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KINEMATIC MEASUREMENTS OF THE HUMAN HEAD DURING VIRTUAL REALITY GAMING

TURKU AMK
TURKU UNIVERSITY OF APPLIED SCIENCES

BACHELOR'S THESIS | ABSTRACT

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Kinematic measurements of the Human head during virtual reality gaming

This thesis focuses on designing and implementing a set of tests for the motion of the human head while using virtual reality glasses. The thesis was executed by using an 3-axis gyroscope, 3-axis accelerometer and virtual reality glasses attached to the head of the test subject.

The testing system consisted of a InvenSense ICM-20601 gyroscope and accelerometer sensor evaluation board and a separate PC controlled INV-ARM connection plate. The testing system was controlled with Data logger -software. Measurements about typical head movements in a virtual reality gaming were implemented by using the testing system session and a final series of movement tests that repeated the most common movements that had occured.

Real physical values such as angular velocity in units of radians per second and the linear acceleration in units of g-values were calculated from the raw data values which were obtained from the measurements. The next step was to define the angular acceleration and the extreme angles in every axis. At the end of the work the collected values were edited into graphical representations from which the relevant conclusions were made.

As a result, this thesis gives a comprehensive understanding of accelerometer and gyroscope sensors, as well as the motions and velocities generated by the human head. This thesis was done for a company called Afore Oy which is a manufacturer of sensor test equipment. The results are to be used as reference material for the human motion simulator development.

KEYWORDS:

Microcontroller, InvenSense, motion modeling, virtual reality

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Ohjaaja: Juha Nikkanen

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PÄÄN LIIKKEIDEN MÄÄRITYS VIRTUAALILASEJA KÄYTETTÄESSÄ

Työssä suunniteltiin ja toteutettiin mittaussarja pään liikkeiden yleisimpien liikkeiden mallintamiseen virtuaalitodellisuuslaseja käytettäessä. Työ toteutettiin päähän kiinnitetyn kolmiakselisen gyroskooppi- ja kiihtyvyysanturin sekä virtuaalilasien avulla.

Testausjärjestelmä koostui InvenSensen ICM-20601 kiihtyvyys- ja kulmanopeusanturista ja erillisestä INV-ARM -liitäntälevystä, jota ohjattiin tietokoneen Data Logger -ohjelmistolla. Testausjärjestelmällä mitattiin pelitilanteen aikana tapahtuvaa pään liikettä sekä näiden pohjalta tehtyä testiliikesarjaa, jossa toistettiin useimmin tapahtuneet liikkeet.

Näistä tuloksena saadut arvot muutettiin ohjelman syöttämästä raakadata-arvosta varsinaisiksi yksiköiksi, joita olivat kulmanopeus radiaaneina sekunnissa sekä lineaarinen kiihtyvyys g-arvoina. Lopuksi kulmanopeudesta määritettiin kulmakiihtyvyys ja maksimikulmat. Viimeiseksi valmiit tulokset muokattiin kuvaajiksi ja niistä esitettiin johtopäätökset.

Lopputuloksena työssä saatiin kattava käsitys kiihtyvyys ja kulmanopeusanturien toiminnasta, sekä ihmisen pään tuottamista liikeradoista ja nopeuksista. Työ toteutettiin anturien testauslaitteita valmistavalle Afore Oy:lle, ja työn tuloksia on tarkoitus käyttää tulevaisuudessa pohjatietona yrityksen mittauslaitteistojen kehitystyössä.

ASIASANAT:

Mikrokontrolleri, InvenSense, liikemallinnus, virtuaalilasit

CONTENT

FIGURES

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1 INTRODUCTION

The purpose of this work was to design and implement a set of tests for the motion of the human head while using virtual reality glasses. The thesis was executed by using an six-axis gyroscope, accelerometer and virtual reality glasses attached to the head of the test subject. This thesis was done for a company called Afore Oy which is a manufacturer of sensor test equipment. The results are to be used as reference material for the human motion simulator development and will be validated with Afore Oy's Metis measuring device. Metis is a 3-axis gimbal test system for IMU (Inertial Measurement Unit) and IoT (Internet of Things) devices.

Afore Oy develops, manufactures and delivers advanced testing solutions for MEMS sensor industry. In addition to this the company delivers customized production automation devices related to sensor manufacturing all from silicon wafers prosessing to the packaking of the components. Afore Oy also provides a testing related laboratory services to the client companies. The company's business were initially based on mechanical design, but the first testing system was already delivered in 1998. The company has been focused on test equipment deliveries since 2009. Clients has been mostly domestic but within last years Afore have established corporate relations and delivered equipment to USA, China and Japan. The Vision of the company is to become an internationally significant MEMS testing system supplier. At present, the company employs 25 people, most of whom are engineers. The turnover in year 2016 was 5,1 M€.

A variety of theses, such as Pearce Jonathan's 'Research and Development of a 6 Degrees of Freedom Electric Motion Platform : Fundamentals of a Motion Platform' (2016) have been done about motion tracking, but none are exactly the same as this nor from the same point of view.

In the next chapter the theory about MEMS sensors, I^2C protocol and virtual reality are presented. The third chapter covers the entire working part, from research to actual measurements and error analysis. In the chapter 4 results and observations are presented.

2 THEORY

2.1 MEMS

MEMS (Microelectromechanical systems) defines the technology of microscopic devices. The term itself qualifies the entire technology, not any specific product. MEMS devices are integration of mechanical elements and electronics on a common substrate though specialized fabrication techniques. The MEMS sensors family ranges from single- and multi-axis gyroscopes to 2- and 3-axis linear accelerometers, sensor modules (Figure 1) and microphones. The electronics are made-up using integrated circuit (IC) process sequences. The micromechanical components are created using compatible micromachining processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices. [1]

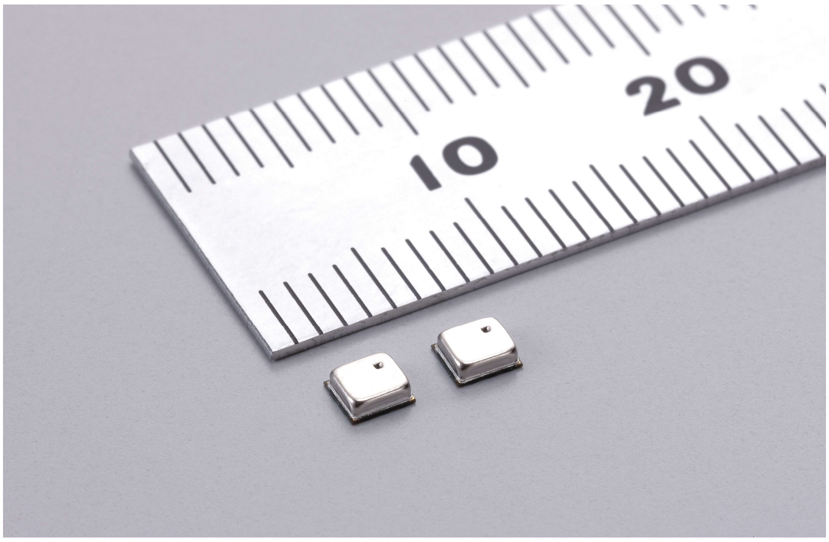

Figure 1. Capacitive type MEMS pressure sensor [2]

2.1.1 MEMS Gyroscope

Gyroscope is a physical sensor that can detect and measure angular movement (pitch, roll and yawn) of an object relative to an inertial frame of reference. Gyroscopes can detect rotational velocity in 1, 2 or 3 directions (Figure 2). Gyroscopes can be divided into two main categories depending on whether the angular velocity or orientation is being measured. [3]

