Laboratory 1B:

Signals from Mobile-IMU
&
Acquire, Plot and First Processing

In this lab 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 smart phones.

1. Setup on Notebook and Mobile

a) On your computer (notebook)
Download and install the Matlab Support Package for smart phone sensors, which can be found under http://ch.mathworks.com/products/matlab-mobile/features.html#acquiring_data_from_sensors

b) On your mobile (smart phone)
Download and install the free Matlab Mobile App. Both IOS (Apple Store) and Android (Google Play Store) versions are available.

c) Set a connection between your computer and your mobile (via Matlab Mobile App)
Open a Matlab session on your computer and type >> *connector on*
We will get the DNS (host) name or the IP address, which your require for the settings of the Matlab Mobile App (under settings > Add a computer). These steps are described in detail under the link below: http://ch.mathworks.com/help/configure-matlab-mobile-on-to-connect-to-your-computer

d) WLAN activation
You will need a working WLAN connection between your mobile and your computer. If you have not yet done it on your mobile, please follow the instructions from our IT services:

ZHAW Android WLAN	https://intra.zhaw.ch/Finanzen_und_Services/wlan_verbinden_android
ZHAW IOS WLAN	https://intra.zhaw.ch/Finanzen_und_Services/wlan_verbinden_ios

2. Accelerometer and Orientation of Sensor Axis

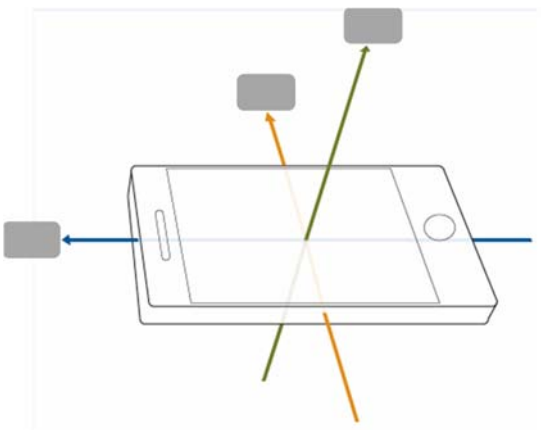


Image source: http://ch.mathworks.com/help/supportpkg/mobilesensor/ug/acquire-sensor-data.html

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.

a) 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?

b) 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).

3. Acquiring sensor data and plotting it in Matlab

a) Open the Matlab script *sisy_lab1b_mobile_imu_sensors_step1.m*
Study the code, and understand what is being implemented.

b) Run the code and during the interval when the IMU signals are logged, make a short sequence of movements with your mobile. In your sequence, make each movements around a single axis, for example, only around x-axis, y-axis and z-axis.

c) Generate a plot of each sensor type (accelerometer / gyro / orientation) and find out which column corresponds to each axis. Document your answer by adding legends in the plots.

d) Compensate the offset in the gyrometer time vector, such that you can compare all sensor data in the same time interval.

e) 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?

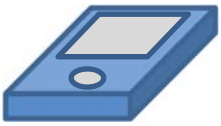
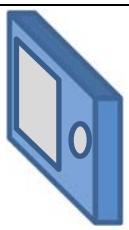
f) Which sensors are measuring the angular velocity? Which unit is used on the sensor raw data? Introduce an scaling factor in order to convert it to degrees/second?

4. Importing and Analysing a set of measurements

a) Save your script from previous session with a new name: *sisy_lab1b_mobile_imu_sensors_step2.m* and implement the following modification:
Instead of acquiring sensor data, import the stored set of measurements: *imu_data_sample1.mat*

b) 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.

