University of West Bohemia
Faculty of Applied Sciences
Department of Computer Science and Engineering

Bachelor Thesis

Driver's attention - auditory stimulation of driver and passenger (ERP Experiment)

Pilsen 2012 Jiří Vaněk

Acknowledgment

I would like to thank to my supervisor Ing. Roman Mouček Ph.D for his advices and also I would like thank to my supervisor's colleague Ing. Pavel Mautner Ph.D.

Statement

I hereby declare that this bachelor thesis is completely my own work and that I used only the cited sources.

Pilsen, May 1 2012

Jiří Vaněk

Abstract

This bachelor thesis deals with analysis of driver's attention, which plays a big role in a driving safety.

Electroencephalography (EEG) measurements, especially Event-related potentials (ERP) are used for detection and analysis of the driver's attention. The analysis is focused on extraction of the P300 component in auditory ERP; attention decrease represented as latency shift is investigated. The purpose of this thesis is to determine if the driving in a monotonous environment has influence on the driver's attention.

For this experiment the scenario was prepared. The group of tested subjects drives in pairs in a monotonous track for 60 minutes, while one of the subjects is driving and the passenger is just focusing on the track. After 30 minutes the driver and the passenger switch their roles and drive for another 30 minutes. During driving subjects are listening to auditory stimuli. To make sure that subjects are focusing also on stimuli and not only on driving, they have to count target stimuli.

The part of this thesis is dedicated to evaluation and interpretation of recorded data. Also software for blinking detection was developed to help recognize EEG blinking artifacts.

Contents

1 Introduction

Driver's attention plays a big role in car accidents. Lots of car accidents could be eliminated or reduced by higher driver's attention. Driver's distraction has been a contributing factor in more than 25 percent of all car crashes [28]. Cameras were used for detection driver's attention in practice, but these methods work only if driver shut his / her eyes or watch something else than the road.

The purpose of this study is to describe whether driving in a monotonous environment has influence on driver's fatigue, attention, respective on the peak latency of the P300 wave via EEG/ERP measurement. Driver is exposed to driving in unvaried and boring environment (a high way) with no traffic to make the driver very tired and bored.

The theoretical part of this thesis contains basic introduction to the EEG and ERP techniques, a basic description of the human brain and it's activity and their connection with problems of attention; rules and principles, which are used for ERP measurement and a description of the major ERP components. Also other experiments which are dealing with attention or ERPs were studied and some of them are described in this section.

The second part deals with design and preparation of the experiment. Hardware and software used for this experiment is described in this part as well. Auditory stimuli are used for subject stimulation. The whole experiment, the procedure of the measurement and the data evaluation are explained in this part.

In the practical part of this work I describe also a software tool Eye Blink Detector, which detects eye blinking from video source with human face.

2 Theoretical Part

2.1 Human Brain

The human brain consists of different parts. The most basic division is forebrain, midbrain and hindbrain. Forebrain consists of two major parts: the diencephalon and the telencephalon. Telencephalon contains the cerebrum, which is divided to left and right hemisphere.[11] Each hemisphere is divided into lobes (Figure 2.1). The brain is also divided into cortexes, in diagram (Figure 2.2) are the major cortexes and their location. These areas control different functions of body and mind. Premotor Cortex, which is responsible for attention [22], is the most important for this thesis.

2.2 EEG

Electroencephalography is a non-invasive method for measuring and recording electrical activity along the scalp. This method is based on measuring voltage changes from neurons of the brain using electrodes. These electrodes are attached to the scalp usually using an EEG cap.

Positions of electrodes are usually described by the 10-20 international system, which is the standard naming and positioning scheme for EEG. The original 10-20 system included 19 electrodes (Figure 2.3), but now this scheme defines positions for even 70 electrodes (Figure 2.4). A disadvantage of this method is that the measured EEG signal represents a lot of neuronal activities and it is really hard to recognize corresponding neurocognitive processes. Another disadvantage is that the EEG signal is corrupted by artifacts; the main interface is from electrical power lines, eye blinking, Eye movement EEG artifacts (EOG) and Muscular EEG artifacts (EMG). One way to get necessary data is focus on EEG signal on specific brain responses associated with specific sensory stimuli. These stimuli are called ERP. [27]

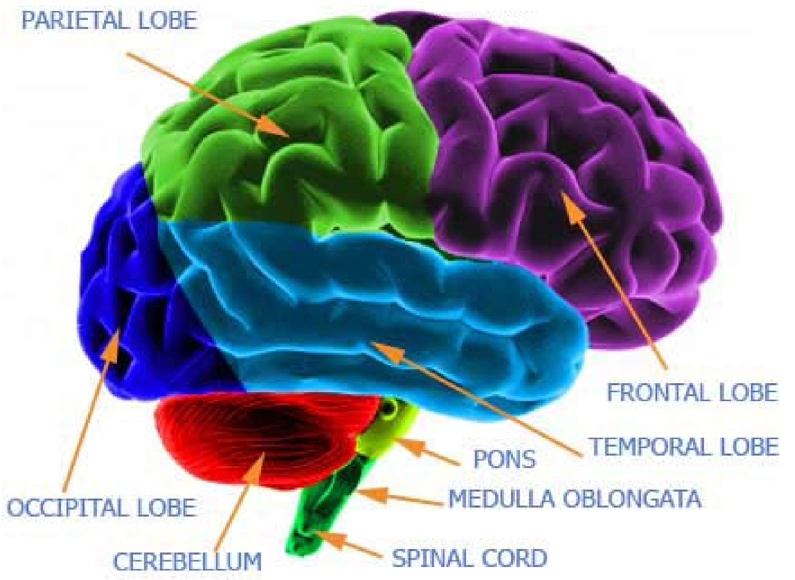

Figure 2.1: Human brain divided to lobes. [22]

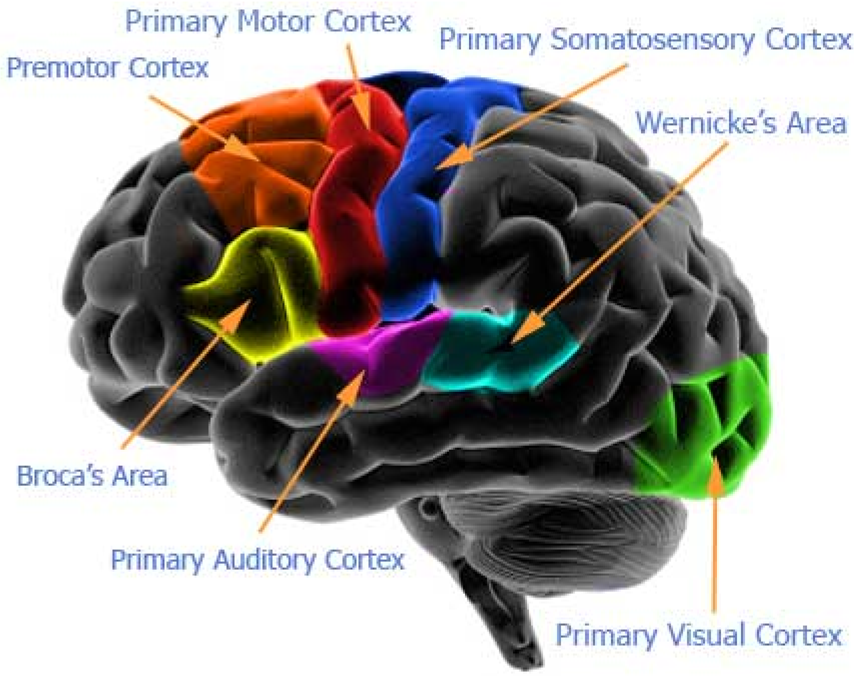

Figure 2.2: Major cortexes of brain. [22]

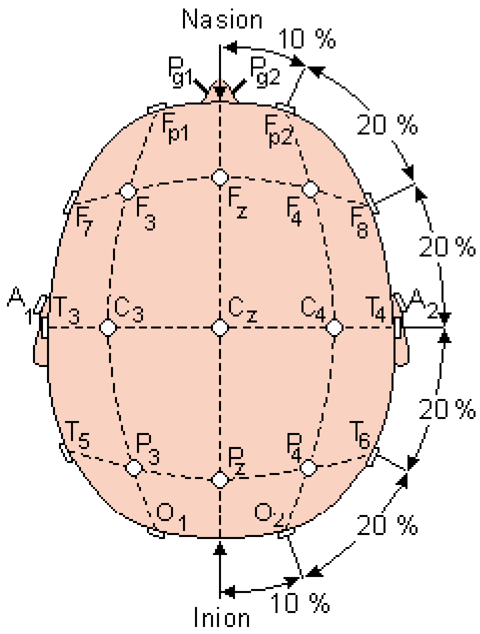

Figure 2.3: Original 10-20 international system. [27]

