

Thesis

Exergaming



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Abstract

The project 'Exergaming for active healthy ageing and rehabilitation' (EXACT) aims to develop a new generation exergames for the elderly to help them stay active in general and as an exercise tool in rehabilitation settings in particular. This is important because the elderly population is outgrowing the number of people working in health care, making it necessary to develop and use technology to be able to give health services to a growing number of elderly with a declining number of health staff.

The current student project served as preparation for an experimental study that aims to study movements, postural changes, and brain activity during exergaming. To this end, all the separate pieces of hardware that will be used during data collection – exergame, force plates, EEG, and Microsoft Kinect v2 – have to start in a synchronized manner. Therefore, a controller was constructed to communicate with the various software to start and stop data acquisition from the hardware. During development, the various options for exergames and the hardware used in the experiment were also looked into. Furthermore, a method was developed for skeletal and point cloud collection from the Microsoft Kinect v2.

During development and the search for a usable exergame, several important aspects related to limiting factors of the EEG machine and force plates were encountered. Furthermore, it turned out that the Microsoft Kinect v2 could not be used as part of the gaming system, but was instead used to capture movements.

The resulting system that was built in the current student project allows for all the hardware pieces to have a synchronized start for data acquisition. All the collected data can be analysed and used for further research in the field of exergaming.

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1 Introduction

In a world where the elderly population is slowly outgrowing the number of caretakers, we need to use technology increasingly for health promotion, prevention of health problems, and rehabilitation after injury or disease [1] [2]. With advancing age comes an increased risk in for functional decline, cognitive impairment, and frailty, which increases the risk for falls. This means there is a necessity for the development of health care technology that can promote healthy ageing, reduce or prevent functional decline and improve the effectiveness of treatment and rehabilitation. This is where the EXACT project at the Norwegian University of Sciences and Technology (NTNU) comes in aiming to develop new technology by using exergaming as a means for increasing the physical activity of older people. This new technology will also be used for monitoring and administering personalized rehabilitation programs [3].

The aim of EXACT is to develop the next generation exergames that can offer guided exercises, provide feedback on performance, and dynamically adapt difficulty level to the progress of the older person. In the first phase of EXACT, the connection will be studied between game characteristics and changes in posture, movements, and ongoing brain activity of the participant while playing the exercise game. Relevant questions include: 'How to motivate older people to follow a personalised exercise program?' and 'How to monitor that they followed instructions and performed exercises the correct way?'.

Currently the hardware systems that are part of the program consist of a force plate system used for studying postural changes of the player. In order to study the effect of cognitive elements of the exergame, the study will use an EEG system to collect data on brain activity. A new addition to the study is the Microsoft Kinect v2 which will be used to track the players' body movements during the exergaming, as well as a game capturing system to record the exergame itself.

Separately, each of these systems has been used in many studies and experiments before [3] [4] [5]. However, using them simultaneously during a single study requires synchronisation of the separate systems, to allow the study of relationships between the different aspects of brain activity, body movements, and postural changes. Without synchronisation, the different data streams have to be aligned manually, which is a time consuming enterprise and carries the risk of human error.

This is where the current student project comes in. The task will be to create a system that communicates with all hardware attached to the EXACT project. This controlling system will be used to start and stop data collection from the various hardware systems and stores them in a fixed location for later analyses by the EXACT researchers. The student aims to familiarize with the various systems, design a method to obtain data from said systems, and synchronize and store the incoming data.

The main question of this thesis is the following question:

How to collect exergame session data out of various sensors so that researchers can analyse synchronised data from the exergame, body movements, postural changes, and brain activity of a player?

For the project there are more in-depth questions for the various systems inside the current student project these will be answered in the conclusion.

The thesis has three parts: The first part identifies what hardware will be used in the project The second part will delve into all the methods used to retrieve the information from the systems & hardware attached to the Exergaming project. The last part will delve into the designing and creating the methods for establishing a communication system that is able to control the data collections and systems of the experiment.

- Materials: What will be used in the exergame project? Here we will go into detail on the organization and the project, taking a look into how all the hardware systems operate and how

they will be used in the project. It will be decided what is the essential data for the project and the exergame itself.

- Methods: How does one create a platform to control all the systems within the exergaming project? This part will lead into the operating and design side of the controller to be used in the exergaming project, including how the separate systems are spoken too.
- Results: How are we getting the data out of the various systems? This extends from the EEG data to a single frame of gameplay of the exergame. Here we will analyse specific issues found with the separate aspects of the project.

1.1 The aim and objectives

In the current student project, the overall purpose is the production of a communication system, which purpose is to communicate with various systems. This system must be able to start and stop recording data from the systems. Furthermore, for the Microsoft Kinect v2 device and game capture system there where separate systems developed to enable the reading and storing of data from these devices.

Following this, the new prototype platform was designed with continuing development. The issues encountered and solutions attempted are detailed according to specific goals, and where relevant to the design of the platform.

Specifically the objectives were:

- Establishing a familiarity with the systems used in the current student project
- Investigating how to retrieve data from said systems
- Investigate how to make a controlling system to control the various systems.
- Investigate how to record in-game footage of a video game.
- Investigate how to connect with the Microsoft Kinect v2 and retrieve data from the device.

2 The organisation

NTNU is Norway's primary institution for education in technology and the natural sciences. It is Norway's largest university with more than 39,000 students and 5,100 employees. NTNU encompasses 14 faculties and 70 departments [6]. Between 250 and 350 PhD degrees are awarded yearly within the fields of technology, natural sciences, medicine, arts and humanities, and social sciences. NTNU has a broad range of contracts with industry and R&D organizations, and hosts 850 international students annually. NTNU is an active participant in the EU R&D Framework Programmes and participated in 98 FP7 projects.

The Faculty of Medicine has 1,200 employees, with 300 students annually entering studies in clinical medicine, bachelor or master in human movement science, as well as master studies in neuroscience, health science and exercise physiology. The Faculty is co-located with St. Olav University Hospital and has an integrated practice, which provides convenient access to patients and locations for running clinical research studies.

The Department of Neuroscience is one of the faculty's five departments, with research foci on movement disorders, geriatrics, orthopaedics, rheumatology, neurology, clinical neurophysiology, physical medicine and rehabilitation, and psychiatric diseases. The Research Group Geriatrics, Movement and Stroke (GeMS) is cross disciplinary and runs clinical trials as well as mechanism studies for movement control, falls prevention studies, method studies and epidemiological studies. This group also has a particular focus on the development and use of technology to monitor and enhance movements. The group is responsible for several well-equipped movement laboratories, has access to a usability laboratory, and has highly competent staff with extensive research and clinical competence regarding age related decline in function, physical activity, and activity monitoring, as well as assessment of balance and gait in different populations. The GeMS group has run several large clinical controlled studies, and coordinates a Research and Innovation Action in EU's Horizon 2020 program [7].

Recently, one of NTNU's 4 focused research areas, NTNU Health, has allocated funding to the Department of Neuroscience to continue and further develop its research program into the use of exercise video gaming or exergaming to motivate elderly people to move more or for use in rehabilitation programs. The current student's project is a precursor to one of the studies in the exergaming research project in which the student is tasked with setting up a system with which data from various separate devices can be collected simultaneously and synchronized.

2.1 Company supervisor

The company supervisor for this project is Professor Beatrix Vereijken at NTNU, who works at the Department of Neuroscience at the Faculty of Medicine.

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She is a Professor in Medicine/Human Movement Science, with a PhD in Human Movement Science from the Free University, Amsterdam (1991) and a, MSc in Experimental Psychology from Radboud University Nijmegen, the Netherlands (1987). She is a member of the extended leader group at the Department of Neuroscience, member of the evaluation committee for professor competence at the Faculty of Medicine, and leader of the multi-disciplinary research network on Human Motor Control. She is a Fellow of the Royal Dutch Academy of Sciences. Editorial board member for two international scientific Journals. She was also cofounder and first Head of the former Department of Human Movement Science at NTNU. She was a member of the Natural Sciences and Engineering Research

Council of Canada, and co-chair of the first Joint World Congress of ISPGR and Gait & Mental Function. Prof. Vereijken has expertise in motor control, mobility and exergaming in the elderly, gait analysis, and changes in postural control and gait across the lifespan. She was a partner in the EU-financed project FARSEEING under FP7. Currently, she is project manager in the current EU-funded project PreventIT, project leader of EXACT, and partner in ADAPT, an ICT fall risk assessment project funded by the Norwegian Research Council. She has over 20 years of experience with teaching and supervision of students at all levels (Bachelor, Master, PhD).

2.2 Mentor

In the role of mentor is PhD student Nina Skjæret Maroni. Her PhD-project is in the field of exergaming, entitled Exergaming in older adults; Use, user experiences, and the relationship between game elements and movement characteristics. She will have a post doc position in the larger EXACT project, functioning as the project manager of EXACT. She has supervised several Bachelor and Master students.

2.3 The student

The student is in his final year of his bachelor studies of Technical Informatics, and will be applying the knowledge gained in this field to assess the different pieces of hardware and concomitant software, design and build a synchronized system and solve potential challenges along the way.

Besides learning how the hardware will be used during the project, a controlling entity needs to be developed for the various hardware systems. This entity needs to be flexible so that it can work in different configurations. With or without certain systems if they are unavailable, even when split across separate workstations the controlling entity needs to be able to communicate with those systems.

3 Materials and Methods – What will be used in the project?

The experimental system consists of 5 separate systems, namely the exergame and game capturing system, a camera monitoring solution, 2 force plates, and an EEG system. These systems need to collect data simultaneously of the exergaming session of each player.

3.1 The (hunt for the) exergame

During development of the project finding an exergame which could be used for the projects goals seemed more challenging than expected. Originally one needed an exergame where in the player would be able to stand on two force plates with both feet and not move off them and not have the player move so violently that it would cause artefacts in the EEG data. To find such an exergame that would fit the needs of the project one looked into the catalogue for Xbox one, Xbox 360 and pc games and would use the Microsoft Kinect 1 or 2. During this time it appeared that the only games which used these platforms were either a yoga or dance games. Which would mean players would step off the force plates or move too much and cause artefacts for the EEG system.

After which one looked into the indie market for possible useful exercise games which had a whole other host of issues from not being sensitive enough in detecting movement or not supporting either of the Kinect(s) or flat out not working.