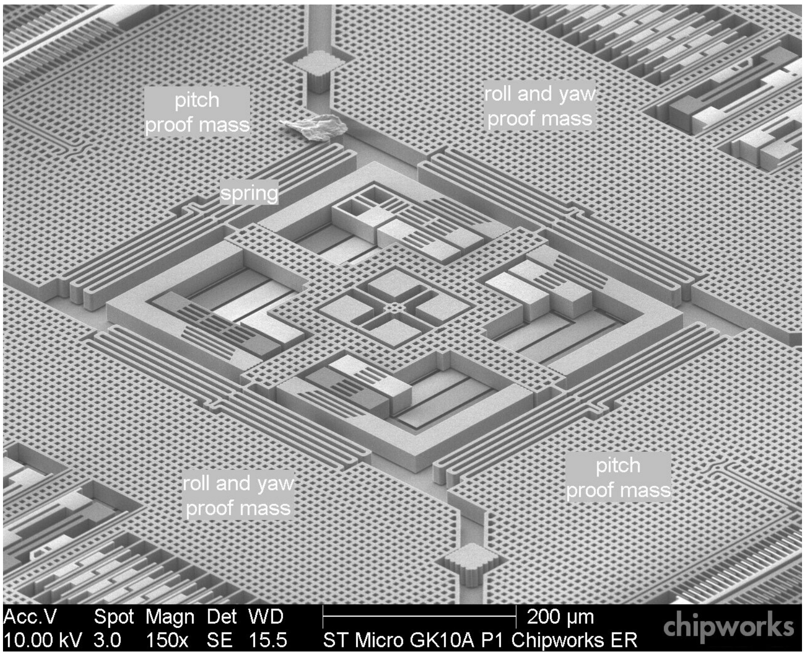

Figure 2. 2-axis MEMS gyroscope [4]

Rate gyroscopes measure the angular velocity, or the rate of rotation of an object. Angle gyroscopes measure the angular position, or orientation of an object directly. Basically all existing MEMS gyroscopes are of the rate measuring type and are typically designated for motion detection (for example, in consumer electronics and vehicle chassis rollover sensing) and motion stabilization and control (for example, robotics movement and platform stabilization systems). [5]

Vibrating structure gyroscopes are MEMS devices that are easily available, inexpensive, and very small in size. The operation of an vibrating structure gyroscope is based on the Coriolis force (Figure 3). The Coriolis force is relative to both the angular velocity of the rotating object (Ω) and the velocity of the object moving towards or away from the axis of rotation (V). Vibrating structure gyroscopes have a micro-machined mass which is connected to an outer housing by a set of microscopic springs. This outer housing is linked to the fixed circuit board by a another set of orthogonal springs. The mass is continuously moving sinusoidally along the first set of springs. Any befalling rotation of the system will cause Coriolis acceleration in the mass and is pushing it in the direction of the second set of springs. The resulting physical displacement is then read using a capacitive sensing interface and from that it is possible to determine the resulting angular movement. [6]

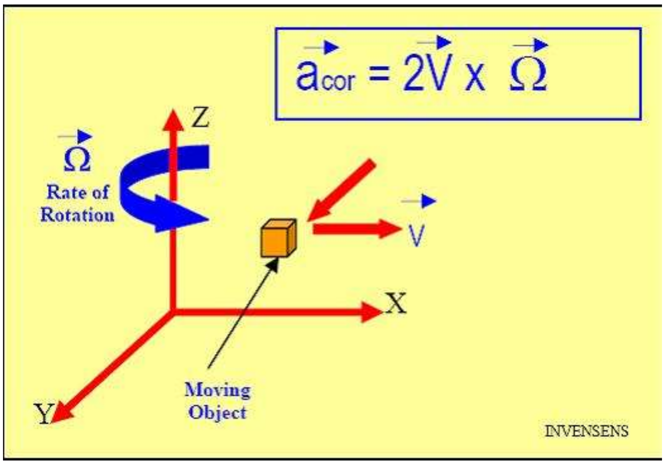

Figure 3. Coriolis effect [6]

2.1.2 MEMS Accelerometer

An accelerometer is an electromechanical device that measures acceleration forces. These forces could be static, like the constant force of gravity, or they might be dynamic, affected by accelerometers motion or vibration. The development of MEMS accelerometers has made them smaller, more low-powered and easily integrated into wide range of applications. There are three main type of technologies in MEMS accelerometers for converting the acceleration into an electrical signal: piezoelectric, piezoresistive and capacitive. [7][8]

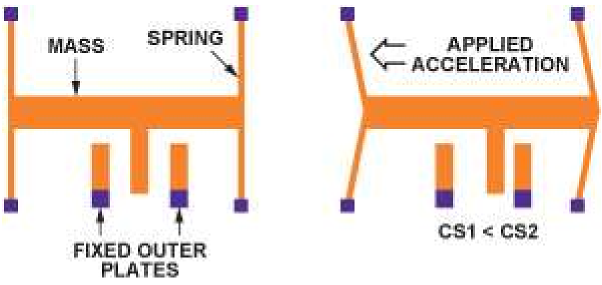

Figure 4. Capacitive MEMS accelerometer structure under zero net force (left) and when acceleration force is caused [9]

MEMS-based accelerometer with capacitors have the best long term stability and high sensitivity. It is typical structure that uses capacitors formed by a moveable plate held between fixed plates (Figure 4). Under zero net force the capacitors are equal, but a variation in force will cause the moveable plate to shift closer to one of the fixed plates, increasing the capacitance, and further away from the other decreasing that capacitance.

This difference in capacitance is discovered and amplified to produce a voltage relative to the acceleration. The dimensions of the structure are of the order of micrometers. [10]

2.1.3 I^2C, Communication

I^2C is a serial protocol for two-wire interface to connect low-speed devices like microcontrollers, EEPROMs, I/O interfaces and other similar peripherals in embedded systems. It was invented by Philips in 1982 and it is now used by almost all major IC manufacturers.

I^2C bus is a standard bidirectional interface which is used for communication between a master (or multiple masters) and a single or multiple slave devices. A slave device will not transmit data unless it has been addressed by the master. Each device on the I^2C bus has a specific device addres to differentiate between other devices that are on the same I^2C bus. A device can have one or multiple registers where data is stored, written, or read. The physical I^2C interface consists of the SCL (serial clock) and SDA (serial data) lines. Both SDA and SCL lines have to be connected to the operating voltage V_{CC} trough a pull-up resistor.

Transfer from/to master device is serial and it is split into 8-bit packets. The original initial I^2C specifications defined maximum clock frequency of 100 kHz. This was later increased to 400 kHz as fast mode. There are also a High speed mode which can go up to 3,4 MHz and a 5 MHz ultra-fast mode. [11]

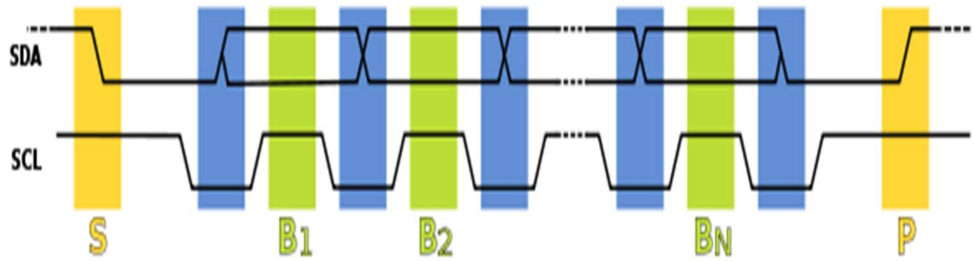

Figure 5. I^2C Timing diagram [12]

In normal state both lines (SCL and SDA) are at high state (Figure 5). The communication is initiated by the master device. It generates the Start condition (S) by pulling SDA low while SCL stays high. SDA sets the first data bit level while keeping SLC low (blue bar) and the data is read or written when the SCL rises for the first bit (B1). This process repeats once all bytes are read or written (B2. Bn). Then SDA is pulled high while also SCL is high and master device generates Stop condition (P). This signals to other devices on the bus that the communication has ended and another device may use the bus. Most I2C devices support repeated start condition. This means that before the communication ends with a stop condition, master device can change the mode from writing to reading and repeat start condition with address byte. [12]

2.2 Virtual Reality

Virtual reality (VR) is a computer technology that uses Virtual reality headsets to simulate a user's physical presence in a virtual environment by generating realistic images, sounds and other sensations. A person using virtual reality equipment is able to explore the artificial world, travel in it and interact with virtual features or items. VR headsets are head-mounted goggles with a screen in front of the eyes. Programs may include audio and sounds through speakers or headphones.

