarat EEG yang kelam kabut. Letupan spora cas-cas ini adalah serupa dengan gerakan jisim alam yang meledak kuat ketika berlakunya phenomena Big Bang. Letupan hebat ini bermula dari satu titik singular yang mencampakkankan jisim ke semua arah, lalu memulakan pengembangan alam semesta. Perjalanan jisim bersama pengembangan alamraya memyediakan satu model yang sesuai untuk perjalanan cas-cas ke kawasan tengkorak semasa serangan rebut sawan. Relativiti umum, menyatakan bahawa daya gravity adalah sama dengan lengkungan ruang masa yang disebabkan oleh kehadiran jirim dan tenaga. Oleh itu, jisim begerak menyusuri lengkungan ruang masa ini. Keadaan ini adalah serupa dengan medan elektrostatik kelompok cas-cas yang melengkungkan ruang masa dan memberikan jejak bagi perjalanan cas-cas semasa serangan sawan. Penyelesaian tepat kepada persamaan medan Einstein bagi bendalir yang juga menerangkan pengembangan alamraya boleh memberikan penyelesaian yang tepat juga bagi medan elektromagnetik kelompok cas-cas. Penyelesaian elektrovakum metrik Reissner-Nordstrőm bagi lubang hitam yang tidak berputar dan tak bercas kemudiannya di suaikan dengan parameter-parameter model. Keputusan yang terhasil dibandingkan dengan keputusan dari kaedah penghasilan imej piksel EEG Datar. Purata peratusan kesamaan adalah 56.3%, dimana angka ini ditentukan dengan menjumlahkan titik-titik piksel yang berada didalam domain sfera yang jejarinya adalah jejak perjalanan kelompok cas-cas tersebut. Yang paling ketara, 33% dari panjang jejak-jejak adalah kurang dari 4mm dalam, sementara 67% yang selebihnya adalah lebih dalam. Nilai ini adalah tepat dengan peratus luas kortex yang terlipat dan jauh dari tengkorak kepala.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The world is a very amazing place to live in. Not only that the whole natural systems work in harmony with each other in achieving balance and order, but also reveal their beauties majestically. From the system where nucleons revolve around each other in the nucleus to the system where celestial bodies revolve around supermassive black holes in their own galaxies, both of them seem to follow the same law and order. Between these two extremes lie countless systems that seem uniquely different from each other in regulating bodies that they are assigned to. Amazingly, they do not oppose or destroy each other but instead, they harmonized and achieve balance. All praise is to the Perfect and Absolute Creator.

Since man realized his existence in this world, the question of how the universe was created and how it ends up to be the way it is today, always has been a long struggle for him to find the right answer. Some do believe that by knowing how, may leads to the way of knowing why. These answers are important for them to plan and path their lives to become harmonize with the whole systems of existence. They knew that any other path will destroy these harmonies, balances and orders which will eventually lead to disasters and finally total destructions. The issue about the world is coming to the end due to biological engineering

predicted by Prof Stephen Hawking did aroused public concern (British Daily Telegraph, 2006).

Nature has always served as models of mimicking and inspirations for human to take advantage upon. Scientific approaches had helped humans understand related phenomena and associated principles in nature by adapting its mechanisms and its capabilities. They engineer novel devices and copy the system process so that they may enjoy more comfortable lives and more conducive working conditions. One such technology is called biomimetics (Yahya, 2006). It is the imitation of methods and systems found in nature to design engineering systems and to enhanced modern technology. A fine example is the development of dirt and water-repellent paint coating from the observation of the surface of lotus flower plant which never gets sticky for anything. The flower never gets dirty even though it lives in dirty swam, thus it is named 'The lotus effect' (Beynus, 2002). Other examples of biomimetics in engineering include the hulls of boats imitating the thick skin of dolphins and also sonar, radar, and medical ultrasound imaging imitating the echolocation of bats (Barbery et al., 1993). Over the years, more and more instruments are developed due to advancement of technology and, more and more events of the nature are understood. Sometimes, when knowing one system in nature leads to the understanding of other system in nature that has the similarity of structure and behavior. Two such systems are the system of brain and the system of the universe.

