AGENT BASED SOLUTION TO IDENTIFY THE PREDOMINANT FACTOR FOR MENTAL DISTURBANCE

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Declaration

I declare that this dissertation does not incorporate, without acknowledgment, any material previously submitted for a Degree or a Diploma in any University and to the best of my knowledge and belief, it does not contain any material previously published or written by another person or myself except where due reference is made in the text. I also hereby give consent for my dissertation, if accepted, to be made available for photocopying and for interlibrary loans, and for the title and summary to be made available to outside organization.

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Abstract

Literature shows that cultivation of cognitive capacities are negatively affected by five major mental factors, namely, Sensory desire, Anger or Ill will, Sloth torpor, Restlessness and Doubt. In many instances they do not appear in isolation, yet as a combination of one or more such factors. Sometimes a factor or more can cause to arise another. This complex behavior results in not being able to exactly determine which one of the factor is dominant. Identifying the dominant mental factor for the disturbance of a person had been a hard task to accomplish since it needs a proper mechanism and a criteria. Yet, it's essential to treat and overcome the disturbance. Identifying the dominant mental factor for the disturbance is a vital lead and kind of a initiative to few other research areas as well. Therefore research into identification of the mental factor that predominantly disturbs a person in his/her studies, daily life and career has become a paramount research interest. A research has been carried out to identify the predominant mental factor for disturbance of an individual by capturing and analyzing Electroencephalography (EEG) brain waves. The research has been conducted to capture EEG wave signals and to train an Artificial Neural Networks for sessions where we exactly know the dominant mental factor. The trained ANN has integrated with a Multi Agent Systems which receives output from ANN for a given EEG waves from of a person in a particular session as percentage values of above mentioned major mental factors, and deliberate on the output generated by the ANN to decide on the most probable. ANN has fourteen inputs which aligns with the sensors of Emotiv EPOC EEG headset and has five outputs which gives percentage values of each mental hindrance that was available in the fed brain wave. Multi agent system consist of five agents representing each mental factor. MAS enhances the result given by ANN and finally come up with the most dominant mental factor for the disturbance of the given brain wave based on mental hindrances. Accuracy of the final result thoroughly depend on data sets which has been used to train ANN and ontology of the agents.

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Chapter 1

Introduction

1.1 Prolegomena

Past few decades has shown a great improvement of usage in AI technologies in research and development perspective. AI technologies has been able to captivate researchers in many fields and has invaded almost all the technical and semi-technical subject areas by its outstanding ability solve various complex real world problems which could not be solved otherwise. In particular the real world systems involving large number of interconnected entities in a distributed environment under unpredictable uncertainty. With the increasing popularity in AI , numerous intelligent techniques including Artificial Neural Networks [1], Genetic Algorithms [2], Expert systems, Multi agent systems[3]. Among other AI techniques multi agent systems together with neural networks has provided effective solutions in cognitive neuroscience where brain-computer interface and human-computer interaction are comprised. One of them is Brain–computer interfaces (BCI) for communication and motor control[4] . Another research is to improve cognitive capacities of a person using BCI[5]. These days BCI is used to control devices[6] , improve mental heath[7] by analyzing brain waves. This project has been conducted to develop multi agent system based solution integrated with artificial neural networks to identify the predominant factor for mental disturbance. In this connection, this chapter itself presents aim and objectives, background and motivation, problem in brief, novel approach to identify predominant mental factor and structure of the overall thesis.

1.2 Objectives

The aim of this project is to develop a multi agent based solution integrated with neural networks in order to identifying predominant mental factor for mental disturbance of a person by analyzing EEG brain waves. In order to achieve this aim following objectives identified.

1. Study about mental factors for the disturbances.
2. Analytically study about cognitive neuroscience where brain-computer interface (BCI) and human-computer interaction (HCI) take place.
3. Critically study about any current approaches on finding out predominant mental factors for disturbance for a person.
4. In depth study on five mental hindrances (pancha neewarana).
5. Critically review the technologies that can solve the above problem with specific reference to multi agent technology.
6. In depth study about multi agent systems, neural networks and Encephalography (EEG).
7. Get hands on experience in capturing and analyzing brainwaves using EEG headset.
8. Design and develop multi agent system integrated with neural networks to identify the predominant mental factor identify the predominant mental factor.

1.3 Background and motivation

Advances in Cognitive neuroscience and brain imaging technologies together with artificial intelligence has facilitated everyone to interact with human brain directly. This was facilitated with use of various sensors which is used to monitor some physical processes that occur within human brain. Theses technology enhancement has been used by researchers to build brain-computer interfaces (BCIs), communication systems that do not depend on the brain's normal output pathways of peripheral nerves and muscles. In this kind of systems, users explicitly manipulate their brain activity to produce signals that can be used to control computers and other sophisticated devices like communication devices. In day today life people are mentally disturbed immensely. It has been effected to decrease the performance in there current engagements and involving. Currently there is no appropriate way to figure out the dominant mental factor for the disturbance. Considering the ultimate features of MAS and ANN, the research was initiated to address above mentioned dilemma.

1.4 Problem in brief

It is identified that there are five major mental factors that disturbs a person in his/her day today life. Though the occurrence of those five factors is complex, yet there is always one major factor at any given moment. Identifying this dominant factor has been a crucial task since the identification of the dominant factor is a big step forward which will enlighten a big area of research opportunities related to cognitive neuroscience. This has been considered as a difficult task but, yet a possible one.

1.5 Novel Approach to identify predominant mental factor for disturbance

The predominant mental factor for disturbance can be identified by analyzing EEG brain waves with applying neural networks and multi agent systems. First some known EEG waveforms are captured to train the artificial neural network. Such as waveforms from a person when he is full of anger, when he is full of laziness etc. An Emotiv EPOC headset [5] was used to record electroencephalograph data. Solution is capable of capturing a general brainwave from a person with EEG headset and input it to the ANN, after the process happened in ANN; it will output the percentage values of separate mental factors. A multi agent system is linked to the results of ANN; basically the system has 5 agents named with those 5 mental factors (attachment, anger, sloth, restlessness and doubt). Those agents may start deliberating upon those outputs received by ANN. Finally Multi Agent System is capable of coming up with final conclusion as the predominant mental factor that disturbed the person.

1.6 Resource Environment

The application has been developed with java JDK 1.7 + .NET 4.5 and can be executed in any operating system which supports java JDK 1.7 and .NET 4.5. Java library called JADE[8] has been used to form and manipulate agents in the program. Java library called NeuroPH [9] has been used to handle neural network functionality

of the application. MAS component and ANN component has been compiled to jar files and integrated with an exe application which runs on dotnet framework. All the Graphical User Interface(GUI) has been created with Visual Studio 2012 express(free students edition)[10]. Therefore running the application is simple as running a exe application.

1.7 Structure of the thesis

Rest of the thesis is organized as follows. Chapter 2 critically review the domain of Brain – Computer Interfacing with EEG brain waves and factors for mental disturbances by highlighting current solution, practices, technologies, limitations defining the research problem. Chapter 3 describe the essentials of multi agent technology, EEG brain waves and ANN showing its relevance to identify predominant factor for mental disturbance of a person . Chapter 4 present our novel approach to identifying dominating mental factor with multi agent technology. Chapter 5 is on the design of multi agent system combined with artificial neural network for identifying dominating mental factor for a disturbance of a person. Chapter 6 contains details of implementation of the MAS solution with ANN system for identifying dominating mental factor. Chapter 7 illustrates a real world application of the novel approach. Chapter 8 reports on evaluation of the new solution by explaining evaluation strategy, participants, data collection, representation and analysis. Chapter 9 concludes the outcome of the research with a note on further work.

1.8 Summary

This chapter described the full picture of the whole research project showing research problem objectives, hypothesis and novel solutions. Next chapter will on literature review of cognitive neuroscience associated with brain computer interface, technologies and issues with a view to define the research.

Chapter 02

Brain Computer Interfacing as a Research domain

2.1 Introduction

For generations, humans have been trying to communicate and interact with machines. The main blocker was 'how' ? Brain computer interfacing provided the answer to that question where people can communicate with any kind of machine with their brain. Friction stories, movies and other medias planted these ideas in human kind in a way that people feel that its not impossible. A lot of frictions books and movies show how a brain computer interfacing could work and what kind of marvelous applications are there. But only in recent past people made some big steps in brain computer interfacing. People use various other AI technologies such as Multi-agent systems, Artificial Neural Networks etc. as helping hands to these researches. Brain computer interfacing is an emerging field. Therefore people do lot of researched based on this. Some have done researches what may happen to the brain waves with the sleeping state of a person [11] . As found by the researchers our brain show a slow-wave activity in non-REM and sleep increases the EEG activity in the frequency range. Electroencephalography (EEG) in the differential diagnosis of dementia [12] is another interesting research that has done in the same domain area of this research but it doesn't talk about any mental disturbances of factors for it. Its mainly talking about how the research domain of EEG is supporting the diagnosis of suspected brain disorders. Cognitive Illusions as Hindrances to Learning Complex Environmental Issues [13] is another research carried out with regard to cognitive aspects of human by analyzing EEG brain waves. IT talks about teaching and learning complex issues is often confounded by the presence of simplistic mental models that are held by students. These simplistic models are described as "cognitive illusions" which could hinder the development and improvements of correct understanding of such issues in science. The study suggests that short-term

interventions can produce some degree of knowledge gains, especially at the factual level, but cognitive illusions continue to be very resistant to change.

2.2 EEG and brain waves as a current trend

Hans Berger, who discovered the human EEG, speculated in his first comprehensive review of his experiments with the "Elektrenkephalogramm" (1929) regarding the possibility of read brain waves by reading thoughts from the EEG which was done by using sophisticated mathematical analyses. Grey Walter, the brilliant EEG pioneer who described the contingent negative variation (CNV), often called the "expectancy wave," built the first automatic frequency analyzer and the computer of "average transients" with the willingness of discriminating not openly displayed thoughts and language in the human EEG (Walter, 1964). Fetz (1969) published the first paper on invasive operant conditioning of cortical spike trains in animals. Recent advancements of EEG and BCI had lead us to have this much of clear communications with our brain.

2.3 How far the brain computer interfacing has come

Regardless the human brain today computers have been developing rapidly. Its too closer on making science frictions in to realities. Getting closer and closer to an amazing technology which never existed before and which makes people to believe in impossible . Imagine someone could hear, see, feel by inputting some kind of sensor output. Imagine a world where people can manipulate machines and computers merely by a thought. It isn't about convenience for severely disabled people, development of a brain-computer interface (BCI) could be the most important technological breakthrough in decades.

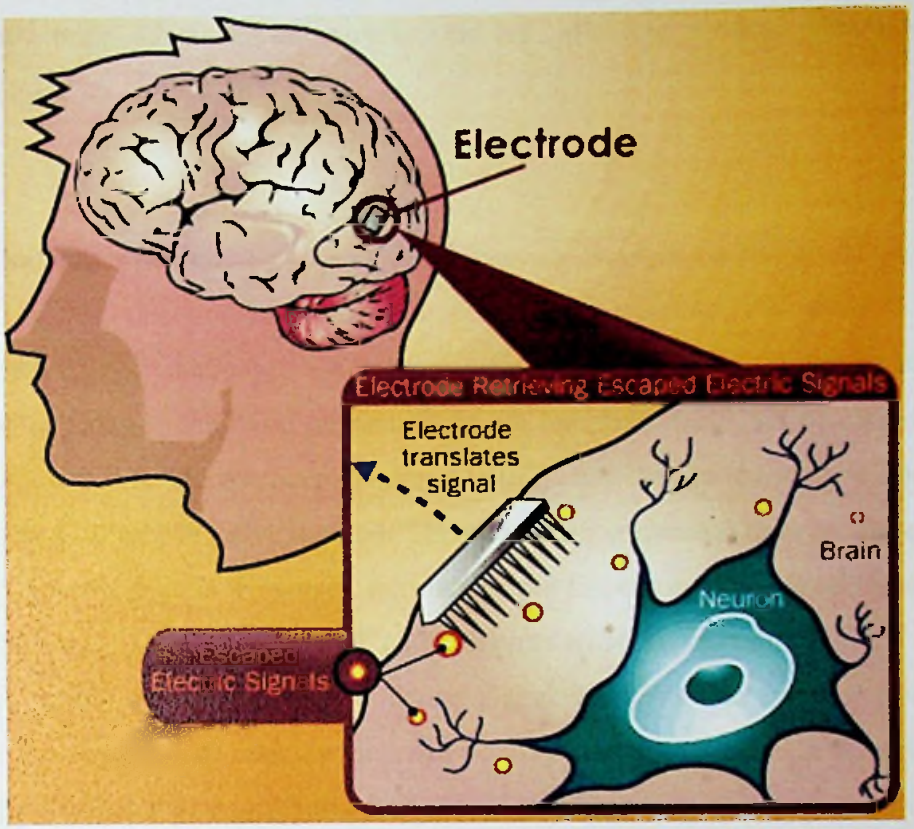

Figure 2.1 : How brain computer interfacing works

The reason a BCI works at all is because of the way our brains function. Our brains are fully composed of neurons, and those individual nerve cells are connected to one another by dendrites and axons. Every time we do some kind of a work like think, move, feel or remember something etc, our neurons are at work. Small electric signals which has the speed of 250 mph [14] and transfer from neuron to neuron will do the job. Those signals are generated naturally by differences in electric potentials (difference with compared to neutral) carried by ions on the membrane of each neuron.