All modern VR displays are based on the same technology developed for smartphones, gyroscopes and accelerometers for tracking head, hand, and body positions, small high quality screens for stereoscopic displays and small, lightweight and efficient processors. [13]

3 MEASUREMENTS

The work started with the research about the test setup needed for the measurements. This was implemented by searching and compairing different types of gyroscope and accelerometer versions from the internet. The main details for the setup were previously agreed with Afore Oy. Most specific details were sufficient sampling rates, high sensitivity sensors and smart connectivity capability. There are only a few manufacturers on the present market but a countless amount of a different measuring sensors with varying technical properties.

After the research the device selected and ordered for this work was the InvenSense ICM-20601 evaluation board. This board was chosen due to its simple connectivity and capability to recognize small and fast movements. This device board is connected to the InvenSense INV-ARM reference board, which provides a bridge function between the sensor board and a PC. These boards (Figure 6) communicate with each other via I^{2}C serial computer bus and are controlled from PC by using InvenSenses' Data Logger software. With this software it is possible to change the properties of the sensor and to import the collected data straight to a Excel file. [14][15]

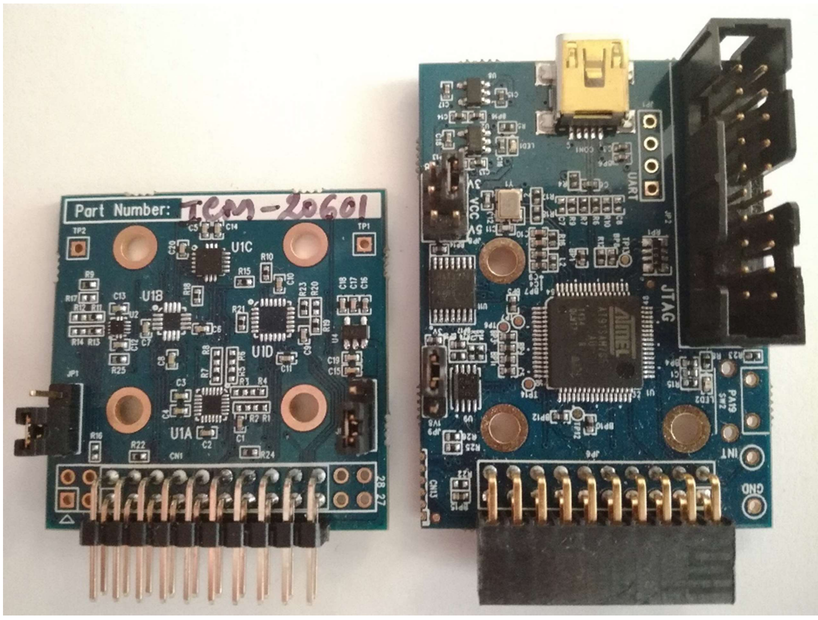

Figure 6. InvenSense ICM-20601 Evaluation board (left) and the INV-ARM reference board

The actual ICM-20601 sensor is a six degrees of freedom Inertial measurement unit that combines 3-axis gyroscope, and a 3-axis accelerometer in a 3x3x0,75mm package. Sensors gyroscope has a programmable full-scale range up to ±4000 degrees/sec and accelerometer up to ±32g. Communication with all registers of the device is performed using either I^2C at 400 kHz or SPI (Serial Peripheral Interface bus) at 8 MHz. It can be found in a sincle chips or in a ready evaluation boards. Within this work I used the ready evaluation board. [15]

Figure 7 shows the position and orientation diagram used later in this work.

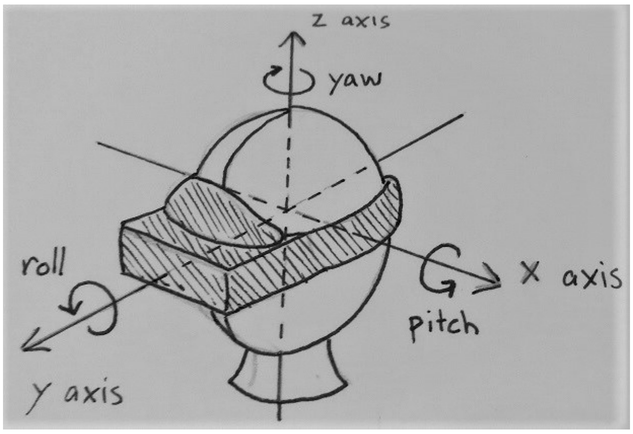

Figure 7. Head tracking position and orientation diagram

3.1 Test setup

InvenSenses Data Logger softwares main purpose is to collect and present the resulting values from the device (Figure 8). It is also used to program the register map of the device, which means changing the sensors settings, for example the sensitive and sample rate. The adjusting of the device is done by changing the specific hexa decimal values from the right folder of the register map. All sensor settings are to be found from the ICM-20601's register map file. The first values used for the register map were chosen by implementing a set of test moves with the sensor device. [16][17]

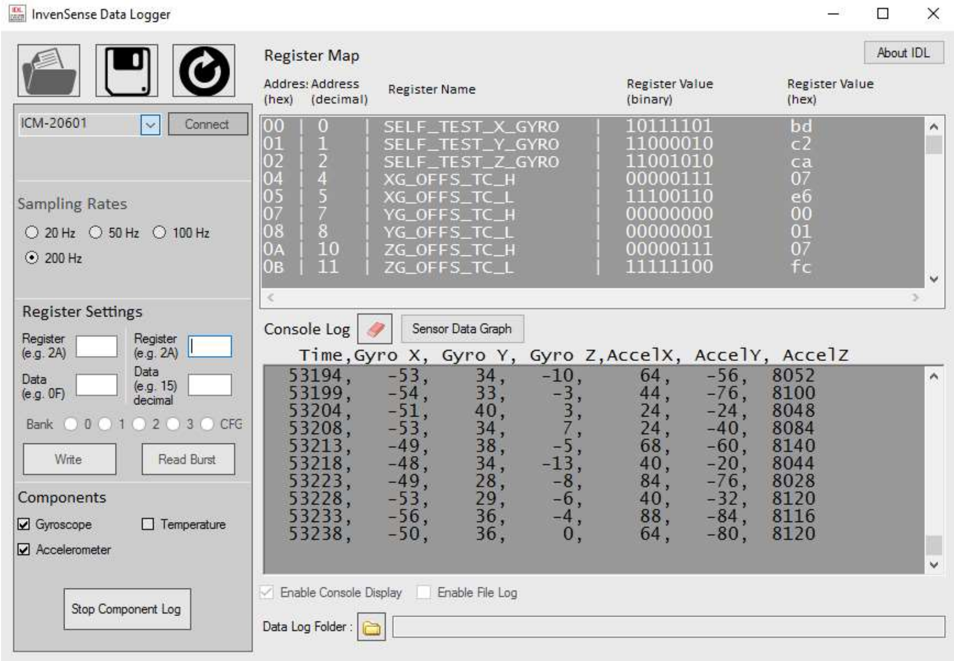

Figure 8. InvenSense Data logger interface

After a small testing the sensitivity for the gyroscope was determined to be ±2000 degrees per second and accelerometers ±8 g's. The sampling rate was selected into a 200Hz so the device collects the values from each axis every 5 milliseconds.

The actual testing system included also the virtual reality glasses. The glasses used within this thesis were Playstation PSVR that Afore Oy provided for the duration of the work.