The structure of brain and its functions are indeed very complex. The brain control all function of the body, which include thoughts, memories, learning and behaviors. Hence, any disturbance or probing into the brain, such as surgeries has the possibilities of damaging it. The need to look into non invasive method has become necessary in order to study the brain effectively.

Epilepsy is a disorder of the brain. It is an event which disrupts the normal function of the brain. For people with epilepsy, problematic brain cells create abnormal electrical activities that cause seizures. A seizure may cause

"jerking" uncontrolled movements. In some cases, seizures cause only a loss of consciousness, a period of confusion, a staring spell or muscle spasms. But in other cases, seizures caused permanent damage to the brain that leaves the epileptic sufferers in coma, become permanently paralyzed and sometimes lead to their death. About half of all patients with epilepsy, there are no apparent cause that can be found. According to a study conducted by World Health Organization WHO in 2005, one in ten Americans will have a seizure at some time in their lives, and at least 200,000 have at least one seizure each month. Although epilepsy is as common in adults over 60 as in children under 10, 25% of all cases develop before the age of five. 50% of the cases develop before the age of 25. About 125,000 new cases of epilepsy are diagnosed each year and significantly enough, the number of children and adults that have never been diagnosed or treated before have epilepsy (World Health Organization, 2005). Our knowledge about epilepsy has been dramatically increase in the past few decades, but the lives of many people whose have to live with this disorder remain a tragedy. The epilepsy research community has continuous efforts on developing safe drugs and on inventing medical procedures that are able to control seizure. In addition to these effort is creating much better tools to diagnose epilepsy effectively. This research undertaken is part of this effort.

Normal brain function involves movements of millions of tiny electrical charges between nerve cells in the brain to different parts of the body. These delicate and complex tasks are carried out by interconnected sets of brain cells called neurons. The neurons transmit information via electric pulses across different parts of the brain. There are approximately 100 billion neurons in the brain. They are interconnected to each other making a long chain of pathways by approximately 10^{14} number of connectors or synapses. Electrical charges flow in an orderly way, allowing a smooth flow of tiny currents. When epilepsy attacks occur, this pattern is interrupted by unusual accumulation of ions at a particular location. Electrical repulsive force created by these accumulated ionic charges initiates a sporadic burst of electrical energy. The excessive electrical energy carried by clouds of charges will finally reach the surface of the head scalp and be detected by the EEG probes that are position all over the brain (Panayiotopoulos,

2010). Epileptic brainstorm of electrical charges or currents of energy can be seen in the EEG monitor as chaotic periodic peak of voltages, that is known as electrical brainstorm.

There are a lot of factors that can cause these disruptions. Among them are traumatic accidents, everyday life stress or traumatic surgery. Internal factors may include improper concentrations of salts within the neuron cell, over activity of brain chemicals known as neurotransmitters located between synapse at the site of nerve conduction or some other combination of these factors.

In order to study these events of brainstorm epilepsy, it is necessary to examine and study other system which is similar to it. The Big Bang phenomenon is an excellent candidate for such an event. The theory postulate that the universe was created from a single point which exploded and throwing matters in all direction. This is very similar to the burst of charges from its epileptic foci and traveling in all direction via 10^{10} neurons in the brain. The fact that there is almost infinite number of pathways, it makes it possible to assume randomness and all direction movements of these charges. The idea to associate these two events was inspired by the revealed knowledge from the Holy book of Al Quran.

إِنَّ فِي خَلْقِ ٱلسَّمَٰوَٰتِ وَٱلْأَرْضِ وَٱخْتِلَٰفِ ٱلَّيْلِ وَٱلنَّهَارِ
لَأَيَٰتٍ لِّأُوْلِي ٱلْأَلْبَٰبِ ﴿١٩٠﴾

"Undoubtedly, in the creation of heavens and earth and in the mutual alternation of night and day, there are signs for men of understanding (thinking)."