This meant for the project to look elsewhere and use the Microsoft Kinect v2 as a monitoring tool instead for processing visual data for an exergame. During the following weeks tests were run with games especially produced for people rehabilitating or for the elderly. In these tests one game stood out a game simple named 'Puzzle Game' from Silverfit (Figure 1). From this point on one could start work on the video capture of said game.

3.2 The exergame

The game that will be used in the experiments in the EXACT project is a puzzle game developed by Silverfit. Silverfit develops products for rehabilitation and activation of elderly through the use of videogames [8].

Within the game you lean with your body to the left or right to fill in the white square on the puzzle. In the example above you can see the reference completed puzzle the player is putting together. So in this example the player would have to lean to the left to select the correct puzzle piece.



Figure 1 - Screenshot from the Silverfit puzzle game

The Silverfit game collection consists of two parts that are important for the capturing of the gameplay footage:

- The menu of the Silverfit package which is built in WPF (Windows Presentation Format). Within this menu one can chose which game from the Silverfit package to run. As the researchers are interested in the movements and activities of the player during gameplay, there is no need to capture footage of the menu itself.
- The puzzle game itself runs in DirectX full screen exclusive mode which means it allows the suspension of windowing system so that drawing can be done directly to the screen. This means only the game gets access to write to the frame buffers of the video card which gets projected on the screen. This also means that any capture system running in the background will not have direct access to read the frame buffer that's been shown on screen.

3.3 Exergame screen capture

To capture the video game footage, the first step that needs to be taken is to find out what renderer the game uses. Because the renderer which is used heavily influences the methods available for one attempting to read the game data (and or store that data) that gets projected on the screen. The Puzzle game used in the current experiment uses the Microsoft XNA (Which acronym changed during development from **X**box **N**ew **A**rchitecture to **XNA** **N**ot **A**cronymed [9]) which provides the same features straight from Win32 and DirectX but then as a natively managed .NET platform [10].

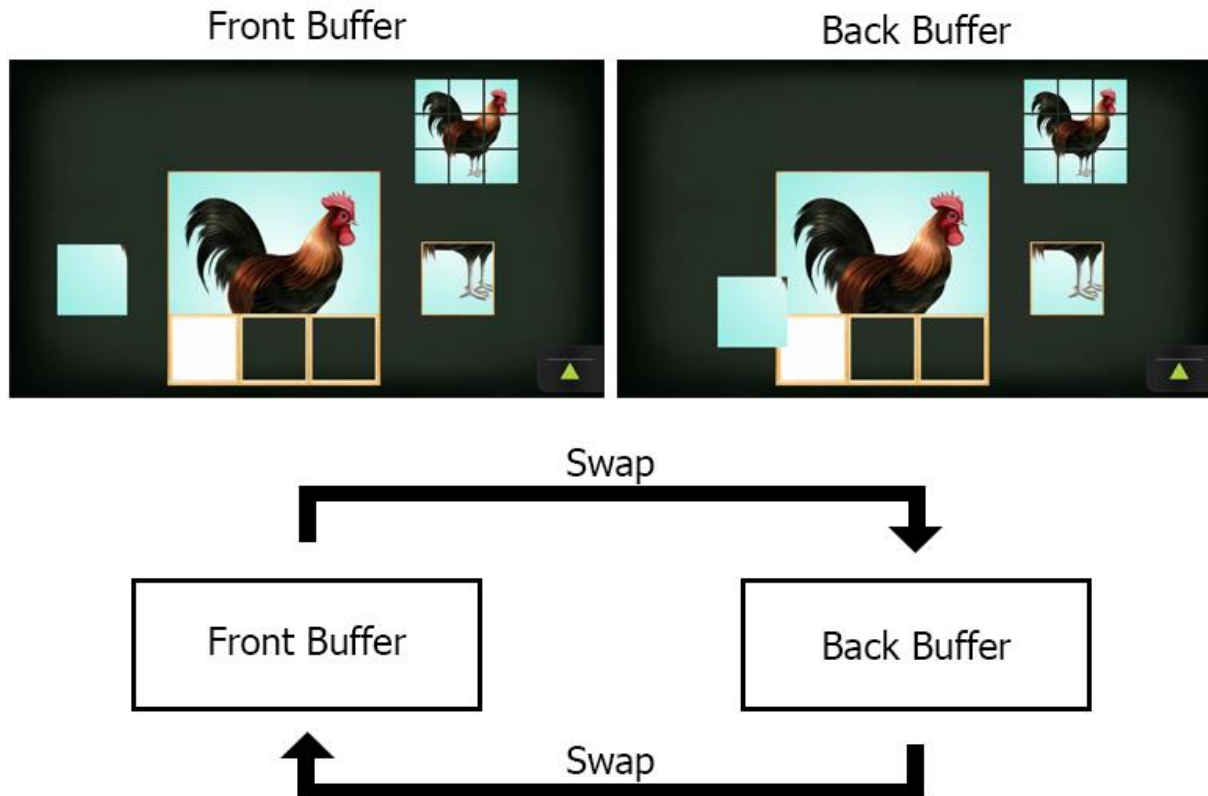


Figure 2 – Image of a simplified depiction of the Swap chain.

Among the DirectX features there are a few interesting mechanics like the 'swap chain' (Figure 2) which uses the front and a back buffer.

The video card holds a pointer to a representation of the image or in case of the experiment a single frame of gameplay being displayed on the monitor which is called the front buffer. The back buffer is the buffer to where the game renders its game footage in preparation for the swap. The 'swap chain' then flips the buffers and the game will start rendering a new frame in the back buffer again [11]. This occurs normally so fast that the player will not notice the swapping. For reference for a normal animation or silent movie plays at the speed of 24 frames per second or 24 buffer swaps using the swap chain.

The game starts by setting the resolution of the front buffer, forcing the renderer into full-screen exclusive mode, and then setting the back buffer resolutions to match [12]. The exclusive mode means that only the game or anything necessary will get loaded by the game and will have access to these buffers with the rendered game frames.

3.4 Camera monitoring solution

The camera monitoring will be done by the Microsoft Kinect v2 (Figure 3), which offers 11 streams:

- Body Frame
- Calibration Data
- Colour Camera Settings
- Uncompressed Colour
- Long Exposure IR
- Sensor telemetry
- Depth
- Infrared
- Opaque data
- Title audio
- Body Index

Normally developers use a combination of the infrared, body, depth or the body streams for their games or research projects to track the human body, and gestures performed by the player.

The Microsoft Kinect v2 is normally used in combination with the Microsoft Xbox One. For use of the Microsoft Kinect v2 on a windows machine you will need a "Microsoft Kinect Adapter for Windows" adapter (Figure 4) to be able to communicate with the Kinect sensors.

As discussed earlier in the (hunt for the) exergame the purpose for the Microsoft Kinect v2 changed throughout the project a couple of times. At first it was supposed to be used in combination with a exergame to read out player movements for interpretation by the game station. Then it changed to a passive camera to record video and audio from the exergame in progress. After some issues arose around the enormous amount of collected raw image data a decision was made to use another feature the Microsoft Kinect v2 is capable of namely the detecting of the player body and more explicitly the skeleton of said player. Which meant expectations and requirements changed for the device.



Figure 3 - Microsoft Kinect v2

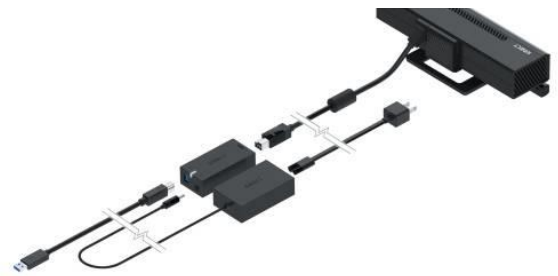


Figure 4 - The Microsoft Kinect v2 with the Microsoft Kinect Adapter for Windows.

3.5 Force plates

The force plates (type 9286A, Kistler Group, Switzerland as shown in Figure 5) are manufactured by Kistler. Each plate is 40cm by 60cm so a player can easily stand on them. During the experiment, both plates are placed side by side, so that they are as close together as possible without touching. In this setup the player will stand with one foot on each plate while playing the exergame, allowing capture of separate data from each foot of the player.

The force plates measure piezoelectric differences which registers registering ground reaction forces and moments for each foot separately which translate to detecting changes in the gait pattern or shifts in the centre of pressure [13] of the person standing or walking on the plates. During the exergame the piezoelectric sensors in the plates collect data of the players leaning by measuring the centre of pressure moving from side to side and forward and backward (See figure 6).

These plates have been used in various projects and experiments within the NTNU primarily for Motion and Gait analysis.

In the exergame, the player has to decide which puzzle piece to select by leaning to the left or right, this decision point can be read in the force plate data by looking at centre of pressure moving towards one side after the player has been stationary for a while.

The force plates have several configuration settings that can be altered to get a better read out of the sensors in the plates. For instance, one can set the rotation which means that the XYZ axes can be aligned with a second force plate prior to data collection. Additionally, you can adjust how sensitive the plates are, allowing for the detection of very small force changes in someone balancing on a single leg to large force changes when someone performs vertical jumps on the plates.

Both plates have a unique calibration datasheet provided by the supplier that needs to be entered into the accompanying software called BioWare [14]. These configuration settings and calibration data is then saved in a XML file on the operating system that runs the BioWare software. The unique calibration data is important for the piezoelectric sensors inside of the plates whom might have a small difference in output compared to the output of other sensors, the calibration data then corrects these output of the sensor to the correct values. This makes the force plates generate the same exact data when tested, and makes the force plates interchangeable.

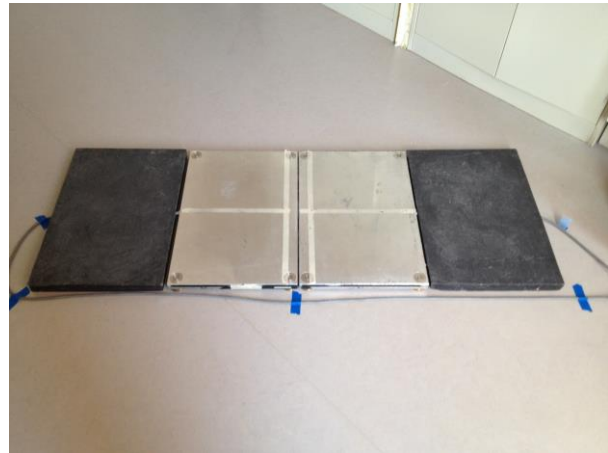


Figure 5 - Photo of the Kistler Force plates set up.