Figure 9. Sony PSVR glasses[18]

Playstation VR (Figure 9) is Sony's virtual-reality head-mounted display (HDM), which is used with the Playstation 4 console. It features a stereoscopic 3D display with optics placed directly in front of users eyes and is coupled with head-tracking that simulates depth and positional awareness within a virtual environment. Playstation VR uses a single 14,5 centimeters 1920x1080p OLED (Organic Light Emitting Diode) display, features an approximately 100-degree field of view and a 120Hz refresh rate panel. [18]

3.2 Measurement

Measurements were completed during gameplay with the playstation 4 and the PSVR-glasses. This part was implemented by self-monitoring the own moves while gaming and also by following the other test persons movements. In this part of the work there were five test persons and each of them played different available games from 30 minutes to one hour. Especially the latter option with test persons provided a lot of useful research information about the actual head movement. Next step was to attach the test setup sensors and make the first measurements (Figure 10). From these results it was possible to add the more specific register map values in to the data logger to get more suitable results.

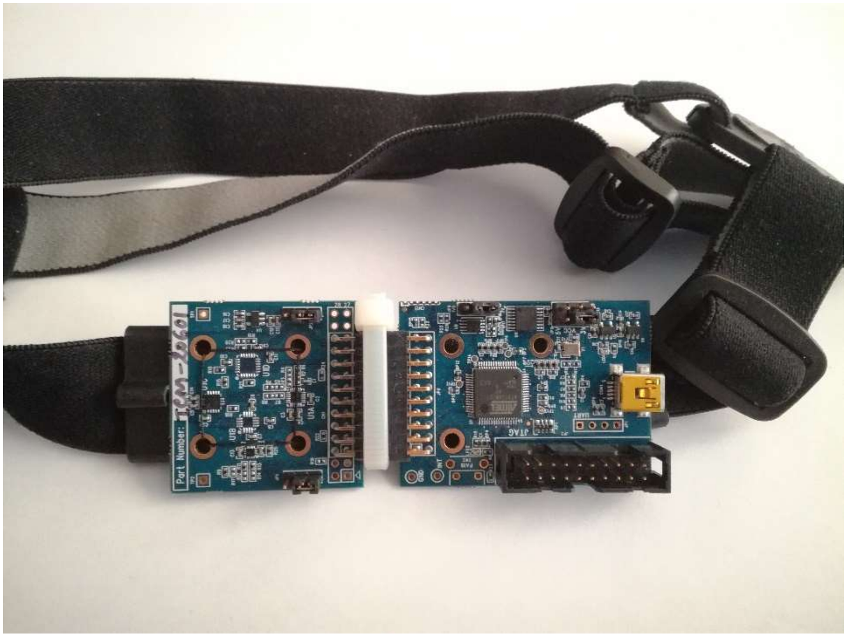

Figure 10. Test setup with the headband

The recording scale from the gaming sessions was kept wide with different games and test persons. The games played during this research were Resident Evil 7, Dirt, VR Playroom, Call of Duty Jackal Assault, Headmasters and Valkyrie. Some games feature their own specific range of head movemement but normally the movement stays about the same. The whole range of movements during the gameplay were then gathered into two pictures, one with the gyroscope values (Figure 11) and other with accelerometer values (Figure 12)

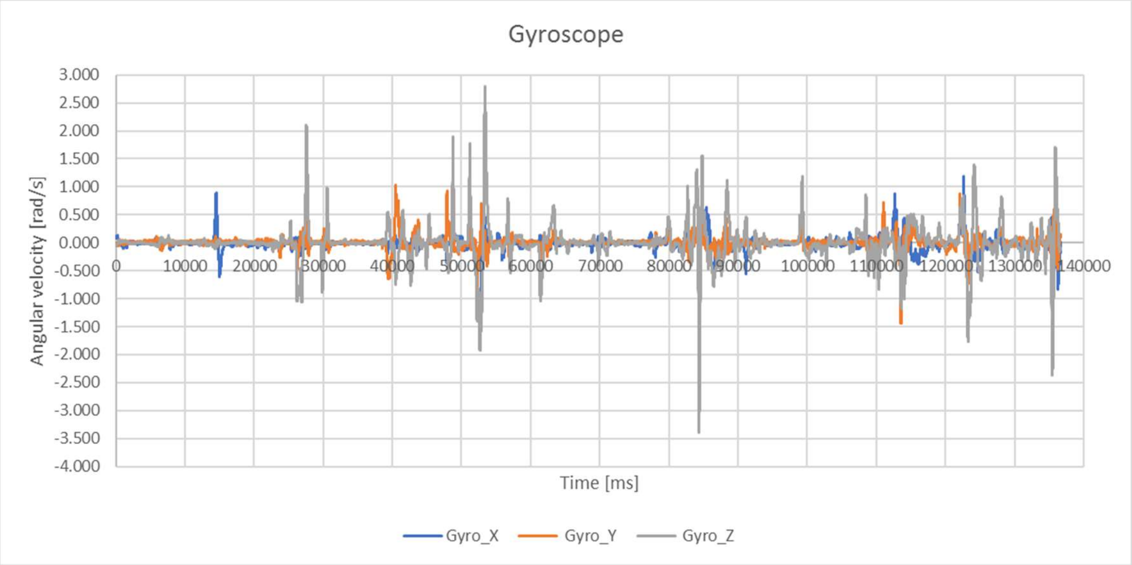

Figure 11. Gyroscope values from measurement done 17.03.2017 while playing the game Valkyrie, Blue = X axis, orange = Y axis and grey = Z axis.

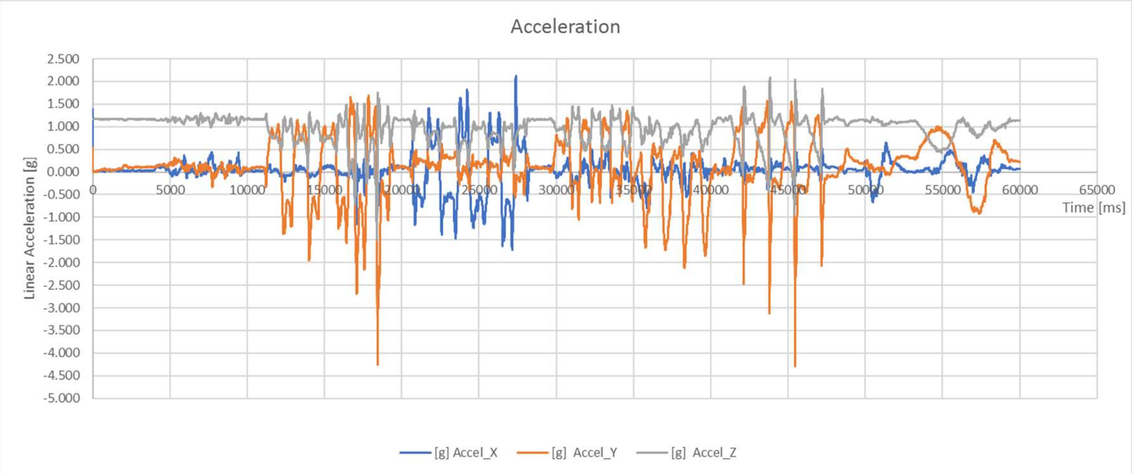

Figure 12. Accelerometer values for every three axis from measurement done 17.03.2017 while playing the game Valkyrie, Blue = X axis, orange = Y axis and grey = Z axis.

3.3 Results processing

Angular velocity was calculated (equation 1) from the raw data values (RAW) by using the sensitivity value (Sensitivity) found from sensors data sheet. It was converted from degrees into a radians per second value. The sensitivity multiplier is depending on the exact sensitivity rate of the sensor. In this case the sensitivity is ±2000 degrees per second and the sensitivity multiplier is 16.4 LSB/(°/s), where LSB means the last significant bit. [14]

$$V_{ANGULAR}\left[\frac{rad}{s}\right] = \frac{RAW\ [LSB]*\pi}{Sensitivity[\frac{LSB}{\frac{\circ}{s}}]*180°} \tag{1}$$

The linear acceleration was calculated by using the next formula with sensitivity scale factor as 4096 LSB/g:

$$A_{Linear}[g] = \frac{RAW[LSB]}{Sensitivity\left[\frac{LSB}{g}\right]} \tag{2}$$

Each axis are to be calculated separately. The acceleration unit used is g-value, which means the multiplier of 9.81 m/s^2. After these calculations the values were modified into characteristics, from which it was easier to monitor the whole data range visually. Both angular velocity and linear acceleration were put into their own charts.