Even though the signal paths are insulated by something called myelin[15], some of the electric signal escapes. Scientists have been able detect those signals and interpret what does that signal mean and use them to direct a device of some kind. It is possible to work in other way around as well. Which means it is possible to figure out which kind of signals are sent to the brain via optic nerve when someone sees a particular color[16]. They could rig a camera that would send those exact signals into

someone's brain whenever the camera saw red, allowing a blind person to "see" without eyes.

2.3.1 Challenges in BCI

One of the biggest challenges for brain-computer interfacing (BCI) for the research community today is the basic mechanics of the interface itself. Set of electrodes, a device known as an electroencephalograph (EEG) , attached to the scalp is known as the easiest and least invasive method. The electrodes connected to brain are capable of reading brain signals. However, because of the thickness of the skull, it blocks a quite amount of the electrical signal, and it distorts what does get through.

To get a much more efficient and strong signal scientists can implant electrodes much more closed to the brain, which will be gray matter area beneath the skull. But this approach has many problems, however. It requires invasive surgery to implant the electrodes, and devices left in the brain long-term tend to cause the formation of scar tissue in the gray matter. This requires surgical expertise knowledge and it has some ethical issues like researchers cant be risking their testers lives. Even if we do so this scar tissue ultimately blocks signals. Regardless of the location of the electrodes, the basic mechanism is the same: The electrodes are monitoring even the smallest difference in the voltage between neurons. The signal is then transferred to device where we can amplify it and filter it. In current BCI systems, computer applications or some advanced computer applications are used to interpret the signal. A computer is capable of converting signals from a input device to voltages. For an example a video camera takes video footages, then the computer turns them into the voltages necessary to trigger neurons. The signals are sent to a proper area of the brain, and if everything works correctly, the neurons fire and the subject receives a visual image corresponding to what the camera sees.

Magnetic Resonance Image (MRI) is an another approach to monitor brain activities. An MRI machine is a massive, complicated device. It is capable of producing high-resolution images of brain activity of the person at that particular moment, but it can't be used as part of a permanent or semi-permanent BCI. Researchers user MRI to

decide the most effective placement of electrodes inside the brain. By analyzing MRI scanned images researchers are capable of finding the best placement that could gain better transmittance of brain signals through out the experiment. For example, if researchers are trying to place the electrodes the process of someone to control a robotic arm with their thoughts, they might first put the subject into an MRI and ask him or her to think about moving their actual arm. The MRI will show which area of the brain is active during arm movement, giving them a clearer target for electrode placement.

2.3.2 BCI Applications

Fast moving and more attractive trend of the decade related to brain wave applications is devices that can be controlled by thoughts. Some of the applications are hard to believe or unimaginable; such as the ability to control a video game by thought. It takes everything to make your day today life more convenient. Changing channel in your television by mind, switching off / on your electrical appliances in home by using your mind. Imagine how convenient the world would be if BCI is taken its place properly.

Basically the bigger picture is there are devices that could re gain the ability to function independently for severely disabled people. For a quadriplegic, it will be something as basic as controlling a computer cursor via mental command. Which would tell the whole world about representing a revolutionary improvement in quality of life.

Early research used monkeys with implanted electrodes. The monkeys used a joystick to control a robotic arm[17]. What they did was , first monkey was asked to control the robotic arm using a joystick, meanwhile it's brain waves were monitored. Gradually scientists transferred robotic arm control authority to the signal coming through monkey's brain , not from the joystick.

Actually its very easy to explain the theory behind controlling a robotic arm or cursor using the brain. But if we maximized or pioneered the mechanism of converting brain waves to control some king of physical device, the opportunities, applications , usages etc are limitless. Cant even imagine where would this be stopped.

2.3.4 Drawbacks of BCI

Although we already understand the basic principles behind BCIs, they don't work perfectly. There are several reasons for this.

The brain is amazingly complex. Everything happens from simple electric signals. There are about 100 billion neurons in a human brain [18]. Each neuron is constantly sending and receiving signals through a complex web of connections. There are chemical processes involved as well, which EEGs can't pick up on. These tiny signals are like something as simple as the blinking eyelids. Which generates much stronger signals. More advancements in EEG related researches may find solutions for signal interference and implants will possibly overcome this drawback to some extent in the future, but for now, reading brain signals is like listening to a noisy phone call. There's lots of interferences. Needs more filtering and amplifying techniques.

Another issue is some BCIs still require a wired connection to the equipment and some are less than portable, and those that are wireless require the subject to carry a computer that can weigh around 10 pounds. Like all technology, this will surely become lighter and more wireless in the future.

2.3.5 Multi agent approach for BCI

Since brain waves are dynamic and complex, these patterns can be modeled in an agent platform. If we consider brain pattern discovery as a clustering problem, we could identify pattern clusters and assign them to Cluster Agents and the most prominent cluster can be identified by negotiation as the required emotion or the intention.

The emergence of consumer level portable brainwave detection devices makes it easy and cheap for researchers to develop BMI solutions effectively. Despite inherent problems of EEG, most devices use it for brain activity detection. Hence for this project, we intend to use a portable EEG device to detect brain activity. The raw

signal from EEG device will be fed to a multi agent system where it will identify patterns and assign the detected signals into clusters.

Hence, we propose that we could model this dynamic behavior of brain by means of developing a Multi Agent System and use this system to identify the most prominent signal pattern among the input signals. One major step in brain computer interfacing is the refinement of input signals from noise and "artifacts". However, since this process is a step in Digital Signals Processing (DSP), it is not one of the objectives or features of the proposed system. We assume that the signals are pre-processed and refined from artifacts and noise before being fed to our proposed system.

The proposed system starts with acquiring Pre-processed, noise removed EEG signals from multiple EEG channels. These EEG Signals are fed to system as EEG Records which contains information about the EEG Channel source, detected EEG Value as frequency or Voltage, Time sequence of the captured record and the sampling rate. These EEG Records are then mapped to an Agent called EEG Record Value agent which initiates the clustering process. The goal of the EEG Record Value agent is to find a suitable cluster or form a new cluster if a suitable cluster is not identified. Clusters are represented as "Cluster Agents". Cluster agents have a cluster evaluation function, which evaluates the Belongingness of EEG Record Values sent by EEG Record Value Agents. This is similar to applying for a membership of a club and club accepts members only on the membership criteria.
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2.4 Role of mental hindrances in researches

Many are the obstacles, which block the road to spiritual progress, but there are five in particular which, under the name of hindrances *(nivarana)*, are often mentioned in the Buddhist scriptures. They are called "hindrances" because they hinder and envelop the mind in many ways, obstructing its development *(bhavana)*. According to the Buddhist teachings, spiritual development is twofold: through tranquility *(samatha-bhavana)* and through insight*(vipassana-bhavana)*. Tranquility is grown by comprehensive attentiveness of the mind during the meditative engagements *(jhana)*. For attaining these concentrations, the overpowering of the five hindrances, at least temporarily, is a preliminary and must condition. Its more important to discriminate five hindrances in order to have more concentration and awake fullness. Most of the meditation and mindfulness related researches have mentioned about mental hindrances. But no one has taken the use of five mental hindrances to identify the mental disturbances in day today life so far.

2.4.1 Sensory desire

The hindrance of sensory desire (kamacchanda) is latching onto thoughts or feelings based on the pleasures of the five senses.

"Sensory desire refers to that particular type of wanting that seeks for happiness through the five senses of sight, sound, smell, taste and physical feeling. It specifically excludes any aspiration for happiness through the sixth sense of mind alone. In its extreme form, sensory desire is an obsession to find pleasure in such things as sexual intimacy, good food or fine music. But it also includes the desire to replace irritating or even painful five-sense experiences with pleasant ones, i.e. the desire for sensory comfort." kāma chanda are anything from the extremes of lust to just being concerned with how the body is doing. Thinking about the letter that you

have to write afterwards, about the rain pattering on your roof, about your kutī (monk's hut), or what needs to be built next, or were you are going to next, that's all in the kāmaloka, the world of the senses, that's all kāma chanda. It's also kāma vitakka, or the thoughts about those things, about family, about health, about coming here, going there, and thoughts about words. Traleg Kyabgon states: "This term alludes to the minds tendency to latch on to something that attracts it--a thought, a visual object, or a particular emotion. When we allow the mind to indulge in such attractions, we lose our concentration. So we need to apply mindfulness and be aware of how the mind operates; we don't necessarily have to suppress all these things arising in the mind, but we should take notice of them and see how the mind behaves, how it automatically grabs onto this and that."

The hindrance of sensory desire is compared to taking out a loan – any pleasure one experiences through these five senses must be repaid through the unpleasantness of separation or loss which invariably follow when the pleasure is used up. There is also interest to be repaid on the loan. Thus, the Buddha said that the pleasure is small compared to the suffering repaid.In order to overcome the hindrance of sensory desire (kamacchanda), the meditator must first apply mindfulness and recognize that the hindrance is present. Then one must look at the hindrance, analyze it, make it the object of our meditation, experience it fully. The meditator can then apply specific techniques such as contemplating the impermanence of the pleasant desire. Ajahn Brahmavamso emphasizes the technique of letting go of concern for the body and the five senses completely

In meditation, one transcends sensory desire for the period by letting go of concern for this body and its five sense activity. Some imagine that the five senses are there to serve and protect the body, but the truth is that the body is there to serve the five senses as they play in the world ever seeking delight. Indeed, the Lord Buddha once said, "The five senses ARE the world" and to leave the world, to enjoy the other worldly bliss of Jhana, one must give up for a time ALL concern for the body and its five senses. Kamacchanda can be compared to giving your approval for kāma-based thoughts and emotions to remain in your mind. It is allowing these thoughts to occupy your mind.

In the Pāli term kāma chanda, chanda is what you have to do if you cannot attend a meeting of the community of monks, and you want to give approval and agreement to what's happening there, you give your chanda to go ahead in your absence. It's agreement, approval, consent, and it's much more subtle than mere desire. This means that you are buying into, giving in to this, you want it, you approve of it, and you allow it to happen. In the same way that we have chanda in the Vinaya, we have that kāma chanda. It's as if you give your approval for the sensory world to be in your consciousness, in your mind, you accept it, approve of it, and you play with it, that's all chanda. It's letting it completely occupy the mind, and it's much more subtle than just mere desire. The kāma part of kāma chanda, that's all that is comprised in kāmaloka, the world of the five senses, which goes from the hell realms, the animal realms, the ghost realms, the human realm, and the Deva realms, to everything that is concerned with those kāmaloka realms. Kāma Chanda is acceptance, agreement, and consent for that world to occupy you.

2.4.2 Ill will (vyapada)

The hindrance of ill will (vyapada) is latching onto thoughts or feelings based on anger, resentment, hostility, bitterness, etc.

Ajahn Brahmavamso states: "Ill will refers to the desire to punish, hurt or destroy. It includes sheer hatred of a person, or even a situation, and it can generate so much energy that it is both seductive and addictive. At the time, it always appears justified for such is its power that it easily corrupts our ability to judge fairly. It also includes ill will towards oneself, otherwise known as guilt, which denies oneself any possibility of happiness. In meditation, ill will can appear as dislike towards the meditation object itself, rejecting it so that one's attention is forced to wander elsewhere." Traleg Kyabgon states: "The second hindrance is ill will; it is the opposite of the first hindrance, being brought about by aversion rather than attraction. Ill will refers to all kinds of thought related to wanting to reject, feelings of hostility, resentment, hatred and bitterness. When they arise, we should take note of them, not

necessarily suppressing them, but seeing how they arise."[19] The hindrance of ill will is compared to being sick. Just as sickness denies one the freedom and happiness of health, so ill will denies one the freedom and happiness of peace. The antidote to the hindrance of ill will (vyapada) is meditation on loving kindness (metta).