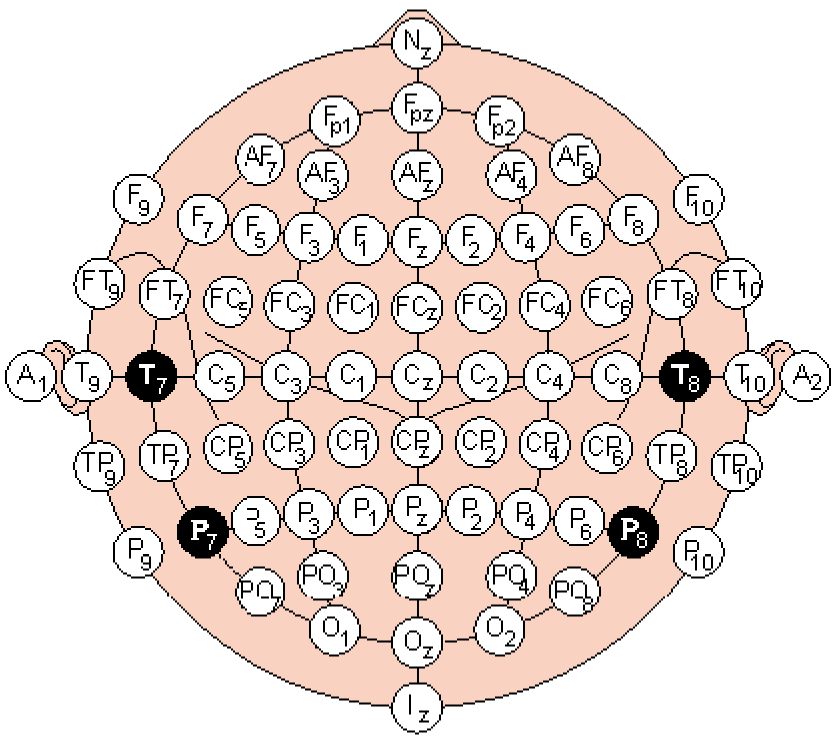

Figure 2.4: Extended 10-20 international system. [27]

2.3 Brain Activity

Electrical recording from the scalp demonstrates that there is continuous electrical activity in the brain. The combination of electrical activity of the brain is called the brain wave or brainwave pattern, because this activity is cyclic and has "wave" nature. We can determine some of these waves by their frequencies. [18, 24]

- **Alpha wave**

  Produced by the healthy, awake and mature brain with closed eyes.

  Frequency 8 - 14 Hz

  Amplitude $30 - 80$ µV

- **Beta wave**

  Higher amplitude with drowsiness. Produced in waking consciousness.

  Frequency 15 - 38 Hz

  Amplitude $10 - 20$ µV, sometimes $20 - 30$ µV

- **Gama wave**

  Produced by movement of fingers and can be connected with stress.

  Frequency 38 - 100 Hz

  Amplitude ≈ 10 µV

- **Delta wave**

  Produced in sleep, in waking state it signalizes attention disorder.

  Frequency 0,5 - 3 Hz

  Amplitude $10 - 300$ µV

- **Theta wave**

  Connected with creativity, fantasy, meditation.

  Frequency 4 - 7 Hz

  Amplitude < 30 µV

- **Lambda wave**

  Can be seen in children in age from 2 to 15. It is produced during watching an illuminated subject.

  Amplitude < 20 µV

2.4 ERP

2.4.1 ERP components

The following information is based on [23].

ERP components are named by their polarity (P - positive, N- negative, C - can be different) and their timing. Components are sometimes renamed (shortened). For example, the P300 component is also called the P3 component. Major ERP components are:

- **C1**

  Generated in the area of the primary visual cortex. The voltage recorded on the scalp can be positive for stimuli in the lower visual field and negative for stimuli in the upper visual field. This component is sensitive to contrast, frequency and other aspects of a stimulus. The C1 wave typically onsets 40–60 ms poststimulus and peaks 80–100 ms poststimulus.

- **P1**

  The P1 wave is the next wave following the C1 component. The P1 wave is largest at lateral occipital electrode sites. The P1 latency can vary depending on stimulus contrast. The P1 wave is also sensitive to direction of spatial attention and (like the C1 wave) stimulus parameters.

- **N1**

  N1 component comes after the P1 component. This wave is s little bit different for auditory and visual stimuli. (The next information is valid for auditory stimuli.) N1 wave has several subcomponents. The first subcomponent peaks 75 ms and it is generated in the auditory cortex, there is also vertex-maximum potential of unknown origin that peaks around 100 ms and a component generated in the superior temporal gyrus peaks around 150 ms. The N1 wave is sensitive to attention.

- **P2**

  The P2 component follows N1 component. This component is larger for target stimuli and it is more larger for infrequent target stimuli. This component is measurable at the central and anterior scalp.

- **N2**

  The N2 wave consists of several subcomponents. A repetitive nontarget stimulus creates basic N2. If other stimuli (also called deviants) are presented repeatedly, a larger amplitude in N2 latency range can be seen. If deviants are task-irrelative, this effect will consist of a mismatch negativity. Auditory and visual (task-related) deviants will elicit the N2b component. This component is larger for not too frequent targets.

- **P3**

  The P3 wave also contains several ERP components. Major subcomponents of the P3 component are the P3a component and the P3b component (Figure 2.5). Both are elicited by unpredictable, infrequent shifts in tone pitch or intensity, but the P3b component is presented only for task-relevant shifts. The P3 component mostly means the P3b component. The characteristics of the P3 wave is influenced by uncertainty of the subject, probability of the task-defined category of a stimulus and others aspects. The P3 wave peak occurs 300 ms after stimulus. The P3 amplitude and latency depends on aspects of stimulus and subject.

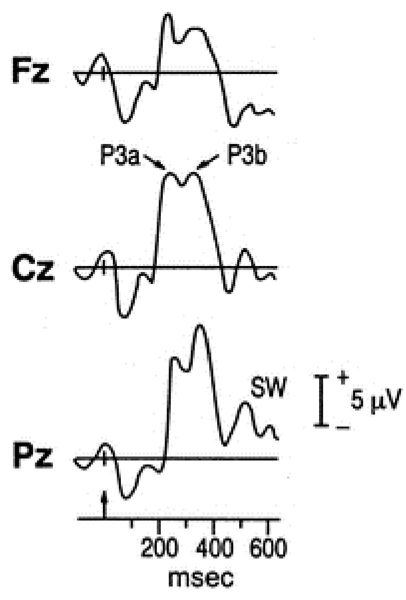

Figure 2.5: The P3 wave.[14]

2.4.2 Principles of ERP experiments

Strategies and rules for ERP experiments are taken from [23]:

- **Strategy 1** Focus on a specific component.
- **Strategy 2** Use well-studied experimental manipulations.
- **Strategy 3** Focus on larger components
- **Strategy 4** Isolate components with difference waves.
- **Strategy 5** Focus on components that are easily isolated.
- **Strategy 6** Use component-independent experimental designs.
- **Strategy 7** Hijack useful components from other domains.
- **Rule 1** Peaks and components are not the same thing. There is nothing special about the point at which the voltage reaches a local maximum.
- **Rule 2** It is impossible to estimate the time course or peak latency of a latent ERP component by looking at a single ERP waveform - there may be no obvious relationship between the shape of a local part of the waveform and the underlying components.
- **Rule 3** It is dangerous to compare an experimental effect (i.e., the difference between two ERP waveforms) with the raw ERP waveforms.
- **Rule 4** Differences in peak amplitude do not necessarily correspond with differences in component size, and differences in peak latency do not necessarily correspond with changes in component timing.
- **Rule 5** Never assume that an averaged ERP waveform accurately represents the individual waveforms that were averaged together. In particular, the onset and offset times in the averaged waveform will represent the earliest onsets and latest offsets from the individual trials or individual subjects that contribute to the average.
- **Rule 6** Whenever possible, avoid physical stimulus confounds by using the same physical stimuli across different psychological conditions (the Hillyard Principle). This includes "context" confounds, such as differences in sequential order.