The angular acceleration values were defined from the characteristics by drawing a tangent which follows the greatest changes within angular velocity. The next figure [Figure 9] shows the example of drawn lines from which the momentary acceleration were calculated by usig the formula:

$$A_{Angular}\left[\frac{rad}{s^2}\right] = \frac{\Delta V_{Angular}}{\Delta t}, \tag{3}$$

where $\Delta V_{Angular}$ equals the change in angular velocity and Δt the change in time.

Actual peak angles were evaluated from the charts by multiplying the angular velocity within the exact move by the elapsed time (equation 4). The first part was to determine the specific spot of the movement and then cut it to a 5 ms blocks. Those blocks were summed up to get the most reliable peak angle from the move in one axis.

$$\propto [rad] = V_1 * 5\ ms + V_2 * 5\ ms + .. + V_n * 5\ ms \tag{4}$$

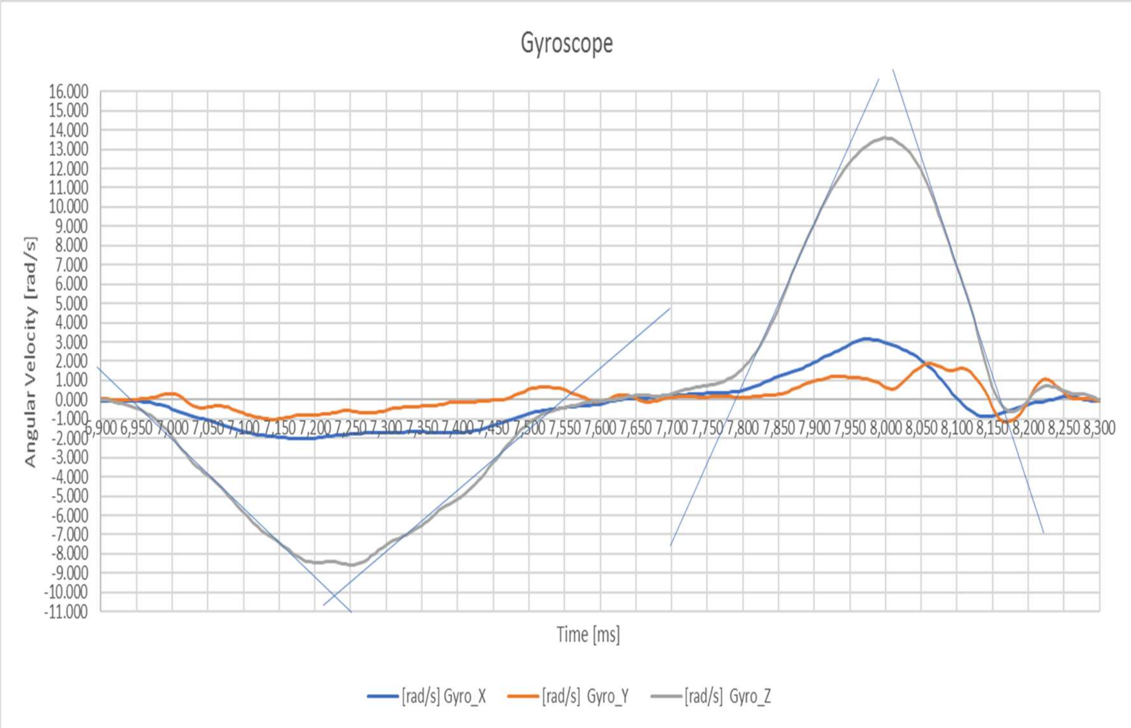

Figure 13. Example how the angular accelerations were calculated, Blue = X axis, orange = Y axis and grey = Z axis.

3.4 Test motion series

The next task was to plan a test movement series designed to include the most common changes of player's head position that happened during gaming. The duration of this series was agreed to be about one minute and including the necessary amount of repetition for enough reference values. This series is going to be tested and validated afterwards with the Afores testing machinery. The test motion series consisted six different moves from which some were quite identical and had been compounded afterwards.

These test motion series were performed by five test participants, all male, height 175-193 cm, age 23-28. After being seated in a back-supported chair with the test setup mounted on the participant's head, a one-minute head movement task was performed from two to three times. After this the results were combined and simplified. Next the average values from each different movement were separated and analyzed.

These following pictures shows the whole characteristics of both gyroscope (Figure 10) and accelerometer (Figure 11) values during the whole test motion series.

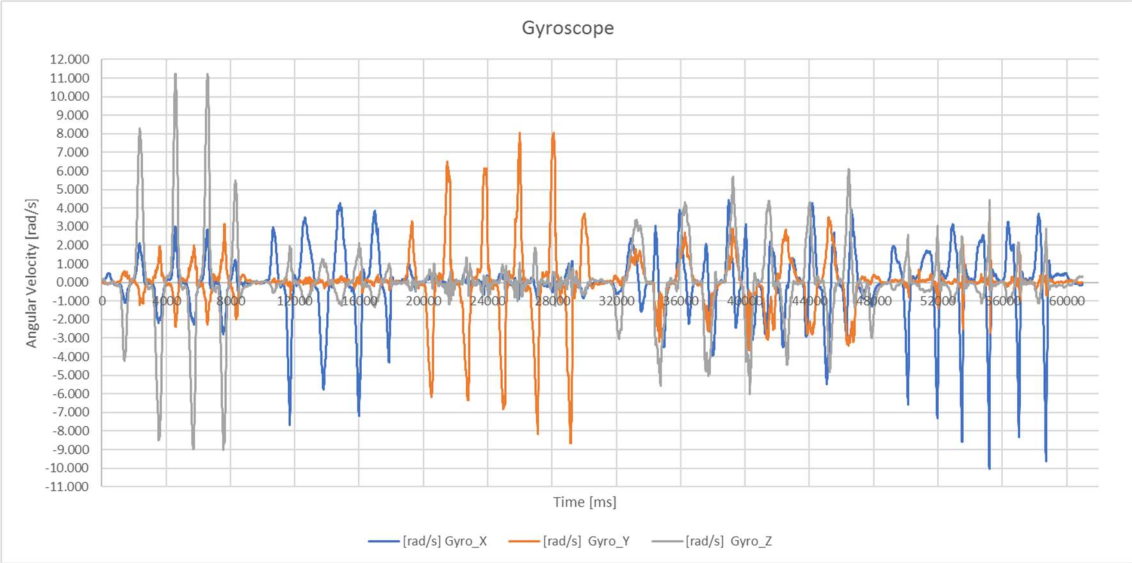

Figure 14. Example of gyroscope values from whole test measurement series, Blue = X axis, orange = Y axis and grey = Z axis.

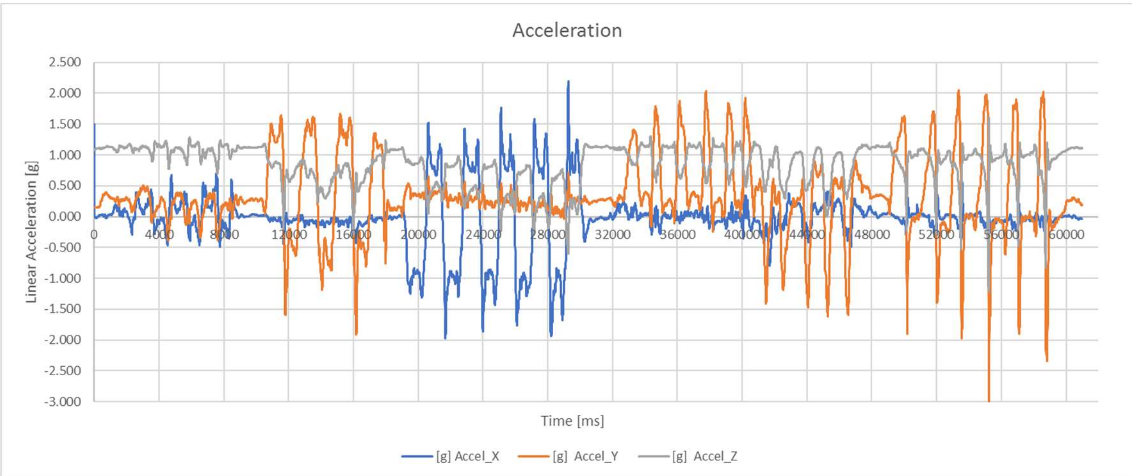

Figure 15. Example of accelerometer values from whole test measurement series, Blue = X axis, orange = Y axis and grey = Z axis.