Ill will is overcome by applying Metta, loving kindness. When it is ill will towards a person, Metta teaches one to see more in that person than all that which hurts you, to understand why that person hurt you (often because they were hurting intensely themselves), and encourages one to put aside one's own pain to look with compassion on the other. But if this is more than one can do, Metta to oneself leads one to refuse to dwell in ill will to that person, so as to stop them from hurting you further with the memory of those deeds. Similarly, if it is ill will towards oneself, Metta sees more than one's own faults, can understand one's own faults, and finds the courage to forgive them, learn from their lesson and let them go. Then, if it is ill will towards the mediation object (often the reason why a meditator cannot find peace) Metta embraces the meditation object with care and delight. For example, just as a mother has a natural Metta towards her child, so a meditator can look on their breath, say, with the very same quality of caring attention. Then it will be just as unlikely to lose the breath through forgetfulness as it is unlikely for a mother to forget her baby in the shopping mall, and it would be just as improbable to drop the breath for some distracting thought as it is for a distracted mother to drop her baby! When ill will is overcome, it allows lasting relationships with other people, with oneself and, in meditation, a lasting, enjoyable relationship with the meditation object, one that can mature into the full embrace of absorption.

2.4.3 Sloth-torpor (thina-middha)

Sloth-torpor is a dull, morbid state that is characterized by unwieldiness, lack of energy, and opposition to wholesome activity.

Traleg Kyabgon states: "When this hindrance is present, we lose our focus in meditation. We may not be agitated in any perceptible way, but there is no mental clarity. We gradually become more and more drowsy, and then eventually go to

sleep." Ajahn Brahmavamso states: "Sloth and torpor refers to that heaviness of body and dullness of mind which drag one down into disabling inertia and thick depression. In meditation, it causes weak and intermittent mindfulness which can even lead to falling asleep in meditation without even realising it!" Ajahn Brahmavamso states: "The mind has two main functions, 'doing' and 'knowing'. The way of meditation is to calm the 'doing' to complete tranquility while maintaining the 'knowing'. Sloth and torpor occur when one carelessly calms both the 'doing' and the 'knowing', unable to distinguish between them."

Ajahn Brahmavamso states: "Sloth and torpor is an unpleasant state of body and mind, too stiff to leap into the bliss of Jhana and too blinded to spot any insights. In short, it is a complete waste of precious time." The hindrance of sloth-torpor is compared to being imprisoned in a cramped, dark cell, unable to move freely in the bright sunshine outside.

"Sloth and torpor is overcome by rousing energy. Energy is always available but few know how to turn on the switch, as it were. Setting a goal, a reasonable goal, is a wise and effective way to generate energy, as is deliberately developing interest in the task at hand. A young child has a natural interest, and consequent energy, because its world is so new. Thus, if one can learn to look at one's life, or one's meditation, with a 'beginner's mind' one can see ever new angles and fresh possibilities which keep one distant from sloth and torpor, alive and energetic. Similarly, one can develop delight in whatever one is doing by training one's perception to see the beautiful in the ordinary, thereby generating the interest which avoids the half-death that is sloth and torpor. Sloth and torpor is a common problem which can creep up and smother one slowly. A skilful meditator keeps a sharp look-out for the first signs of sloth and torpor and is thus able to spot its approach and take evasive action before it's too late. Like coming to a fork in a road, one can take that mental path leading away from sloth and torpor." Traleg Kyabgon states: "When this happens, instead of persisting with the meditation, it is better to try to refresh ourselves by getting up and going for a walk or washing our face, after which we return to our meditation."

2.4.4 Restlessness-worry (uddhacca-kukkucca)

The hindrance of restlessness-worry (uddhacca-kukkucca) refers to a mind that is agitated and unable to settle down.

Ajahn Brahmavamso states: "Restlessness [uddhacca] refers to a mind which is like a monkey, always swinging on to the next branch, never able to stay long with anything. It is caused by the fault-finding state of mind which cannot be satisfied with things as they are, and so has to move on to the promise of something better, forever just beyond. Remorse [kukkucca] refers to a specific type of restlessness which is the kammic effect of one's misdeeds."Traleg Kyabgon states: "The fourth hindrance is restlessness and worry, which refers to all the mental activities that go on in our mind due to its restless nature.Gil Fronsdal states: "The discomfort of restlessness creates an outward looking [tendency] – what can I do to fix this? What can I do to settle this? So the challenge in restlessness is how to turn towards it and be present for it and engage it." Restlessness (uddhacca) is compared to being a slave, continually having to jump to the orders of a tyrannical boss who always demands perfection and so never lets one stop.

Ajahn Brahmavamso states "Restlessness [uddhacca] is overcome by developing contentment, which is the opposite of fault-finding. One learns the simple joy of being satisfied with little, rather than always wanting more. One is grateful for this moment, rather than picking out its deficiencies. For instance, in meditation restlessness is often the impatience to move quickly on to the next stage. The fastest progress, though is achieved by those who are content with the stage they are on now. It is the deepening of that contentment that ripens into the next stage. Remorse [kukkucca] refers to a specific type of restlessness which is the kammic effect of one's misdeeds. The only way to overcome remorse, the restlessness of a bad conscience, is to purify one's virtue and become kind, wise and gentle. It is virtually impossible for the immoral or the self-indulgent to make deep progress in meditation. Gil Fronsdal states: "There are a variety of ways to engage restlessness, be present for it. One is learning, reflecting, meditating and contemplating what the nature of restlessness is. There might be a really good cause for you to be restless. Maybe you

haven't paid your taxes in ten years. In this case you don't need meditation, you need to pay your taxes. You don't use meditation to run away from the real issues of your life. Sometimes what's needed is to really look and understand are there root causes for being restless."

2.4.5 Doubt (vicikicchā)

The hindrance of doubt (vicikicchā) refers to doubt about one's ability to understand and implement the meditation instructions, as well as about the teacher and Buddhist teachings in general.

Ajahn Brahmavamso states: "Doubt refers to the disturbing inner questions at a time when one should be silently moving deeper. Doubt can question one's own ability "Can I do This?", or question the method "Is this the right way?", or even question the meaning "What is this?". It should be remembered that such questions are obstacles to meditation because they are asked at the wrong time and thus become an intrusion, obscuring one's clarity." Traleg Kyabgon states: "When we meditate in the presence of this hindrance, we have a constant nagging feeling: "How do I know what I am doing is right? How do I know if this thing really works and if I am not just wasting my time? How do I know what the Buddhist teachings say is true? How do I know if that what the meditation teachers have taught me is right and that they are not deluded? " Doubt is compared to being lost in a desert, not recognising any landmarks.

Such doubt is overcome by gathering clear instructions, having a good map, so that one can recognise the subtle landmarks in the unfamiliar territory of deep meditation and so know which way to go. Doubt in one's ability is overcome by nurturing self-confidence with a good teacher. A meditation teacher is like a coach who convinces the sports team that they can succeed. The end of doubt, in meditation, is described by a mind which has full trust in the silence, and so doesn't interfere with any inner speech. Like having a good chauffeur, one sits silently on the journey out of trust in the driver.

2.5 Summary

Most of the researches are to detect brain waves to handle some physical tasks mainly and some cognitive tasks a bit as well. BCI research fuels strong anticipation and belief of thought and emotion recognition and conversion from brain states. There's no proper research that has been carried out to detect and identify mental factors for a disturbance of a person's mind.

Chapter 3

Technologies Adapted

3.1 Introduction

In this research some major technologies used can be identified as follows. Multi agent technology, Artificial Neural Networks and Encephalography. Among that the core of this solution is a multi agent system. It's the crucial element or rather the major element that endures the shoulder of this proposed solution. Multi agent systems are systems composed of multiple interacting entities, known as agents. Agents can be considered as computer systems with two major capabilities. First they are capable of autonomous action, which deciding for themselves what they need to do in order to satisfy the given task or the designed objective. Second, they are capable of interacting with other agents not simply by exchanging data but by engaging various kind of social activity that we all engage in our day today life such as cooperation, coordination and negotiation etc.

3.2 Multi Agent Technology

3.2.1 Agents for Human- Computer Interfaces

The emergence of consumer level portable brainwave detection devices makes it easy and cheap for researchers to develop BMI solutions effectively. Despite inherent problems of EEG, most devices use it for brain activity detection. Hence for this project, we intend to use a portable EEG device to detect brain activity. The raw signal from EEG device will be fed to artificial neural network and then to a a multi agent system where it will identify patterns and assign the detected signals into clusters and based on the agent deliberation it will give out the final result.

Hence, we propose that we could model this dynamic behavior of brain by means of developing a Multi Agent System and use this system to identify the most prominent

signal pattern among the input signals. One major step in brain computer interfacing is the refinement of input signals from noise and "artifacts". However, since this process is a step in Digital Signals Processing (DSP), it is not one of the objectives or features of the proposed system. We assume that the signals are pre-processed and refined from artifacts and noise before being fed to our proposed system. And moreover a library has been used to filter brain wave noises and clean up the input before feeding in to the artificial neural network.

3.2.2 Multi Agent Terminology

Agent architecture – Basic structure and the behavior of agents. How they are formed, what are their duties and responsibilities, how they are interconnected, how they communicate etc.

Multi-agent organization – This basically tells about the whole system which is called as MAS and which is formed by set of agents Multi-agent system (MAS) is a technology widely used to model complex and dynamic systems in an efficient manner. One particular advantage of using MAS is its ability to adapt into dynamic environments and solve complex scenarios using message passing. Number of properties or features in multi agent systems can model the dynamisms and complexities very successfully. On the other hand, brain is the most complex organ in human body. It consists of billions of neurons and can process large amount of information simultaneously. There have been previous attempts to use multi agent technology brain computer interfacing. Yet these studies are mostly oriented around using multi agent technology to study brain activity and prediction, but not to model brain activity as agents in a multi agent system.

3.2.3 MAS Organizational model

In the last few years, a large variety of agent internal architectures were introduced by agent researchers and developers. Broadly speaking, MAS are organized in one of the following ways: hierarchy, flat organization (sometimes referred to as democracy), sub assumption, and a modular organization. Hybrid model are are even possible. Due to drawbacks of one system and advantage of another system, which means more accurately pros and cons of several systems can be eliminated and a better organization model can be formed by a hybrid system.

Since brain waves are dynamic and complex, these patterns can be modeled in an agent platform. If we consider brain pattern discovery as a clustering problem, we could identify pattern clusters and assign them to Cluster Agents and the most prominent cluster can be identified by negotiation as the required emotion or the intention.The emergence of consumer level portable brainwave detection devices makes it easy and cheap for researchers to develop BMI solutions effectively. Despite inherent problems of EEG, most devices use it for brain activity detection. Hence for this project, we intend to use a portable EEG device to detect brain activity. The raw signal from EEG device will be fed to a multi agent system where it will identify patterns and assign the detected signals into clusters. Hence, we propose that we could model this dynamic behavior of brain by means of developing a Multi Agent System and use this system to identify the most prominent signal pattern among the input signals.

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3.2.4 Multi Agent systems milestones and new horizons

Research in the area of Distributed Artificial Intelligence DAI has concentrated on developing computational contrivances by which multiple intelligent and

autonomous agents can efficiently coordinate. The field is reaching the end of its second decade of existence. As to be estimated this sub area of AI have ripened over time. Lately new stimuli and growths in related areas are helping restyle and vitalize the field. To affect the focus of interest of the active researchers the field has now adopted the name of Multiagent Systems in the past this name was used to refer to a sub area in the field. This growth was obeyed closely by the development of a new international conference in the area.

Like most of AI , MAS research have shifted focus from building grand unified theories to developing specialized techniques to address requirements fro well defined problem classes. I believe this trend will continue over the next few years primarily due to the need for developing fielded applications. To be successful, MAS technology should complement other well-understood technology developed in computer science. For example, MAS architectures can be gainfully employed for integrating multiple standalone legacy systems. Another area that is likely to receive increasing attention is the use of multiagent architectures for information retrieval or for developing digitized information repositories. The first genres of these systems are already being tested in university lab oratories. Other viable and highly probable application areas for MAS include electronic commerce over the internet. Long distance medical care electronic help desk platforms agents for managing integrating and disseminating information in organization wide information sources.