- **Rule 7** When physical stimulus confounds cannot be avoided, conduct control experiments to assess their plausibility. Never assume that a small physical stimulus difference cannot explain an ERP effect.
- **Rule 8** Be cautious when comparing averaged ERP that are based on different numbers of trials.
- **Rule 9** Be cautious when the presence or timing of motor responses differs between conditions.
- **Rule 10** Whenever possible, experimental conditions should be varied within trial blocks rather than between trial blocks.
- **Rule 11** Never assume that the amplitude and latency of an ERP component are linearly or even monotonically related to the quality and timing of a cognitive process. This can be tested, but it should not be assumed.
- **The Hillyard Principle** Always compare ERP elicited by the same physical stimuli, varying only the psychological conditions.

2.5 State of the art

This topic is interesting and important for driving safety and a lot of articles, theses and experiments are dedicated to the problem of the driver's or cognitive attention. However, no experiment so far deals with driver's and passenger's attention; therefore this thesis fills the gap in this area.

2.5.1 Experiment 1

Driver's Attention and Auditory Stimulation (ERP Experiment)

This experiment [13] deals with driver's attention in stereotypical driving on a highway. This experiment uses a car simulator and auditory stimuli. It shows that driving time has to be chosen realistically (about 35 minutes), because some subjects get headache and feel uncomfortable. The experiment also shows that a shorter auditory stimulus is better for good component analysis.

2.5.2 Experiment 2

The Structure and Diagnostics of Development Coordination Disorder in Children at School Age

This study[17] deals with children's attention and their reactions to the auditory stimuli. Twenty-four children were tested in this experiment. These are auditory stimuli, which were used:

- stimulus S1 - sound of frequency of 800Hz, with duration time 75 ms and probability of occurrence 0.82
- stimulus S2 - sound of frequency 800Hz, duration time 35 ms with probability of occurrence 0.16
- stimulus S3 - sound of child crying with duration time 600 ms and probability of occurrence 0.02

The whole simulation session consists of six subsessions with approximately 170 stimuli. Each subsession was followed by 1 minute pause. During the stimulation sessions, the subjects watched the video (the ignored stimulation protocol was used).

This experiment shows that it is suitable to divide experiments into blocks to prevent over-stimulation of the tested subject.

2.5.3 Other Experiments

Other studies and experiments were studied. They deal with driver's attention [12], driver's distraction and dual-tasks [21], car simulators and their usage for EEG stimulation [20] or recorded data treatment [25].

Described experiments show that a car simulator can create realistic environment and the subjects sitting in the car simulator receive similar feelings as in real environment. Simulated 3D environment can induce a motion sickness. Experiments show that it is better to focus on a single task (and one ERP component).

3 Realization Part

3.1 Design of Experiment

The purpose of the experiment is to determine if driver's and passenger's attention decreases while they drive on a monotonous track. I suppose that driver's attention is over time decreasing and driver loses the ability to quickly react (respond) to the stimuli. I expect that response time to the stimuli will be extended.

Recognition of the subject's fatigue is based on changes in the P300 component latency in tested persons' reaction time. The change in reaction time is measured by comparing the peak latency of the P3 component. Subjects are stimulated by auditory stimuli, which are mediated through headphones.

The whole experiment is based on a video game, where the driver is driving and counting target stimuli. The passenger is just watching the road and counting stimuli in the meantime. The subject's fatigue is increased by stereotypical monotonous driving on a boring track with no traffic. They drive approximately 60 minutes. The drive is divided into eight blocks:

- The first block is without stimuli, it takes 5 minutes and its purpose is to make subjects comfortable in the car and get familiar with the driving and the simulation.
- The second block takes 10 minutes and in this block the subjects are stimulated by auditory stimuli.
- The next block is again without stimuli to make sure that subjects do not get used to the target stimulus; it takes 5 minutes.
- The last block is with stimuli and takes again approximately 10 minutes.

After these four blocks the driver and the passenger switch their positions and drive other four blocks.

After each block with stimuli the driver and passenger announce the total number of the counted target stimuli. The subjects measured by using the

BrainAmp DC device played always the role of the driver in the first part of the experiment.

The stimuli are auditory and they are mediated by headphones with 1,5 second pause. Target and non-target stimulus are 0,100 s long and have different frequency. The occurrence of the target stimuli is 20 percent. The tested subject uses always the same measuring device and the same headphones for both parts of the experiment.

Men and women were chosen as a group of subjects. They rode on the monotonous highway track. They are asked to drive with maximum speed of 130 km/h. They were listening to the audio stimuli. Stimuli were played randomly and they were independent on the position of the subject on the road.

3.2 ERP Laboratory

For this experiment it is necessary to have a laboratory with adequate hardware equipment and software tools for measuring and representation of ERP recordings. The laboratory at the University of West Bohemia was used for this experiment. This laboratory is located at the Faculty of Applied Sciences (FAV)/Faculty of Mechanical Engineering (FST) building in the university campus Bory. This laboratory (Figure 3.2) is equipped with this hardware:

- Car simulator

  The car simulator is the Škoda Octavia car (Figure 3.1) with the game steering wheel, pedals and gear from Logitech (specifically it is Logitech G27 Racing Wheel [6]) and two web cameras, which are situated in front of measured subjects.

- Projector

  The projector is situated upper the car simulator and projects a scene on the wall in front of the car.

- Two Computers with software Brain Vision Recorder

  These computers record ERP measurement by software Brain Vision Recorder [15]. These computers also record video using web cameras.

Figure 3.1: Car simulator.

- Two computers with software Presentation

  These computers produce stimuli using software Presentation from Neurobehavioral Systems company [8]. Each computer produces stimuli to the driver and passenger using headphones. The stimuli are also synchronized with measuring devices.

- Computer with video game

  The video game World Racing 2 run on this computer. This computer projects the video game using projector and is connected to the car simulator steering wheel and speakers. Sound from the video game (the engine sound and the sound of brakes, tires) is distribute through speakers in a car.

- EGG caps

  EEG caps used for the experiment have positions of electrodes described by the 10-20 system. The only exception is reference electrode, which is placed above the root of the nose.

- Headphones

  Headphones are used for producing stimuli to subjects. Standard headphones from Sennheiser and Koss company are used. The subject always has the same headphones, to avoid possible differences between headphones.

- Measuring device BrainAmp DC

  This measuring device has 32 EEG channels and it is powered by BrainAmp Battery. It is connected to the computer via Universal Serial Bus (USB) port with USB2 adapter.

- Measuring device V-Amp

  This equipment is a compact and mobile version of BrainAmp DC. The V-Amp has 16 EEG channels and it is powered and connected to the computer with USB cable.

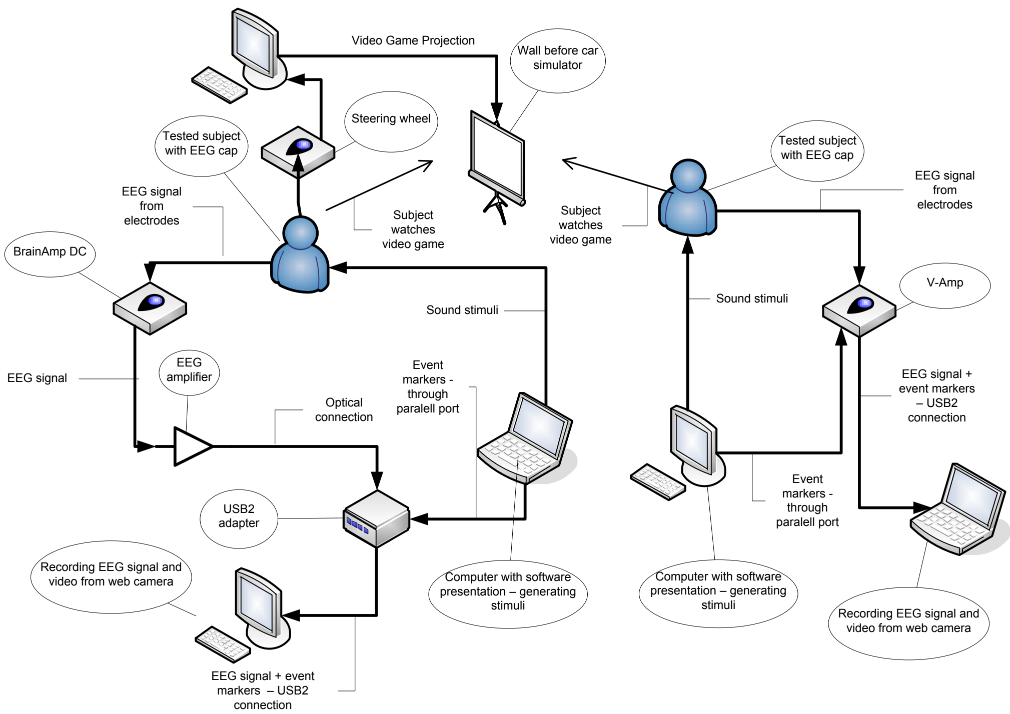

Figure 3.2: EEG laboratory.