(The Holy Qur'an, 3:190**) (**Ahmad, 1995)

The Big Bang Model is a broadly accepted theory and currently the best theory to explain the birth and the subsequent evolution of our universe. It postulates that, at about 15 billion years ago, there was nothing. There was no space and no time. A process known as vacuum fluctuation created a point of gravitational singularity. Point of gravitational singularity is sometimes called point of nothingness because there is no space and no time flowing. It is an infinitesimally small, infinitely hot and infinitely dense point with infinite mass. An enormously huge gravity coming from this infinite mass pulls space around it into zero space or nothingness. From the theory of general relativity, time is the same entity as space. It is also being pulled and eventually going slow and finally stops. From this singularity point, a tremendous explosion gave birth to the universe and started the space expansion of the universe. At the same instant, time begins. Matters of the universe moves away from each other as the universe cools and as the time flows until 15 billion years later, the universe looks like what we observed today. See Figure 1.1.

If the clock is running backward to zero time, all galaxies in the universe today would move closer and closer together, until eventually they all get crushed together into point of singularity.

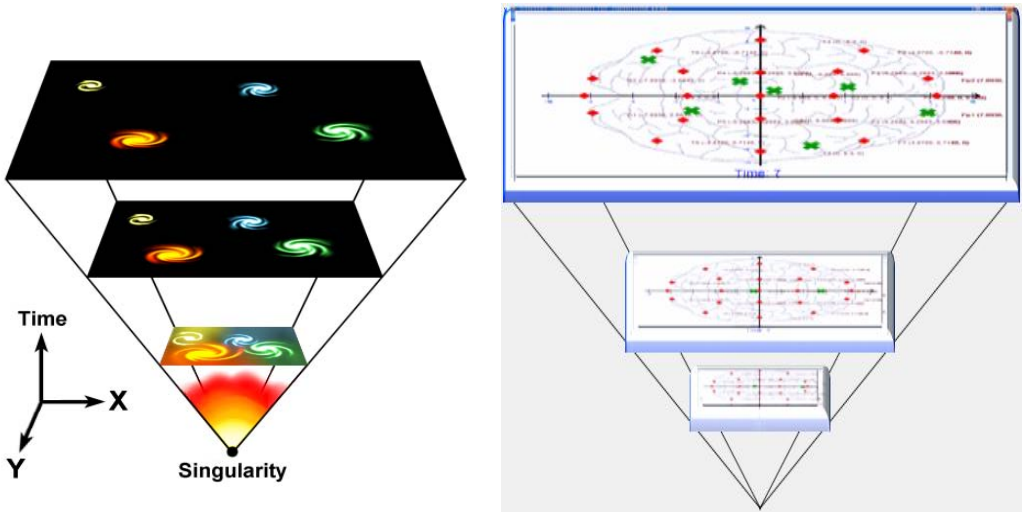

Figure 1.1 The spreading of galaxies from singularity is similar to the spreading of clusters of charges (green crosses) from epileptic foci (Big Bang, 2008).

A model will be developed that describes the bursting effect of the foci and the journey of electrical charges from these foci to the scalp of the brain. The model will be based on the bursting effect of the Big Bang and the subsequent expansion of the universe that follows. Later, in this research it was found that a lot of events that occur in the universe from its very beginning seem to repeat themselves again and again in different structures of the universe. Since the Big Bang theory is a theory that explains why he universe is like it is today, which starts from the time of big bang itself up to the current state, it is necessary to simplify the model by looking at structures that are similar to the Big Bang such as the supernova which is sometimes called the smaller Bangs, or the white holes, which are the inverse process of the black holes. Furthermore, fitting of the variables of the model and as well as making assumptions for the model later are much easier.