3.2.5 JADE as a Development Environment

JADE is a completely distributed middleware system with a flexible infrastructure allowing easy extension with add-on modules. This sophisticated framework provides the ability to create agents, define their behavior , their interconnections etc and many more. More additionally it provides an graphical user interface too. As JADE is written completely in Java, 3rd party custom made libraries are common, therefore huge community is around this remarkable framework to get their agents functioning properly as per their requirement, and thus offers a rich set of programming generalizations permitting developers to construct JADE multi-agent systems with somewhat slight knowledge in agent theory. JADE was initially

developed by the Research & Development department of Telecom Italia, but is now a community project and distributed as open source under the LGPL license.

3.3 Artificial Neural Networks

3.3.1 Background and overview of ANN

The first artificial neural network was invented in 1958 by psychologist Frank Rosenblatt. Called Perceptron, Main aim of it was to learn and model how human brain is working. Later this was used with more improvement for detecting and researching more on human brain cognitive capabilities. Eventually, people realized that in supplement to affording perceptions into the functionality of the human brain, this could be useful for further more researches accompanied with human brain. This could solve so many problems that standard computational devices were unable to solve, some of them were pattern matching, learning etc.

3.3.2 Structure of an ANN

ANN structure is very similar to actual brain neurons, it communicates each other neurons in order to accomplish certain task. Physically constructed neurons or it can be simulated by a digital computer. Each neuron takes many input signals, then, based on an internal weighting system, and produces a single output signal that's typically sent as input to another neuron. There are basically three layers, input layer ,out put layer and intermediate layers. These intermediate layers can be any amount as per the requirement of learning process. The input layer is to receive the input. The output layer is to return the final output. Usually one or more hidden layers are sandwiched in between the two. This structure makes it impossible to predict or know the exact flow of data.

3.3.3 Features of ANN

Artificial neural networks usually start out with randomized weights for all their neurons. This means that they don't "know" anything at first hand and must be trained , and it will learn to solve the particular problem for which they are intended. There are two methods for training an ANN, This categorization is upon the intended problem they are going to solve. A self-organizing ANN (often called a Kohonen after its inventor) is exposed to large amounts of data and tends to discover patterns and relationships in that data. Researchers often use this type to analyze experimental data. A back-propagation ANN, conversely, is trained by humans to perform specific tasks. Which is more similar to what we do as trial and error. During the training period output is evaluated whether it is correct or not. If it's correct, the neural weightings that produced that output are reinforced; if the output is incorrect, those weightings responsible are diminished and will be assigned an another accurate value for the next turn. This type is most often used for cognitive research and for problem-solving applications.

3.3.4 Current Applications of ANN

Since this ANN models human brain, this has been taken as the central processing unit where a learning process is required. A system which needs a self thinking ability, ANN will takes places. In most of the cases , kind of a severe issue that researches faced was having something that works as human brain. ANN has the answer to that. Early stages this was more to do pattern recognitions and speech recognition etc. But in later stages this was used to solve more complex problematic scenarios. Now ANN has been used in wide spectrum of area. Following list may provide necessary evidence.

Whole robotic industry, aeronautical engineering, and data analysis an prediction , and many more pattern recognition applications can be seen in today as ANN usages. Some of the areas can be listed as follows. In science and technology this has been used in may areas like odor analysis and identification, biological systems analysis, chemical compound identification, recognizing genes, pattern recognition, ground

level ozone prognosis, recipes and chemical, signal processing: neural filtering, physical system modeling, botanical classification, formulation optimization, polymer identification, ecosystem evaluation etc. In energy sector ANN has been used in areas like hydro dam monitoring, electrical load forecasting, power control systems, energy demand, predicting gas/coal index prices, forecasting, short and long-term load estimation etc. In financial sector this has been used in areas like economic indicator forecasts, stock market prediction, price forecasts, credit worthiness, fraud detection, credit rating, property appraisal, bankruptcy prediction etc. In medical sector also ann has been used quite a lot. In areas like treatment cost estimation, medical diagnosis, detection and evaluation of medical phenomena, patient's length of stay forecasts etc.

Financial	Medical	Industrial
Stock Market Prediction Credit Worthiness Credit Rating Bankruptcy Prediction Property Appraisal Fraud Detection Price Forecasts Economic Indicator Forecasts	Medical Diagnosis Detection and Evaluation of Medical Phenomena Patient's Length of Stay Forecasts Treatment Cost Estimation	Process Control Quality Control Temperature and Force Prediction
Science	Educational	Data Mining
Pattern Recognition Recipes and Chemical Formulation Optimization Chemical Compound Identification Physical System Modeling Ecosystem Evaluation Polymer Identification Recognizing Genes Botanical Classification Signal Processing: Neural Filtering Biological Systems Analysis Ground Level Ozone Prognosis Odor Analysis and	Teaching Neural Networks Neural Network Research College Application Screening Predict Student Performance	Prediction Classification Change and Deviation Detection Knowledge Discovery Response Modeling Time Series Analysis

Identification		
Sales and Marketing	Operational Analysis	HR Management
Sales Forecasting Targeted Marketing Service Usage Forecasting Retail Margins Forecasting	Retail Inventories Optimization Scheduling Optimization Managerial Decision Making Cash Flow Forecasting	Employee Selection and Hiring Employee Retention Staff Scheduling Personnel Profiling
Energy	Other	
Electrical Load Forecasting Energy Demand Forecasting Short and Long-Term Load Estimation Predicting Gas/Coal Index Prices Power Control Systems Hydro Dam Monitoring	Sports Betting Making Horse and Dog Racing Picks Quantitative Weather Forecasting Games Development Optimization Problems, Routing Agricultural Production Estimates	

Figure 3.3 – Applications of Artificial Neural Networks in various domains

3.4 Electroencephalography (EEG)

Brain wave signals are read by the EEG by placing electrodes on the scalp. It could measure weak(5-100 nano volts) electric signals generated by the brain. Because of the fluid, bone, and skin that separate the electrodes from the actual electrical activity, signals tend to be smoothed and rather noisy. Hence, while EEG measurements have good temporal resolution with delays in the tens of milliseconds, spatial resolution tends to be poor, ranging about 2–3cm accuracy at best, but usually worse.

3.4.1 Brain waves

Our thoughts, emotions and behaviors everything generates a electric pulse inside neurons in th brain, that electric signal is the communication medium between neurons. Brainwaves are produced by synchronized electrical pulses from masses of neurons communicating with each other. Brainwaves are detected using sensors(more correctly electrodes) placed on the scalp.

Our brainwaves differ fitting to out thoughts (what we're doing and feeling). When slower brainwaves are dominant we can feel tired, slow, sluggish, or dreamy. When we feel weird or hyper-alert high frequencies can be observed.

The explanations that monitor are only broadly descriptions – in real world things are far more complex, and brainwaves reflect different aspects when they occur in different locations in the brain.

Brainwave speed is measured in Hertz (cycles per second) and they are dived into bands delineating slow, moderate, and fast waves.

Delta brainwaves are the slowest but loudest brainwaves (low frequency and deeply penetrating, like a drum beat). They are generated in deepest meditation and dreamless sleep. Theta brainwaves occur most often in sleep but are also dominant in the deep meditation. Alpha brainwaves are dominant during quietly flowing thoughts, and in some meditative states. Alpha is 'the power of now', being here, in the present. Alpha is the resting state for the brain. Alpha waves aid overall mental coordination, calmness, alertness, mind/body integration and learning. Beta brainwaves dominate our normal waking state of consciousness when attention is directed towards cognitive tasks and the outside world.

Due to the simultaneous data processing and complex structure of brain, brain activity detection is itself a complex task. Interference from external sources is another issue when using EEG like technique for brain activity detection. Due to the complex nature of brain wave patterns, identifying the correct pattern corresponding to an emotion or an action is again a challenging task.

Beta brainwaves dominate our normal waking state of consciousness when attention is directed towards cognitive tasks and the outside world. Beta is a 'fast' activity, present when we are alert, attentive, engaged in problem solving, judgment, decision

making, and engaged in focused mental activity. Beta brainwaves are further divided into three bands; Low Beta (Beta1, 12-15Hz) can be thought of as a 'fast idle, or musing. Beta (aka. Beta2, 15-22Hz) as high engagement. Hi-Beta (Beta3, 22-38Hz) is highly complex thought, integrating new experiences, high anxiety, or excitement. Continual high frequency processing is not a very efficient way to run the brain, as it takes a tremendous amount of energy.

Gamma brainwaves are the fastest of brain waves (high frequency, like a flute), and relate to simultaneous processing of information from different brain areas. It passes information rapidly, and as the most subtle of the brainwave frequencies, the mind has to be quiet to access it. Gamma was traditionally dismissed as 'spare brain noise' until researchers discovered it was highly active when in states of universal love, altruism, and the 'higher virtues'. Gamma rhythms modulate perception and consciousness, disappearing under anaesthesia. Gamma is also above the frequency of neuronal firing, so how it is generated remains a mystery. The presence of Gamma relates to expanded consciousness and spiritual emergence.

Our brainwave profile and our daily experience of the world are inseparable. When our brainwaves are out of balance, there will be corresponding problems in our emotional or neuro-physical health. Research has identified brainwave patterns associated with all sorts of emotional and neurological conditions. Over-arousal in certain brain areas is linked with anxiety disorders, sleep problems, nightmares, hyper-vigilance, impulsive behaviour, anger/aggression, agitated depression, chronic nerve pain and spasticity. Under-arousal in certain brain areas leads to some types of depression, attention deficit, chronic pain and insomnia. A combination of under-arousal and over-arousal is seen in cases of anxiety, depression and ADHD. Instabilities in brain rhythms correlate with tics, obsessive-compulsive disorder, aggressive behaviour, rage, bruxism, panic attacks, bipolar disorder, migraines, narcolepsy, epilepsy, sleep apnoea, vertigo, tinnitus, anorexia/bulimia, PMT, diabetes, hypoglycaemia and explosive behaviour.

To alternate your brain waves ,by rule of thumb, any process that changes your perception changes your brainwaves. Chemical interventions such as medications or recreational drugs are the most common methods to alter brain function; however brainwave training is also very effective. Over the long term, traditional eastern

methods (such as meditation and yoga) train your brainwaves into balance. Of the newer methods, brainwave entrainment is an easy, low-cost method to temporarily alter your brainwave state. If you are trying to solve a particular difficulty or fine-tune your brainwave function, state-of-the-art brain training methods like neurofeedback and pEMF deliver targeted, quick, and lasting results.

3.5 Summary

MAS and ANN are two amazing technologies that threats conventional systems by doing the things which are more complex and considered as impossible. Because of that it has been able to grab the attention of not only the AI community but also in whole world. As a summary we can say that MAS and ANN is used a lot in brain computer interfacing while analyzing captured brain waves and generating final output as a result. There are a lot of features in MAS and ANN other than any other technology that will make it a success in designing and developing a solution for identifying dominant mental factor for disturbance of a person.

Chapter 04

Identifying Dominant Mental Factor for Disturbance

4.1 Introduction

With the facts in previous two chapters its obvious that multi agent system incorporated with artificial neural network system could be a potential approach to develop novel solution for identifying dominant mental factor for disturbance of a person. This chapter present our approach by describing the hypothesis, inputs outputs , process, features and users for novel solution for identifying the dominant mental factor for disturbance of a person. The solution has been made as DMF Finder , an acronym for Dominant Mental Factor Finder.

4.2 Hypothesis

The predominant mental factor for disturbances can be identified by analyzing EEG wave signals with the use of neural networks and multi agent systems.

4.3 Inputs

System will receive EEG wave signals generated by EEG headset which has 14 output channels. Emotive EPOC headset has wet sensors to get brain waves from human scalp.

4.4 Outputs

Output will be obvious as the system will state the predominant mental factor for the disturbance of that person at that particular moment.

Eg : anger

4.5 Process

System will use EEG brainwaves to analyze and generate the output. Some known brainwave patterns are used to train the ANN. First some known EEG waveforms are captured to train the artificial neural network. Such as waveforms from a person when he is full of anger, when he is full of laziness etc. An Emotiv EPOC headset (Emotiv Systems Inc., San Francisco, CA, USA) was used to record electroencephalograph data. SDK provided with EEG headset is used to get high quality raw EEG data. The headset was fitted with 14 Au-plated contact-grade hardened BeCu felt-tipped electrodes that were saturated in a saline solution. ANN is capable of giving the percentage values of each mental factor. Here we will use five hindrances. Agents in the system may start deliberating upon those percentage values. In this process 5 major types of agents namely AngerIllWillAgent, DoubtAgent, RestlessnessAgent, SensualDesireAgent and SlothTorporAgent are defined to the system. The knowledge required for these agents to operate are stored in a personal ontology of each. Ontology has knowledge required for identifying mental factors that can occur together, cannot occur together and factors that can cause to another factor etc. Further context-based details such as problem solution conclusion related information are also available in the ontology. The multi agent system is capable of giving the dominant mental factor after deliberating based on outputs provided by ANN.