These measuring devices are not the same and for this reason the results measured using different devices are not directly comparable.

3.3 Software Equipment

- The BrainVision Recorder 1.20

  This software (Figure 3.3) from the Brain Products GmbH company reads and saves EEG recordings from measuring devices.

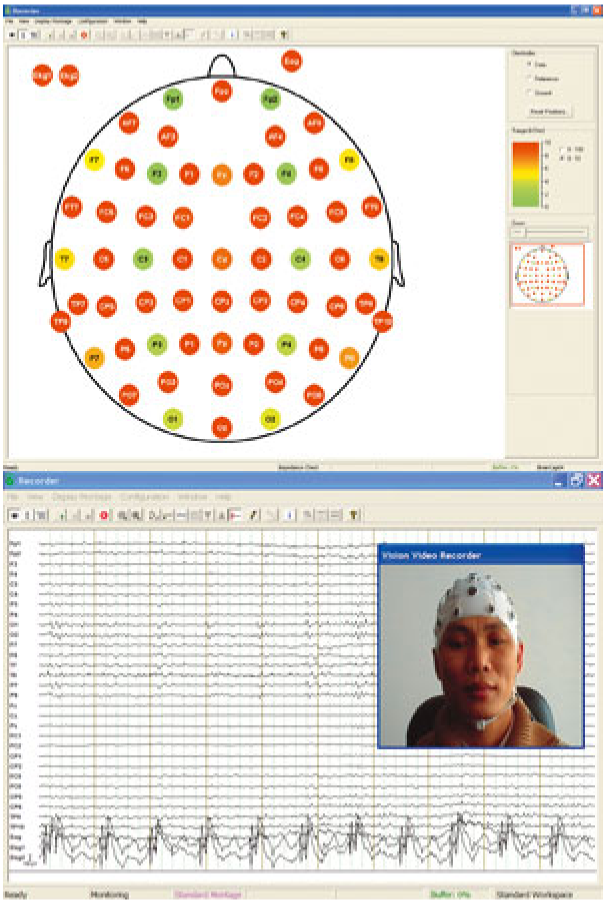

Figure 3.3: The BrainVision Recorder 1.20 [15]

- The BrainVision Analyzer 2.0

  This software is also from the Brain Products GmbH company and it is used for analyzing and editing EEG recordings. (Figure 3.4).

Figure 3.4: The BrainVision Analyzer 2.0

- World Racing 2

  It is a video game, which is used for simulation driving. (Figure 3.5).

- VirtualDub 1.9.11

  VirtualDub[19] is used for video recording. I chose this software because it is a simple tool for video and audio recording and it is also released under GNU General Public Licens (GPL). VirtualDub offers lots of options for video recording and compression. The video codec Lagarith [16] is used for video capture for its good speed and compression and codec XVID [10] is used for video storing.

- Presentation 15.1

  This software generates and produces auditory stimuli in accordance with the created program (Figure A.5). The Presentation also generates target markers and sends the markers to recording devices through the parallel port.

- Audacity 2.0

  This software [2] was used for generating sound stimuli for the experiment.

Figure 3.5: World Racing 2

- EditCar v1.5e

  This software [4] was used for editing a car model for the game World Racing 2.

3.4 Experiment Preparation

The first step for the experiment design was to choose a proper simulator. I looked for some specific driving simulators, but none of them provided a cost effective solution and usability in our conditions. Then I focused on computer games. This solution was already used in experiment [13]. I found the video game Life for Speed [1] which is very realistic and good looking, but it offers a few options to create and edit tracks and race cars. For these reasons I chose the game World Racing 2 developed by the game studio Synetic [9]. This game offers reasonable graphics processing and great options to edit the game scenery. The used scenery for the experiment was created by Jan Rada [26]. The race car Škoda Octavia was edited by the program EditCar [4].

3.5 Course of Experiment

3.5.1 Before the experiment

Tested subjects do not need any preparation, the only exception is washing their hair before experiment (for better scalp conductivity). Test subjects are introduced to basics of EEG measurement (e.g.no talking, reducing movement to minimum, turning off their phones etc) before starting the experiment. Also they get familiar with the game controls and the volume of stimuli is adjusted to a pleasant limit. Subjects are also asked to fill questionnaire (Attachment A.1). Then each subject gets EEG cap. After that the electrodes on the EEG cap are lubricated by special EEG gel, ground electrode and reference electrode are attached. Then electrodes conductivity is measured by BrainVision Recorder and if it is necessary they are corrected. After these steps subject are situated to car simulator and they set their seats to comfortable positions. They get headphones and conductivity of electrodes is again measured to prevent possible artifacts.

3.5.2 During the experiment

After subjects are prepared for the experiment, EEG recording, video recording and stimulation are launched. During experiments are subjects overseen by experimenter via web cameras and the EEG recordings are also controlled. After 30 minutes subjects switch their seats and prepare for the next part of the experiment. The state of electrodes is checked and the second part of experiment is started. When the experiment finishes, subjects are asked to answer a few questions about the experiment which are stored in the EEG/ERP portal [3].

3.6 Data Recording

The EEG/ERP brain activity was recorded using the standard 10-20 EEG cap, but for processing only the electrodes Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, Fz, Cz and Pz were used. These electrodes are referenced to the electrode, which is located above the subject's nose and linked to earlobe ground.

The signals were recorded using BrainAmp DC and V-Amp equipments of Brain Products GmbH company. Sampling frequency was set to 1kHz and all analog filters were switched off.

3.7 Data Processing

The recorded signals were adjusted and analyzed in these steps:

- Application of IIR Filters using digital band-pass filter with cut-off frequencies 0.2 Hz and 20 Hz. (Figure 3.6).

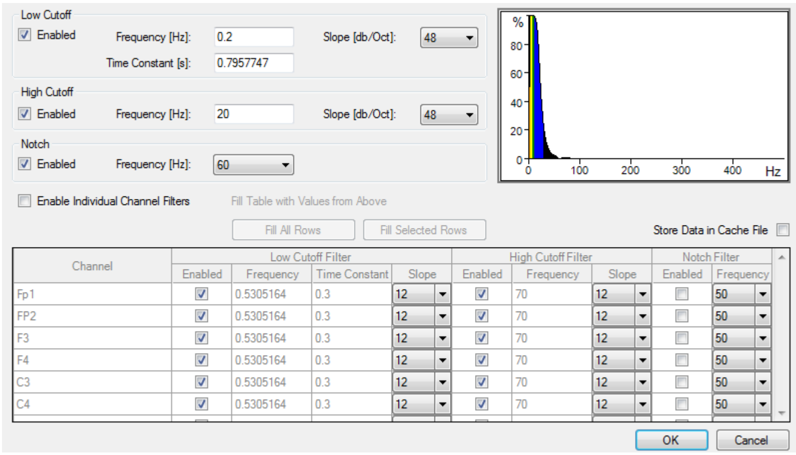

Figure 3.6: IIR Filters from Analyzer 2.0.

- Segmentation of the EEG signal according to markers of the stimuli. Time segments were created from the 100 ms pre stimulus to 550 ms post stimulus. The segments are chosen shorter then it is usually because a lot of subjects blink very often and with a shorter stimulus segment is probability of blinking in the whole segment smaller.
- Correction of the baseline. The baseline was corrected using interval <-70 ms, 0ms> pre stimulus.
- Artifacts rejection. For artifacts rejection automatic and semi automatic methods of the Analyzer 2 were used. Used criteria for artifact rejection were:

- The gradient criterion with maximum allowed voltage step 50 μV/ms
- the Max-Mix criterion with the maximum allowed absolute difference 180 μV
- the amplitude criterion with the maximum allowed amplitude 80 μV and the minimal allowed amplitude -80 μV
- the Low Activity criterion

The EEG signal with a detected blink artifact is shown in Figure 3.7.

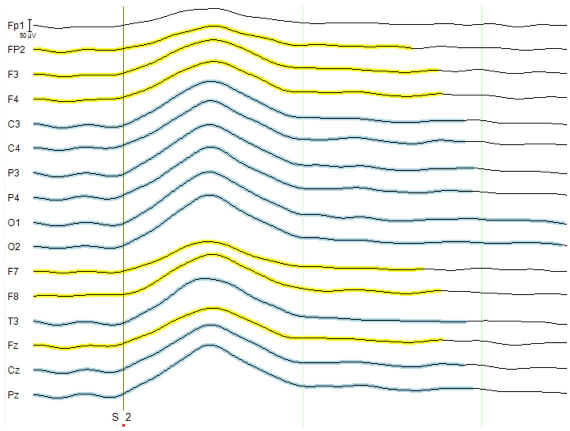

Figure 3.7: EEG signal with blink artifact.

