Graz University of Technology

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Working Group Navigation

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Navigation Systems
Winter term 2025/26

2nd Lab Program
Pedestrian Navigation

Objective

This program deals with one subtask of Pedestrian Navigation: Pedestrian Dead Reckoning. For positioning within a navigation system, it is most suitable to use an absolute positioning solution and a relative positioning solution to continuously estimate the current position.

A relative position solution, specifically designed for the gait pattern of pedestrians, is called Pedestrian Dead Reckoning (PDR). Beginning at a given start point, an indoor pedestrian trajectory has to be computed. Inertial data from a smartphone are provided, which were collected while walking within the building Steyrergasse 30 in Graz, while holding the smartphone in walking direction. Due to the large sensor errors within smartphone sensors, the approach of a step-based PDR has to be computed.

The result should be a visualization of the pedestrian trajectory starting at the given starting point, moving along the hallways and stopping at the end of the time series.

Data source

The data given is a time series of roughly 3 minutes and taken directly from smartphone (iPhone 12 mini) sensor readings. The smartphone was hand-held by the pedestrian in walking direction while walking within a building. The inertial data provided are accelerations, angular rates and magnetometer measurements in three orthogonal axes. Furthermore, barometric measurements, reference orientation (roll, pitch, yaw) and a ground truth path are given. The reference orientation is obtained from the smartphone, and the ground truth path is supplied by a camera-based tracking system. Note that the ground truth is available at the start and end of the trajectory only. The data is provided in the CSV files, which have the following structure:

<u>Smartphone sensor data:</u>

accelerometer.csv:	time [ms], acc_x[m/s²], acc_y[m/s²], acc_z[m/s²],
magnetometer.csv:	time [ms], mag_x [μT], mag_y [μT], mag_z [μT]
gyroscope.csv:	time [ms], $gyro_x$[rad/s], $gyro_y$[rad/s], $gyro_z$[rad/s]
barometer.csv	time [ms], $pressure$ [mBar]

<u>Reference/ground truth data:</u>

referenceOrientation.csv:	time [ms], roll [rad], pitch [rad], yaw [rad]
groundTruth.csv	time [ms], x[m], y[m], latitude [°], longitude [°]

The **starting point for the trajectory** is approximately given with:

$$\varphi = 47.06422\,°,\ \lambda = 15.45291\,°$$

For visualizing the calculated indoor trajectory of the pedestrian, you are free to use any tool you prefer (e.g., using a GIS). Note that the **building layout** for this laboratory is **incorporated within google maps**.

Algorithm

The algorithm of a step-based PDR is divided into four steps:

- Step detection
- Step length estimation
- Direction estimation
- Step counting (computing displacement)

For step detection algorithms, the peaks correlated to the human gait cycle have to be detected. Therefore, the total acceleration is used most often with $acc_{total} = \sqrt{acc_x^2 + acc_y^2 + acc_z^2}$. Within a clear acceleration signal, the gait peaks equal the steps and may be detected with simple thresholds within a segmentation process.

After detecting a step, the step length of this detected step has to be computed. Therefore, empirical models are available where the most basic model is the assumption of a fixed step length of e.g. 0.8 m, depending on the user. Your step length estimation should also consider varying step lengths depending on whether the user is walking stairs or along the hallway.

For the direction estimation, the magnetometer data may be used. The magnetometer measurements in three axes can be levelled purely with the acceleration measurements, see lecture notes. After that, a magnetic heading can be calculated which may be used directly as step direction. Consider the magnetic variations within a building structure. Due to magnetic variations, the direction derived from the magnetometer measurements will vary systematically as well as randomly.

For each step of the PDR, the step detection, the step length estimation and the direction estimation, thresholds have to be set, step length models have to be defined and possibly a heading filtering has to be conducted. Analyse and explain all chosen models and assumptions within your work.

For the visualization of your results, a spherical approximation of the trajectory (for calculating φ, λ [°] coordinates out of the x, y [m] of the PDR) is valid and generally acceptable for indoor dimensions of a building scale. Therefore, you might as well use $R = 6378137\ m$ as the Earth's radius. However, the use of basic mapping equations is even more appropriate.

Deliverables

- Short technical paper of your work (3 pages) in English (according to IEEE format):
  - Use the provided template or visit ieee.org for word or Latex templates or use the Overleaf template (Follow the IEEE two-column template).
  - Your paper should include:
    - Abstract
    - Introduction
    - Clear explanation of your methodology, including
      - Analysis of the given dataset
      - Explanation of your algorithm, including all formulas
      - Explanation of the chosen step length estimation
      - Explanation of any other used models and assumptions
    - Results
      - Visualization of the step detection and step direction estimation
      - Visualization of the estimated heights
      - Visualization of the derived trajectory indoors
    - Analysis and interpretation of your results
    - References

- Source code of developed software. The source code should be named as follows: *lab02_ws2025_26_GROUP#_SURNAME1_SURNAME2.py* (the file extension may vary, depending on the used programming language). If your code consists of multiple files, add a suffix to the file names (e.g. *lab02_ws2025_26_GROUP#_SURNAME1_SURNAME2_main.py*).

The technical paper and the source code have to be uploaded to the TeachCenter by January 12th 2026, 08:00 a.m.. The interview will take place on January 19th 2026. You can register for a time slot for the interview in the TeachCenter.

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