4.6 Features

The following features are available with the system. Minimal resource usage, portable, easy to operate, Track record of history of mental disturbances of a person and wireless access to headset etc. We are using JADE library and JAVA open source platform. So the application can be installed and run in any Operating System. Since the solution is OS compatible.

4.7 Users

I hope this novel approach is a giant step forward in research community. For any person in today, a mental disturbance is a common issue. That may affect his/her studies, career, health and many other aspects. Once the dominant factor is identified for this mental disturbances treating that and cure it will be easy. So people who do mediation, teachers, students, sportsmen, doctors, psychiatric patients may get find the value of this solution.

4.8 Summary

This chapter discussed about the approach to find dominant mental factor for the disturbance of a person. Also, this chapter includes users of the system and non-functional requirements of the system. Next chapter, discusses the system design of the proposed system.

Chapter 5

Design of DMF Finder

5.1 High Level Architecture of the solution

The solution has been made up with two major components. ANN component and the MAS component. ANN gets brain waves from the EEG headset and process on the input. After the processing it output 5 values accordingly the percentages of five mental hindrances, which caused for the disturbance. MAS will start deliberate upon those five output values came from ANN. Finally the MAS component will give the final result which suppose to be the dominant mental factor for the disturbance. In later parts of this chapter will describe the solution components in detail.

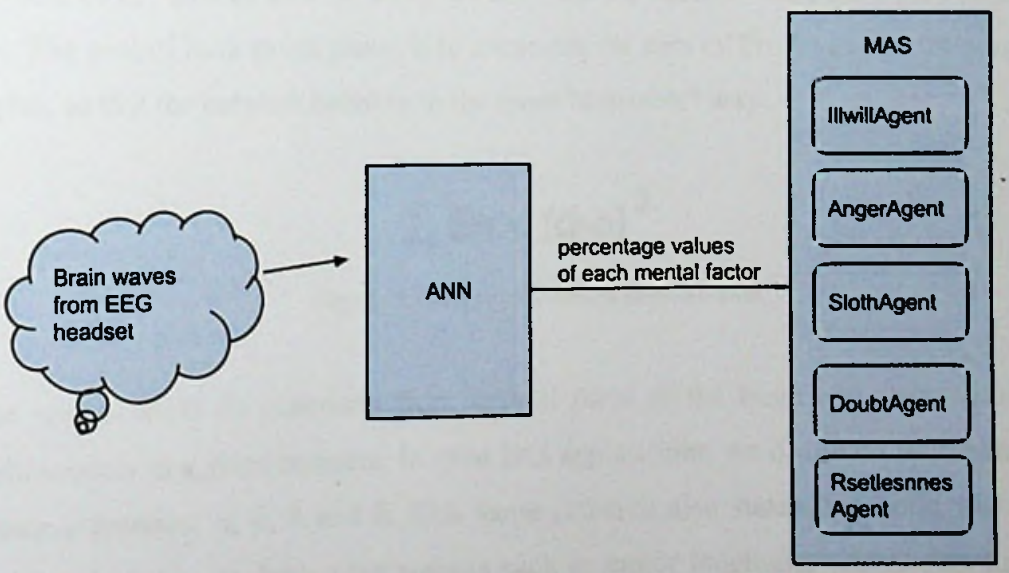

Figure 5.1: High Level Architecture of DMF Finder

5.2 Artificial Neural Network component

ANN component is the component which takes input on behalf of the system. This has fourteen input nodes and hidden layer with 14 nodes and a out put layer with 5 nodes. Back propagation has been used.

Learning in feed-forward networks belongs to the realm of supervised learning. There we feed input and output values to the neural networks for many cycles until the error goes lower the expected value. There the network learn the relationship between inputs and outputs. In back propagation learning, every time an input vector of a training sample is presented, the output vector o is compared to the desired value d.

The comparison is done by calculating the squared difference of the two:

$$Err = (d-o)^2$$

Figure 5.2 : Error calculation of ANN

The value of Err tells us how far away we are from the desired value for a particular input. The goal of back propagation is to minimize the sum of Err for all the training samples, so that the network behaves in the most "desirable" way.

$$\sum Err = (d-o)^2$$

Figure 5.3 : Error calculation minimization

These waves could be generated from several parts of the brain and may occur simultaneously in a given moment. In most BCI applications, we deal with four main brainwave patterns; α, β, δ and θ. This same research also states that brain wave signals could get noise from other sources such as motor functions, central nervous system and eye movement. Hence identifying the correct emotion involves careful analysis and using correct signal processing techniques.

The main issue with brain wave detection is the complexity of brain functionality. Brain is like a machine which runs continuously till the day a human die. Therefore, brain continuously process large amount on information in a particular time. Different parts of brain handle different activities. And for a given action/emotion/thought, multiple areas could be responsible. Millions of neurons fire simultaneously and all these generate electrical signals in different areas. Hence to monitor brain activity effectively it is required to cover the areas of brain as much as possible.

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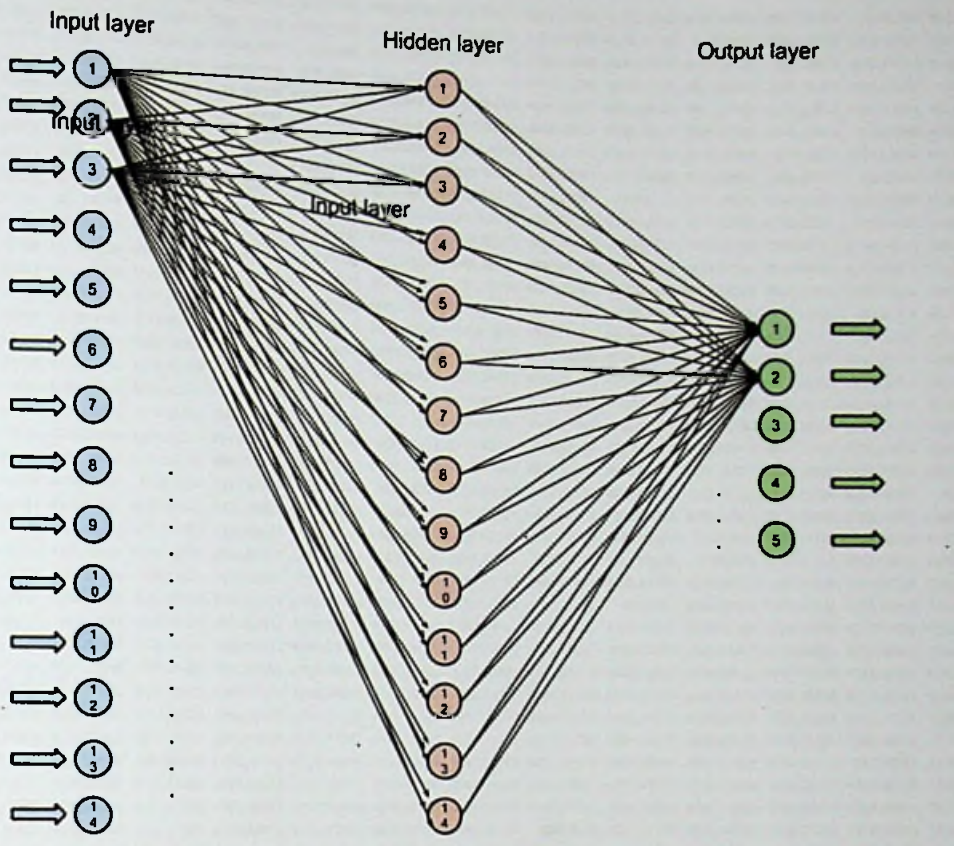

Figure 5.4 : Architechture of ANN

Neural network was fed by a csv file while training. The csv file contains a strea of everage values continuously captured brain wave. Example of a csv file can be showed as below. This is a section of that whole file.