Figure 6 - Photo of a player leaning to the left on the force plates wearing the EEG cap with the amplifier in the backpack.

3.5.1 InstaCal

The InstaCal software is software that detects measurement hardware and assigns resources for Ethernet, USB, PCI, web or Wi-Fi boards [15]. For the experiment we will use the USB protocol to see whether or not the External Control Unit / DAQ-System (data acquisition and analysis tool for biomechanics) is attached to the system. With this system one can also see whether there are force plates attached to the DAQ (Figure 7).

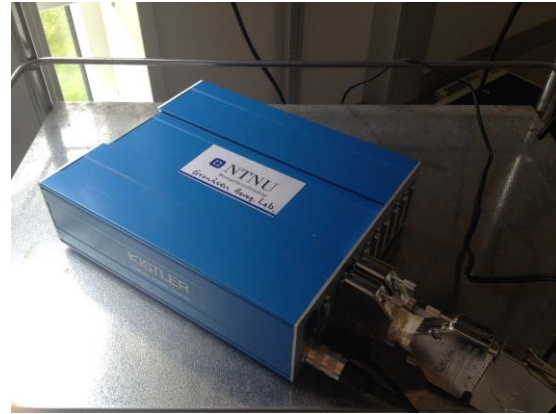


Figure 7 - Data Acquisition System (DAQ) for up to 8 force plates.

3.5.2 BioWare® Software for Data Acquisition of Force Plates

The BioWare® software [14] is used for configuring the settings of the force plates. These settings can be changed if needed for other experiments. Within these settings is also calibration data for the separate plates. Within the software there is a distinction between the configuration and settings part. The configuration relates to the force plates themselves and all the settings specifically for the force plates such as the sensitivities, serial numbers, type numbers and which data channels they use on the DAQ.

The settings are for all the software sided settings such as the location of the data storage and how the triggering (that starts the recording of the force plates) is setup along with information on how the incoming data should be interpreted just to name a few possibilities.

3.6 Electroencephalography (EEG) system

EEG is an electrophysiological monitoring system which will be used by NTNU in collaboration with the University of Paderborn. This system has 32 channels that reads out electrical activity on the surface of the brain. The software for this specific system uses a Universal Serial Bus (USB) dongle as a license key and the scan software runs on a Windows XP machine.

With the EEG system, the researcher can investigate the relationships between cognitive elements in the exergame puzzle and cortical activity across the different areas of the brain.

So far, there has been very limited research with EEG systems while the subjects are actively moving (Figure 8), so movement artefacts in the data will be a challenge that needs to be dealt with in post-processing. However, the focus in the current student project is to simultaneously collect data from EEG and the other systems, not the data analysis.

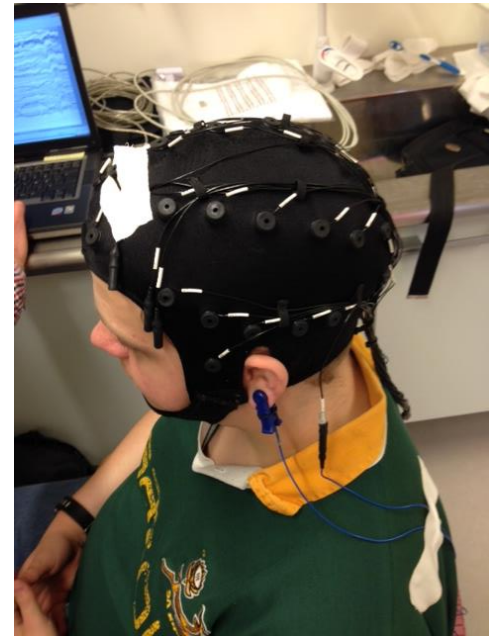


Figure 8 - Testsubject with EEG cap mounted during testing of the impedance.

4 Results

In this chapter the results of what we accomplished within the project will be discussed.

4.1 The exergame

The exergame for the current student project is the puzzle game by Silverfit. After a long search for a compatible exergame, which had to fit the criteria of the player being able to stand on force plates and not move too violently to cause artefacts in the data. After 2 test runs with multiple exergames or semi fitness games this one turned out the most qualified for our purpose.

4.2 Exergame Capture Software

Throughout the project, there was the goal to be able to record and store video footage of a exergame. Researchers used a video camera to document what happened on screen in front of a player in earlier trials with test subjects. Also during one of the test trials there was a wish from the EEG engineer to have the system be able to detect when a puzzle game would start so it could automatically set a marker in the EEG data. The student faced many issues with trying to access the DirectX buffers, and in the end none of the tried methods worked well enough without slowing down the game. Because of separation of the EEG system from the system and time restrictions the decision was made to use Open Broadcast Software. For additional information on the iterations of the game capture system developed by student see Appendix 10.2.

4.2.1 Open Broadcast Software

Open Broadcast software (OBS) [16] is used for capturing game footage and audio. This has a simple graphical user interface wherein the student configured the windows to record.

Within the program hotkeys were set for starting and stopping recording, and this method worked without major problems. The OBS software should be started after the puzzle game is started so OBS can hook into the game. There is an issue with minimizing the game and restoring it. This will cause the OBS to be unable to read the footage and will read and record a black screen.

4.3 Socket Server

The socket server has seen multiple iterations and the current version is designed with the 'Keep-It-Simple-Stupid' approach.

The server connects to itself and binds the Port number so anything that talks to his IP address and port number will get connected. It was designed and developed to be modular and look to whatever is connected to the server and start it.

The server would just handle requests for connecting and whether or not the client or responder had all the software installed was checked on the client side.

This meant that technically the system could be run with none of the software installed.

Also the possibility to differentiate the installations of the software and switch the hardware around on separate machines if needed. The clients just check to I have a program or process named this way if so read the command and execute it. The server has 2 primary functions:

4.3.1 ClientThread

The ClientThread receives data from the client and then sends that broadcast data to the broadcast_data method.

4.3.2 Broadcast_Data

The broadcast_data function sends data to everyone connected to the server.

4.4 Socket Client

The socket client is very straight forward. It connects to the socket server and then the user can give orders to send over the socket server to the receivers.

This client is just used for manually starting or stopping applications.

4.5 Socket Responder

The socket responder just reads out commands coming from the socket server and client indirectly.

The responder reads these commands and interprets them.

To name the important ones:

EEGSTART	First looks if the EEG executable is on the hard drive if so. Start the EEG
EEGSTOP	Stop recording on EEG
EEGKILL	Runs the taskkill command to shut down the acquire software (the scan4.5 data collection executable).
GAMESTART	Starts the puzzle game
GAMESTOP	Runs the taskkill command to shut down the puzzle game.
KINECTBOOT	Runs the Kinect application which first checks whether or not the Kinect is attached to the platform.
KINECTSTART	Opens the Kinect sensor and starts the recording of the joint positions and Point cloud data.
KINECTSTOP	Stops the recording with the Kinect also turns of the Kinect Sensor.
KINECTKILL	Runs the taskkill command to shut down the Kinect application.
RECORD	Presses f10 key on the responders system. This is a hotkey in OBS to start recording.
STOPREC	Presses f11 key on the responders' system. This is a hotkey in OBS to stop recording.
BOOT	Check if the data gathering applications exist and then runs them.
BYE	Runs taskkill command on all possible attached programs that could have been started by the responder.

4.6 Data collection with the Microsoft Kinect V2

For the Microsoft Kinect v2 there are options for the retrieval of Colour, Depth, Infrared, Body and Audio stream. The more streams one wants to collect the more powerful of a machine you need to have to be to cope with the incoming data.

Within the software written for the Kinect it checks whether or not the Kinect is connected in the first place. If it is then the sensor will be opened and a MultiSourceFrameReader started frames one wants to collect.

4.6.1 Microsoft Kinect v2 – Colour frame

In general, the Colour, Depth and infrared frames are very similar in handling.

Example colour frame:

```
width = colorFrame.FrameDescription.Width;
height = colorFrame.FrameDescription.Height;
PixelFormat format = PixelFormats.Bgr32;
byte[] pixels = new byte[width * height * ((format.BitsPerPixel + 7) / 8)];
if (colorFrame.RawColorImageFormat == ColorImageFormat.Bgra)
{
    colorFrame.CopyRawFrameDataToArray(pixels);
}
else{
    colorFrame.CopyConvertedFrameDataToArray(pixels, ColorImageFormat.Bgra);
}
stride = width * format.BitsPerPixel / 8;
camera.Source = BitmapSource.Create(width, height, 96, 96, PixelFormats.Bgr32, null,
pixels, stride);
SaveColourTimestamps.AddLast(DateTime.Now.ToString("yyyy:MM:dd hhmm:ssfff"));
SaveFramecounter.AddLast(frameCount);
SaveColourFrames.AddLast(pixels);
```

This just grabs the frame takes out the information of the frame. Reserves memory to temporary save the image. Finds out how to handle the frame. And then saves it timecoded this is necessary for the synchronisation of all the data.

4.6.2 Microsoft Kinect v2 – Audio frame



Figure 9 - SDK Browser v2.0 - Showing the Audio Basics Sample.

For the audio recording the student used the waveFile library from the KinectV2-Audio SDK samples. One can acquire the sample libraries by using the SDK browser 2.0 which is bundled with the Kinect for Windows SDK 2.0. There was no specific wish for doing something special with the audio besides storing it.

It involves looping through the audioBreamFrameReader and writing the frame a buffer and writing that away to the library.

```
audioBuffer = new byte[_sensor.AudioSource.SubFrameLengthInBytes];
audioBeamFrameReader = _sensor.AudioSource.OpenReader();
void audioBeamFrameReader_FrameArrived(object sender, AudioBeamFrameArrivedEventArgs e)
{
    using (var audioFrame = e.FrameReference.AcquireBeamFrames())
    {
        if( audioFrame == null)
        {
            return;
        }
        var subFrame = audioFrame[0].SubFrames[0];
        subFrame.CopyFrameDataToArray(audioBuffer);

        waveFile.Write(audioBuffer);
    }
}
```

4.6.3 Microsoft Kinect v2 – Body Frame & Depth frame

For the skeletal frame or body as it's been renamed to since v2 of the SDK.

The development shifted to C++ which had as most important benefit the speed at which reading from multiple frameReaders could be achieved.