1.2 Statement of the problem

One third of patients with epilepsy usually do not response to medication for cure. This makes it necessary to surgically remove the problematic neuron cell that initiates the brainstorm. Sometimes it becomes the only option for cure. There is a case where doctor have to remove half of a brain in order to save a patient's life (Celizik, 2010). Multiple and constant reoccurrences of epileptic attacks damage the brain and the physical body of sufferers since they seems to hurt themselves each time the attack occurs such as severely knocking themselves to walls and floors rigorously. Therefore, knowledge of the exact location of the problematic brain cells becomes extremely important. To do this, qualitative measurements of data is necessary. Modeling in this case is the best option so far, since it gives us the output that is needed, with the data input that is available, without having to know every step of the event or process, especially when the event is extremely chaotic. Furthermore, when the data was collected was relative instead of exact, model have great freedom of multiple adjustments.

Modeling epileptic brainstorm is a difficult task simply because it is a very chaotic event and as well as very unpredictable one. Just like lightening that starts at a location and travel across the sky during stormy weather, epileptic brainstorm also starts at a point and spread across the whole brain. As sometime we see different array of lightening paths, starting from a few locations and then branching out in the sky, epileptic brainstorm event also has few epileptic foci burst at one time in which electric pulses branch out in neurons and spread across areas of the brain. These electric pulses are mixed and the signals recorded by probing device are also mixed. The task of locating where the attack starts and which problematic brain cells starts the abnormal firing of the electric pulses become almost impossible.

On the electroencephalography (EEG) monitor, the epileptic brainstorm is seen only as sudden peaks of voltages which lasted from a few seconds to minutes. These peaks of voltages however, are sufficient only to diagnose some of the neurological disorders qualitatively and to give qualitative information about the overall general activities of the brain. They do not point to where the epileptic foci situated or how deep they are inside the brain from the scalp area. In conclusion, doctors give only qualitative opinion based on those peaks of voltages. Those readings don't provide quantitative information on how the brain actually works. The needs for quantitative evaluation of epileptic brainstorm event therefore become necessary.

Therefore, this research will attempt to trace the electrical pulses paths of the brainstorm event right from the scalp of the head to the point where they started (i.e. the foci). It is an inverse problem. It will hopefully answer the question of how deep inside the brain the epileptic brainstorm starts.

1.3 Research Framework

The initial part of the research involves the detail study of two events which are the brainstorm epilepsy event and the Big bang event. Parallelism that occur in both events such as their process they undergoes, the energies that were generated, the evolution of structures that occurred were studied in detailed. This is to identify the relevant variables which will be used in the mathematical model and the irrelevant variables which should be discarded from the model. Furthermore, assumptions may have to be made when it become necessary to simplify the model. Hence, detail knowledge of the two events is eminent.

The second part of the research involves studying the physical laws and principles that govern the two events. Again, similarities between the two are taken into account. Relations in terms of equations are then noted. Einstein's new theory of gravitation that underlines the general theory of relativity is the backbone of the big Bang theory. Therefore, it is studied intensively. The Lambda Cold Dark Matter (ΛCDM) theory which is the extended part of the Big Bang theory explains about the evolution processes of all the celestial structures that we see in the universe today. The epileptic brainstorm has no yet rules for its chaotic event. So the study goes into getting information about the mechanics of detection and the reading techniques of EEG signals in order to understand and to interpret results of the model later.

The third part of this research is to develop and derive the mathematical model for the epileptic brainstorm event. It involves the derivation of the equation which has all of the available variables measurements detected from the brainstorm event.

The fourth part involves testing the model. Flat EEG data will be used. The results will be the paths of the electrical charges' journey as well as the location of these paths. The domains of these paths are further illustrated when they are plotted using the MATLAB. The results obtained will be compared to results

obtained using other methods. The research framework is summarized in Figure 1.2.

