Mobile Sensing: Spring 2015
Home Exam

Due on 1th June 2015 by 23:59 PM.

Instructions: All course participants are requested to submit their solutions electronically to the instructors (samuli.hemminki at cs.helsinki.fi and teemu.pulkkinen at cs.helsinki.fi), as well as to the course lecturer (petteri.nurmi at cs.helsinki.fi) by the due date. In all tasks, do not just give the answer, but also the derivation how you obtained it. In programming tasks, return also the code that was used to obtain the results.

Concepts (6 pts)

a) Describe three main differences between traditional wearable sensing (i.e., where sensors are attached to the user) and sensing performed on smartphones. What new benefits and challenges does smartphone as a sensing platform provide?

b) Preprocess accelerometer data by splitting the data into frames of 10 samples with 50% overlap and calculate median of each frame. Compare the original and preprocessed signals by calculating standard deviation of both.

c) Given the gyroscope measurement x=0.05182, y=0.00709, z=-0.01376, perform a rotation on the gravity estimate vector G: x=0.18592,y=0.01663,z=0.17850 using the gyroscope rotation matrix:

1	$-\omega_z$	ω_y
ω_z	1	$-\omega_x$
$-\omega_y$	ω_x	1

d) What is windowing in the context of audio sensing? Why is it important? List three examples of popular window functions in audio signal processing.

e) What is the cepstrum and why is it important? What is liftering and why is it performed?

f) What is the basic principle in photoplethysmography? What information can be extracted using it and how?

2) Classification evaluation (10 pts)
Given the ground truth labels in gt and the predicted labels in predicted, calculate the following evaluation metrics: **insertion, merge, overfill, deletion, fragmentation, underfill**, as well as the **fragmentation, overfill** and **underfill rates**.

For more details on what these metrics mean, see
Ward, J. A., Lukowicz, P., and Gellersen, H. W.: **Performance Metrics for Activity Recognition** *in ACM Transactions on Intelligent Systems and Technology (TIST), 2011*

(Link: https://dl.acm.org/ft_gateway.cfm?id=1889687. Use HUPnet or VPN to access. If that fails, ask us for the article.)

Activity and Motion Sensing – choose one (1) of the following two (2) tasks:

3) Pedestrian Detection (10 pts)

Load the training and testing data sets [1] and implement a pedestrian detection system in four parts:

a) Split the data into frames of 2 seconds duration.

b) For each frame, compute L2-norm of the measurements and calculate features: Variance, Number of mean-crosses, and amplitudes of 1,2 and 3Hz (FFT).

c) Using the training data, train a decision tree classifier with maximum depth of 20. Test the classifier using the testing data set.

d) Evaluate prediction accuracy using a recall, precision and F1-score metrics.

4) PDR (10 pts)

Perform pedestrian dead reckoning using the data in data.csv[2] by doing the following:

a) Estimate steps from the accelerometer data by calculating the magnitude over a suitable window and defining a threshold.

b) Estimate your orientation (coarsely) by calculating $atan(y/x)$ from the magnetometer. (See Ex6.2a)

c) For each detected step, adjust your location as follows:
$x_t = x_{t-1} + distance * cos(heading_{t-1})$
$y_t = y_{t-1} + distance * sin(heading_{t-1})$,
where the heading is in radians.

d) Plot your trajectory. Assuming the measurements started at (0,0) and stopped at the same location, how far off was your final estimate (e.g. in meters)? What would you consider to be the weak link in this process?

You can assume the average step is 70cm long.

[1] In the data, columns 1 to 4 corresponds to: [timestamp, x, y, z]
[2] Data format: [timestamp,acc_x,acc_y,acc_z,$magn_x$,$magn_y$,$magn_z$]

Choose one (1) of the following two (2) tasks:

5) Sound Sensing (10 pts)

Consider the audio files given in A, B and C (sampling rate: 7418Hz).

1. Implement a significant audio event detection algorithm and apply it for all three datasets. Identify periods that correspond to silence in the data. Consider at least two different features for detecting these periods. Return the code for identifying audio activity and plots showing the original audio together with class labels inidicating significant/non-significant periods.

2. Implement (on top of the significant audio event detection algorithm) an audio classification algorithm that uses zero-crossing rate and (at least) four different spectral features (i.e., min 5 features in total). Train the classifier using datasets A, B and C, and apply it to test data given in file D. Return the confusion matrix of the classifier together with the code for extracting features and performing classification.

6) Prosodic Sensing (10 pts)

Consider the speech signal given in speech11k.csv (sampling rate: 11025Hz).

1. Implement voicing detection and apply it on the given dataset. Plot the speech signal together with the voiced/unvoiced detection results.
2. Calculate the speech rate of the user in the given signal.
3. Implement a pitch estimator and and apply it on the signal (on voiced segments only).
4. Calculate the following features from the signal: mean and standard deviation of energy, mean and standard deviation of F0. Given these features and the speech rate, do you think the speaker is an introvert or extrovert? You can also listen to the sample.

BONUS: Motorised Tracking (10 pts)

This task is not mandatory and it is intended as a supplement for those participants that require further points due to insufficient exercise activity. **NOTE:** you can not supplement exam points with this task.

Load the data [3] collected during a car drive. Estimate the car's velocity and distance in three steps:

a) Estimate gravity component by using one of the methods presented in the lecture slides. Using the gravity component, estimate the car's linear acceleration on horizontal plane.

b) perform PCA on the horizontal acceleration to estimate the forward moving direction. The forward direction is roughly given by the 1st PCA component.

c) Project the horizontal linear acceleration along the identified forward direction. Estimate velocity and distance of the vehicle using integration and double integration respectively. Hint: for better estimation accuracy, you can detect stationary periods to reset velocity estimation to zero.

[3] In the data, columns 1 to 4 corresponds to: [timestamp, x, y, z]