SOFTWARE REQUIREMENTS SPECIFICATION REPORT

MasterMind
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1. Introduction

Investigating the brain functions has long been a matter of discovery for human beings. In an attempt to accomplish this aim, Brain Computer Interface (BCI) systems have been introduced. BCI systems arose to be an alternative communication system between the brain and the outer world. BCI systems can be defined as systems that use ways to send data to an electronic device by means of brain activity.

Electroencephalography (EEG) is a well known BCI technique in which through placing electrodes on the scalp it is possible to record the summed electrical activity of the cortex. EEG-based BCI’s are mostly used and popular through other techniques, because it has the maximum information transfer rate, up to 10-25 bits/min.

BCI systems and EEG devices consist mainly of three parts: Signal Acquisition, Signal Processing and the Output Device.
As can be inferred from the diagram above; first phase is collecting data, which is electrical activity in the case of EEG, through brain-waves which can be recognized as signals. In the second phase, Signal Processing, digitizing the signal is required. Moving on to Signal Processing, at first feature extraction should be done, which consists of determining amplitude values of EEG signals, band powers (BP), power spectral density (PSD) values, autoregressive (AR) and adaptive autoregressive (AAR) parameters, time frequency features etc... This step involves also clearing noise and outliers. After feature extraction is done the translation algorithm comes into consideration. It, translates these signal features into device commands orders that carry out the user’s intent.

Then we come to the output device, which will the main concern of our project. The main point is that if all these datas, after going through a serious of processes and translation, could be used in a software environment to gain information from brain.

The answer is yes, and there are many studies working on these issues. Although the improvement in this area is far from science fiction movies in which people can pilot aero plains still they are promising.

Using EEG-based BCI’s, data can be collected and translated to the digital world. The new question is that: Can this data be used to give feedback to the person/user which uses the device, such that the person/user benefits from this in some manner?

Currently there are many studies which aim to provide the users, who may be completely paralyzed; with basic communication capabilities so that they can express their wishes to the caregivers or even operate word processing programs or neuroprostheses. As can be
inferred from these information, users can benefit from BCI devices in vital and non-vital circumstances.

1.1. Problem Definition

Many people, especially the children, the elderly, the sportsman and the businessmen are suffering from attention deficit disorder and concentration problems. There are many treatments offered to this problem. On the other hand, still none of these treatments can capture all groups of patients. Especially for children, an effective and interesting solution has not been fully developed yet.

1.2. Purpose of the Project

The purpose of this project is to develop a software product that would meet the needs mentioned above in the problem definition. It is aimed to be done via a software product, namely a computer game. It is planned to make use of the data acquired through Emotiv device as an input in the game. Through this means user/patient will gain proficiency over controlling his attention and concentration level.

1.3. Scope of the Project

Neuro-feedback is a mechanism that enables illustrating brain activity. Using this mechanism it is possible to control nervous system activity of the patients. Within the scope of this project this mechanism will be utilized. The users/patients will be presented with a
computer game in which they should concentrate on certain stimuli. As the patient’s concentration level decreases, it will be recorded by the Emotiv device and transmitted to the computer. In response to this, the game requirements will increase and the input will serve as neuro-feedback to the patient. Consequently, the patient will be forced to improve his/her management skills in order to win the game. It is aimed to help both the diagnostic and the treatment processes through these means. In addition, patients will be able to see brainwaves feedback from computer screen and manage to control their brainwaves by audio - visual feedbacks coming from the system.

1.4. User and Literature Survey

Literature survey is covered above in the introduction section. In addition, more detailed information on the survey will cover market and technology aspects of the product in the following sections.

1.5. Definitions and Abbreviations

- BCID: Brain Computer Interface Devices
- EEG: Electroencephalography is the recording of electrical activity along the scalp produced by the firing of neurons within the brain
- Neuro-feedback: A mechanism that enables illustrating brain activity
- Brain-waves: A rhythmic fluctuation of electric potential between parts of the brain,
- Emotiv EPOC: A EEG-based BCI device.
1.6. References


2. Overall Description

The software product will concentrate on alpha and beta waves in order to help the patient with his/her management skills. In addition to this, a table will be displayed on one side of the screen during the game, which gives information on the patient’s concentration and attention level. At the end of the game, a document will be provided for the psychologist or neurologist. This report will serve as a report and will include graphics and data about the patient’s progress.
2.1. **Product Perspective**

Our software structure will be probably like the picture below:

- In Graphical View Part: User can see his/her brainwave values simultaneously while s/he is using the software.

- In Game Part: User can play the game with both using standard input devices (keyboard, mouse etc) and his/her brainwaves. The game will probably be Pong.

- In Log Part: User can see the logs related to interpreted brain signals.

2.1.1. **Market Research**

We have conducted a market research on the Brain Computer Interface Devices similar to our product, and also games using brain control that we can get inspire or ideas.