This is because the older method used Windows Presentation Format that uses a background thread running and then a UI thread per open window. Which caused some interesting issues while having to loop through 2 framebuffers from the Kinect that offered coloured frames and Audio frames. It is possible to start new Threads but that requires opening new windows via a dispatcher those will then automatically get a new Thread to manage. This for a time meant the collection of audio and colour frames was kept away and ran in two separate applications.

Another benefit was we could now more easily run unmanaged code for example OpenGL in the form of GLUT. This meant it became possible to see depth by rotating a digital camera.

Basically the method for retrieving the bodyFrame is not different from the other frames. It looks if the frame it is offered is a bodyFrame if that is the case then it tries to find a body inside of the frame. If it finds one it will change the tracking mode of that body to 'Tracked' and start displaying all the joints it found. By using this method one can track up to 6 bodies using the Microsoft Kinect v2.

For the current project the Kinect will be used to capture the skeletal frame of the player during the exergame for later analyses. Internally in the Kinect it has two states:

- Tracked, a tracked skeleton provides detailed information on position of the player and of the joints of the players' body (Figure 11).
- Position only, only shows where the position of the user is but no information on the joints of the player (Figure 10).



Figure 11 - Skeletal / Body frame retrieved from the Microsoft Kinect v2. Showing a tracked state.

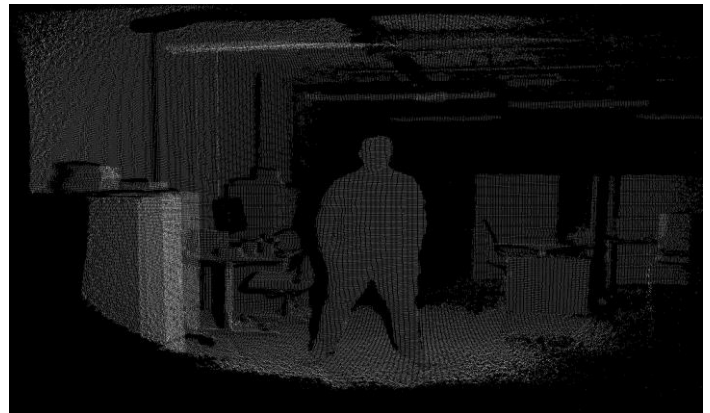


Figure 10 - Depth Images mapped with white pixels shown in a XYZ coordinate system (Point Cloud). Showing a position state.

Which in combination was developed in combination with GLUT a OpenGL toolkit. To give be able to view that Point cloud data in a 3d environment.

Inside of the Tracked state on is able to read out all the positions it sees a joint. By drawing lines to from and to these positions one is able to get a skeleton of the player.

For the depth map we store all pixels with a value of XYZ axes. So during later analyses one can reconstruct what the camera saw and how the person is moving through the reconstructed imagery.

4.7 Force plate

Two Kistler force plates will be used during exergame. They will be set side by side (Figure 2) so that the XYZ axes is similar on both force plates. The main benefit is that the researchers will be able to quickly see how the centre of pressure (COP) is moving (Figure 12) when the player changes his posture. By looking at the moving COP of the player during the exergame one can see the point where one has made the decision on which puzzle piece to select during the exergame.

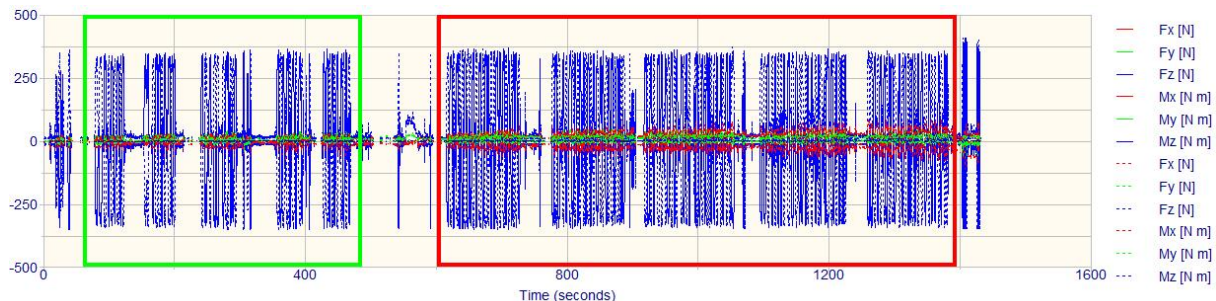


Figure 12 – Image of the data generated by the force plates peaks in the data show the movement of the player during the easy puzzles (depicted in the green square) and the harder ones (depicted in the red square).

The BioWare software has all functions build in to start recording and has an option of saving settings in a XML file. Which is handy for not having to insert all the calibration data for every test run. The Kistler force plates work together with InstaCal (4.2.1) [17] and BioWare (4.2.2) [14] software. The latter one is used for setting the parameters for operating the force plates. BioWare is then used to start the data collection from the plates. The plates were calibrated prior to each trial connect to two of the eight analogue channels giving three force variables and three movement variables.

4.8 Electroencephalography (EEG) system

The electroencephalography (EEG) system works with a Compumedics Neuroscan Nuamps 40-channel EEG/ERP amplifier (Figure 13) [18]. This amplifier works together with the Advanced Medical Equipment Scan 4.5 [19] software running on the work station. The amplifier connects to the workstation via USB. To use the Advanced Medical Equipment Scan 4.5 [19] software an USB license dongle is needed.

Dependent on which EEG cap one is using, one can either use the individual touch proof connectors on the front of the amplifier or use the high density cap connector on the bottom of the amplifier (as shown on figure 14).

The NuAmps amplifier also amplifies noise and can, as demonstrated during one of the trial runs, amplified the AC power signal coming from the power supply of the laptop running the Scan 4.5 [19] software package. Furthermore, the EEG cap itself is highly susceptible to outside interferences like magnets, radio frequencies and other electric signals just to name a few.

Another issue with the NuAmps amplifier is that it may only be used with 32-bit operating systems since there is no 64-bit driver [20]. This limits the possibility of moving this specific EEG system to a newer machine. Since modern machines almost exclusively have 64 bits' processors it would mean that one has to install a 32 bits operating system to be able to use the Compumedics Neuroscan



Figure 13 - Compumedics Neuroscan Nuamps 40-channel EEG/ERP amplifier.
n.p., n.d. Taken from <http://compumedicsneuroscan.com/nuamps-eegerp-amplifier/>

Nuamps system. For a more in-depth look in why this matters see appendix 16.3: The differences in addressable memory between 32 and 64 bits' operation systems".

The EEG system itself needs time to be set up, preparing the player by attaching the cap and making sure the electrodes have a good connection with the skin. One does this by installing QuikCells in all the electrodes of the cap. Then place the cap on the player. Then insert a blunt tipped pipette or injection needle all the way through the electrode hole to the bottom of the QuikCell sponge. Hydrate said sponge and reduce the impedance. You can also go too far with the hydration and bridge a connection between two electrodes with the gel. After you have successfully lowered impedance on all of your electrodes you can continue.



Figure 14 - EEG Cap attached to Amplifier with high density cap connector not shown on image.

The most important thing is to have a good ground connection. If this is not the case one won't be able to get any data from the system. When everything looks good on the density screen of the program one could start the data recording with the EEG. Because of this starting mechanism the time synchronization of the EEG system was done by setting markers in the EEG data where the baseline recording started and where the puzzle games started and ended.

When using the EEG system, the researchers should record a baseline recording before starting the actual exergame. This creates a reference for the data analysis of the player in rest against the active player moving and thinking during the exergame. During recording the researcher can add markers to the data for later analyses so for example 'Exergame starts', 'Exergame ends' or 'start of baseline recording'. These markers could help researchers during the analysis phase to identify certain parts within the data. The scan software can then store the collected data on the hard drive of the researcher monitoring the Scan 4.5 software package.

Within the recording the EEG system works in the frequency ranges of 0 Hz to 80 Hz.

In combination with event-related potential (ERP) are event where the brain reacts in electro physical reaction to an event. An example of these would be: audio tones, light flashes or in the case of the experiment and decision event where the player has to make a choice in a exergame.

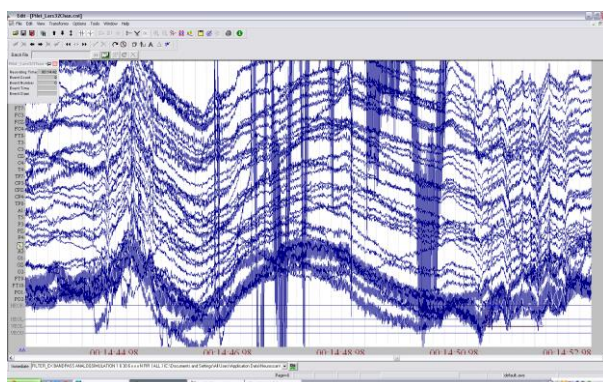


Figure 15 - EEG data where the subject has interfered with the data either by using their jaw muscle or in this case by tapping the electrodes on the cap.

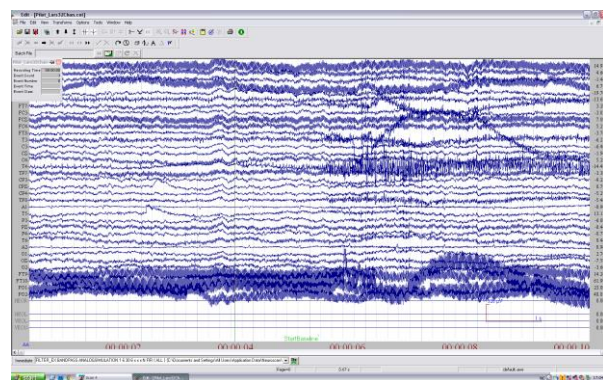


Figure 16 - Normal EEG Data of a subject in rest. Small section of the baseline recording.

The generated data by the amplifier (as shown in figure 16 and 17) could then be analysed in MATLAB [21] with the EEGLAB toolbox [22], or combine MATLAB with the ERPLAB open-source toolbox for processing and analyzing event-related potential (ERP) data in the MATLAB environment [23].

5 Conclusion

This chapter concludes the findings and produced systems and will answer the research question the student originally set out with.

5.1 The original goal

The goal for the current student project is to write a controlling system that is able to interface with the various data gathering software, and collect the various data generated by the different systems, and to store the data so that the researchers have access to all the collected data together in one folder.

The controlling system must be user-friendly so behavioural researchers can use it without being dependent on additional technical support.

