POC – Body Motion

Contributor(s):

Shallwin Silvania – 495141@student.fontys.nl /+31 0616866849 (emergencies)

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| **Version:** | **Date:** | **Changes:** |
| Incomplete V1.0 | 27-10-2022 | Start |
| Incomplete V1.1 | 29-10-2022 | Added all information necessary to using BM as input. |
| Complete V1.0 | 3-11-2022 | Added more info, added conclusion. |

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# Introduction

This document will show how inertia can be measured and used as input for the EdTech project (link). This document will consist of a brief introduction to Inertial Measurement Units (IMU), data processing and data usage (as input). A prototype of the EdTech project will be made using this document.

# Inertial Measurement Unit

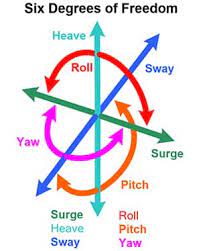
In the passage there will be an introduction to Inertial Measurement Unit (IMU), this information will be used to better understand the capabilities and/or limitations.

## What is IMU?

IMU are electronic devices that measure body specific forces, angular rate and in some cases, orientation using accelerometer (sensors/tool that measures acceleration in the X, Y, Z axis), Gyroscope (sensor/tool that measures angular velocity) and magnetometer (sensor/tool the measure the magnetic field of the earth) (Wikipedia Contributors, 2022).

## Tools

IMU are mostly used in vehicular objects to measure body displacement (velocity, height etc.) and orientation (which side is the object pointing to). This sensor can determine the six-degrees of freedom (the possible movements of a rigid body within a 3D space) of an object using the tools (accelerometer, gyroscope, and magnometer) at its disposal.



As previously mentioned, IMU uses a combination of accelerometers, gyroscopes and in some cases magnetometer. Here follows the

### Accelerometer

Accelerometer is a tool that measures acceleration (change in velocity) of body in its own rest frame (acceleration relative to free-fall or inertial). This means that the object is in constant free-fall due to gravity (9.81m/s^2) and is constantly detecting and downwards motion. Besides that, it also has drift that increases over time.

### Gyroscope

Gyroscope is a tool that measures orientation and angular velocity. It is unaffected by linear motions and mount rotation, as the spinning disk is complete free in its own respective axis (Wikipedia Contributors, 2022). Gyroscopes are a also subject to error biases making them also drift overtime, but can be combated using higher frequencies (N.P.Palanisamy, 2016).

A picture containing candle

Description automatically generated

### Magnetometer

Magnetometer is a tool used to measure direction, strength and/or relative change in the magnetic field in the tools current position (Wikipedia contributors, 2022).

# Data processing

In this passage there will be useful/required steps to make the data obtained from IMUs useable. This passage will mainly focus on the filtering of input data and the extraction of valuable information from the IMU.

## KALMAN Filter

KALMAN filter (in the context of IMU) Is a recursive predictive filter that estimates body state based on a predict and correct method using the dynamic model (transformation of the state vector) for the prediction and the observation model (relationship between state and measurements) for correction (N.P.Palanisamy, 2016). Meaning that the output is an average of the predicted state of the body.

Diagram

Description automatically generated

## Finite Impulse Response Filter

FIR Filter is a filter with no feedback in its equation, making it a stable filter (Oshara.R, 2012, chapter 7). It is a time-domain filter that uses data from fixed timestamps in the data to determine input quality.

## Low Pass Filter

In a LP filter filters out high-frequencies (by reducing their amplitude) and let low frequencies through. This stabilizes the data by filtering out white noise (high frequencies due to random spikes). Hence the reason why LP is a frequency-domain filter.

## Comparison.

The following is comparison of the analyzed filters.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Filter:** | **Processing requirements** | **Implementation Difficulty** | **Speed** | **Adaptability** |
| Kalman | High | Medium | Low/Medium | Prediction based\* |
| FIR | Medium | Medium | Medium |  |
| LP | Low | Low | High | Fixed |

# Data usage

In this passage there will be an explanation as to how the filtered data will be used as inputs in the EdTech project.

The data that is outputted from IMU sensors is velocity, angular velocity, and sometimes magnetic field.

|  |  |  |
| --- | --- | --- |
| **Data** | **Extraction** | **Formulas/Tools** |
| Velocity | Speed based on time-elapsed, and displacement based on absolute position obtained using historic position and speed. | Speed = Velocity / Time-Elapsed  Displacement = current position + Speed \* Time-Elapsed |
| Angular velocity | Angular rotation based on time elapsed. | Angular rotation = Angular Velocity \* Time Elapsed. |
| Magnetic field | Can be used to filter and correct data. | X |

# Conclusion

In conclusion, for rigid body displacement as input one can use IMU sensor. It is not necessary to have high accuracy for the EdTech objects so for the purpose of prototyping a simple MPU6050 or LSM6DS3 will be used to test research. Besides that, A low pass filter will be used to clean the data mostly due to the fact the that it’s lightweight and efficient (necessary seeing that there will be more process running on the microcontroller).

# Summary

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*6.1 Angle of Rotation and Angular Velocity | Texas Gateway*. (n.d.). Retrieved November 3, 2022, from <https://www.texasgateway.org/resource/61-angle-rotation-and-angular-velocity>