# Homework #2, AA2020-2021:

# Pedestrian Dead Reckoning

In navigation, Pedestrian Dead Reckoning (PDR) is the process of calculating the current position of a moving pedestrian by using a previously determined position, or fix, by using estimations of speed, heading direction, and course over elapsed time.

In this exercise, the student receives as data the inertial parameters[1]: inertial accelerometer $\mathbf{A} = (\mathbf{a}_x, \mathbf{a}_y, \mathbf{a}_z)$ and gyroscope $\mathbf{G} = (\mathbf{g}_x, \mathbf{g}_y, \mathbf{g}_z)$ sensor measurements from a pedestrian's smartphone while walking along an circle-shaped trajectory (see video while acquisition). Goal is to count the steps (Exercise 1) from the acceleration hits, andthen (Exercise 2) estimate by the Bayesian stochastic filtering the trajectory of the target (smartphone) from the inertial parameters, knowing the shape of the trajectory. There are two set of experiments, with some increasing complexity: *HW2.1.mat, HW2.2.mat.* In detail: in the experiment of file *HW2.1.mat*, the smartphone moves around with (approx) still orientation of the sensors w.r.t. the direction of motion, and in file *HW2.2.mat* the position of the smartphone was slowly changing w.r.t. the direction of motion. All measurements are within the capability of the experimenter (see 1).

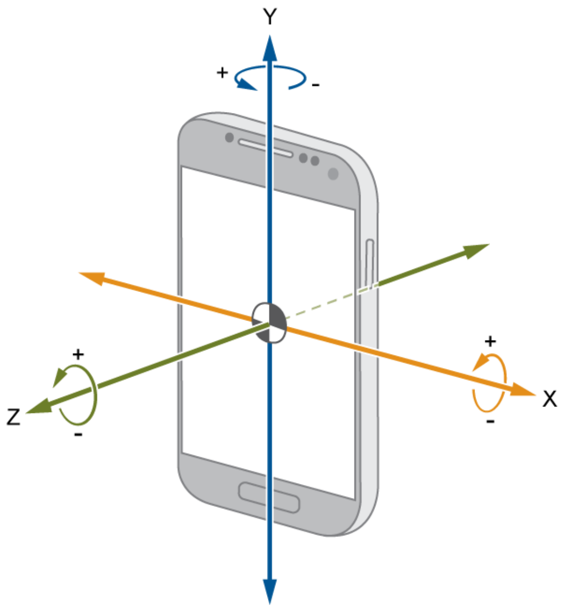


Figure 1: Typical smartphone axis orientation

**Exercise 1** In the two experiments with the two files:

a) Using the file *HW2.1.mat*

1.a.1 Using the accelerometer data in *HW2.1.mat* estimate the number steps computed by pedestrian

1.a.2 Using the accelerometer data in *HW2.1.mat*, estimate the step length

1.a.3 Using the gyroscope data in *HW2.1.mat*, for each step in 1.a, estimate the heading of the pedestrian

1.a.4 Given the step length in 1.b and the heading in 1.c, compute the relative positions for each step (starting from $P_0 = (0, 0)$)

1.a.5 Define the tracking problem from the estimated positions in 1.d of a pedestrian moving at a constant speed.

b) Using the file *HW2.2.mat* repeat the same problems above.

[1] The accelerometer measures the acceleration of a body in its own instantaneous rest frame. For example, an accelerometer at rest on the surface of the Earth will measure a gravity acceleration of $9.8m/s^2$. The Gyroscope measures angular velocity of the axis of a body in rad/s over a predefined orientation set (in figure).

**Exercise 2** In the experiments with the two files *HW2.x.mat* use the Bayesian tracking to estimate the evolution of the position of the smartphone using the inertial parameters only. Evaluate the speed along the trajectory, and quantify numerically how distorted is the trajectory from a true circle.

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Students can verify the accuracy of their algorithms also by using their smartphone and downloading any free app that provides inertial sensor measurements. Once downloaded the app. you can do small experiments (small trajectories) and generate inertial sensor data from your smartphone, which you can import into Matlab for all the processing.

The data provided in these exercises were generated by the app. PhyPhox: https://phyphox.org/, available for Android and IOs. You can also find in the link a script that allows you to upload and pre-process the sensor files generated by PhyPhox.

Suggestion for Exercise 1: you might refer to the following article for the most common techniques in the estimation of steps, step lengths and heading in PDR systems:

A. R. Jimenez, F. Seco, C. Prieto and J. Guevara, A comparison of Pedestrian Dead-Reckoning algorithms using a low-cost MEMS IMU, 2009 IEEE International Symposium on Intelligent Signal Processing, Budapest, 2009, pp. 37-42, doi: 10.1109/WISP.2009.5286542.