5.2 Description of expected results – What was expected

The overall goal was to create a user-friendly system consisting of several different pieces of hardware allowing non-technical behavioural researchers to collect data from several systems simultaneously without the need for additional technical support, as possible. In this chapter it will be further specified what was expected for the separate components in the project.

5.3 End result

The end result will be a prototype which would directly interface with the various software used for interaction with the various hardware.

5.4 Video game capture

After a lot of different methods and experimentation with working on the game capture system and losing too much time on getting it to work. The game capture program was replaced for an open source project called OBS [16]. Instead of using OBS for its broadcasting capabilities we only use that recording feature which uses a multitude of craft designed system hooks specially crafted for a big range of videogames or other software applications. Currently there is an implementation in the Socket Network to trigger the set Hotkeys for OBS for the start and stopping of the game recording.

5.5 Kinect

Currently mainly captures point cloud data and the skeleton of the player.

It has the option to add colour to the point cloud data but that adds complexity because then one needs to downscale the 1920x1080 colour frame to a 512x424 depth frame. And then store the colour values next to the point cloud's XYZ axes. By using timestamps one can go through the data knowing certain frames have appeared.

This means the old methods for storing the colour and audio are still there.

However it no longer involves storing raw image data and a wavfile that needed to be added together using FFMPEG. Which was running afterwards anyway because of fear of it slowing down the data collection of other systems. Currently there is an implementation into the Socket Network to remotely start the Kinect software.

5.6 Force plates

The force plates didn't involve that much work. They start and stop without much hassle. For the calibration data one can override the XML file with all the settings before the experiment starts to be certain everything acts the same.

Furthermore, when starting the force plates, it first does a check to see if there is a current running through the plates. Which is its method of checking if the plates are attached or not. Currently there is an implementation into the Socket Network to remotely start the BioWare software.

5.7 EEG

Because of the setup procedure there is before one can record data using the EEG system the setup of said device has been kept out of the controlling system.

However, one can start the recording when the setup procedure has been completed and the cap is securely attached to the players' head. Furthermore, after a discussion with the EEG system analyst it became clear that perhaps we should leave the EEG system outside of the controlling system. Because of the possible interference it could apply in the data generated by the EEG amplifier.

5.8 The controller and server. Socket Network

These talk to each other via a socket server and depending on the commands coming through the socket server one or the other should start or stop certain activities.

6 Discussion

Within this project there was a controlling system developed and a system for using the Microsoft Kinect v2 for generating data. For the purpose of tracking a test subject while playing an exergame.

The controlling system needs to start all the software for collection data simultaneously so that the data is synchronized. However, prior to data collection, the EEG and the force plates need a short time to 'zero' out and reach a baseline. The force plates need a small time before starting the data collection to communicate with the electronics inside the plates before actually starting. Which is its check to see if the plates are actually attached. Here for the Controller a prestart command just to start the different pieces of software in preparation of actually starting the experiment and recording all the data.

6.1 Findings in the current student project.

6.1.1 Which sensors will be used to collect the essential data?

As explained in the introduction the current project involves a exergame from which we are capturing the game imagery with Open Broadcast System, then there is the camera system a Microsoft Kinect v2 used for Point cloud data & skeleton collection, Force plates from Kistler for detecting the movement and forces of the player, and an EEG cap and amplifier from Compumedics Neuroscan for collecting brain activity.

6.1.2 How to get data out of the EEG system?

The EEG-system uses a software package named Scan 4.5. This reads out the amplified signals from the amplifier. Within the Compumedics Neuroscan Scan 4.5 [19] software one can save the recorded EEG data in the file types: EEG, AVG or CNT.

What are the possibilities of saving the various data?

During the project we will be using 'cnt' files which can be acquired by running the Compumedics Neuroscan Scan 4.5 [20] software in continuous mode. The CNT files contain all of the data, not just pieces of the data that you would have with epoched files, which would be the EEG file types [20]. These files can then be read into a Matlab software package named: EEGLAB [22] which is a toolbox which offers functionality to Matlab for storing, accessing, measuring and manipulation EEG data.

6.1.3 How to get data out of the Force plates?

The force plate system works with a software package name BioWare. Where in one can read out the piezoelectric sensors from inside the force plates.

What are the possibilities of saving the various data?

Force plate data normally gets stored in a BioWare .dat file. You can also save to c3d, inf, frf, and txt for Matlab or Microsoft Excel. The researchers have used these specific plates for multiple experiments and require no alterations to the current process of saving data.

6.1.4 How to capture Game footage?

The current game capture is being done by Open Broadcast system (OBS) [16]. OBS is an open source software project that is normally used for streaming video to websites like Twitch.tv or Youtube.com. For this project we will use it to record the gameplay and store it on a hard drive.

There were other attempts in self-creating the game capture system but this however took so many attempts and so much time I had to drop the system and replace it with OBS.

What are the possibilities of saving the various data?

Depending on which codec one uses for the current student project it is mp4.

6.1.5 How to get the data from the Microsoft Kinect V2

To get data out of the Kinect one has to use the frameReaders with which the sensor offers certain frames which then can be read and manipulated if needed.

The Microsoft Kinect v2 can save various data streams to various of file types. How the data stream gets saved mainly depends on how one wants to analyse the stored data. For instance, the audio stream can be saved to WAV file type or whatever other file type or codec you wish for as long as you program it to use that codec. One could even store it to a binary file if one wanted.

What are the possibilities of saving the various data?

For using the colour frame, you can also use a specific video codec for storing the colour frames as a video. Another method is to use an encoder to save the image data to either: JPG, PNG, BMP, Tiff. This can be done by using the windows media imaging namespace from the .NET framework. From here one can use the bitmap encoders [24].

To retrieve these data streams from the Microsoft Kinect v2, the software necessary has to be manually developed for the purpose of retrieving data from the Microsoft Kinect v2 sensors and storing the acquired data.

In the current project we save the audio recording to the WAV format and the colour frames to PNG. In a later phase of development the Microsoft Kinect v2 now saves the Point Cloud Data from the depth map to a binary file consisting of all the XYZ coordinates of all the pixels on the depth map and the skeleton data.

6.1.6 Which methods of data presentation presents the best overview of data for the researchers?

Most of the software coupled with the research system already stores data in a way that is easily interpreted by the Data Analysts. There is therefore no real need to change the current protocols.

6.1.7 Is it possible to save game footage w/o the Microsoft Kinect V2 Camera footage during an 'exergame'?

Yes, although throughout the project the Microsoft Kinect 2 became repurposed. Because the exergame that would be used during the experiment became the puzzle game from Silverfit, and that uses a separate camera. This meant the Microsoft Kinect v2 went from being used by the game to detect the player and his or hers gestures to being a monitoring camera for the experiment.

Offering an overview of what was happening during the experiment. And the game footage itself is recorded by OBS as declared in the chapter 4.2 Exergame capture software.

6.1.8 How to design the platform to be futureproof so that the possibility exists to add more sensors to the platform?

Depends on what has to be added. It is fairly easy to add to the controlling system. Basically if you can automate it by just using keyboard presses or mouse clicks. One can use some of python tools to retrieve mouse locations for where to click and python can press keys. Essentially if it has got a software package to control the hardware with if so one could add the keyboard and mouse inputs needed to send commands to the software.

6.2 Current experiment testing trail

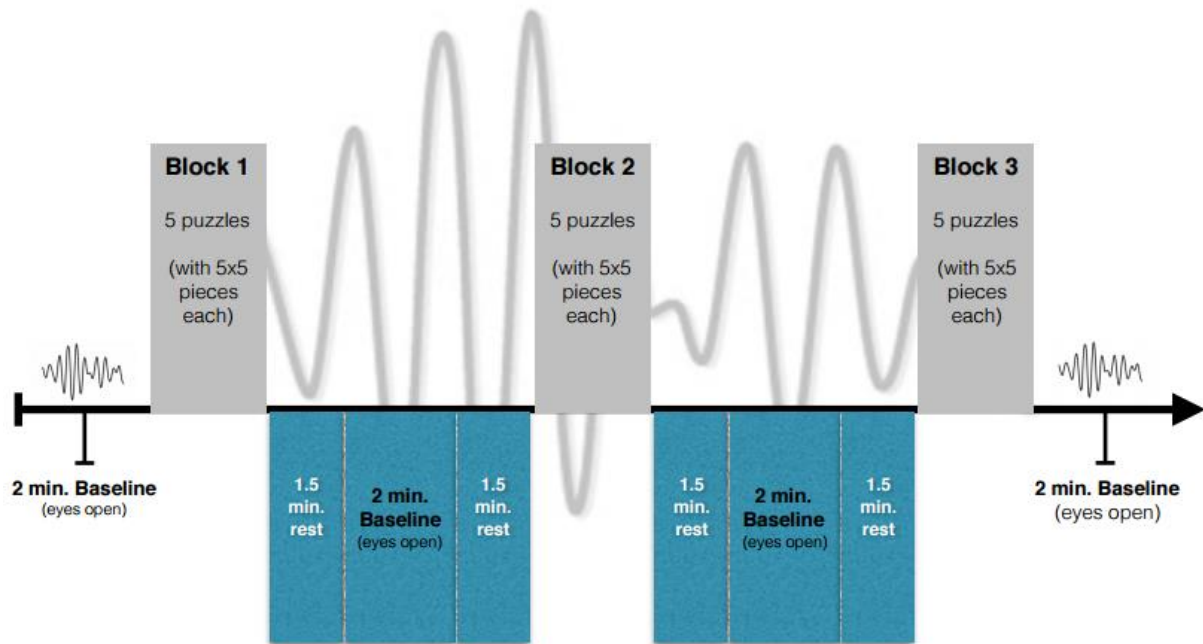


Figure 17 - Current trail from a EEG standpoint. Created by Tim Lehmann. EEG lines taken from bcf.uni-freiburg (2015). Hirnstrommessung - Was die Methode alles kann. n.p., n.d. Web. 9 Feb. 2015. <https://www.bcf.uni-freiburg.de/press/presscoverage2012>

During the student project, a pilot study was run on 12th of May to test the experimental set-up. The following protocol was used:

- 2 minutes of standing rest - Baseline recording EEG
- Approximately 5 minutes - 5 Exergame puzzles on an easy setting
- 2 minute of standing rest
- Approximately 5 minutes - Exergame puzzles on a harder setting
- 2 minutes - Rest

As one can tell from the new proposed trail it will have 2 extra baseline recordings and more rest for the player. Which should lead to a calmer signal pattern for the EEG analyst. And more moment the analyst could use for the study.