- Averaging of the epochs with the stimuli in the same block of the P3 component.
- Peak detection of the P300 component. Semiautomatic tool of Analyzer 2.0, with reference Cz electrode, is used for the peak detection. The P3 component is detected at all recorded electrodes.
- Peak comparison. The peak latency was compared between subjects at the same position with the same measuring device.

3.8 Evaluation of Results

Twenty-two subjects at the age 20 - 26 were measured in this experiment. Eighteen of them were men and four women. The half of subjects were measured using BrainAmp DC and the second half using V-Amp. Unfortunately for some technical issues with measuring device BrainAmp DC, most of recorded data on this device are corrupted. Result in Table 3.2 could be inaccurate. A few experiments were also ended earlier because of subjects physical conditions (they started to feel sick) or technical difficulties. Twenty subjects with driver license and two subjects without were involved in tested groups. Four tested subjects were left-handed. All recorded data are included in attachments on DVD with exception of video records, which are located at EEG/ERP portal server [3].

The measured results from V-Amp device are described in Table 3.1. The results from BrainAmp DC are in Table 3.2. Peak time of the P3 component was calculated from all channels with reference on the electrode Cz (in the case of V-Amp measurement) or C4 electrode (BrainAmp DC).

Stimuli bock	1 - passenger	2 - passenger	3 - driver	4 - driver
Subject number	Peak of the P3 component [ms]			
Subject 2	331	339	??[1]	??[1]
Subject 4	311	296	??[1]	??[1]
Subject 5	374[2]	345[2]	??[1]	??[1]
Subject 8	306	286	292	283
Subject 9	292	287	290	278
Subject 12	381	397	345[2]	286[2]
Subject 13	287	291	307	306
Subject 15	312	303	335	356
Subject 17	343	359	301	282
Subject 20	274	264	291	272
Subject 21	324	318	315	283
Average	365	350	297	279

Table 3.1: The P300 component peaks. (V-Amp used)

[1] Experiment was prematurely aborted.
[2] Not enough clear target segments. Data could be inaccurate.

Stimuli bock	1 - driver	2 - driver	3 - passenger	4 - passenger
Subject number	Peak of the P3 component [ms][3]			
Subject 1	331	271	??[1]	??[1]
Subject 3	302	294	??[1]	??[1]
Subject 6	349	308	??[1]	??[1]
Subject 7	292	288	345	308
Subject 10	305	305	349	301
Subject 11	297	308	281	293
Subject 14	344	363	342	322
Subject 16	285	284	300	278
Subject 18	277	319	325	316
Subject 22	289	258	265	269
Average[4]	307	295	278s	276

Table 3.2: The P300 component peaks. (BrainAmp DC used)

The average peak latency of the P3 component is computed from the average of all recorded and edited signals and then detected via the Peak Detection tool of the Analyzer. The averaged signals (recorded using V-Amp device) from passenger's part of the experiment are in Figure 3.9 and from driver's part in Figure 3.11. The averaged signals (recorded using BrainAmp DC) from driver's part of the experiment are in Figure 3.13 and from second (passenger's) part of the experiment are in Figure 3.15.

The processed data shows that my presumption about increasing the P3 component latency with increasing subject's fatigue was not confirmed.

[1]Experiment was prematurely aborted.
[2]Not enough clear target segments. Data could be inaccurate.
[3]Signal from electrode C4 is used because of interference in Cz, Pz and Fz
[4]Average was calculated on electrode C4, because of corrupted signal on Cz, Fz and Pz electrodes.

The grand average from all tested subjects (without artifacts) recorded using the V-Amp device.

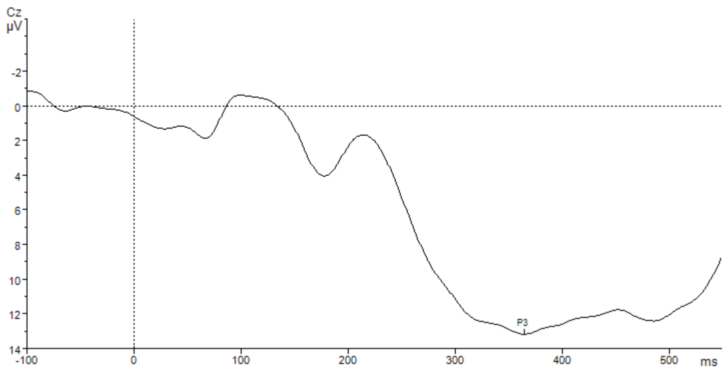

Figure 3.8: The grand average of the P300 Component in the first (passenger) stimulation block with the peak 365 ms.

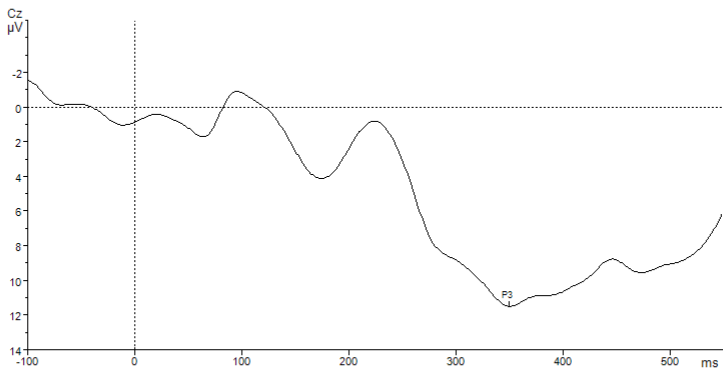

Figure 3.9: The grand average of the P300 Component in the second (passenger) stimulation block with the peak 350 ms.

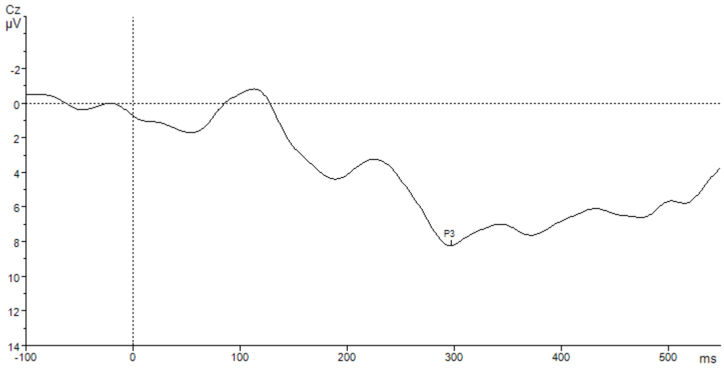

Figure 3.10: The grand average of the P300 Component in the third (driver) stimulation block with the peak 297 ms.

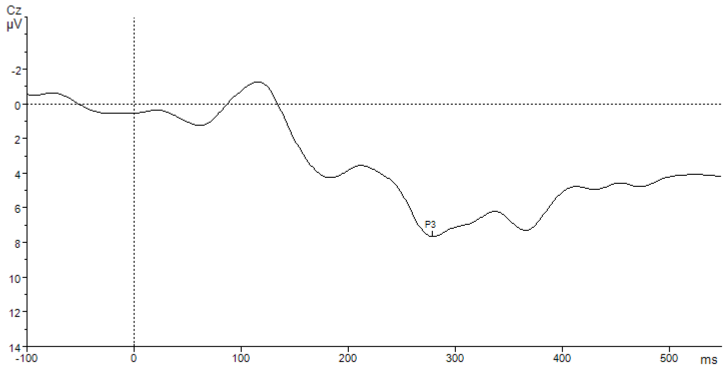

Figure 3.11: The grand average of the P300 Component in the fourth (driver) stimulation block with the peak 279 ms.

3.9 Eye Blink Detection Program

The part of my work was also development of the program, which is able to detect human eye blinking from picture of the human face. This program is written in the .NET platform in the program language C#. This program should help to detect and recognize eye blink artifacts in EEG measurement.

The grand Average from all tested subjects (without artifacts) recorded using the BrainAmp DC device.