2.1.1.1. **Interactive Productline Introduces the Mindball Game:**
Mindball Game was launched during spring 2003. Mindball Game is a two persons' game controlled by the players' brain waves. The player being most relaxed wins the game.

The goal in this game is to train the ability to obtain a relaxed and focused state of mind. A state of mind that, after some training, can be obtained in other situations.

2.1.1.2. NeuroSky Solutions:

NeuroSky has publicly demonstrated two emotions reading with their brainwave sensors. Attention meter is a reading of how attentive the user is feeling. Meditation meter is a reading of how relaxed the user is feeling.

NeuroSky has created a game to demonstrate their product, which allows players to push objects such as cars or furniture by concentrating on them (attention), and to levitate objects by relaxing (meditation). Movement and view control would still be done using conventional game controls.

2.1.1.3. OCZ Technology Introduces Neural Impulse Actuator:

The name Neural Impulse Actuator implies that the signals originate from some neuronal activity; however, what is actually captured is a mixture of muscle, skin and nerve activity including sympathetic and parasympathetic components that have to be summarized as biopotentials rather than pure neural signals.
2.1.4. Mattel Solutions:

Mindflex is a toy by Mattel which apparently uses brain waves to steer a ball through an obstacle course. The brain waves are captured with the enclosed EEG headset, which allows the user to speed up or slow down a fan, thus lifting or lowering the blue styrofoam ball.

2.1.5 Emotiv Solutions:

Emotiv System's only current product is the Emotiv EPOC, for gaming on Windows PCs. Emotiv Systems claims the headset will make it possible for games to be controlled and influenced by the player's mind, and facial expressions.

The Emotiv EPOC will ship with a game by Demiurge Studios, previously called "The Game", built on the Unreal engine. The sky changes color according to the mood of the player. Demonstrated activities in the game include pushing and rotating giant stone structures into the shape of stone henge, then raising a temple from below the ground; levitating a large rock and some smaller ones; repairing a bridge; bending a tree; and scaring away glowing spirits with scary facial expressions.

2.2. Product Functions

To understand the functionality of this software better use cases should be analyzed:
2.2.1 Use Case Diagram

2.2.1.1 Use case scenarios

2.2.1.1.1 Use case 1: Game Application

This use case for data acquiring from user who is playing game with Emotiv device

Actors: User (Patient)

Pre-Condition: The user should wear Emotiv device

Post-Condition: Emotiv device should be connected to pc

Basic Flow:

1. The User (Patient) should start playing game
2. Emotiv will send wave status to game application through pc
3. Game application will interpret information which is received from Emotiv.
   3.1. Interpretations’ results will affect game difficulty immediately
   3.2. Data about user’s concentration, wave changes and game will be gathered
4. Gathered data will be sent to Logs.
2.2.1.2 Use case 2: Logs

This use case is responsible for keeping user’s (patient) game logs. It also, works as database for experts. Experts can use these data to analyze user’s concentration status and to diagnose user’s problem.

Actors: Psyhologist experts

Pre-Condition: User(Patient) should have played game with Emotiv device

Post-Condition:

Basic Flow:

1. Keeping and updating Users’ logs
   1.1 It will keep Users’ logs in database
   1.2 It will update Users’ logs in database. User can play game multiple times hence, their records should be kept up to date.

2. It will serve as a database to experts. An Expert can reach users’:
   2.1 Information
   2.2 Concentration status logs
   2.3 Brainwave changes logs
   2.4 Game logs

3. Experts will evaluate logs

4. Experts will provide feedback to users.

2.3. Constraints, Assumptions and Dependencies

Converting brainwaves to alpha and beta values will be done through the SDK provided by Emotiv. SDK converts these waves into wave groups named alpha, beta, and gamma using Fourier transformations. For our purposes, we will mostly concentrate on the alpha and beta
waves. Although this Fourier transformation is made by SDK, it is possible to make use of some other transformations that convert to alpha and beta.

Our software is limited to owners of Emotiv EPOC because the software needs this device’s inputs to interpret them in the game.

### 3. Specific Requirements

#### 3.1. Interface Requirements

As we mentioned before our project will use a Brain Control Interface Device for users. For this purpose we needed to search for current devices for reading and interpreting EEG data. At first glance we have the following options

- **Emotiv EPOC**
- **NeuroSky Mindset**
- **Neural Impulse Actuator**

#### 3.1.1. Emotiv EPOC

Below advantages and disadvantages of Emotiv EPOC can be seen.