4090.25631	4733.84604	4107.69221	4271.79477	4347.17938	4734.87168	4633.84604	3973.33324	4047.17939	4025.12811	4481.53835	4568.71784	4202.564	4329.23066
4097.94862	4735.3845	4114.35887	4273.84605	4344.61528	4734.35886	4623.58963	3975.89734	4053.33323	4036.92298	4492.8204	4566.15373	4213.33323	4343.07682
4098.46144	4736.92296	4116.41016	4273.84605	4346.15374	4731.79476	4617.43578	3976.92298	4053.84605	4039.48708	4491.79476	4567.6922	4215.89733	4345.64092
4088.20503	4732.8204	4108.20503	4266.66656	4346.15374	4735.3845	4624.10245	3974.8717	4046.15375	4026.15375	4478.46143	4569.74348	4203.07682	4330.2563
4083.58964	4728.71783	4102.05118	4264.10246	4344.61528	4736.92296	4625.64091	3973.84606	4044.10247	4021.53836	4472.30758	4567.17938	4195.38451	4325.64092
4091.79477	4729.74347	4108.71785	4266.66656	4346.15374	4733.33322	4624.10245	3977.94862	4048.20503	4030.76913	4474.87169	4566.15373	4199.9999	4334.35887
4099.48708	4733.33322	4117.94862	4269.74349	4349.74348	4733.84604	4630.2563	3977.4358	4050.25631	4038.97426	4479.99989	4567.6922	4203.58964	4337.43579
4099.9999	4733.33322	4119.9999	4270.76913	4348.71784	4735.89732	4632.8204	3975.38452	4049.23067	4037.94862	4479.99989	4568.20502	4202.564	4337.43579
4098.46144	4730.76912	4117.94862	4269.23066	4345.64092	4735.3845	4631.28194	3980.51272	4049.23067	4034.8717	4477.43579	4567.17938	4201.53836	4339.99989
4095.38452	4728.71783	4117.4358	4268.20502	4343.07682	4734.87168	4632.8204	3979.9999	4047.69221	4033.84606	4474.35886	4566.66655	4199.9999	4336.92297
4093.84605	4728.71783	4117.94862	4266.66656	4341.53836	4735.3845	4633.33322	3968.20503	4043.58964	4030.25631	4474.87169	4565.64091	4198.46144	4331.79477
4094.35887	4728.71783	4116.92298	4263.58964	4342.564	4734.35886	4631.28194	3966.15375	4044.61529	4023.58965	4474.87169	4566.66655	4197.43579	4332.30759
4093.84605	4726.15373	4116.92298	4265.64092	4343.58964	4735.3845	4629.74348	3972.3076	4049.74349	4019.9999	4474.35886	4569.23066	4198.46144	4339.48707
4097.4358	4728.20501	4120.51272	4271.28195	4345.64092	4736.92296	4631.79476	3973.33324	4052.82041	4019.9999	4484.10245	4567.6922	4202.564	4347.17938
4102.05118	4735.89732	4119.9999	4271.28195	4347.17938	4735.3845	4634.87168	3972.3076	4051.79477	4019.48708	4493.84604	4566.15373	4208.71785	4346.15374
4098.46144	4735.89732	4118.46144	4269.23066	4348.71784	4734.35886	4630.76912	3970.76913	4048.20503	4016.41016	4491.28194	4565.12809	4211.79477	4339.99989
4095.38452	4735.89732	4124.61528	4272.30759	4349.74348	4735.89732	4624.61527	3970.25631	4051.28195	4015.38452	4494.87168	4563.58963	4212.82041	4341.53836
4103.07682	4746.66655	4130.76913	4280.51272	4352.82041	4735.89732	4628.20502	3972.82042	4053.84605	4013.84606	4507.17938	4568.20502	4218.46144	4346.15374
4106.15375	4750.25629	4130.25631	4281.02554	4354.35887	4735.3845	4632.8204	3973.33324	4045.12811	4001.02554	4508.71784	4571.28194	4216.41015	4343.58964
4102.05118	4738.46142	4128.20503	4278.46143	4349.23066	4735.89732	4630.2563	3972.82042	4038.46144	3987.69221	4503.58963	4567.17938	4205.64092	4338.97425
4100.51272	4736.92296	4129.74349	4280.51272	4349.74348	4733.33322	4629.23066	3978.97426	4046.15375	3991.28195	4506.15374	4565.12809	4208.20503	4340.51271
4097.4358	4746.66655	4128.20503	4279.9999	4357.43579	4737.9486	4632.8204	3978.46144	4053.33323	4000.51272	4510.76912	4568.71784	4213.84605	4342.564
4092.82041	4744.10245	4123.07682	4278.46143	4358.97425	4749.23065	4632.8204	3973.33324	4052.82041	3997.4358	4508.20502	4571.28194	4208.71785	4336.92297
4094.35887	4738.46142	4121.53836	4278.97425	4356.41015	4744.61527	4633.33322	3978.46144	4052.30759	3993.33324	4507.6922	4569.74348	4208.20503	4333.84605
4096.41016	4743.07681	4119.48708	4278.97425	4356.92297	4735.3845	4635.3845	3986.15375	4054.8717	4001.02554	4510.2563	4567.17938	4215.38451	4339.48707
4094.35887	4744.61527	4115.89734	4278.97425	4356.92297	4742.05117	4632.8204	3986.15375	4058.97426	4005.64093	4510.76912	4567.17938	4215.89733	4342.05118
4093.33323	4742.05117	4116.41016	4281.02554	4357.43579	4751.28194	4634.35886	3985.12811	4060.51272	4002.564	4508.20502	4568.20502	4214.35887	4341.02553
4092.82041	4744.61527	4119.9999	4282.05118	4361.53835	4749.74347	4642.56399	3992.82042	4063.07682	4003.07683	4508.71784	4568.20502	4217.43579	4341.53836
4095.38452	4749.23065	4123.58964	4281.02554	4360.51271	4745.12809	4639.99989	3997.4358	4066.15375	4009.23067	4509.74348	4565.64091	4215.38451	4342.05118
4097.94862	4747.17937	4124.10246	4283.07682	4361.02553	4743.58963	4630.76912	3991.28195	4065.64093	4008.71785	4508.20502	4565.12809	4215.38451	4342.05118
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4089.23067	4736.92296	4113.33323	4275.89733	4359.99989	4744.61527	4636.41014	3996.41016	4064.61529	4006.15375	4505.64092	4569.23066	4211.28195	4339.48707
4090.76913	4733.84604	4113.33323	4275.89733	4356.92297	4743.07681	4632.30758	3996.92298	4061.53836	4004.10247	4505.64092	4568.71784	4203.58964	4335.89733
4096.92298	4740.5127	4119.9999	4281.53836	4358.46143	4739.48706	4629.23066	3994.35888	4057.94862	4001.53836	4505.12809	4566.15373	4211.28195	4340.51271
4101.02554	4748.20501	4128.20503	4285.64092	4358.46143	4735.89732	4636.92296	4004.10247	4063.58964	4007.69221	4509.74348	4564.10245	4222.05118	4349.23066
4101.53836	4743.07681	4127.69221	4285.64092	4355.38451	4734.35886	4643.07681	4006.66657	4068.20503	4013.33324	4516.41015	4566.66655	4218.97426	4354.35887
4098.97426	4733.33322	4122.05118	4283.07682	4355.38451	4734.87168	4636.92296	3992.30759	4059.9999	4007.17939	4510.76912	4569.23066	4216.41015	4351.28194
4098.46144	4735.89732	4126.15375	4281.02554	4355.89733	4734.87168	4630.76912	3989.23067	4051.79477	4002.564	4506.15374	4567.6922	4219.48708	4349.23066
4105.1281	4745.12809	4134.35887	4284.10246	4357.94861	4735.3845	4631.28194	3996.41016	4059.48708	4010.25631	4516.92297	4569.23066	4218.97426	4355.38451
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4101.53836	4739.48706	4129.74349	4285.1281	4360.51271	4738.46142	4628.71784	3996.41016	4056.92298	4015.89734	4507.17938	4568.71784	4217.94861	4356.92297
4099.48708	4736.92296	4123.58964	4284.10246	4356.92297	4736.92296	4629.23066	3991.28195	4058.46144	4017.94862	4512.8204	4570.2563	4219.48708	4356.41015
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4088.71785	4733.33322	4112.82041	4278.97425	4356.92297	4733.33322	4627.17937	3998.97426	4053.33323	4012.30759	4506.66656	4569.74348	4214.87169	4346.15374
4090.25631	4732.8204	4115.89734	4278.97425	4358.46143	4732.30758	4622.05117	3999.48708	4050.25631	4007.17939	4504.61527	4568.71784	4215.38451	4343.07682
4088.71785	4735.89732	4115.89734	4282.564	4356.41015	4733.33322	4623.58963	3997.94862	4051.79477	4009.23067	4502.56399	4568.20502	4215.89733	4339.99989
4089.23067	4738.97424	4114.87169	4283.58964	4359.99989	4737.9486	4628.20502	3998.97426	4052.30759	4011.28195	4504.61527	4569.74348	4215.38451	4339.99989
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4091.79477	4743.07681	4116.92298	4285.1281	4365.64092	4733.33322	4632.8204	4001.53836	4048.71785	4011.28195	4504.10245	4568.20502	4217.43579	4346.15374
4093.84605	4748.20501	4121.02554	4287.6922	4366.66656	4738.97424	4629.74348	3995.38452	4051.28195	4015.38452	4504.10245	4566.66655	4219.48708	4351.79477

Figure 5.5 : CSV file segment of a captured brain wave

5.3 Multi Agent component

Multi Agent System compromise of five agents representing five mental hindrances and a initialize agent. It takes the out put from ANN as a input the discuss upon those values. Basically the system has 5 agents named with those 5 mental factors (attachment, anger, sloth, restlessness and doubt). Those agents may start deliberating upon those outputs received by ANN. Finally Multi Agent System is

capable of coming up with final conclusion as the predominant mental factor that disturbed the person.

MAS enhances the result given by ANN and finally come up with the most dominant mental factor for the disturbance of the given brain wave based on mental hindrances. Accuracy of the final result thoroughly depend on data sets which has been used to train ANN and ontology of the agents. Agents have two way communication among agents.

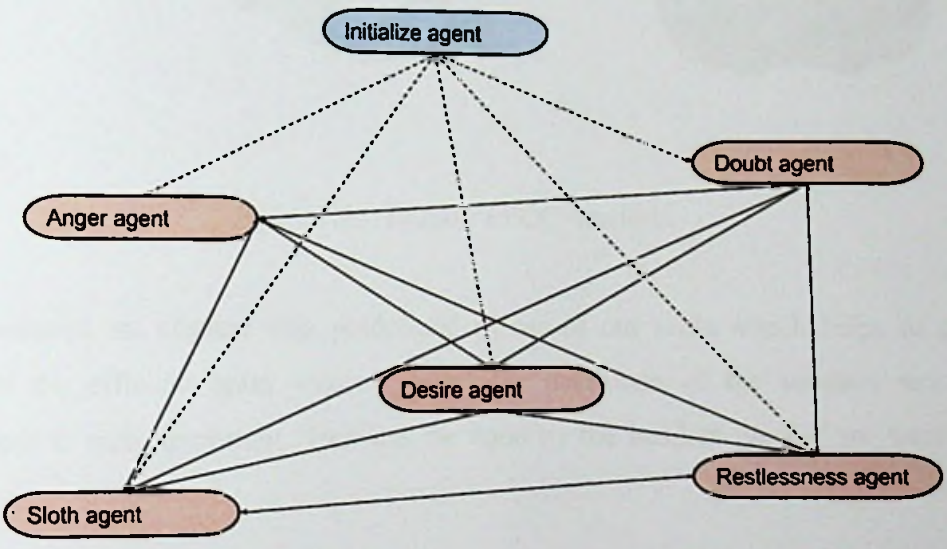

Figure 5.6 : Communication model of agents

5.4 Brainwave capturing using EEG

The device called Emotive EPOC headset captures brain waves. It has fourteen sensors. When the EPOC control panel says all the sensors are noise free then we are ready to capture brain waves from our solution.

Figure 5.7 : Emotiv EPOC headset

These sensors are aligned with predefined places of our scalp which helps to get more of the efficient brain waves. To get the maximum of the solution sensor placement is quite important. That will be done by the headset itself if we wear it properly.

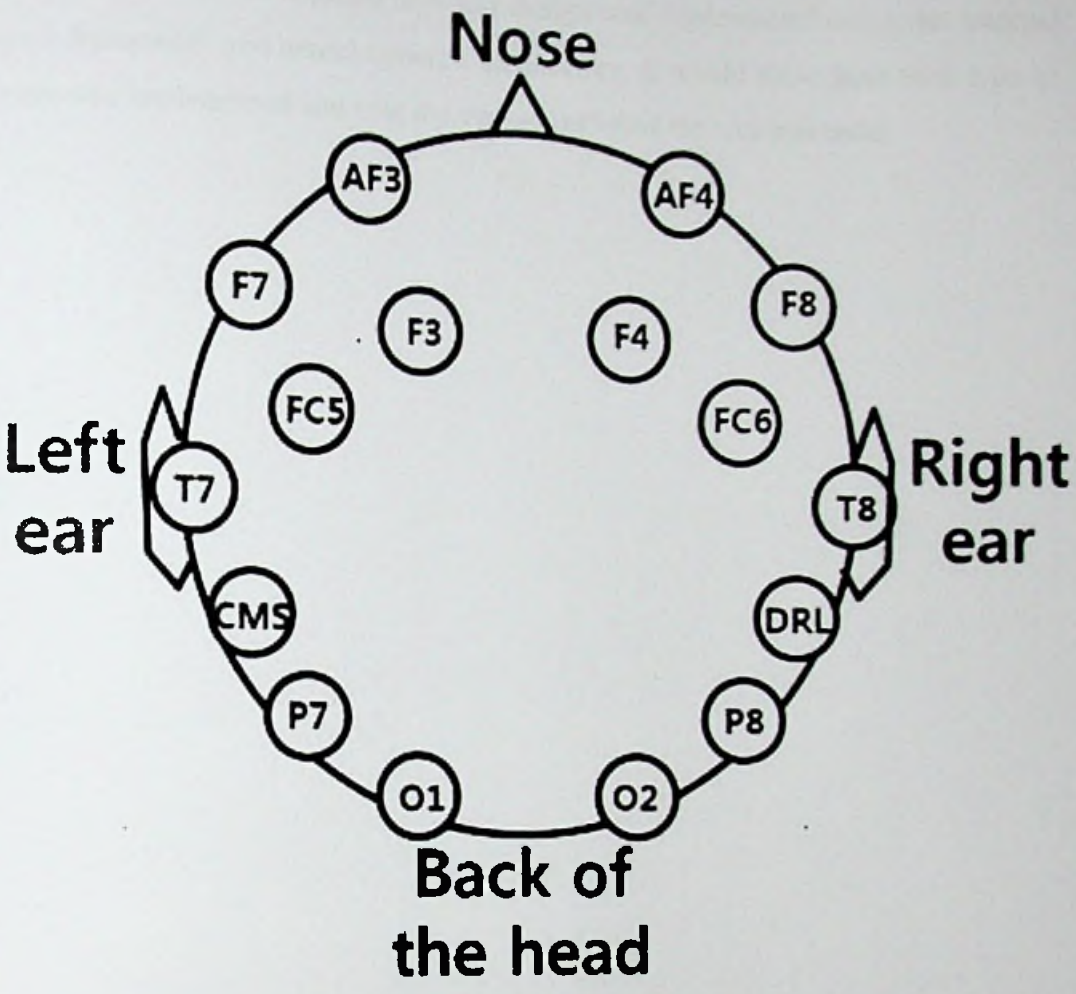

Figure 5.8 : Sensor placement on the scalp of EEG headset

5.5 Summary

This chapter discussed about the design of DMF Finder. Discussed the ANN architecture and MAS model used in the solution. There are several agents involved in the MAS who communicate and negotiate in order to carry out an action as per user's brain activity. The multi agent system would acquire continuous EEG signals coming through an EEG device and identify emotions or intentions within those signals.

The next section will describe how this design was implemented using the selected agent framework and neural network architecture. It would show how each type of agent was implemented and how the system performs the required tasks.

Chapter 6

Implementation of DMF Finder

6.1 Introduction

Previous chapters discussed about the topic of brain computer interfacing, complexity, multi agent technology and how multi agent technology can be used as an effective method for brain computer interfacing. And the usage of ANN when analyzing brain wave patterns etc. Last chapter described the design of the proposed solution in this thesis. This chapter discusses how to implement the proposed solution based on the design given in Chapter 5.

6.2 Artificial Neural Network Implementation

To implement artificial neural network we have used open source library called "NeuroPH"[21]. NeuroPH can be named as the best ANN forming tool available for java developers. Its light weight. It is open source. Also has nice user friendly GUI. Has more features than any other library which is available open source for java developers so far. There is a huge community around this as well. Therefore knowledge gathering is a easy task for the users of this library.

There were some researches[22,23,24,25] done using EEG brainwaves captured by Emotiv EOPC headset. I was able to grab those sample data which were tested thoroughly and most suitable for my scenario as well. For an example I needed some known brain waves of a person who is in full anger. Like wise I wanted to train my ANN with known data. I used data from above mentioned researches to train my ANN. But I used 80% of them , and kept 20% of them to test the system.

