**Laboratory 1B:**

**Signals from Smartphone Sensors**

How does a smartphone measure movements or positions? For example, a step-counter, or the control between portrait and landscape orientation.

In this laboratory, you experiment acquiring sensor data from your smartphone and implement first signal processing steps. You acquire data from the sensors of the inertial movement unit (IMU) found in a large number of smartphones nowadays. Most IMUs contains 3D-gyrometers (measuring rotation movements), 3D-accelerometers (measuring acceleration from translation movements) and 3D-magnetometers (measuring magnetic field).

We experiment with the data acquired by gyrometers and accelerometers, inclusive examples showing limitations of these sensors.

# Setup on Smartphone (mobile device)

1. **WLAN activation**

Activate and configure the WLAN connection. You use the WLAN connection to download an App, and to share the sensor log files with your computer. If you have not yet registered the ZHAW network on your mobile, please follow the instructions from our IT services:

ZHAW Android WLAN <https://bit.ly/2NKazZU>

ZHAW IOS WLAN <https://bit.ly/2OUFejJ>

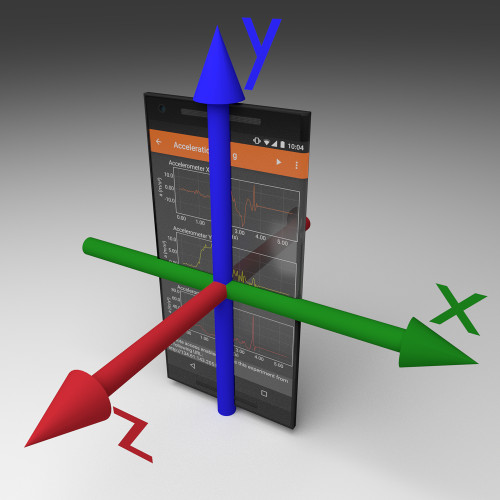
1. **Phyphox App**

Download and install the free app: [phyphox](https://phyphox.org/) - Physical Phone Experiments (AppStore , GooglePlay).

Obs.: if you can not install, or do not dispose of a mobile device, you can use provided \*.csv files

# Experiments with Rotation Movements

The gyroscope sensors measure rotation rate in rad/s or degrees/s around three axis: X-Y-Z. The coordinate system of phyphox is oriented as shown in the figure below:



Source: <https://phyphox.org/sensors/>

1. **Measuring rotation around each axis**

We start with simple movements around each rotation axis:

* In phyphox start menu select Gyroscope (rotation rate) under “Raw Sensors”.
* Start and stop recording sensor data with play and pause. Register a short sequence of rotation movements of about 10-20 seconds. Make a sequence of movements around single axes, for example, 1st only around x-axis, then around the y-axis and then around the z-axis. The intention is to easily recognize your movements in the logged sensor data.
* Press the upper right menu and select “Export Data”. Select one of the CSV formats (for example Tabulator, decimal point) and share the file with yourself (via email, messager,…), such that you can save and open the file in your computer.
* Start Matlab and use menu **Home > Import Data**  
  Navigate to the directory containing the CSV-file and select it. Then set in the import window: **Output Type > Column vectors** and **Import Selection > Generate Script**
* Save the generated script with an adequate name (e.g. sisy\_lab\_x\_exer\_y.m) and add a new section to start processing the data acquired. Define new variables containing the rotation rates in degrees/second, for example:

%% Process & Plot sensor data recorded

Ang\_Velocity\_x\_degs = 180/pi \* Gyroscopexrads;

* We want to calculate the angular position by integrating the rotation rates. The integral is numerically approximated with cumsum()\*tstep. But in most smartphones the sampling step can vary between measurements. Therefore, it is more accurate to calculate a delta-time-vector, containing the delta between each 2 measurement points. For example:

delta\_t = [0; Times(2:end) - Times(1:end-1)];

Question: why do you think it is convenient to add a zero as 1st element of this vector?

* Calculate now the angular position along X, Y, Z using your delta-time-vector and generate a plot showing both the rotation rates and the angular positions. For example:

Ein Bild, das Text, Karte enthält.

Automatisch generierte Beschreibung

Compare your plot to the sequence of movements you recorded.

In which direction is the rotation positive?

Alternative (if can not measure), take file:

RawData\_gyro\_1.csv

1. **Analyzing recorded sequences of movements**

* *Hint:* in this section we import several different CSV-files. If you prefer to have a slimmer script, you can generate an import function (**Import Selection > Generate Function**) and then change only the datafile name, while invoking the generated import function.
* Import the datafile RawData\_gyro\_2.csv and produce a plot like in item (a). Which sequence of movements was recorded in this datafile? Introduce a wrap-around threshold value in the angular position, to make the visualisation of a 360° rotation easier.
* Import the datafile RawData\_gyro\_3.csv and produce a plot like in item (a). Which sequence of movements was recorded in this datafile? Consider that the initial position of the mobile was position **A** from table below.

Reproduce the same sequence of movements with your telephone and compare the registered data. Does the phone end in the same position as it starts? Is this visible in your angular position plot?

Some possible positions

|  |  |
| --- | --- |
| **A**  flat laying  over table | **B**  flat laying sideways  over table.  Top to the left |
| **C**  up right  facing  display | **D**  up right  sideways  display to the right |
| **E**  Long side down  display to the left | **F**  Long side down  display to the right |
| **G**  up right  sideways  display to the left | **H**  flat laying sideways  over table.  Top to the right |

# Experiments with Translation Movements

Change now the selected Raw Sensor to Acceleration (without g). Record a short series of movements in all axes, starting and ending in a resting position. Specially in the end, record at least 10 second in resting position.

Import the data, generate the delta-time vector and calculate two integrals: 1st integral from acceleration (in m/s^2) to velocity (in m/s), and second integral to position (in meters). Plot and observe your results:

* Which limitations do you see in this measurement?
* Can you imagine how a combination with the gyrometer data would helpt to improve the results of this measurement?