Next chapters will display the results of each individual movements.

3.4.1 Horizontal movement

In this first move of the test motion series persons head turns straight to each side (Figure 16). According to the practical research done earlier it is the most common of the head movements while wearing the virtual reality glasses.

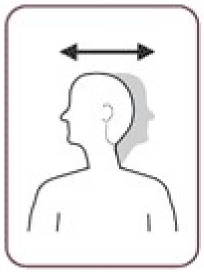

Figure 16. Horizontal movement

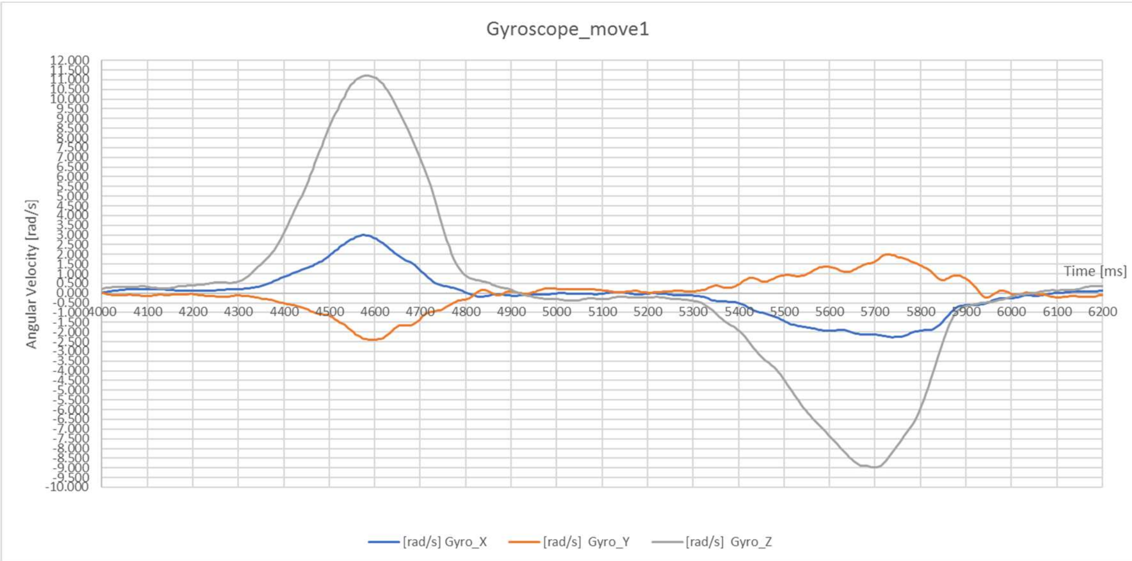

Figure 17. Example of gyroscope values from first test move, Blue = X axis, orange = Y axis and grey = Z axis.

As can be seen from the Figure 17, the angular velocity is rather powerfull in this move. The momentary peak values are -14 rad/s ja +13 rad/s. These were admittedly the extreme peak values and were reached only in a few measurement. The major time of the measurements were shoving the peak values to be around ±10 rad/s. Within the normal gaming session this moves angular velocity is approximately ± 5 rad/s.

The angular acceleration within this move were also relatively high, the extreme peak values were over ±150 rad/s^2. The maximum angle in Z-axis were calculated to be approximately ±1,2 radians (±68.8 degrees). There is no real linear acceleration (Figure 18) in this move, due to the placement of the sensor. The sensors of the virtual glasses would in fact have a small amount of acceleration in the direction of the X-axis.

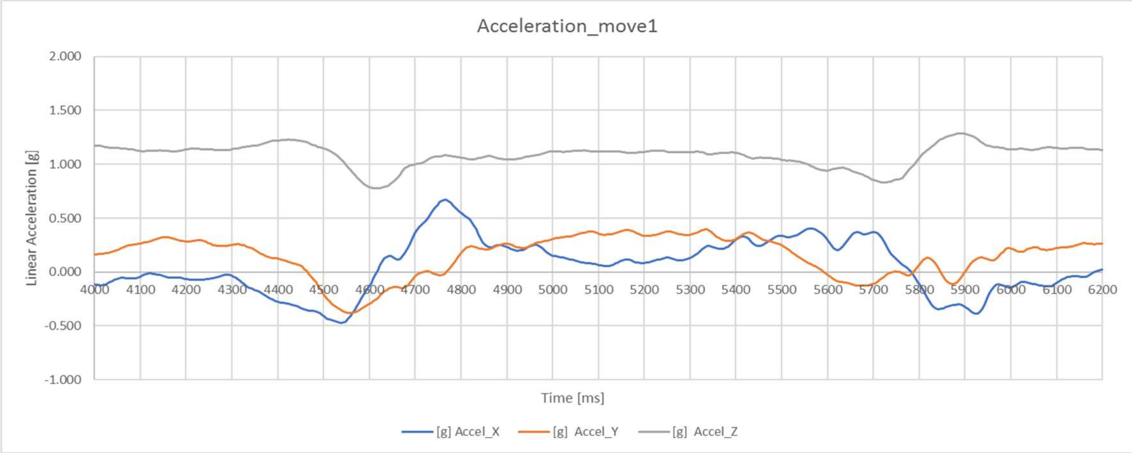

Figure 18. Example of accelerometer values from first move, Blue = X axis, orange = Y axis and grey = Z axis.

3.4.2 Vertical movement

In this move the persons head moves straightly up and down (Figure 19). It is also very common movement while wearing the virtual reality glasses.

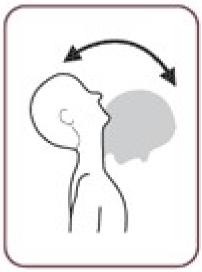

Figure 19. Vertical movement

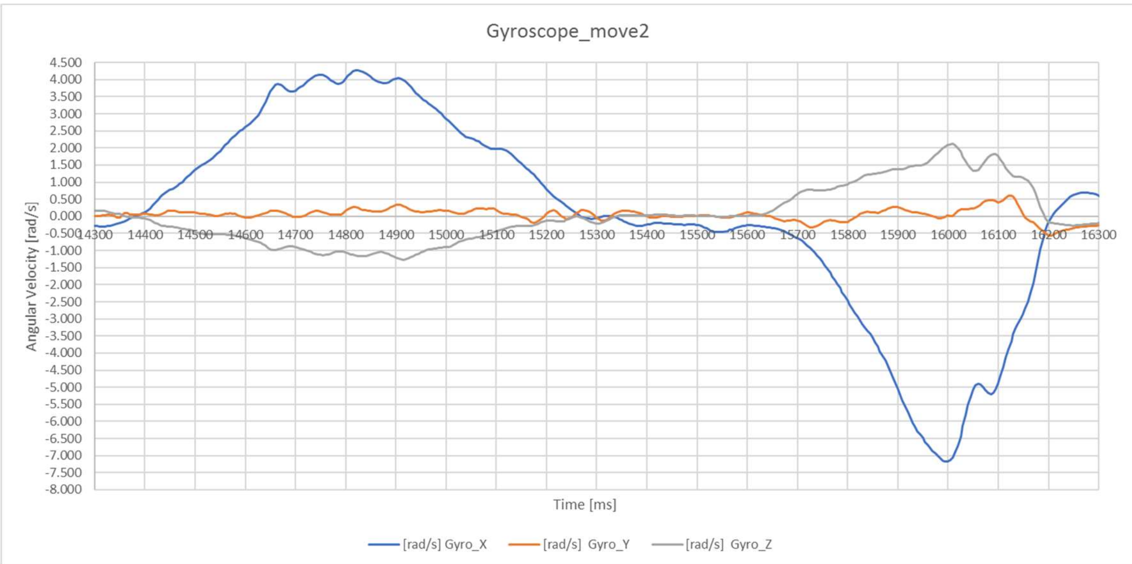

Figure 20. Example of gyroscope values in vertical movement, Blue = X axis, orange = Y axis and grey = Z axis.