6.3 Multi agent Implementation

To develop the proposed multi agent system, a multi agent framework is also required. Since multi agent frameworks have the core functionality of a multi agent system, it would be appropriate to use such framework. After studying several multi agent frameworks, the "Java Agent DEvelopment Framework (JADE)" was chosen as the framework to build the proposed system. This framework was developed by Telcom Italia Lab and conforms to Multi Agent standards such as FIPA and ACL.
Multi agents contain rules which are formed from the behaviours of mental hindrances. Source code of agents can be found in Appendix. I used Ajahn Brahmawansa thero's book[26] and some other sources[27,28,29] to get the behaviours and inter combination of five mental hindrances. And I met a monk who lives in a aaranya senasana and grabbed some awesome knowledge about mental hindrances. Based on those findings I defined the rules of the agents. Some of the rules can be summarized as below.

- Sense desire arises because of pleasant sense experience.
- Sloth and desire can't be together
- Anger causes restlessness
- Doubt causes anger
- Doubt causes restlessness
- Anger causes sloth
- Ill will(anger) and sense desire are simillar, we are strongly attached to an object

With the call of the initialize agent all the agents are given the value which they deserve from the ANN output. When running agents are having another value which changes dynamically according to the agents discussion. While running in the agent message parser its clearly visible that the values own by agents are changing.
According to above bullet point data agents run with switching values, assigning new values, reducing values, increasing values, neglecting suggestion etc. This MAS

rules are based on mental hindrance behaviors and features, therefore if the causer value is greater than causee value then decision is taken as causer is dominant. if not causee can have the causers value. Check rules for assigned value for each time when the new value is assigned for a particular agent , like sloth n desire can't be together ,anger causes sloth n restlessness , therefore on of these three should be dominant. Compare and switch ill will and sensory desire agents' values. Because they are quite similar in appearance. Sometimes they switch the values and see how it goes. Update and check with both values swapping. If all the rules are satisfied then proceed to next discussion or the suggestion and that assigned value will be confirmed. Otherwise the process will break from that point and discussion will go in another direction.

6.4 Integrating components with GUI

GUIs is been created using .NET framework and have integrated all the component as jar files via JVM integrator for dot net. For that I have used IKVM.NET [30]. IKVM.NET is the best tool for developing .NET applications in JAVA. This will provide the feature for the developer to use existing JAVA API's and libraries which are written in a .NET language. So the developers get the ability to develop use .NET to develop applications with JAVA libraries in cooperated with it. I have used C# for making DMF Finder.

A powerful .net library has been used to integrate core functionality with the GUI of DMF Finder. IKVM.Net is been used as the mediator between .net platform and JDK plat form in order to get this DMF up and running with total functionality.
IKVM.NET is a powerful library that give the user the capability of running a java virtual machine .net. And also it supports to implement .net libraries using java libraries. Simply it can be considered as a .net implementation of more sophisticated java libraries that lack the availability with .net environment. .Net version 4.5 has been used and java JDK 1.6 has been used to develop this sophisticated DMF Finder. C# has been used and all the GUI work has been done in .net.

There are sections in GUI to train neural network , or simple use the existing trained network. And there is the main functionality to get the out put just from the ANN or after further processed with MAS. All the features are made user friendly so that its easy to learn and use the application.

Figure 6.1 : Flash screen of DMF Finder

The main screen is as follows. It contains four major aspects

- Run EPOC control panel, which is provided by the Emotive SDK.
- Capture brain waves
- Run multi agents
- Train neural network
- Find DMF

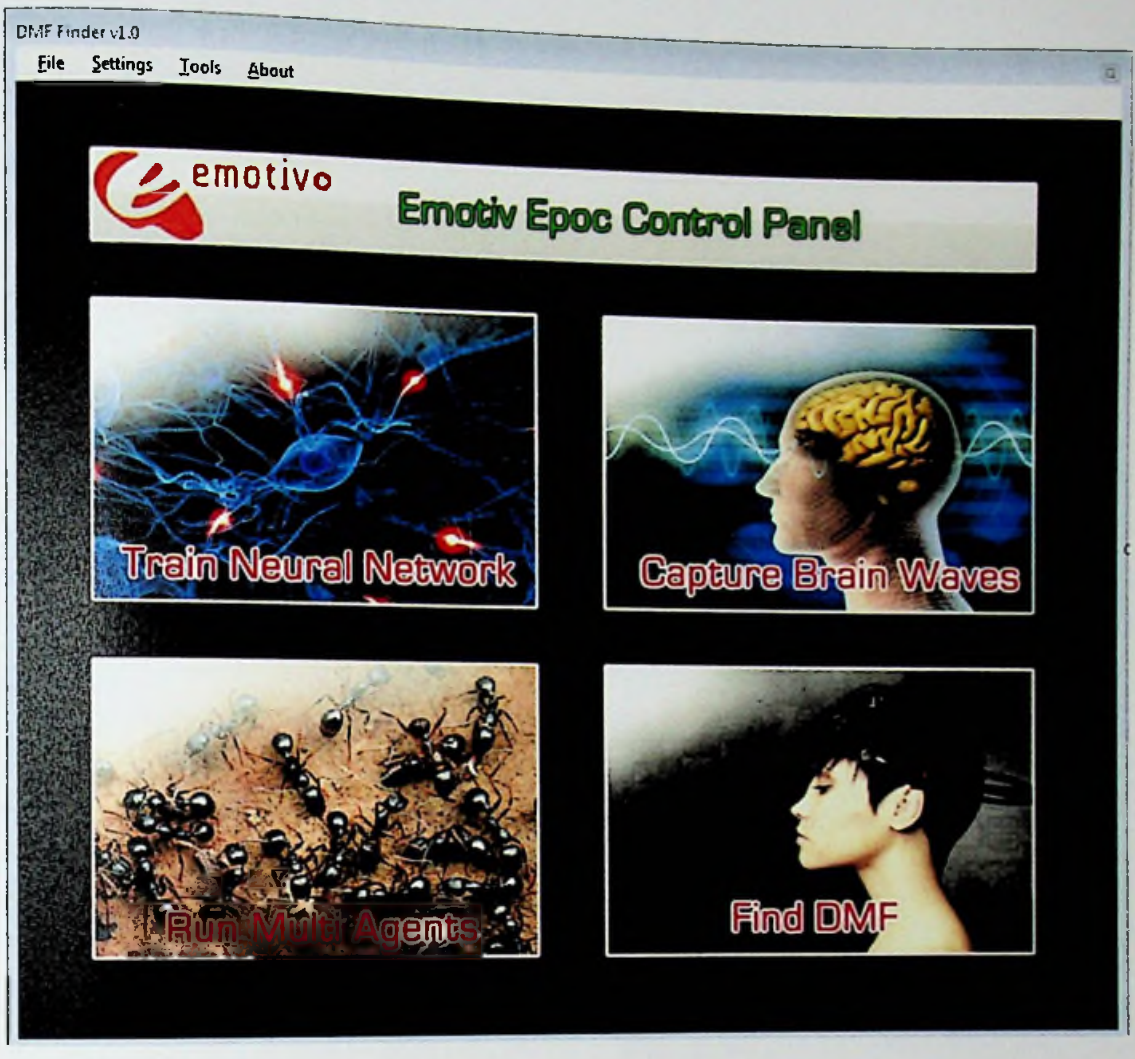

Figure 6.2 : Main screen of DMF Finder

Neural network training interface is as follows. Which allows user to input training data sets as much as he want and finally train them using mentioned atchitecture in chaper 5. Once the ANN is trained its enough for lifetime if theres no any new training data to be added. All the trained ANN is dumped in to a tempory file inside the solution. It's a lifetime one and not a runtime one.

6.5 Summary

In this chapter, implementation of the DMF Finder was discussed in detail. MAS and th ANN implementation were discussed in detail. Component integration was described as how to integrate two different frameworks (Java and dotnet).

Next chapter will discuss about the evaluation of the system which will decide whether the proposed system can be used by the target users.

Chapter 7

Evaluation

7.1 Introduction

In the previous chapter we described how our solution was implemented. There we showed how the multi agent system was developed on top of JADE multi agent framework. It also described the agents in the agent environment and their goals.

This chapter discusses the experiments conducted during the research and the testing of proposed solution.

7.2 Design of Experiments

In order to evaluate the system , two experiment types were carried out. Though out all the experiments , the headset should be worn properly in order to get the correct brain waves.

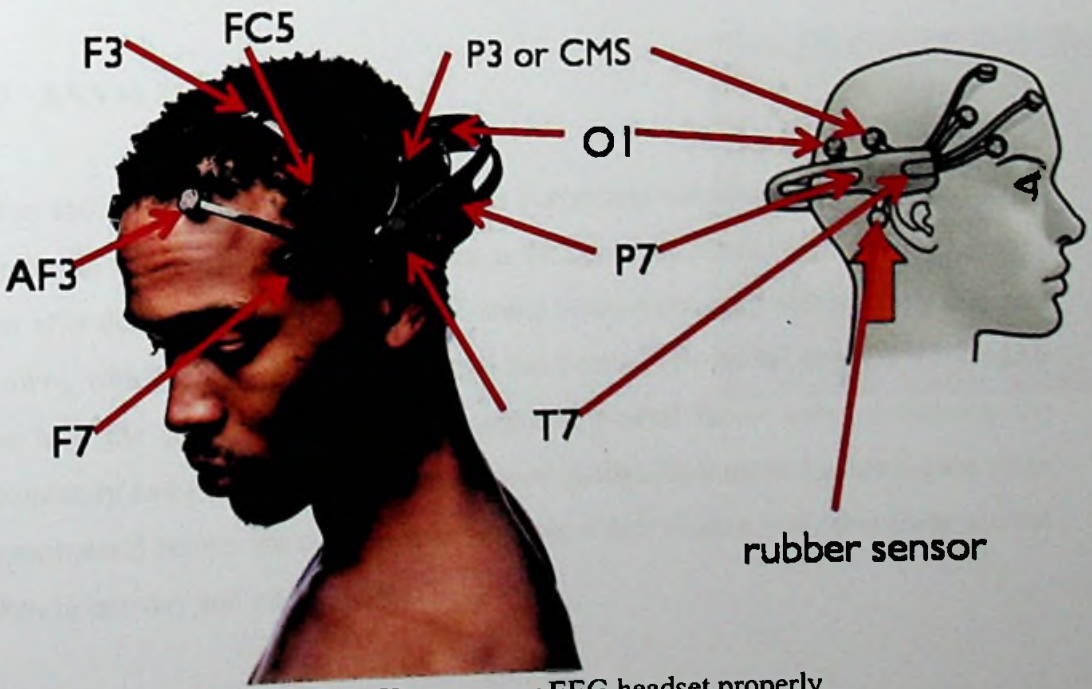

Figure 7.1 : How to wear EEG headset properly

7.2.1 Feed the neural network with a known brain wave

Here what we did was, we got known brain wave samples for all the mental hindrances. Out of that samples 80% were used to train the ANN and other 20% was used to test the ANN. ANN was capable of giving the correct values as expected for all attempts.

7.2.2 Feed the ANN with regular brain wave of the normal person

Here we carried out the evaluation in many ways. Just captured a brain wave in a normal time of a person. This was done several times. So the system was capable of giving one mental hindrance as the result, and the result was consistent for a particular time for a person. Proving that at that time that person's dominant mental factor was the given result.

Same procedure was carried out after a sleepless night. And also after a remembering sad incident, after remembering a incident which caused anger etc. All the time the system was capable of giving very consistent and dominant answer, which varied from case to case.

7.3 ANN vs MAS

Even though some times the ANN gives percentage values , indicating that mental hindrance which owns the highest value is the dominant mental factor.
But after deliberation happens in MAS some times it come up with a totally different answer, which means the usage of MAS has been improved the solution a lot. MAS has lead the solution to have most probable mental factor with considering the complexity and combinational occurrence of mental hindrances. Following are some experimental results we could obtain from the DMF Finder. Note that these are not taken in one day and one person.

