**Laboratory 1B:**

**Signals from Mobile-IMU**

In this laboratory, you will experiment acquiring sensor data from your mobile telephone and implementing first signal processing steps. We will work with the built in 3D- accelerometer and gyrometer from the IMU, (inertial movement unit), found in most smartphones.

# Setup on Mobile (smartphone)

1. **WLAN activation**

Activate and configure the WLAN connection. You use the WLAN connection to download an App, and to upload sensor log files to Mathwork cloud. 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. **Matlab Mobile App**

Download and install the free Matlab Mobile App. Both IOS (Apple Store) and Android (Google Play Store) versions are available. From R2018a onwards, you need to give your Mathworks login and password, and connect to Mathwork cloud, in order to be able to start Matlab Mobile App.

Your Mathwork account is connected to your Matlab academic license. Use your ZHAW email to register, and enter a password to create an account.

1. **Logging Sensor Data**

In Matlab Mobile App upper panel, you can select sensors, then activate for example the acceleration sensors and observe the outputs. On the lower part of the screen, you can select the log option, and the sampling frequency in Hz.

1. **Importing the Log-Files in Matlab**

Once you have stored a sequence of measured sensor data in a log file, you can upload the log file to Matlab Drive in the cloud, and recuperate the file in a browser, under the URL: <https://drive.matlab.com/>

**Alternatively** you can connect your phone to the PC using an USB cable, allow the computer to access the data in the smartphone, and search for you sensor data under the folder:

<Phone>\Documents\MATLAB\SensorLogs (or a similar location)

The imported log file will probably be a \*.mat or a\*.csv. For both formats, we will find corresponding commands in Matlab to import the data file into the workspace.

# Accelerometer and Orientation of Sensor Axis



Image source: https://ch.mathworks.com/de/products/matlab-mobile.html#acquire-data-from-sensors

Start the Matlab Mobile App and select the sensor pane (where different sensors can be activated and current sensor data can be visualised). Activate only the accelerometer sensor to start out.

1. Place the mobile over the table and check the read out of the three axes: x, y and z.   
   Which acceleration is shown on this read out, even if your mobile is resting over the table?
2. Move the mobile on different positions and find out the orientation of the accelerometer sensor axes (x, y and z) with respect to the mobile device. Mark your answers in the figure above (page1).

# Acquiring sensor data and plotting it in Matlab

1. Open the Matlab script *sisy\_lab1b\_exer3.m*   
   Study the code, and understand what is being implemented.
2. Start the Matlab Mobile App and activate the tracking of acceleration, angular velocity (gyrometer) and orientation. Record a log file of about 30 seconds. During this interval, make a short sequence of movements with your mobile.

***Hint:*** 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. Such that you can recognize your movements in the logged sensor data.

1. Import the log file in Matlab, and adapt the script *sisy\_lab1b\_exer3.m* in order to generate a plot of each sensor type (accelerometer / gyro / orientation). Find out which column corresponds to each axis. Document your answer by adding legends in the plots.
2. Compensate eventual offsets of the time vectors, such that you can compare all sensor data in the same time interval.
3. Study the plot outputs (accelerometer, gyrometer and orientation data), and make sure that the movements you have logged are correctly identified. For example, if you rotate around the y-axis, how is this movement visible in the accelerometer data? And how is it visible in the gyro data?
4. Which sensors are measuring the angular velocity? Which unit is used on the sensor raw data? Introduce a scaling factor in order to convert the units to degrees/second.

# Importing and Analysing a set of measurements

1. Start a new script named *sisy\_lab1b\_exer4.m* and import the stored set of measurements: *imu\_data\_sample1.mat*

Obs.: the sensor data and time values are already stored in vectors with easy and recognizable names!

1. Generate plots and analyse them, in order to determine the sequence of movements measured in this data set. Describe the sequence identifying the positions at the relevant time points. Suppose you start with position A. Identify eventual sign mismatches on the axes with respect to the figure on page 3.

Some possible positions

|  |  |
| --- | --- |
| **A**  flat laying  over table | **B**  flat laying sideways  over table |
| **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 |

Reference of mobile IMU axes (positive directions can vary from device to device):

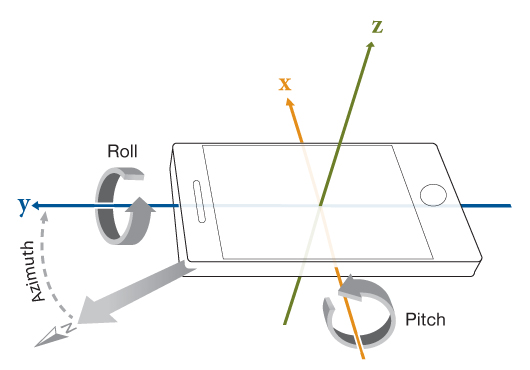


Image source: http://ch.mathworks.com/help/supportpkg/mobilesensor/ug/acquire-sensor-data.html

# Challenge: Calculate the orientation based on the sensors raw data

Your mobile is calculating the orientation data based on the sensors raw data. Let us experiment to implement a **simplified version** of this calculation. Save your script from exercise 3 with a new name: *sisy\_lab1b\_exer5.m* and extend it with the following calculations:

1. Suppose that the initial orientation of the mobile device is known, and calculate the current orientation based on the gyrometer raw data only.

*Hint:* you need the numerical approximation of an integral.

*Observation:* integrating the gyro sensor data, gives a rough estimation of the current position, which matches the actual position only if the movements are around a single axis, and return to the initial position.

1. Compare the plots of the orientation data (pitch, roll and azimuth –or yaw-), with your estimation based on the gyro data only. Are the movements correctly identified? Where do you see potential errors?
2. How could you use the readings of the accelerometer sensors in order to calculate the inclination of the mobile device with respect to an axis which points to the earth center? Test your calculation making a measurement in a tilted position. Hint: the Matlab function *atan2()* is helpful. Start with a simple estimation, considering for each angle 2 axis at a time.

Local horizontal plane

g

(gravity direction)

**z**

**y**

**x**

Strapdown IMU

(fixed on body)

Uses body coordinates x,y,z

1. Add in the plot output, the orientation you calculated based on gyro and accelerometer data.
2. Is your mobile using the data from gyros, the accelerometers or a combination of both to calculate the orientation? Can you identify situations where this combination is needed?   
   Which other sensor in your mobile device can be used to improve the estimation of the azimuth?

***Further links with interesting info on mobile sensors:***

<http://ch.mathworks.com/help/supportpkg/mobilesensor/android-sensors-data-acquisition.html>

<http://www.digikey.com/en/articles/techzone/2011/may/using-an-accelerometer-for-inclination-sensing>

<https://developer.tizen.org/development/guides/native-application/location-and-sensors/sensors>