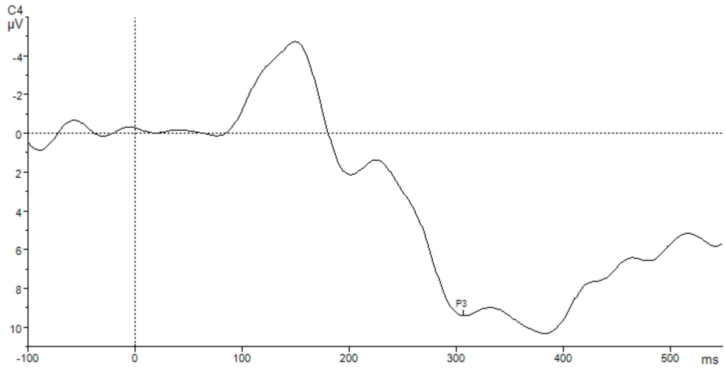

Figure 3.12: The grand average of the P300 Component in the first (driver) stimulation block with the peak 307 ms.

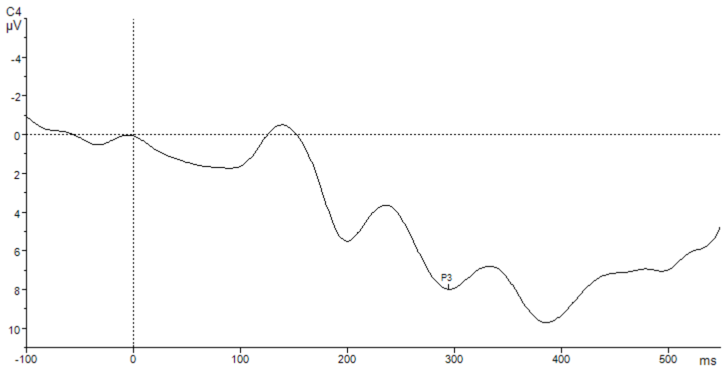

Figure 3.13: The grand average of the P300 Component in the second (driver) stimulation block with the peak 295 ms.

3.9.1 Requirements for the program

The main requirements for the program were:

- To implement methods for detecting human blinking from video records or the web camera.
- To implement an option to save detected blinks to a text file for the next processing.

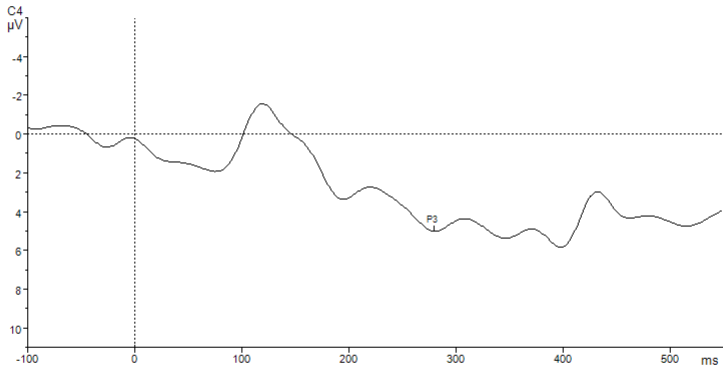

Figure 3.14: The grand average of the P300 Component in the third (passenger) stimulation block with the peak 278 ms.

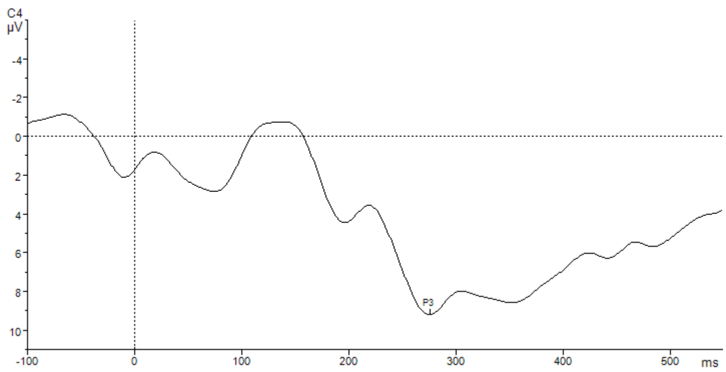

Figure 3.15: The grand average of the P300 Component in the fourth (passenger) stimulation block with the peak 276 ms.

- To create Graphical user interface (GUI) for this application.

3.9.2 Software description

The software tool was developed in C# language with using Intel Open Source Computer Vision (OpenCV)[7] libraries. Because OpenCV is originally designed in language C, .NET wrapper for .NET Emgu CV[5] is used for my program. (Figure 3.16). Program is designed to run on operating systems Windows with .NET 4.0 framework or higher. OpenCV method HaarDetection is used for the face detection. Then basic heuristic [29] is applied to determine position of the eyes. Then hypothetical places, where the eyes can be, are searched with Haar or Hough Circles Eye Detection method. If face and both eyes are detected, no blink is registered. Program uses three-tier architecture (Figure 3.19).

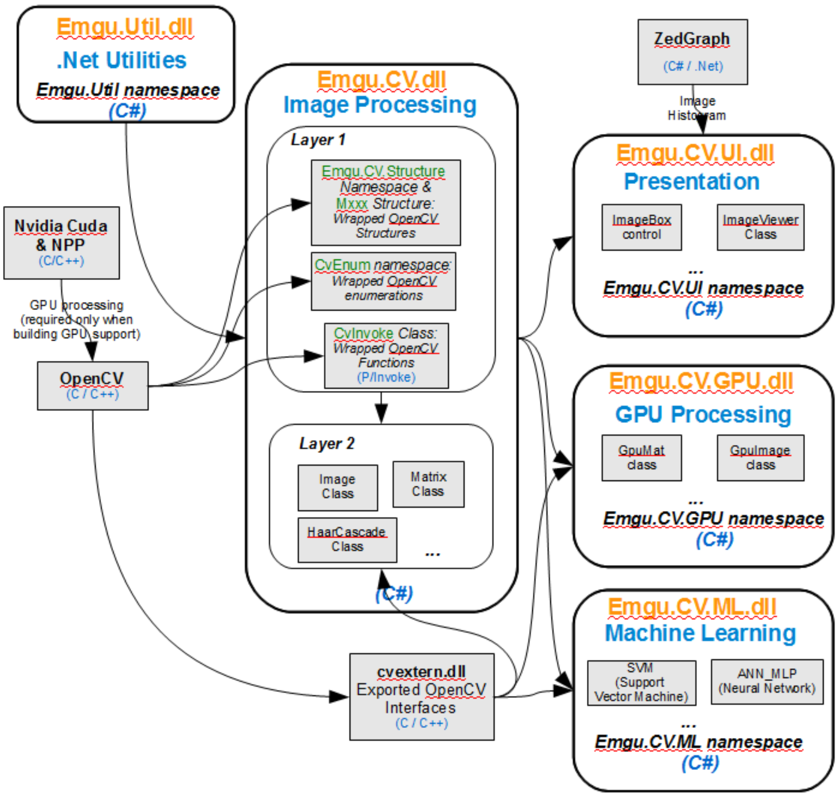

Figure 3.16: Emgu CV - Architecture Overview [5]

- The data tier is represented by the classes User.cs, Blink.cs and Settings.cs.
- The application layer is represented by the class Video.cs, this class uses the library function of OpenCV.
- The presentation tier includes Form.cs and SettingsForm.cs.

Types of processed information

- **Input files** - A video from a file or a camera. Supported video formats depend on installed video codecs.
- **Output files** - One file with information about detected blinks with their corresponding frame numbers in video.
- **Configuration files** - Default configuration is saved in the configuration file. This file contains settings of all methods and information texts. A user can create his / her own configuration files.

The context diagram is displayed in Figure 3.17.

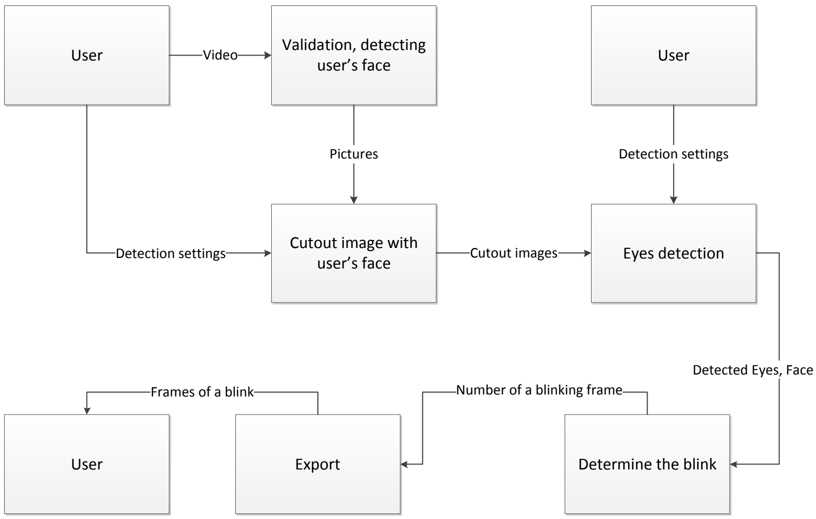

Figure 3.17: Blink Detector - context diagram.