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):

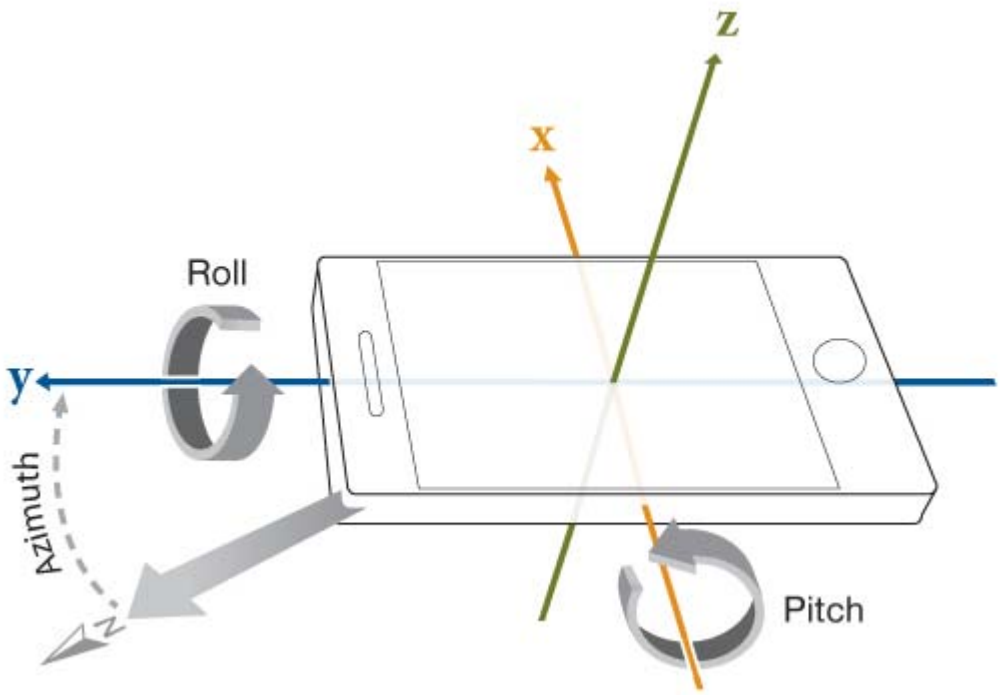


Image source: http://ch.mathworks.com/help/supportpkg/mobilesensor/ug/acquire-sensor-data.html

5. Challenge: Calculate the orientation based on the sensors raw data

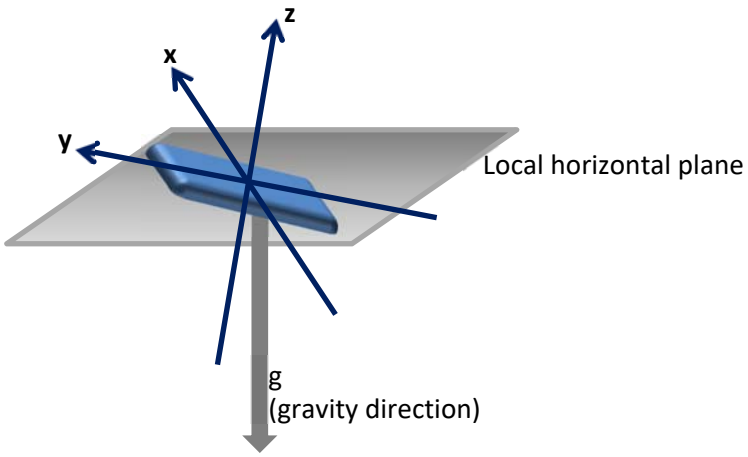
Your mobile is calculating the orientation data based on the sensors raw data. Let us experiment to implement a simplified version of this calculation. Save your script from previous session with a new name: *sisy_lab1b_mobile_imu_sensors_step3.m* and extend it with the following calculations:

a) 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.

g) 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?

b) 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.

Strapdown IMU
(fixed on body)
Uses body
coordinates x,y,z



c) Add in the plot output, the orientation you calculated based on gyro and accelerometer data.

d) 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?
For example import the data set *imu_data_sample2.mat*, and verify which estimations are valid.
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