**Advantages:**

- 14 electrodes to collect data
- Community to get support
- Lots of example games to see device’s potential
Disadvantages:

- Considerably expensive

3.1.2. NeuroSky Mindset

NeuroSky Mindset is another option for Brain Control Interface Device

Advantages:

- Not expensive
- Examples available

Disadvantages:

- Basically, only two emotions can be measured
- Single electrode to collect data

3.1.3. Neural Impulse Actuator

Advantages:

- Cheapest

Disadvantages:

- No SDK released
- Different signal processing procedure

As a result, after the research we have conducted on Brain Control Interface Devices; we decided on using Emotiv EPOC, because it seems to be more convenient for our project.
Also, The Emotiv EPOC has significantly more electrodes than its competitors and is not considerably more expensive. There are no other interface requirements at all.

### 3.2 Functional Requirements

There is no functional requirement for this project.

### 3.3 Non-functional Requirements

#### 3.3.1 Performance requirements

Our project will be for single player. User’s brainwave information and standard inputs will be handled and affect the game with informations’ interpretation.

#### 3.3.2 Design Constraints

##### 3.3.2.1 Software Requirements

- A computer with windows or linux operating system
- Available libraries for pattern matching algorithms

##### 3.3.2.2 Development Environment Requirements

- Netbeans
- Software Development Kit of Emotiv EPOC
- Test Bench of Emotiv EPOC
3.2.2.3. Programming Language

When we look at all the possible technologies, libraries, platforms that we will use in our project; we have seen that the most convenient programming language is Java. Since libraries which will be given by our sponsor are written in Java, also our desire to functionality and support led us to use Java language as our applications default developing language. And also we will develop our application in NetBeans environment.

4. Data Model and Description

In this section of this document contains data description related diagrams and data dictionary for these diagrams.

4.1. Data Description

In MasterMind project there are two types of data will be collected from users which are processed by our product. First of those data is game instructions. Instructions that user provides for game while s/he is playing. In other words, this type of data are game playing instructions which affect game play directly. Other data type is, data which are collected by Emotiv device. Emotiv data do not affect game directly. After processing phase, game difficulty will be changed in order to result of Emotiv data. Furthermore, our program will provide logs (users’ game and brain activity records) for experts who will interpret those particular data types. Experts can evaluate logs and decide treatment for user who suffers inattentiveness problems. Brief demonstration of data-flow of software is depicted below.
4.1.1 Data objects

As mentioned in previous parts our project contains three data types. Those data types can be considered as objects such that: Game play data, Emotiv data and Log data.
**Game play data**: Game play data object keeps game instructions. Its main purpose is providing interaction between game and user. User can play game and see her/his result. Also, difficulty changes will be transmitted to user via game play data object.

**Emotiv data**: This data object contains data received from Emotiv device. They are going to use to figure out user’s attention and focus levels which are going to use determining difficulty level. Emotiv data object contains variables such that Brainwave, wave magnitude and wavelengths changes. By interpreting these changes software will decide difficulty levels. If user’s attention level is getting lower, game will become harder to force user to gather her/his attention to game.

**Log data**: Log data object is created for experts who will evaluate the results. It contains logs which keep concentration status, brainwave changes and game records. By examining those expert can interpret user’s concentration and focusing status. Also, they can develop accurate solutions for increasing user concentration level.

### 4.1.2 Relationships

In this project, there are six entities. These are User (Patient), Device (Emotiv), Emotiv Data, Game, Logs and Psychology experts. Relations between them are formed as: User play game and use device. Device create inputs (brainwave, magnitude lengths changes). This input data are transmitted to game. Then game provides logs for psychology experts. After evaluating logs, experts will treat user's problem. Treating user is not part of our project; nonetheless it is part of the project concept. Hence, it is included in relations and diagrams.

### 4.1.3 Complete Data Model

To illustrate and detail relationships we prepare Entity Relation Diagram of our project. It contains entities, relations and attributes. As it can be seen in diagram below user is input supplier. It has relations with game and device. User plays game synchronously uses device.
Device creates data which are transmitted to game. In other words, user sends game play inputs and brain activity input simultaneously. Brain activity inputs are sent via Emotiv. Emotiv is used for monitoring brain activities. It also creates usable data for the game. These data are going to be acquired brain activity changes. Those data are processed and with game inputs from user affect game playing. While game is being played, logs are created. Logs are about brain activity changes, concentration level changes and game result. At this point our group’s aim is providing additional data to experts besides forcing user to enhance her/his attention level. Those logs reveals game records, users’ attention level, ability to adapt changes, brain activity records. Logs are important part of our design. They will be kept orderly for each user. After a multiple tests for any patient we could acquire accurate logs which can be used further treatment by psychology experts.

Entity Relation Diagram in the below depicts relations between entities of project.
4.1.4 Data Dictionary

Name: Play

Description: Play stands for relation between game and user. It shows that user plays game and provides inputs.

Name: Use

Description: Use depicts user use Emotiv device and provides inputs for device
Name: Create
Description: Creates shows Emotiv device creates usable inputs from user's unprocessed inputs.