3.9.3 Blink detection

For detection of subject's blinking the following algorithm is used. Figure 3.18.

```
if (face is detected)
{
    detect left eye;
    detect right eye;
    if (left eye or right eye is not detected)
    {
        register blink;
    }
}
capture next frame
```

Figure 3.18: Eye blinking detection algorithm.

Recognition of the subject's face and eyes is resolved by the OpenCV object detector and classifier with the Haar like feature. Configuration files from OpenCV are used for classification.

3.9.4 Software testing

The Eye Blink Detection program was tested on six computers with the operating system Microsoft Windows XP, Windows 7 Home Premium 32-bit and Windows 7 Ultimate 64-bit. Testing was focused on the functional verification of the program and verification functionality of the used blinking detection algorithm. The program was tested on video files and web cameras. One of the tested subjects had glasses.

The software tool works well, but its success depends on the light conditions (especially for people with glasses), the angle of the recorded face and speed of blinking. Tests showed that the application detected the most of intentional blinking, but the natural blinking was mostly not detected. The situation is critical for videos from a web camera, because the number of processed frames depends on computing power of the computer. The situation is better with video files because the program is not limited by computing power and it is able to process all recorded frames.

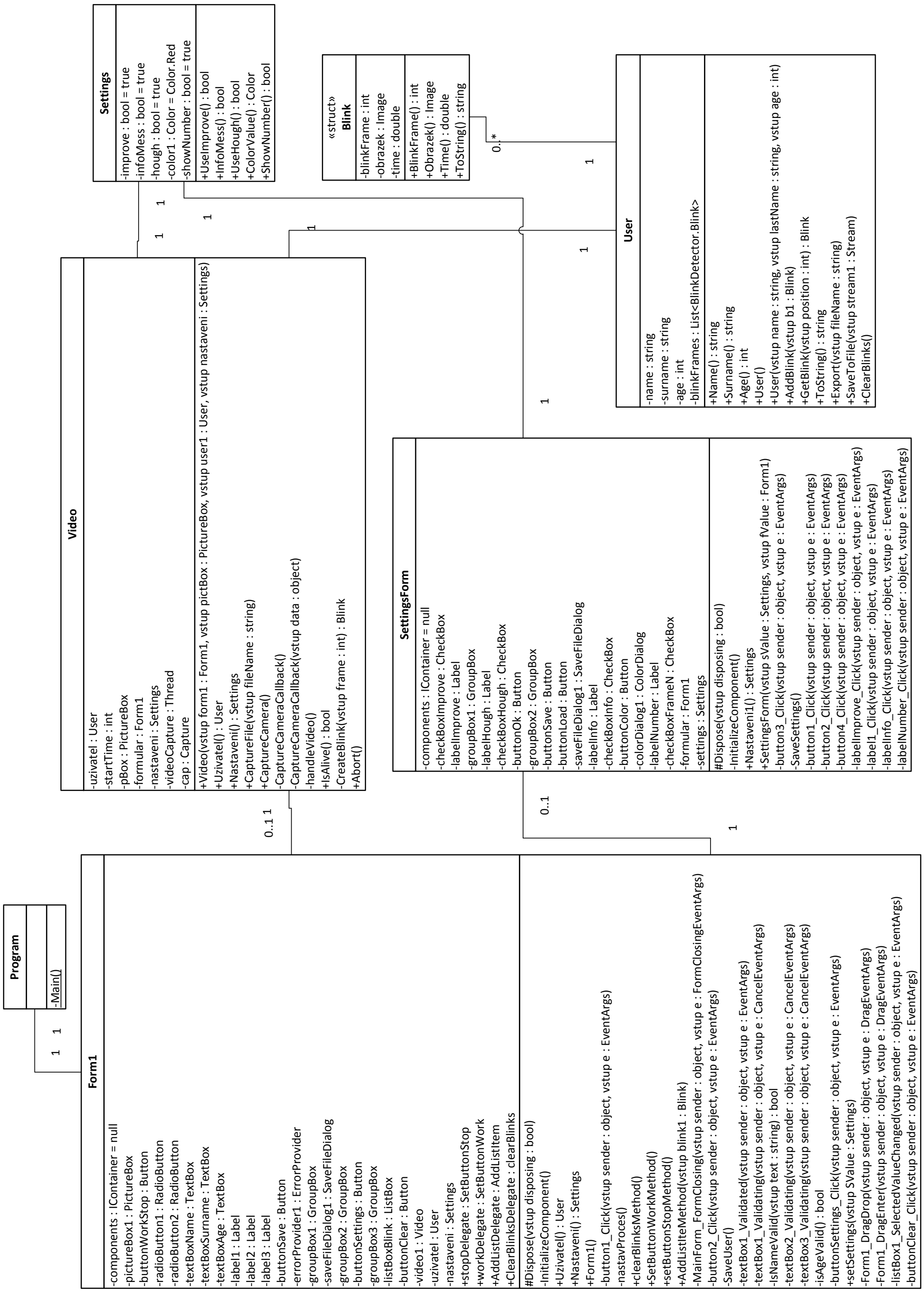

Figure 3.19: Eye Blinking Detector - UML diagram.

4 Conclusion

The main goal of my bachelor thesis was to learn about ERP experiments and create an appropriate scenario for the measurement of driver's and passenger's attention, and learn to process measured data.

The video game World Racing 2 with a custom high way track and a custom car was used for the scenario. EEG data were measured using the program Recorder. Auditory stimuli were generated via the Audacity software tool and produced using the program Presentation. The source code of stimuli Presentation program is included in attachments A.5. The recorded data were processed in the program Analyzer 2.0.

Subject attention was investigated as subject's reaction to stimuli and related change in P300 component latency. The assumption that subject's attention decreases with more fatigue was not confirmed. Some of the tested subjects had a larger P300 wave latency, but this phenomenon is unobservable in the average. Even the P300 latency mildly decreases in time. This effect could be caused by a short scenario time or by the fact that the subject is more focused on stimuli after some time. The grand average of all recorded signals with peak detection is showed in Figure 3.9, Figure 3.11, Figure 3.13 and Figure 3.15. In the experiment 22 subjects were measured, but for some technical difficulties with one measuring device are half of recorded data non-standardly processed and their comparison could not be direct.

Another part of my thesis was to create a program, which will be able to detect eye blinking from the picture of subject's face. The program was tested on several computers and four subjects. Unfortunately its accuracy is not the best. This problem is caused by the speed of human blinking, which is too fast for a classic camera, but for recorded videos from a high speed camera the situation could be better.

In the future it would be suitable to make identical measuring conditions for all subjects (measurements in the same day time with the same temperature, etc). A longer scenario length or division of the scenario to more blocks could be beneficial for the experimental results. Also using headphones with better noise reduction may bring better results.

The possible extension of the software tool could be an improvement of parameters for detection of eye blinking.

List of Figures

List of Tables

Acronyms

EEG Electroencephalography. 1–3, 10, 13–15, 18–21, 24, 29, 30

EMG Muscular EEG artifacts. 2

EOG Eye movement EEG artifacts. 2

ERP Event-related potentials. 1–3, 6–10, 18, 21, 29

FAV Faculty of Applied Sciences. 12

FST Faculty of Mechanical Engineering. 12

GPL General Public Licens. 16

GUI Graphical user interface. 24

OpenCV Open Source Computer Vision. 24, 26

UML Unified Modeling Language. 28, 31

USB Universal Serial Bus. 14

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A Attachments

A.1 User manual for Eye Blink detector

A.1.1 Requirements for launching

- Operating system Windows
- .NET framework 4.0 or higher

A.1.2 User manual

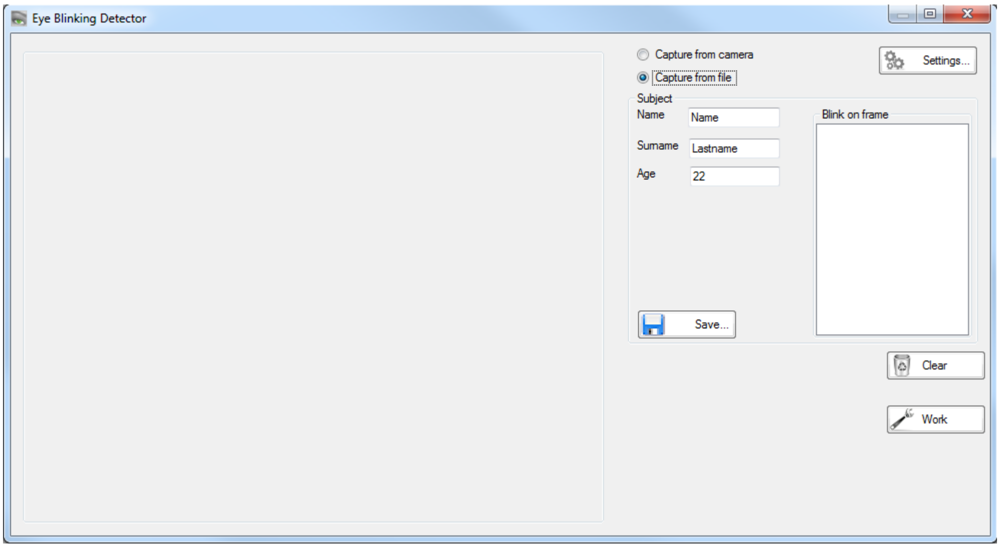

Figure A.1: GUI of the Eye Blink Detector

After launching it is necessary to choose the source of video (a file or a camera). It is possible to customize detection via the setting, which offers the change of color of the information texts and editing of the detection method.