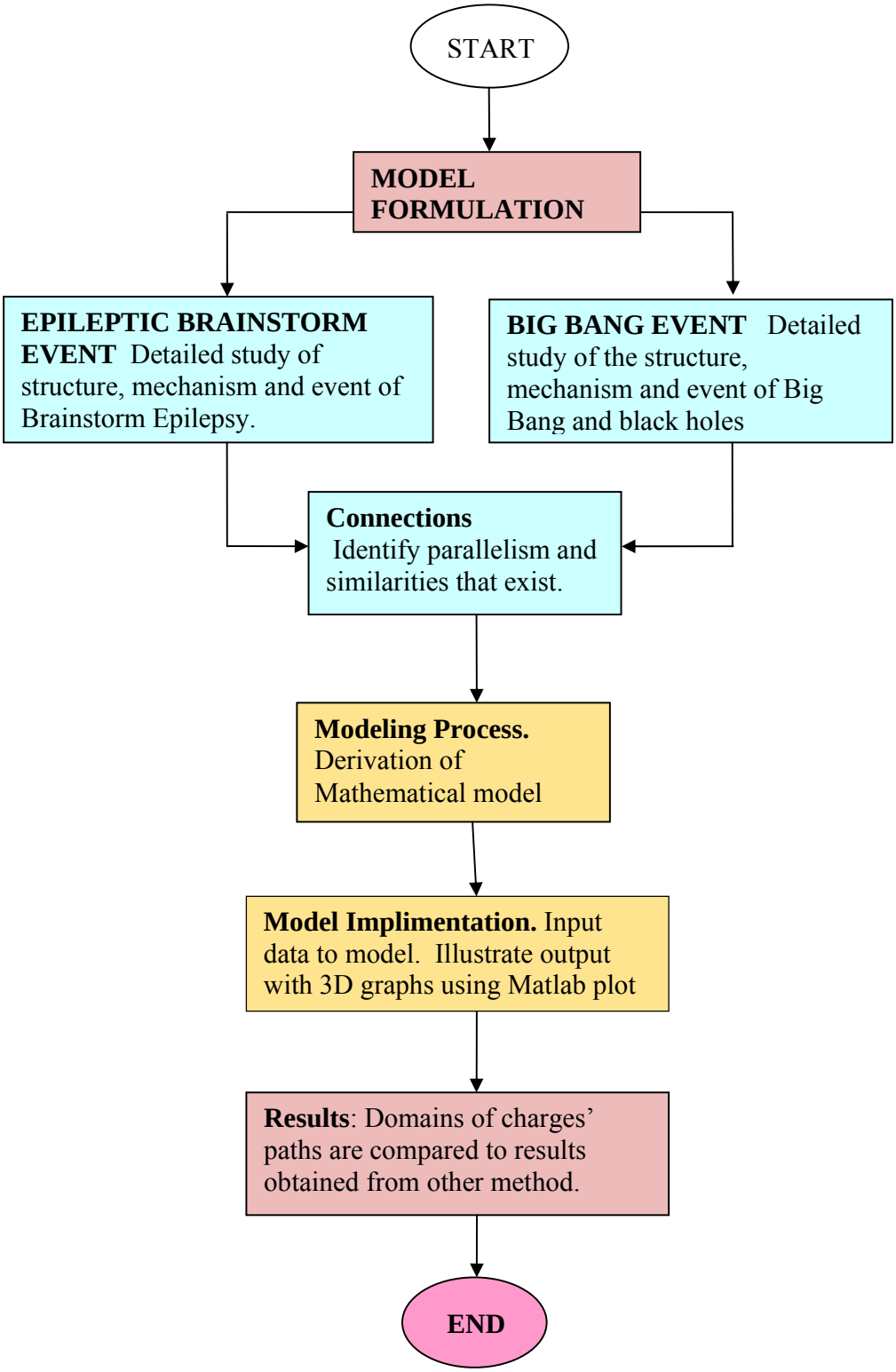

Figure 1.2 Research Frameworks

1.4 Research Scope

The scope of this research initially covered detailed study of three area of sciences, which are medical, cosmology and mathematics. The area of medical is the anatomy of brain which includes brain structure and its functional parts. The working mechanisms of the brain during normal function and during the event of epilepsy attack are studied. The encephalograph (EEG) is a device to record and read electrical pulses which is the activity of the brain. Real timed data which are represented on flat 2 dimensional surfaces as Flat EEG is used in this research.