6.3 Some interesting issues

6.3.1 The Kistler Force plates

During test runs if the InstaCal setup was completed for a force plate board I later on does not check whether the power of the DAC is turned on or whether the force plates are actually attached at all.

6.3.2 Issues with finding a suitable exergame

During research for finding exergames to be tested, there weren't that many games actually using the new Microsoft Kinect v2. Turns out that during the launch of the Xbox One game console in May 2014 the Microsoft Kinect v2 was bundled in with Microsoft claiming that the Xbox One required the Kinect v2 to be connected at all times. This increased the price of the bundle while they were trying to compete with the latest installation of the Sony PlayStation system which was cheaper. To drive the sales and make it more appealing to the general public they dropped the Kinect v2 from the bundle 2 months later.

Officially Yusuf Medhi from Microsoft stated in June that they wanted to: "[offer] a choice to people that would allow people to buy an Xbox One and then ramp up to Kinect when they can afford to" [25]. This also meant that games running on the platform would receive more processing power which was previously reserved to be used for the Kinect.

7 Recommendations

7.1 Most practical hardware setup

The best practical set up at the moment is to have a system with the Microsoft Kinect v2 and the Socket server running. This system will be used by the supervisor of the project.

This system would then connect over Ethernet to a 2nd system running the exergame and force plate software.

The 3rd system left out of the loop will then run the EEG system over the whole duration of the project. The person running the experiment should then set markers in the EEG data for the starts of the exergame and or puzzles for later analysis.

7.2 Possible improvements

7.2.1 Socket server GUI

If time permits there will be an interface to select to do certain tasks. As well as a system to check whether or not a system has silently dropped from the network. During trial runs this happened a couple times because the network was run over a busy hospital router.

7.2.2 BioWare needs focus

The hotkeys one used with for example the OBS. Only work with BioWare if the application itself is select. Which becomes troublesome if there is a game running on top of it.

This means to start or stop the recording with the force plates one has to minimize the game.

This is troublesome because if the exergame capturing has started and the game minimizes and the system returns to the desktop, it causes the game capture software to only capture a black screen until the game capturing software restarts.

8 Evaluation of the process

The process has been a struggle in trying a balance to the writing of the thesis with the specific goals for the HU and on the other side trying to get a working prototype for the NTNU.

The thesis itself has had many iterations as shown in the change list. This is due to feedback from various sources and done by checking the work against that of others.

The prototype on the other hand the controller early on had some success with and then certain issues arose with trying to use it in combination with or systems. The Kinect as written about in earlier chapters had changed of purpose on a couple occasions. This in combination with the fact that the Kinect generates a lot of data to be send over USB 3 connection to the hard disk for storing. Meant that earlier iterations of the Kinect software would not have enough speed to write away all of the collected data to the hard disk. This would then cause the memory to fill up and after that was gone the Processors caches would have to help out and then the system would freeze to work it all away.

Another issue with the Kinect was that most of the information available for the Kinect is meant for the 1st generation. Which is unusable because of the hardware alteration in the generations of the Kinect. Also a lot of the library calls were replaced and or renamed. So if you were following a certain manual on how to get certain it would more often than not result in looking up namespaces just to find the new names.

In kind of the same line the video capture system also had many iterations and attempts to be able to read the buffers of the game. Unfortunately, the methods tried and tested were not stable and or fast enough. This meant that nearing the end of the project the self-developed game capture system was replaced by Open Broadcast Software.

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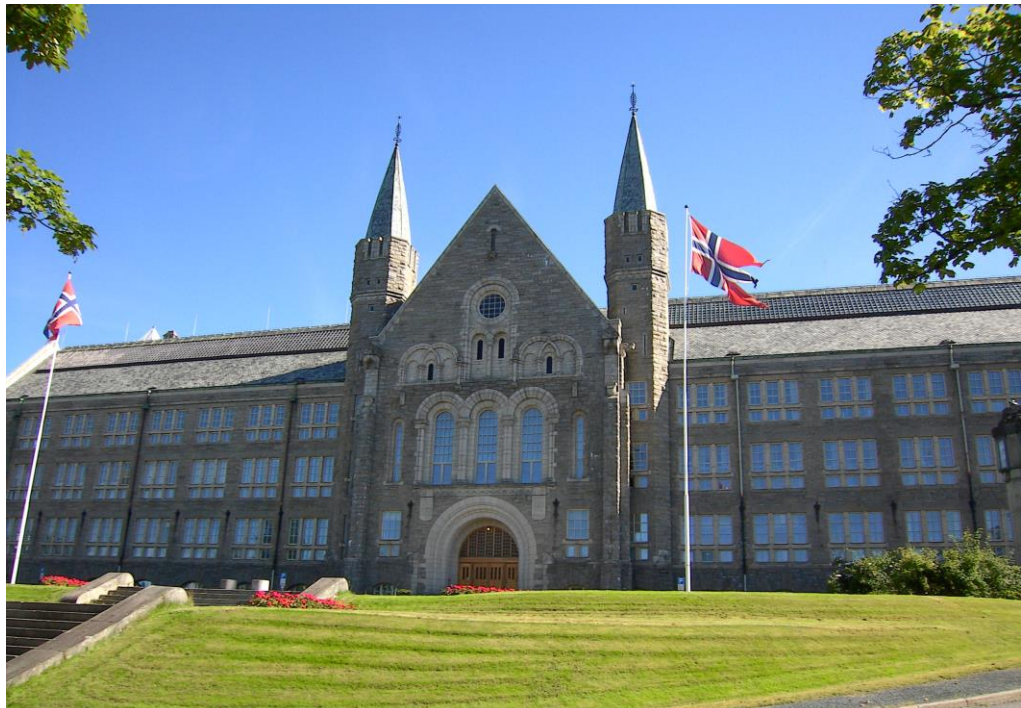
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10 Appendixes

10.1 Plan van aanpak

Plan van aanpak

Exergaming



Lars Veenendaal

1633223

15 Februari 2016

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Versiebeheer

Versie	Datum	Aanpassingen
0.0.1	15/02/16	Layout opgezet.
0.0.2	24/02/16	Invulling geschreven
0.0.2.1	29/02/16	Taalfouten corrigeren en addities
0.0.2.2	14/03/16	Addities: Probleem analyse en inleiding
0.0.2.3	21/03/16	Herstructurering en aanvulling aan 'Aanleiding en context' en 'Probleemanalyse en probleemstelling'
0.0.3	24/03/16	Randvoorwaarden en Aanpak aangepast. Verwerking opmerkingen docentbegeleider.
0.0.3.1	25/03/16	Delen herschreven voor een beter lopend verhaal. Paginanummering & taalfouten.
0.0.3.2	26/03/16	Planning bijgewerkt. Bronnen toegevoegd.

1 Inleiding

Hoe krijgen we de ouderen meer aan het bewegen? Dit een van de vragen die de onderzoekers in Trondheim zich afvragen. De onderzoekers hebben ingezien dat deze groep mensen het meest gebruik maakt van de gezondheidszorg in de westerse samenleving. Met de projecteerde groei van de ouderen en niet het personeel die meegroeit om voor hen te kunnen zorgen, wil men kijken naar mogelijke systemen om hen te ondersteunen in het gezonder ouder worden en een inkijk te krijgen naar de effectiviteit van mogelijke behandelingen of revalidatie trajecten.

De doelstelling van de onderzoekers is om exergaming (spellen waarin de speler dient te bewegen als hij of zij verder in het spel wil komen) als een complete training of als revalidatie technologie te gebruiken voor preventie en of behandelen van leeftijd gerelateerde functionele achteruitgang. Hiervoor wil men de afhankelijkheid van exergaming verbeteren doormiddel van zelfaanpassing van de individuele doelen, behoeftes en of belemmeringen. Daar in is het ontwikkelen van een exergaming revalidatie systeem welke toepasselijke oefeningen aanraadt en hierin zijn 'speler' motiveert door middel van persoonlijke instructies, feedback en/of andere berichten een belangrijk aspect.

Daarnaast willen de onderzoekers kijken naar de cerebrale activiteiten van de patiënt om specifieke oefeningen voor de revalidatie van de brein activiteiten en/of functies te selecteren. Met als doel om de patiënten toegang te bieden tot mogelijk verbeterde revalidatie programma's, intensiteiten van de trainingen en daarmee het effect van de revalidatie.

2 Aanleiding en context

Binnen de Norwegian University of Science and Technology (verder in dit document benoemt als NTNU) wordt een onderzoek opgestart naar het gebruik van speltechnologie om oudere mensen aan het bewegen te krijgen en aan het bewegen te houden. Vooral op het vlak van revalidatie komt het nu vaak voor dat de betreffende patiënt thuis verschillende oefeningen zelfstandig moet uitvoeren om herstel na een ziekte of ongeval te bevorderen, zonder dat er tijdens deze oefeningen instructies of feedback wordt gegeven.

Hiervoor wil men dus kijken naar spel technologieën en specifiek naar 'exergames' (games waarbij lichaamsbewegingen gebruikt worden om het spel te besturen). Deze exergames zullen de basis vormen in het onderzoek naar hoe een patiënt/speler de informatie van het spel interpreteert en op reageert. Vanwege de apparatuur om de speler heen tijdens het experiment zal er gekeken worden naar exergames met gelimiteerde bewegingen.

De afstudeeropdracht is een voorbereidend element voor dit onderzoek. De student zal zich verdiepen in het samenvoegen van meerdere stukken hardware om zo een prototype systeem op te zetten waarmee de onderzoekers data kunnen verzamelen. Hierbij wordt in eerste instantie gedacht aan krachtplaten, EEG, motion capture en het spelsysteem zelf. Deze gekoppelde sensordata maakt het mogelijk inzicht te krijgen in hoe de speler beweegt tijdens het spelen van verschillende zogenaamde 'exergames'.

Dit maakt het mogelijk te analyseren in hoeverre de gemaakte bewegingen overeen komen met de gegeven instructies en/of het lichaamsgewicht in voldoende mate wordt verplaatst, en welke delen van de hersen actief zijn bij verschillende soorten exergames.

Dit geeft inzicht hoe de toekomstige exergame eruit moet komen te zien. Waarna er gekeken moet worden naar hoe je de speler motiveert om door te spelen en later ook terug te komen en zijn of haar training te hervatten zodat hij of zij niet beperkt wordt in de bewegingsvrijheid.