Processing of the video is possible to stop by using **Stop** (**Work**) button.

The button **Clear** deletes all detected blinks and information about subject.

The **Save** button exports information about subject and detected blinking frames to the text file.

The **Settings** button opens Settings Dialog. (Figure A.2.)

After detection the user can browse a list of the detected blinks with corresponding frames which are shown in the left panel.

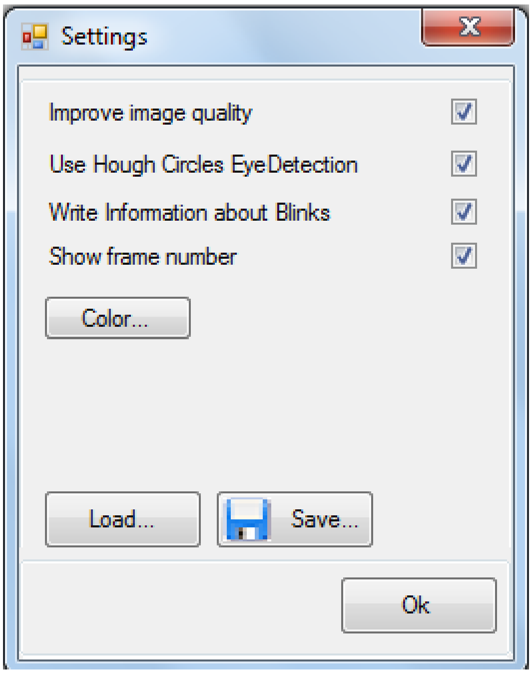

Figure A.2: Settings Dialog

A.2 Content of the DVD

- **Bachelor thesis**

  This folder contains this bachelor thesis, source files for LaTeX and all used pictures.

- **Data**

  This folder contains all raw recorded EEG data, Recorder workspaces, Analyzer 2.0 workspaces, history files of EEG signals and the anonymous questionnaires of the measured subjects.

- **Scenario**

  This folder contains a map and a car for the game World Racing 2, the program for Presentaion and used auditory stimuli.

- **Software**

  This folder contains software, which were used for the experiment.

- **Eye Blink Detector**

  This folder contains source files, binary files and user manual to the Eye blink Detector.

A.3 Questionnaire

Birth date:	
Sex:	
Left/ right-handed:	
Vision problems:	
Hearing loss:	
Driver license:	
Active driver:	
Diseases:	
Feelings during measurement	
Evaluation of fatigue before experiment: (1 - 5, 5 maximum fatigue)	
Evaluation of fatigue after experiment: (1 - 5, 5 maximum fatigue)	

Table A.1: Questionnaire for tested subjects.

A.4 P300 Component - Cz electrode

The example of detected P3 peaks on the Cz electrode - Subject 9, V-Amp device used.

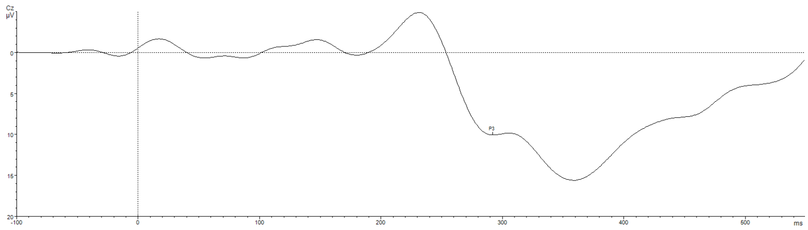

Figure A.3: The P300 Component in the first (passenger) stimuli block. The peak latency is 292 ms.

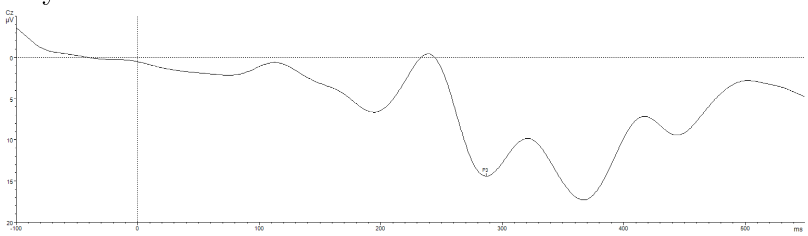

Figure A.4: The P300 Component in the second (passenger) stimuli block. The peak latency is 287 ms.

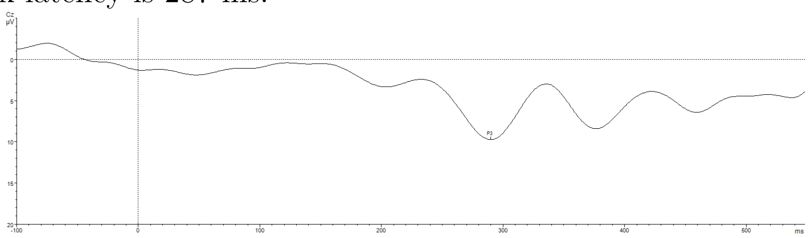

Figure A.5: The P300 Component in the third (driver) stimuli block. The peak latency is 290 ms.

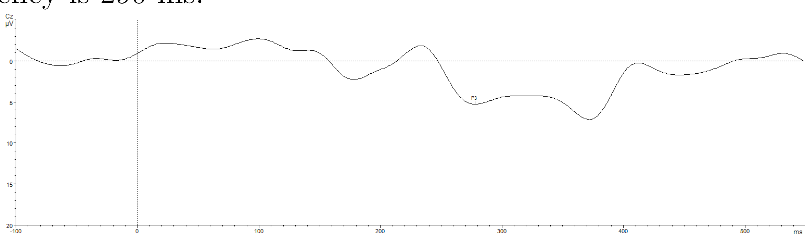

Figure A.6: The P300 Component in the fourth (driver) stimuli block. The ppeak latency is 278 ms.

A.5 Presentation scenario

The program written for Presentation.

```
scenario = "Driver Attention";
write_codes = true;
pulse_width = 100;
$delay=1500;

begin;
array
{
sound {
      wavefile { filename = "stimul.wav"; };
    } nonTarget; # nontarget stimul
   sound {
      wavefile { filename = "target.wav"; };
   } target;   # target stimul
}sounds;

trial
{
start_delay=$delay;
stimulus_event {
nothing{};
} mainEvent;
}main;

#SDL section
begin_pcl;
#wait rutine
sub
   wait( int waitTime )
begin
waitTime= waitTime*60*1000;
   loop
      int waitEnd = clock.time() + waitTime
   until
       clock.time() >= waitEnd
   begin
```

```
       # do nothing
   end
end;
array <int> stimuliArray[400];

loop int j = 1 until j > stimuliArray.count()
  begin
    stimuliArray[j] = 1;
    j = j + 1;
  end;
int start = 1;
int stop=5;
loop int j = 1 until j == 80
  begin
    int pozice = random(start,stop);
    stimuliArray[pozice]=2;
    start = stop+1;
    stop = stop+5;
    j = j+1;
  end;
#scenario
loop int i = 0 until i > 1
begin
  wait(5);
  loop int j = 1 until j > (400)
  begin
    mainEvent.set_stimulus(sounds[stimuliArray[j]]);
    mainEvent.set_port_code(stimuliArray[j]);
    mainEvent.set_event_code(string(stimuliArray[j]));
    main.present();
    j = j + 1;
  end;
  i = i + 1;
end;
```