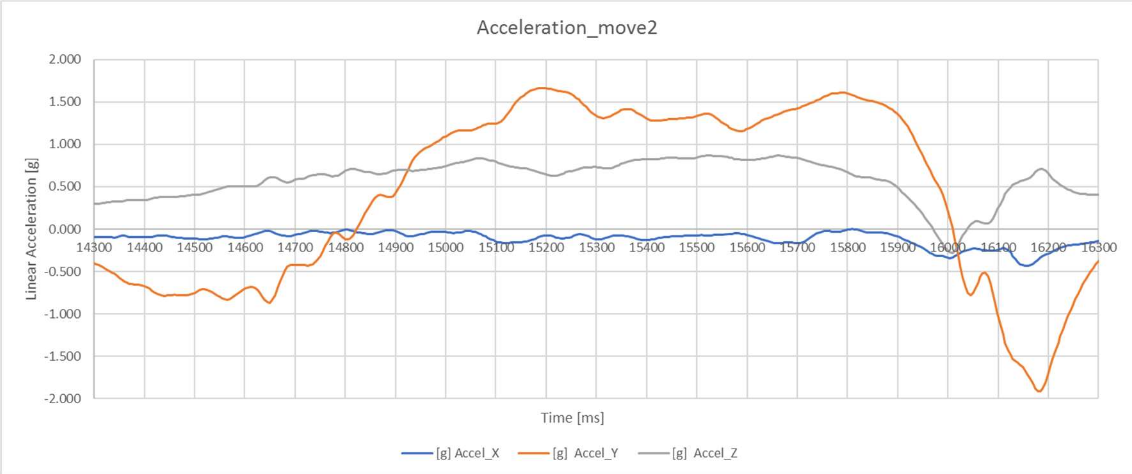

Figure 21. Example of accelerometer values in vertical movement, Blue = X axis, orange = Y axis and grey = Z axis.

In this nodding movement the maximum momentary angular velocities were -9 rad/s and +7 rad/s, but mostly stayed between ±5 rad/s (Figure 20). The momentary maximum acceleration with this move was ±100 rad/s2 Most of the time peak accelerations were about ±60 rad/s2.

The maximum angles were about ±1,1 radians (±63 degrees). Linear acceleration (Figure 21) happens according to the Y-axis with approximately ±1 g from the baseline.

3.4.3 Tilting movement

This movement considers a persons head tilting straight to either side, according to the Y-axis (Figure 22). As a movement it is not as common as the first two moves but still occurs in some specific games or videos, in which user needs to dodge forward objects.

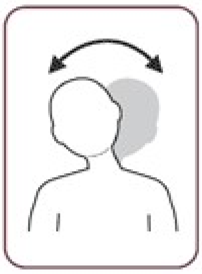

Figure 22. Tilting Movement

The maximum angular velocities in this movement were -9 rad/s and +12 rad/s (Figure 23). There were a significant differences between the results from different test persons, while some made the move strightly with their neck (as it was planned) and others with the whole upper bodies. Within the normal virtual reality activity the angular velocities were around -2 rad/s and +4 rad/s. In the angular acceleration the slowdown of the move were a lot of stronger than the positive acceleration. The maximum values were around -100 rad/s^2 and + 40 rad/s^2.

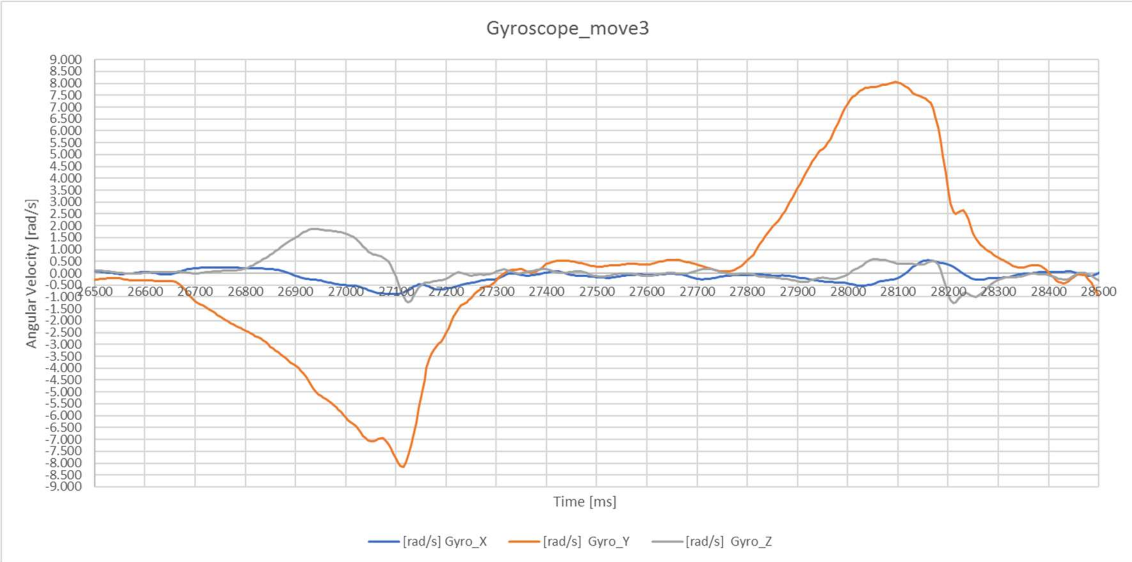

Figure 23. Example of gyroscope values in tilting movement, Blue = X axis, orange = Y axis and grey = Z axis.

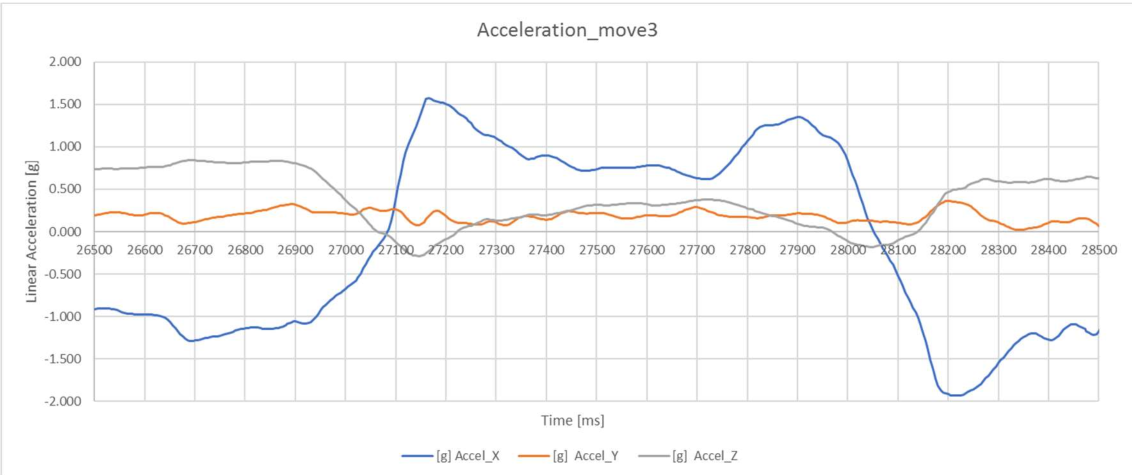

Figure 24. Example of accelerometer values in tilting movement, Blue = X axis, orange = Y axis and grey = Z axis.

The maximum angles while tilting the head were ±1,2 radiaania (±69 degrees). The linear acceleretion within this movement occurred parallel to the X-axis. The momentary maximum values varies between ±3g from the baseline (Figure 24).