3 Opdrachtgever

De NTNU en in specifiek de afdeling van Neuroscience in het bewegingscentrum wil een onderzoekstraject opzetten om ouderen aan te sporen om meer te bewegen door middel van een exergame. Als voorloper voor dit onderzoek moet de student een systeem opzetten waarmee de onderzoekers verschillende data mee moeten kunnen vergaren om dan een trainingsprogramma op te zetten voor de ouderen.

3.1 Bedrijfsbegeleider

De beoogde bedrijfsbegeleider is professor Beatrix Vereijken medewerker van de Technisch-natuurwetenschappelijke Universiteit van Noorwegen. Werkzaam bij de afdeling neurowetenschappen en de faculteit van geneeskunde.

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4 Probleemanalyse en probleemstelling

Het probleem op het moment is dat de hardware die gebruikt wordt voor de experimenten los van elkaar draait. Dit maakt dat alle verkregen data van de hardware dan ook niet synchroon loopt. Verder is de wens om ook te kijken naar de hersenactiviteiten van de speler doormiddel van het gebruik van een EEG systeem. Voor dit onderzoek is dan ook de vraag:

·Hoe verzamel je tijdens een exergame sessie data uit de verschillende sensoren zodat onderzoekers inzicht kunnen krijgen in de bewegingen en hersenactiviteiten van de speler?

Het eerste deel van het vraagstuk is wat willen de onderzoekers aan sessie data verkrijgen uit de verschillende hardware en hoe moet deze data opgeslagen worden. Vervolgens zal er gekeken moeten worden naar wat de exergame sessie inhoudt en hoe de verschillende apparatuur zo opgestart kan worden dat het synchroon de sessie data bijhoudt. Dit gebeurt op het moment nog niet waardoor het voor de onderzoekers lastig is om uitlezen wanneer er precies iets gebeurt in het experiment.

Dit levert een aantal problemen op bijvoorbeeld dat data handmatig nagesynchroniseerd moet worden voordat je met de data kunt werken. Dit probleem wordt uiteraard groter hoe meer data stromen je uit verschillende hardware wilt halen.

Bijvoorbeeld: Stel de speler moet bepaalde houdingen aannemen en de exergame wacht net zolang tot het de speler lukt deze houding aan te nemen. Dan moet je kunnen weten wat er op een bepaald moment op het scherm stond en vanaf wanneer de speler een nieuwe houding moest aannemen. Dit zorgt ervoor dat de timing voor elke speler en elke exergame sessie varieert. Dit maakt het lastig om je data na te synchroniseren.

Om dit probleem te verhelpen in het exergaming onderzoeksproject moet de verschillende software en/of hardware simultaan gestart worden. Of zal een andere oplossing moeten komen waardoor de onderzoekers een mijlpaal krijgen in hun data om te herkennen wanneer het experiment of exergame gestart werd.

Hiervoor zal een software applicatie geschreven moeten worden om de sessie data van de verschillende hardware in te zamelen. Onder deze hardware valt een krachtplaat, EEG, motion capture en het spelsysteem. De data die hieruit komt moet per sessie gecombineerd opgeslagen worden.

Voor andere verschillende onderdelen moeten meerdere kleinere oplossingen gevonden worden. Bijvoorbeeld: Een applicatie om de camera beelden uit het motion capture systeem uit te lezen en op te slaan.

Deze beelden kunnen dan gebruikt worden voor validatie of de speler wel echt de oefeningen doet.

Het huidige EEG systeem is tevens geleend van Prof. Dr. Jochen Baumeister van de universiteit van Paderborn in afwachting tot er een vervangend model geleverd kan worden. Dit systeem werkt alleen met een USB dongle en op een losse laptop waar nog Windows XP op draait. Dit is voor het synchroniseren onhandig en er zal hiervoor onderzocht moeten worden wat de mogelijkheden zijn om dit systeem te verhuizen naar een van de systemen in het lab.

Verder zal er onderzocht moeten worden wat de mogelijkheden zijn voor het opnemen van de exergame beelden en krachtplaat data. Voor de krachtplaten zal er gekeken moeten worden naar de mogelijkheid om configuratie data mee te sturen voor kalibratie en oriëntatie van de platen.

Verder moet onderzocht worden wat de mogelijkheden zijn om dit gecentraliseerd aangestuurd te maken zodat de experimenten gestart en gestopt kunnen worden. Waarna er gekeken zal worden naar de toekomst en hoe er nieuwe hardware onderdelen aan de software applicatie toe te voegen.

4.1 Afbakening

Voor de afbakening van het project is er een Moscow analyse voor het project gemaakt:

Must:

- Het starten van het verzamelen van de data output van de hardware moet synchroon in- en uitgeschakeld kunnen worden.
- Data verzamelen van de krachtplaten en EEG systeem.
- De beelden van de motion capture systeem en van de exergame sessie dienen opgenomen te worden en bij de rest van de data worden opgeslagen.
- De data moet achteraf samen per exergame sessie opgeslagen worden.
- De mogelijkheid om een configuratie bestand in te laden voor bepaalde hardware voor de start van een experiment.

Should:

- De Microsoft Kinect zou gestures of wel sommige bewegingen kunnen herkennen (zoals leunen naar links of rechts).
- Mogelijkheid binnen om de verzamelde data beschikbaar te maken voor Matlab of andere softwarepakketten die de onderzoekers mogelijk kunnen gebruiken.
- Gidsen opleveren voor toekomstige studenten om ze te informeren over het juist gebruiken van de hardware in dit project.

Could:

- Beginnen met ontwikkelen van een proof-of-concept exergame op basis van de Microsoft Kinect gestures herkenning.

Won't:

- Er zal geen complete exergame gemaakt en of bedacht worden door de student.
- Er zullen geen 'black box' drivers ontwikkelt worden voor de verschillende hardware.

5 Doelstelling en eindresultaat

5.1 Doelstelling

Het doel van het afstudeerproject is het samenbrengen van de verschillende hardware onder een overkoepelend systeem. Met dit systeem kunnen de onderzoekers in het exergaming project het vervolgens gebruiken voor het verzamelen van hun onderzoeksdata.

5.2 Eindresultaat

Het eindresultaat zal een prototype systeem waar de onderliggende delen van de hardware synchroon kunnen starten en eindigen. De genereerde data zal dan op tijd synchroon opgeslagen worden per patiënt en experiment. Dit systeem zal dan een configuratie kunnen inladen per experiment.

Verder zal er een Capture systeem gemaakt worden om beelden van de Microsoft Kinect en speldata op te slaan. Daarnaast zal een scriptie opgeleverd worden waarin de keuzes en ontwikkelingen in beschreven staan.

6 Aanpak

In dit hoofdstuk zal toegelicht worden wat er precies onderzocht moet worden en de mogelijke risico's en randvoorwaarden voor het succesvol afronden voor dit project.

6.1 Onderzoeksvraag

Om dit systeem op te kunnen zetten zal de student onderzoek moeten doen met de (concept) hoofdvraag:

Hoe verzamel je tijdens een exergame sessie data uit de verschillende sensoren zodat onderzoekers inzicht kunnen krijgen in de bewegingen en hersenactiviteiten van de speler?

6.2 Deelvragen

Hierna krijgt de student nog een aantal deelvragen om zichzelf naar het uiteindelijke doel toe te werken:

- **Uit welke sensoren wordt er data verzamelt?**
Voor deze vraag zal er een interview plaatsvinden om informatie in te winnen over welke hardware onderdelen er geïmplementeerd worden in het project.
- **Wat zijn de verschillende mogelijkheden om de verschillende data uit te lezen?**
Om een antwoord te bieden voor dit vraagstuk zal er gekeken moeten worden naar de individuele apparaten en welke data er aangeboden wordt. Dit zal gebeuren met een literair onderzoek. Voor het EEG systeem er zal gekeken worden naar de "Brain Activity in Biathlon - A Comparison between Experts and Novices and Acute Effects of Exercise" (Luchsinger, 2015) voor de krachtplaten zal er gekeken worden naar "Designing for Movement Quality in Exergames: Lessons Learned from Observing Senior Citizens Playing Stepping Games" (Nina Skjæret, 2014) en Exercise and rehabilitation delivered through exergames in older adults: An integrative review of technologies, safety and efficacy (Nina Skjæreta, 2015).
- **Welke methode van datapresentatie is het meest overzichtelijk voor de onderzoekers?**
Om inzicht te krijgen hoe de onderzoekers hun data willen krijgen zal er per hardware deel een interview gehouden worden met de onderzoekers die met de data omgaan.
- **Wat zijn de mogelijkheden om de verschillende data op te slaan?**
Om inzicht te krijgen hoe de onderzoekers hun data opgeslagen willen hebben zal er een interview plaats vinden met een van de professoren die het project zal gaan leiden.
- **Is het mogelijk om spelbeelden en of Kinect camera beelden tijdens een 'exergame' uit te lezen?**
Om deze vraag te kunnen beantwoorden zal er een literatuuronderzoek of dit eerder gedaan en wat de bevindingen van andere onderzoekers te vinden. Vervolgens een analyse op de eerder verzamelde bevindingen. Verder zal er gekeken worden naar mogelijke andere onderzoeken die ook de Kinect gebruiken. Daarnaast voor het gebruik en het programmeren tegen de Kinect aan zal er "Making Things See" (Borenstein, 2012) en "Programming with the Kinect for software development kit" (Catuhe, 2012).
- **(Zo niet) Zijn er mogelijkheden om indirect de beelden van de Kinect of het spelplatform uit te lezen?**
Mocht de eerder gestelde vraag onmogelijk zijn qua tijd of technische limitatie dan zal er een literatuuronderzoek plaats vinden of een interview om te een manier te vinden om als nog een acceptabele uitkomst te kunnen bieden.
- **Hoe zorg ik ervoor dat het systeem later uitgebreid kan worden als er meer sensoren aan het platform gekoppeld worden?**
Om bestand te zijn voor de toekomst zal er een interview plaats vinden met de project leider om te kijken wat de eerste mogelijkheid heden zijn voor expansie van het systeem. Vervolgens kan er doormiddel van een literatuur onderzoek van de handleiding (van dit systeem) gekeken worden naar manieren om deze aan het systeem te kunnen toevoegen.

6.3 Randvoorwaarden

Huisvesting

Voor het project is een werkplek nodig op locatie en een werkplek in het Laboratorium waar een gedeelte van de apparatuur is gehuisvest. Dit brengt ons direct bij het volgende punt.