The cosmological part of this research is the study of the event of Big Bang, the expansion and cooling of the Universe up to the formation of cosmic structure such as galaxies, stars and black holes. The dark matter and the dark energy are also discussed to highlight the energy of the ever growing and ever changing universe. The singularities of black holes and singularities before the big bang is carefully understand to formulate and model the brainstorm event.

General Relativity is written in the language of tensors. Hence mathematics of tensors and vector fields are carefully studied including the tensors of different manifolds in differential geometry. The solution to Einstein Field Equation of fluid dynamics excellently describes the expansion of the universe, i.e. the Friedmann–Lemaître–Robertson–Walker (FLRW*)* metrics, are intensively studied. Exact Electromagnetic Field solutions of this metrics which is Bertotti-Robinson electro vacuum solution is a solution for non rotating black holes. It is the one that being used in this research. Research scope is summarized in Figure 1.3 below.

THREE AREAS OF SCIENCES

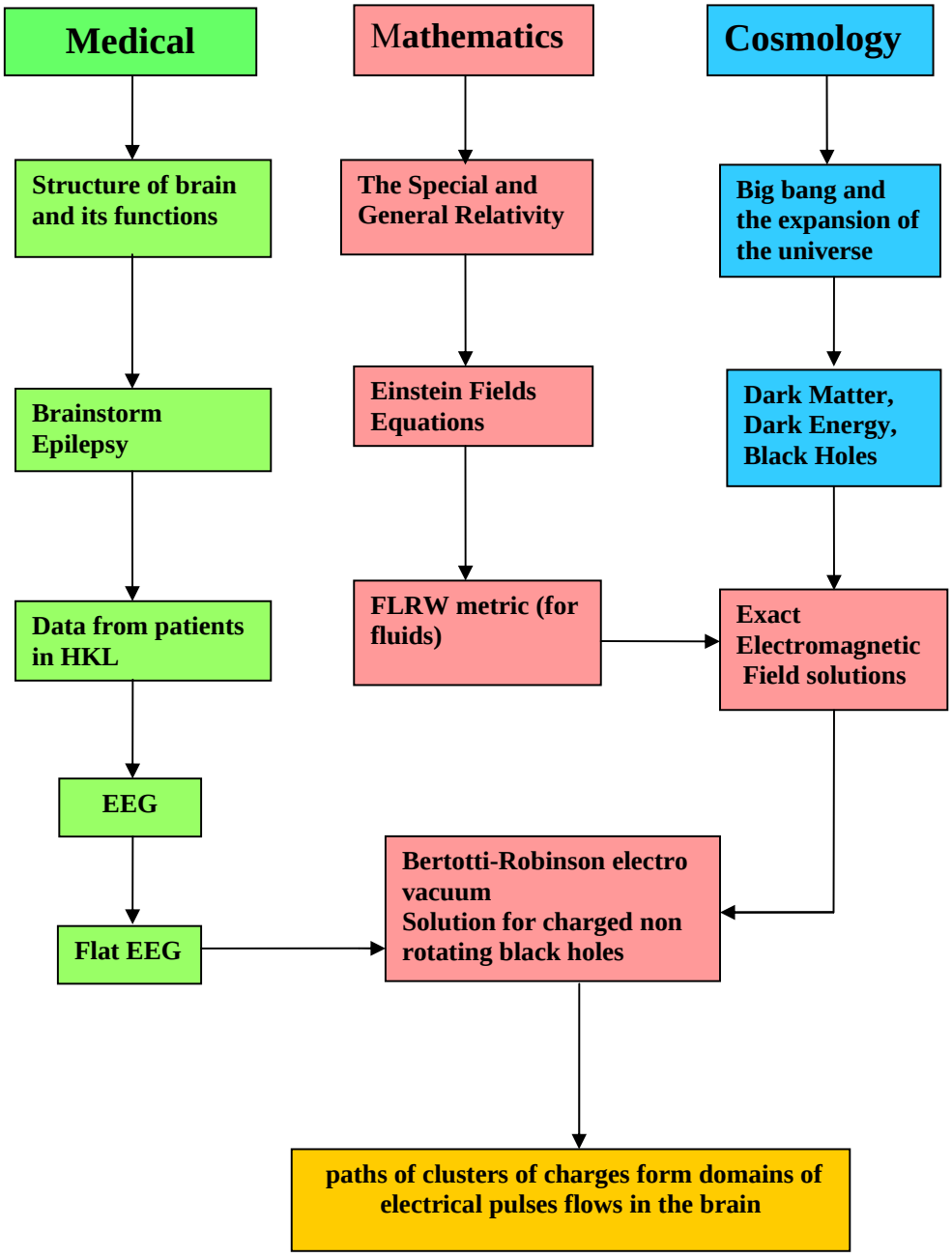

Figure 1.3 Research Scope

1.5 Research Objectives

- Information on the structure of the universe before and after the Big Bang including its current state.
- Stages of events that occurred, the evolution process and the rules and principles that governed these processes. Most importantly, sources of energy that enables those processes to take place.
- Information about structure of the brain and how it works normally and during epileptic seizures. Also, type of energy involved.
- Connecting the two events in order to find the similarities in either the structure or process or both.
- The behavior of the model uses the principles in the Big Bang theory. It represents the event process of the epileptic brainstorm in the simplest form and will process all inputs to obtain the desired output.
- Model is tested using Flat EEG. Result will be compared to pixel image method. Further verification involves calculating the number of pixel image points actually resides in spherical domain of electric pulses path. Error analysis of output will be conducted.

1.6 Outline of Presentation

Chapter 1 gives a brief introduction and overview of the whole research undertaken. It gives statement of the problems, research frameworks, research scope, and research objectives as well as significant of the research.