Name: Transmit
Description: Transmit refers that usable Emotiv inputs are sent to game.

Name: Provide
Description: Provide means game keeps records and arrange them as usable logs.

Name: Evaluate
Description: Experts evaluates logs which are provided by game. Then evaluation results helps to determining suitable treatment for users.

Name: Treat
Description: After determining suitable treatment Experts begins implementation of treatment. Treat symbolizes that phase. Although, this relation is not part of project it is related to general concept. For this reason it is added to diagram.

5. Behavioral Model and Description

In this section of this document contains project data processing, data-flow diagram, state transition and user cases.

5.1 Description for software behavior
To describe behavior, data-flow of software should be presented. Data-flow begins with user. It flows in two ways. First, playing game which is direct communication with software. Second, flow via Emotiv device. This way indirect communication with software. Data is processed by device first then transmitted to game. While user is playing game Emotiv device collects data from user's brain. After conversion, usable data will be sent to pc which software is working. Pc has mutual data flow with pc since game works on it. Game acquires usable Emotiv data and interprets them. If concentration level is decreasing game respond it with increasing difficulty. In our case, Pong ball becomes faster. By doing so, user is forced to increase focusing on game. At this point, other than user game/pc flow new data-flow is begun. All game history will be stored as logs. Logs contain game play records; brain activity changes records and concentration status records. All these records are related to each other. When brain activity is changed, concentration status is also changed. This situation affects game difficulty and then game difficulty affects game playing. After the logs phase interaction begins between experts and user. This data flow is not relevant with program but it is conceptually relevant, so it must be described. Logs are prepared for evaluation of experts. According to result of log evaluation experts should provide user with feedback and develop treatment/therapy for their problem.

To understand better we prepare detailed data-flow diagram:
### 5.1.1 Data Dictionary of Data-flow diagrams

<table>
<thead>
<tr>
<th>Name</th>
<th>Input to</th>
<th>Output from</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainwaves</td>
<td>Emotiv device</td>
<td>patient (user)</td>
<td>sends information to Emotiv device from users’ brain</td>
</tr>
<tr>
<td>Brainwaves changes</td>
<td>pc</td>
<td>Emotiv device</td>
<td>send brainwave changes to pc</td>
</tr>
<tr>
<td>brainwaves magnitude changes</td>
<td>pc</td>
<td>Emotiv device</td>
<td>send brainwave magnitude changes to pc</td>
</tr>
<tr>
<td>brainwaves wavelength changes</td>
<td>pc</td>
<td>Emotiv device</td>
<td>send brainwave wavelength changes to pc</td>
</tr>
<tr>
<td>PC inputs</td>
<td>pc</td>
<td>MasterMind Project</td>
<td></td>
</tr>
</tbody>
</table>
Description: sends inputs to pc from game (user’s actions)
Name: PC inputs
Input to: MasterMind Project
Output from: pc
Description: sends processed Emotiv data to game

Name: Playing game
Input to: MasterMind Project
Output from: Patient (User)
Description: sends user’s instructions to game

Name: Game result
Input to: Patient (user)
Output from: Mastermind Project
Description: sends game result to user

Name: Difficulty changes
Input to: Patient (user)
Output from: Mastermind Project
Description: Changes on difficulty due to concentration level

Name: Concentration status logs
Input to: Psychology experts
Output from: Pc
Description: Sends user’s concentration changes logs to experts
Name: Brainwave changes logs
Input to: Psychology experts
Output from: Pc
Description: Sends user’s brainwaves status changes logs to experts

Name: Game logs
Input to: Psychology experts
Output from: Pc
Description: Sends user’s game playing logs to experts

Name: Feedback
Input to: Patient (user)
Output from: Psychology experts
Description: Experts gives feedback to users about their mental performance

Name: Treatment
Input to: Patient (user)
Output from: Psychology experts
Description: Experts treat users
6. Planning

6.1. Team Structure

Our team consists of three people:

- Çoban Hasan Faruk
- Özdemir Ercan
- Ceylan İsmail İlcan
6.2. Estimation (Basic Schedule)

We plan to keep up with the Computer Engineering Design Course Syllabus. Our schedule will be as close as the CENG 491 Course Schedule.

6.3. Process Model

We do not have a strict organizational structure in the team. Everyone contributes to each part of the work in order to have an idea about the whole project. We gather each week to discuss the developments and requirements. In addition to these we make use of a web-based system, Basecamp, where we share documents, make discussions, assign to-do’s and communicate easily with our assistant.

7. Conclusion

Our project can be classified as “Application of Cognitive Science”. Our group focuses on the connections between The Neural and Cognitive Sciences and the computer. After mentioned requirements satisfied, we aim to contribute to people's mental health by making EEG biofeedback training easy and fun.