Materieel

Het doel van dit project is dat er verschillende hardware samenwerkt en dat de data van de experimenten kunnen opgeslagen worden. Hiervoor is dus een systeem nodig in het laboratorium om het project op te draaien. Daarnaast is nodig een krachtplaat, EEG, motion capture en het spelsysteem die de data zal voorzien voor de onderzoekers.

Tijd en Expertise

Voor verschillende onderdelen zal ik afhankelijk zijn van uitleg van professoren die met de hardware werken of gewerkt hebben. Tijdens de opleiding van de student is er bijvoorbeeld niet eerder met een krachtplaat of EEG systeem gewerkt en zal dus naar de expertise van de professoren van de NTNU of bevriende instituten gevraagd worden. Hiervoor zal gekeken moeten worden naar het tijdsschema waarin zij tijd hebben om mogelijk uitleg te geven of aan te geven wat zij van het project willen hebben.

6.4 Risicoanalyse

Ontbrekende of defecte hardware

Om de software te ontwikkelen zal dit met de hardware moeten kunnen communiceren. Zonder de hardware zal dit proces zeer moeilijk tot onmogelijk zijn. Bij defecte hardware zal de apparatuur opgestuurd moeten worden waarna deze gerepareerd en teruggestuurd moet worden. Wat uiteraard veel tijd kost. In dat geval zou ik me kunnen focussen op de andere hardware onderdelen.

Toegang tot het lab

De hardware zelf is gesitueerd in het zogenaamde Oqus lab. Dit lab kan gereserveerd worden voor onderzoeken zoals bijvoorbeeld het exergaming onderzoek. Het kan dus voorkomen dat ik geen toegang heb tot het lab en dus niet kan werken met de hardware op bepaalde tijden of dagen. Mocht dit het geval zijn dan is er de mogelijkheid in overleg met de beheerders van het lab om bijvoorbeeld 1 van de krachtplaten mee te nemen naar de werkplek van de student en daar te testen. Daarnaast kan er ook verder gewerkt worden aan de Microsoft Kinect camera systeem.

Expertise

Voor dit project moeten er systemen gekoppeld worden waarmee de student nog niet bekend is. Bijvoorbeeld de EEG versterker is een zeer specialistisch stuk hardware en daarvoor dient een proces voltooid te zijn voordat je daarmee aan de slag kunt gaan. Dit zelfde geldt ook met het interpreteren van de verkregen data. De student zal bijvoorbeeld de data moeten doorspelen naar ervaren EEG gebruikers om te identificeren of de data correct is.

7 Planning

De aanpak van dit project is een iteratief proces. Om de onderzoeksvragen te kunnen beantwoorden moeten er een aantal onderdelen uitgezocht worden. Deze onderdelen worden opgesplitst en komen op een 'product backlog'. Dit heeft een aantal voordelen bijvoorbeeld als de benodigde apparatuur niet beschikbaar is of als er beslissingen genomen worden over details van het project. Dan kan er door gewerkt worden aan andere taken op de 'product backlog'.

Verder wordt er gewerkt met een ToDo list op basis van Urgentie, Non-urgent, Grotere taken, delegeer taken. Urgentie zullen dingen zijn al uitzoeken wat de opties van X zijn zodat er een keuze gemaakt over kan worden en eigenlijk alles wat direct belangrijk is voor het project. Non-Urgent zijn taken die kunnen wachten tot de rest van de lijst verwerkt is.

Grotere taken houdt in de grote stukken die opgeleverd moeten worden en mogelijk verder opgedeeld moeten worden voor op de urgentie lijst. Delegeer taken houdt in dat dat het iets is waarover ik iemand anders aan moet sturen. Als in opvragen wanneer hardware X beschikbaar is. Of wanneer het lab ongebruikt wordt.

Voor de globale deadlines binnen het project geldt dat er begonnen is op 1 februari en gewerkt zal worden tot 31 mei. Hierin zal het prototype ontwikkelt moeten worden.

In eerste instantie zal er gekeken moeten worden naar hoe de data uit verschillende hardware gelezen kan worden. Voor omgang met het EEG systeem is er de masterthesis van Harry Luchsinger over hersenactiviteit in een Biatlon (Luchsinger, 2015) beschikbaar. De krachtplaten zijn gebruikt als bron voor de data in onderzoeken naar hoe je bewegingskwaliteit ontwerpt in exergames (Nina Skjæret, 2014) en het oefenen en revalideren van ouderen met de hulp van exergames (Nina Skjæreta, 2015) geschreven binnen de NTNU en een aantal onderzoekers zijn nog werkzaam bij de NTNU en benaderbaar voor meer informatie.

Dit zal in zichzelf wel een aantal mogelijke problemen kunnen opleveren voor synchronisatie van de data. Er zal dan per onderdeel een gedeelte gemaakt moeten worden voor het overkoepelende systeem om deze te ondersteunen. Deze stap wordt herhaalt tot de gevraagde hardware meewerkt met het overkoepelende systeem.

Daarnaast moet er gekeken worden naar de mogelijkheden om van het motion capture systeem de beelden te kunnen vergaren en op te slaan. Waarna afhankelijk van de keuzes over het spelsysteem zal dan een screen capture systeem gemaakt moeten worden voor het spel op een windows platform. Of zal er gekeken moeten worden naar een capture card om de hdmi uitgang van een Microsoft Xbox 360 of Xbox one op te slaan. Voor omgang met de kinect zal ik gebruik maken van de volgende werken (Catuhe, 2012) en (Borenstein, 2012). Verder zal er gezocht worden in de bibliotheek van de NTNU naar relevante literatuur over de andere stukken hardware.

Als dit allemaal goed samenwerkt, zal er gekeken worden naar de mogelijkheid om een configuratiebestand te schrijven waarmee het overkoepelende systeem de verschillende hardware zou kunnen configureren. Dit configuratiebestand zou dan mogelijk gebruikt kunnen worden om specifieke waarden voor experimenten in voor te configureren bijvoorbeeld de maximale lading van de krachtplaat kun je laten variëren met als reden of je een stap of een sprong wil detecteren.

8 Bronnen/literatuurlijst

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10.2 'Kubrick' Game Capture System

During development of the project the student worked on a game footage capturing system, it got the nickname of Kubrick, in spirit of the infamous film director demanding up to 127 retakes of a scene. This was mainly because of the many iterations the system has had. It would often change in new found methods for trying to read the game screen, while it was at that time still unclear which exergame would be used in the trails. To not flood the thesis with unfinished code it has been left out for readability.

10.2.1 Windows GDI+

The first iteration was written in C++ using the Windows GDI+ (Graphics Device Interface) API. The Program worked well in early tests with just recording the desktop. It became apparent that it was too slow in processing the collected data and running an actual game at the same time. It became from there on vital not to cause too much strain on the processor during gameplay. Even when easing the speed of the data collection by taking screenshots every 200 milliseconds(ms), which was tested by recording a stopwatch (on screen). The method would occasionally surpass the 200ms threshold. This deemed the method as too slow early on in development.

10.2.2 Python

Secondly, the python approach using PIL's Imagegrab method. Which ran in a speed from around 40 ms per frame. This worked well with tested indie games running in a windowed environment. During development the exergame got picked. Which became Silverfit's Puzzle game where in PIL's imagegrab method does not work because the game runs in DirectX full screen Exclusive mode. (See Chapter 3.3 Exergame screen capture for more details.)

10.2.3 System wide hook

Thirdly, another method one wrote was a low level keyboard system hook. This meant the system would get loaded into every process that the system would start. With that hook the game process would start and load all the needed drivers and indirectly load the created keyboard hook. During multiple test runs it caused glitches and game crashes when attempting to store the front buffers data. The problem was that the method was too slow (80-120ms). Simply reading the front data and writing it away, before the swap chain could swap the buffers meant that either the capturing system would be halted or the game would freeze. The worst possible outcome would be that the capturing system and the video card driver are waiting for permission to access to the buffer causing a deadlock on the workstation.

10.2.4 DirectX EndScene Injection hook

Fourthly, tested a DirectX EndScene hook which would load when the process started (in the case puzzlegame.exe).

This was a two-step approach:

1. First you had to get loaded in a process of the puzzle game.
This was achieved by using a separate injector focused on only the game executable instead of the entire operating system.
2. Secondly, the injection would focus on hooking into Direct3dCreate inside of the DirectX library.
That would give access to an instance a IDirect3D9 object inside the game.
From here one could use the VTable to lookup the addresses dynamically at runtime.
Then it would hook into the IDirect3DDevice9::EndScene Method.

After the hook onto a EndScene method inside the DirectX 9 library. The method would return a "D3D_OK" if a scene would have been queued up for the rendering by the driver [26]. The lack of resources available for this approach made it extremely hard to program and debug. The system was not very stable and the search for a more suitable method continued.

After which the student tried using the SlimDX library [27] in an attempt to write a stable version of the keyboard hook for DirectX. However, during development the injection method was abandoned because of time restraints of the project. With the deadline looming the game capturing software was switched out with OBS.

10.3 The differences in addressable memory between 32 and 64 bits' operation systems

The difference in 32-bit and 64-bit operating systems mostly affects the size of a pointer/reference and the possible available addressable memory. On 64 bit machines one can reference an address in a 64-bit address range (giving one 2^{64} bytes = 18,446,744,073,709,551,616 bytes which translates to $18,446,744,073,709,551,616 / (1,024 \times 1,024) = 16\text{EB}$ (Exabyte's)). On 32 bit you can only address 2^{32} bytes (= 4,294,967,296 bytes $4,294,967,296 / (1,024 \times 1,024) = 4,096 \text{ MB} = 4 \text{ GB}$). When you look at modern computers it becomes obvious that 32 bit cannot easily address all the memory. If that machine has more than 4 GB of memory it would mean they wouldn't be able to use more than 4GB of the memory. One thing to notice to these limits that it is not just Random Access Memory (RAM) but the 4GB and 16EB limits are made up from combining System RAM, Graphics (Video Card) RAM, PCI memory range, ACPI and some other bobs and pieces [28]. So one could as example install 3 video cards with 1 GB RAM on them and then have 1 GB of System RAM remaining to be used by the system. At the moment the 16 Exabyte's of memory is something that cannot be reached with normal desktops as modern operation systems don't support the full 16 Exabyte's the Windows 10 Enterprise/Education and Pro version enable one to have 2Tb's of memory [29].

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