Chapter 2 discusses events of the epileptic brainstorm and the Big Bang event. It starts with discussion on their structure and then on their processes they undergo. The Big Bang event model that is proposed in this research will be discussed including its subsequent evolution of the cosmic structure, which include black holes, white holes, worm holes, dark matter and white matter because they are also part of the big bang theory itself. It also discusses about the structure of

human brain and its neuronal activity. History of seizure prediction and methods of its prediction is also part of this chapter. There are a few method of recording the EEG data with each of them has advantage depending on the diagnostic values that researchers are looking for. There is also short introduction of electroencephalography (EEG) instrument and its reading technique including detecting abnormal reading of epileptic seizures.

Chapter 3 discuss on parallelism and similarities that exists between the two events above in terms of structure and processes. Additional supportive evidences are also presented.

Chapter 4 starts with a topic of scientific model in general and then explaining mathematical model in detail. Every component of the modeling process will be related to the ongoing modeling of the epileptic brainstorm. The step by step process is further explained by the use of diagrams. Then the chapter presents the mathematics tools of the big bang event. The rules that govern the Big Bang event and its subsequent evolution is explained by the differential geometry of general relativity. Einstein Field Equation together with its solution related to the case of black holes is explained. The mathematical model that will be built is based on these solutions.

Chapter 5 starts with establishment of the axis of orientation which is crucial for detecting the approximate location of the signals or EEG reading. It then presents the established results from previous researcher which is the flattening of EEG signal which provides excellent data which identifies cluster centers of EEG signal. It also presents the equations for the transformation from 2 dimensional to 3 dimensional and theirs inverses. The derivation of radial distance of curved space then followed which is the mathematical model for this research.

Chapter 6 presents the table of flat EEG data and its diagram in two dimensional plain. Then, the results of the three dimensional data are tabulated in tables and illustrated in 3 dimensional coordinate after the transformation. Next,

domains of the ionic charges' tracks are calculated and the results are drawn in 3 dimensional graphs as interacting spheres. The results are compared to results using pixel image method.

Chapter 7 concentrates on error analyses that are performed in order to measure the accuracy of the results. It conform the validity of the model. Significant contribution of the research is highlighted.