3.4.4 Hybrid movement

Hybrid movement within this work means the movement happening around two or more different axis (Figure 25). These kind of movements are also common while using virtual reality glasses. The first part of this chapter considers the head movement from one side to another from below and the second part otherwise the same but from above.

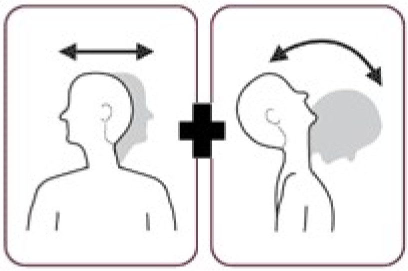

Figure 25. Horizontal movement

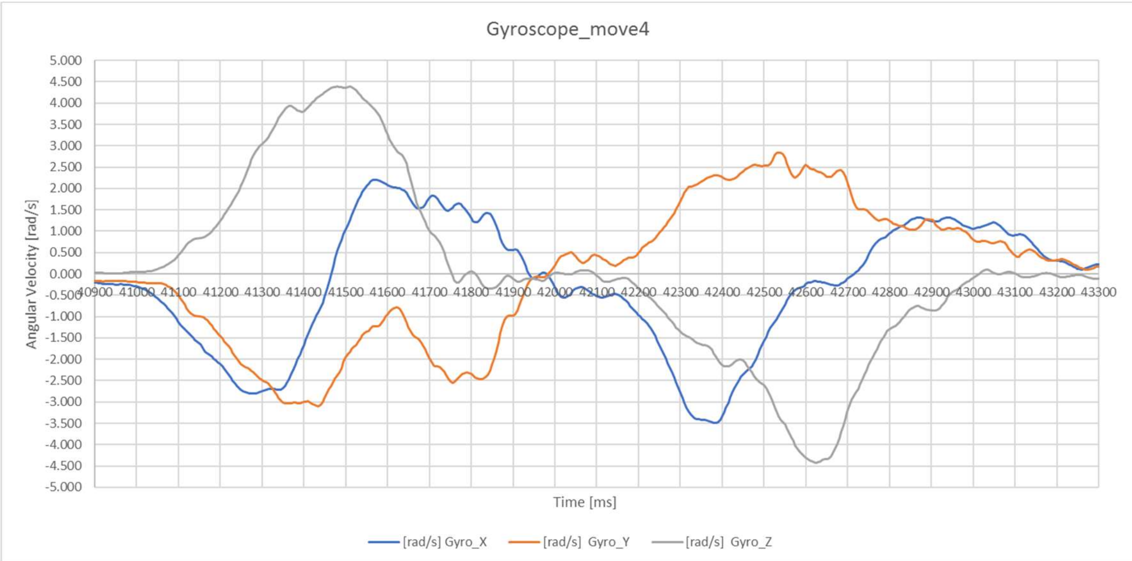

Figure 26. Example of gyroscope values in hybrid movement, Blue = X axis, orange = Y axis and grey = Z axis.

Within this movement there were also some differences between the results of the test persons, mostly due to the redundant tilting of the head. This tilting part of the movement has not been dealth with in this part of the work since it was occurring only in a few of the series.

While turning the head each side from below, the maximum angular velocities within the X-axis were about ±5 rad/s (Figure 26) and the angular acceleration ±40 rad/s^2. With the Z-axis the values were -5,5 rad/s, +8 rad/s and ±50 rad/s^2. In the normal gaming situation the angular velocities were relatively short, about ± 3 rad/s in both axis. The maximum angles whithin each axis were equal to the values shown before at the previous chapters and are not to be presented anymore in this part. The linear acceleration happens according to the Y-axis with around +2g acceleration from the baseline (Figure 27).

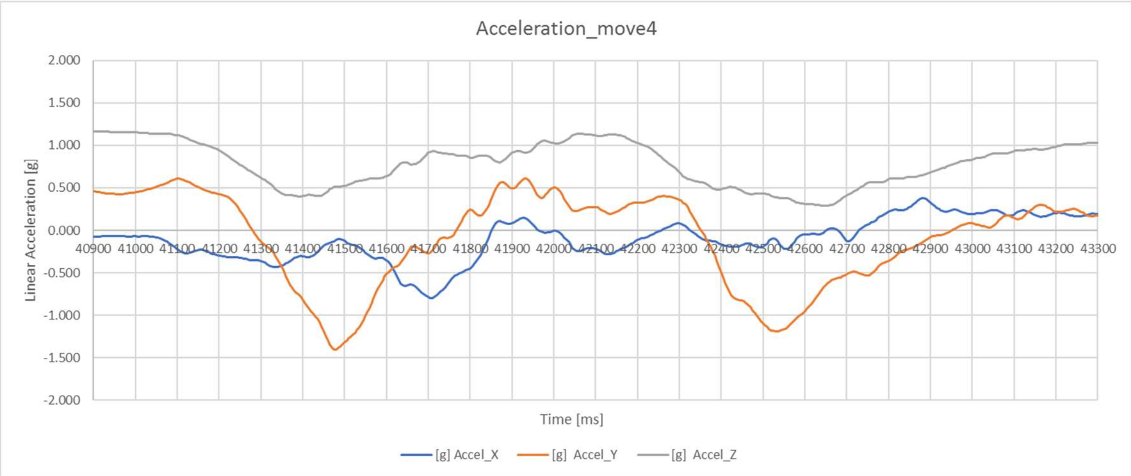

Figure 27. Example of accelerometer values in hybrid movement, Blue = X axis, orange = Y axis and grey = Z axis.

The second step in this move was to turn head from one side to other from above. The angular velocities obtained were relatively same with the previous one and are not been further elaborated. With the linear acceleration the Y-axis values stays also same but are on the negative side.

3.5 Error analysis

During this work the errors might have caused especially by the location of the testing sensor. Inside the glasses that are currently on the market the gyroscope and accelerometer are located near the users eyes while in the testing situation the sensors were set on top of the persons head. This was done because of the easier stabilization, but at the expense of the accelerometers results. This error might be possible to calculate off by measuring the distance between the actual place of the sensor and the wanted position. With distance and angular velocity it is possible to calculate the actual velocity in another position.

This work was carried out with five test persons which is relatively small group and there were quite large variation between the results gathered. There were also a certain error rates inside the testing sensors. The errors at room temperature (+25°C) in ICM-20601's gyroscope were ±2% (sensitivity scale factor tolerance) and in accelerometer ±2% (initial tolerance).[14]

For the following works similar to this, the testing setup should be located into a better position. With this the acceleration values would especially be more accurate. Also the amount of the test persons should be larger so that the average values would be more reliable. Naturally this would increase the workload and be much larger project.

4 SUMMARY

The goal of this thesis was to examine the typical human head movement while wearing the virtual reality glasses. This was done by first exploring the most common movements during the game situation and after that those movements were repeated using a head-mounted gyroscope and accelerometer sensor. Those results were then converted into real values and motion-specific graphs.

As a result, the human head is capable to produce a remarkably high angular velocities and accelerations. The main part of the time while using the virtual reality glasses the moves remain mainly restrained and the strength and amount of different moves naturally depends on the activity done and especially the player itself. The most common individual movements while wearing the glasses are thr straight horizontal and vertical moves and while mostly the velocities stay under a ten radians per second they also can reach even to twenty radians per second. Angular accelerations peak values can rise to over a hundred radians per second squared –readings.

Taking the above-mentioned issues into account, this target was mostly accomplished. The main moves during the virtual reality gaming were researched and the approximate velocities and angles were obtained. These results will serve as a basis for the company’s future projects and will be validated with Afore Oy’s Metis measuring device with which the machines ability to repeat these collected movements is also to be tested. Metis is a 3-axis gimbal test system for IMU (Inertial Measurement Unit) and IoT (Internet of Things) devices. The trajectories of Metis are designated to match the results obtained during this work. This testing with Metis can be done by using a table run function in which the device is associated with momentary time-coordinate information. For this purpose, the results must be modified to a different table where the previous results have been calculated as axis-specific position points.

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