Background	ANN outputs	MAS output
After recalling a past incident which makes angry.	Anger - 26 Sloth - 0 Desire - 3 Doubt - 20 Restlessness - 51	Dominant factor is Anger – 54%
After a sleepless night.	Anger - 10 Sloth - 3 Desire - 3 Doubt - 8 Restlessness - 76	Dominant factor is Restlessness – 70%
After getting blamed by somebody.	Anger - 23 Sloth - 18 Desire - 3 Doubt - 8 Restlessness - 48	Dominant factor is Sloth – 44%
Writing a software code	Anger - 8 Sloth - 6 Desire - 22 Doubt - 32 Restlessness - 32	Dominant factor is Restlessness – 38 %
Sloving a maths problem	Anger - 7 Sloth - 5 Desire - 51 Doubt - 8 Restlessness - 29	Dominant factor is Desire – 52 %
Meditating	Anger - 3 Sloth - 42 Desire – 10 Doubt - 15	Dominant factor is Doubt – 43 %

	Restlessness - 30	
Watching a film	Anger - 12	Dominant factor is Desire
	Sloth - 3	– 58 %
	Desire - 58	
	Doubt - 8	
	Restlessness - 19	

Table 7.1 : Experimental results under different backgrounds.

7.4 Summary

In this section we described at how the proposed system was evaluated. The first step was to define types of experiments to be performed and what type of subjects to be chosen for each experiment. Then these experiments were carried out with human subjects to acquire sample data. Next, these acquired data was analyzed and processed to be fed to the proposed system as input data. And finally the experimental results were recorded and summarized to be presented and to decide the final outcome of the experiments.

The next chapter would discuss the final outcome of the evaluation and this research. It would demonstrate the final conclusion of this novel method for Brain Computer Interfacing. Further, in there we would discuss about the problems occurred during the research as well as further enhancements for the proposed solution.

Chapter 8

Conclusion and further work

8.1 Introduction

When considering applications of Brain Computer Interfacing, we can list many benefits of this proposed solution. As explained earlier, one main benefit of brain interfacing is accessibility for disabled persons, psychiatric patients and people who do meditation.

One main advantage of using multi agent technology for dynamic pattern recognition would be that the ability to adapt to new or unknown combinations of emotions. Since human brain is inherently complex, we cannot anticipate the level or combination of emotions of a person. Therefore, this solution provides a methodology to model this complex and dynamic behavior when identifying mental hindrances. This involves high level of signal analysis. Since this signal analysis can be considered as a clustering problem it could also be modeled in the multi agent system. But that would be considered a future extension to the current solution.

8.2 Achievements of the research

As initially planned, project was succeeded to gain the dominant mental factor for the disturbance of a person at a time. This value might have some accuracy deviations , but yet the solution provides a result we cant depend on and carry out any further work.

8.3 Quick glance back

At first, a literature review was conducted to identify the methods and technologies used for Brain Computer Interfacing (BCI). Hence it was discovered that BCI is still in a developing stage and most studies and applications are still at research level. As discussed, it was several studies mentioned that Brain Wave detection is a

challenging and time consuming task which requires considerable expert level knowledge to process brain waves. This is mainly due to complex nature of human brain. Among the many brain activity detection techniques, Electroencephalography (EEG) proves to be an effective technique for BCI.

In this research, it describes how Multi Agent Technology or Multi Agent Systems (MAS) has been used to model complex systems and the limitations of such systems. There, it was also mentioned about previous attempts to model human emotions using multi agent technology. Further, we also discussed about a method which was proposed by George Rzevski et al to use MAS to cluster dynamic data. Thus, from this literature survey we understood that it is possible to use MAS to model human emotions.

Since this proposed solution is related to Brain Wave detection, a method to capture EEG signals was required. For this purpose the Emotiv EPOC Neuro Headset was used mainly due to the wireless capability and considerable amount of EEG channels. Emotiv also provides a library, known as Emotiv EDK, which enables to read raw EEG signals in real time. At first stages of the study this method was used to capture data, yet due to performance problems it was altered to offline data retrieval method. Therefore, EEG Records saved in Comma Separated Variable (CSV) files were used as input data.

In order to develop the proposed MAS, a Multi Agent Framework was required. Among many Open Source and free Multi Agent Frameworks, JADE Multi Agent framework was selected for this system. The proposed MAS contained several key agents. The Sampling Agent was responsible for acquiring EEG Data from a given source. The system was designed to accept several forms of EEG Data sources, and the system was tested using Emotiv CSV Data files.

8.4 Further Work

As the further work, the fine tuning of ANN and MAS is needed. For that we need more and more training data sets for ANN and more ontology or more rules to execute for the MAS.

At the moment the system gives the output after capturing the brain wave and processing. But if it can be nearly real time that would be great. So as a further work it will be done.

8.5 Summary

This chapter presents the overall conclusion of this research. The first section discusses the achievements of the study and the overall conclusion. It is further supported by the next section which is the suitability of the proposed solution for real world applications. Again, this chapter also discusses the problems that were faced during this research and the limitations of proposed solution. The chapter concludes by providing a list of enhancements to the current solution for better results and real world applicability.

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Appendix A

Souce code of Agents

A.1 Setting up other agents inside initializing agent

```
protected void setup() {
    System.out.println("Setting up the Initialize Agent..... ");

    // create the agent description of itself
    DFAgentDescription dfd = new DFAgentDescription();
    dfd.setName(getAID());
    try {
        DFService.register(this, dfd);
    } catch (FIPAException e) {
        e.printStackTrace();
    }
    PlatformController container = getContainerController(); // get a container controller for creating new agents
    getPercentageValuesFromFile();
    try {
        AgentController angeragent = container.createNewAgent("Anger_Agent", "AngerAgent", anger);
        angeragent.start();
        AgentController desireagent = container.createNewAgent("Desire_Agent", "DesireAgent", desire);
        desireagent.start();
        AgentController doubtagent = container.createNewAgent("Doubt_Agent", "DoubtAgent", doubt);
        doubtagent.start();
        AgentController restlessagent = container.createNewAgent("Restlessness_Agent", "RestlessnessAgent",
                                                                  restless);
        restlessagent.start();
        AgentController slothagent = container.createNewAgent("Sloth_Agent", "SlothAgent", sloth);
        slothagent.start();


        ACLMessage message = new ACLMessage( ACLMessage.INFORM );
        message.setContent("Agents., you may deliberate on your percentage values");

        message.addReceiver(new AID("Anger_Agent", AID.ISLOCALNAME));
        message.addReceiver(new AID("Desire_Agent", AID.ISLOCALNAME));
        message.addReceiver(new AID("Doubt_Agent", AID.ISLOCALNAME));
        message.addReceiver(new AID("Restlessness_Agent", AID.ISLOCALNAME));
        message.addReceiver(new AID("Sloth_Agent", AID.ISLOCALNAME));

        send( message );

    } catch (ControllerException e) {
        e.printStackTrace();

    }

}
```

A.2 Getting percentage values from ANN output

```
private void getPercentageValuesFromFile() {

    BufferedReader br = null;
    try {
        br = new BufferedReader(new FileReader("/Users/mcrox/Documents/MSC_AI/EMOKIT_JAVA/hintrance-agents/data/percentage-values.txt"));
        List<String> list = new ArrayList<>();
        String str;
        while ((str=br.readLine()) != null) {
            list.add(str);
        }
        String[] stringArr = list.toArray(new String[list.size()]);

        anger = new Integer[1];
        anger[0] = Integer.valueOf(stringArr[0]);

        desire = new Integer[1];
        desire[0] = Integer.valueOf(stringArr[1]);

        sloth = new Integer[1];
        sloth[0] = Integer.valueOf(stringArr[2]);

        restless = new Integer[1];
        restless[0] = Integer.valueOf(stringArr[3]);

        doubt = new Integer[1];
        doubt[0] = Integer.valueOf(stringArr[4]);

    } catch (FileNotFoundException e) {
        e.printStackTrace();
    } catch (IOException e) {
        e.printStackTrace();
    } finally {
        try {
            br.close();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }

}
```

Reading data from Emotive


```
    private final EmotivHid raw;
    private final AtomicBoolean accessed = new AtomicBoolean();
    private final Cipher cipher;
    private final EmotivParser parser = new EmotivParser();

    @Getter
    private final String serial;

    private final Executor executor;

    /**
     * @throws IOException if there was a problem discovering the device.
     */
    public Emotiv() throws IOException {
        raw = new EmotivHid();
        try {
            cipher = Cipher.getInstance("AES/ECB/NoPadding");
            SecretKeySpec key = raw.getKey();
            cipher.init(Cipher.DECRYPT_MODE, key);
        } catch (Exception e) {
            throw new IllegalStateException("no javax.crypto support");
        }
        serial = raw.getSerial();

        Config config = ConfigFactory.load().getConfig("com.github.fommil.emokit");
        int threads = config.getInt("threads");
        executor = Executors.newFixedThreadPool(threads);
    }

    /**
     * Poll the device in a background thread and sends signals to registered
     * listeners using a thread pool.
     */
    public void start() {
        if (accessed.getAndSet(true))
            throw new IllegalStateException("Cannot be called more than once.");

        Runnable runnable = () -> {
                try {
                    poller();
                } catch (Exception e) {
                    Emotiv.log.log(Level.SEVERE, "Problem when polling", e);
                    try {
                        close();
                    } catch (IOException ignored) {
                    }
                    fireConnectionBroken();
                }
        };

        Thread thread = new Thread(runnable, "Emotiv polling and decryption");
        thread.setDaemon(true);
        thread.start();
    }
```

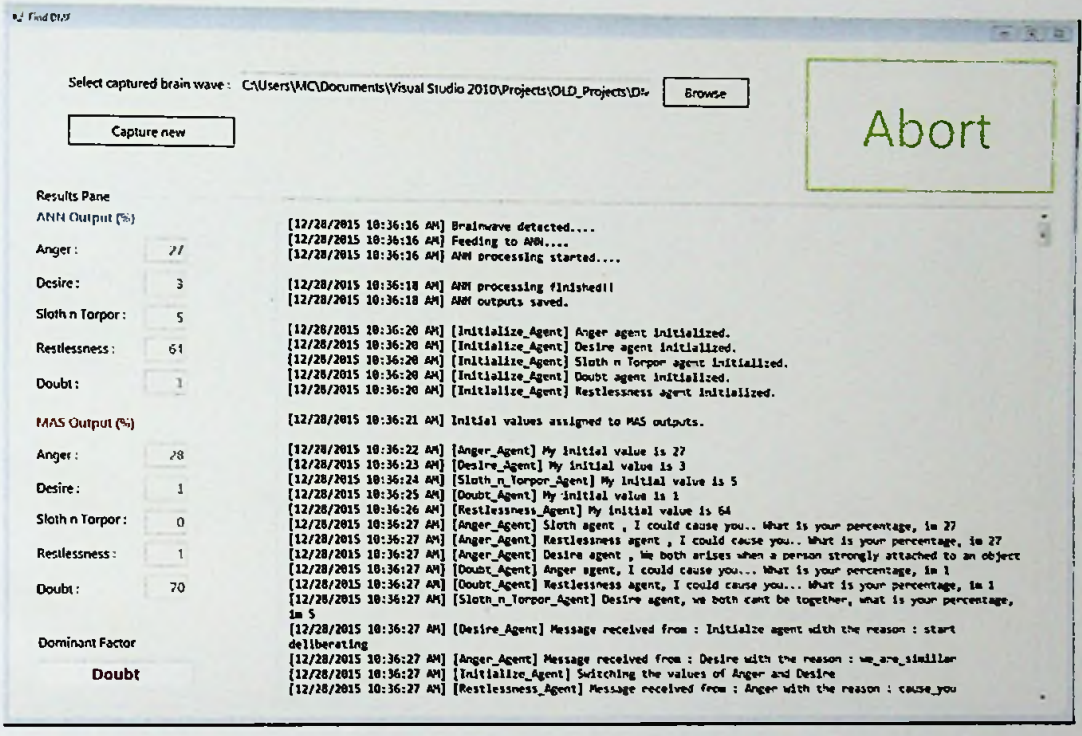
```
public final class Emotiv implements Closeable {

    public static void main(String[] args) throws Exception {
        Emotiv emotiv = new Emotiv();

        final EmotivSession session = new EmotivSession();
        session.setName("My Session");
        session.setNotes("My Notes for " + emotiv.getSerial());

        final Condition condition = new ReentrantLock().newCondition();

        emotiv.addEmotivListener(new EmotivListener() {
            @Override
            public void receivePacket(Packet packet) {
                EmotivDatum datum = EmotivDatum.fromPacket(packet);
                datum.setSession(session);
                Emotiv.log.info(datum.toString());
            }

            @Override
            public void connectionBroken() { condition.signal(); }
        });

       emotiv.start();
       condition.await();
    }
```

* Full Source code is attached in a Compact Disk

Appendix C

User Interface of the DMF

C.1 Deliberating agents on the ANN output



C.2 User interface for training ANN