Chapter 8 concludes the research and suggested a few ideas for further research on this same topic.

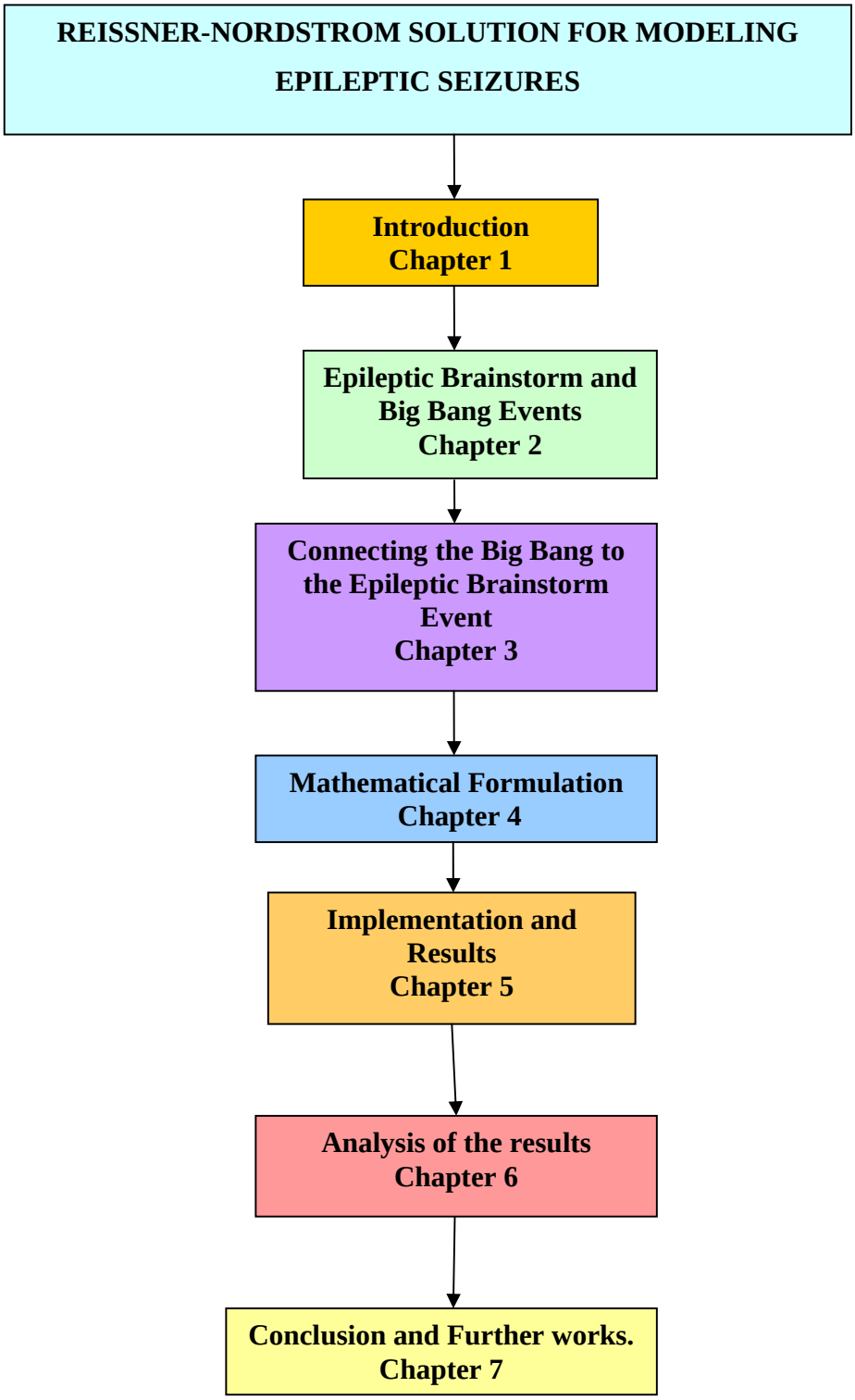

Figure 1.4 Outline of Presentation

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