Project Assignment –Tracks: Wireless Communication and Sensing

Radar & AI for Human Computer Interaction via Hand Gestures

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Context & Purpose

When you hear 'radar', you may think of big antenna dishes and large clunky devices on a ship or at the airport. Those are certainly radars, but today, thanks to great advances in microelectronics, radar systems can be integrated into a single chip and nicely embedded into everyday devices such as a mobile phone or the bumper of a car. For example, radars embedded in everyday devices can be used for smart, non-verbal interaction between users and objects or to decode and interpret sign language.

In this Final Project Assignment you will work with a simplified problem of human hand gesture recognition using radar data, leveraging on a shared dataset (*DopNet*) that was originally collected by the Radar Group at University College London. The dataset contains data from 6 individuals performing 4 different gestures, namely wave, pinch, swipe, and click. A general description of the dataset and the radar used for the collection of the data can be found in the GitHub page (https://github.com/UCLRadarGroup/DopNet). Please carefully read those pages as they tell you the context of these data, which you will need to set up a meaningful classification pipeline.

As at this stage of your MSc journey you (most likely) don't have all the fundamental knowledge about radar systems and related signal processing, so the data provided are already in the form of usable *spectrograms*. These are originally complex-valued (as in real and imaginary) matrices that represent the velocity of the fingers over time. If you plot the absolute value of the spectrograms in logarithmic (dB) scale, you can treat the resulting images as the input to your classification/pattern recognition problem. Each image represent 'one sample', one gesture that needs to be classified out of the 4 classes, regardless of the person that performed such gesture. Note that the data provided to you for training are already in logarithmic scale, whereas the GitHub link provides also the original complex-valued data (if you are confused about these steps of processing, feel free to contact the responsible lecturer).

So, the aim of this Final Project Assignment is to develop a classification pipeline for automatic gesture classification. By developing this assignment, you will put into practice all the learning concepts introduced so far in your lectures.

Resources

You will also receive feedback from a Lecturer on Week 7.

Instructions Activities

There are two partially interrelated tasks that need to be performed.

-Task 1

Perform data pre-processing activities. This may include data cleaning, normalization, standardization of the spectrograms treated as images, as well as optional extraction & analysis of explicit features.

-Task 2

Develop one/more model(s) for automatic classification of the gestures for an unseen test dataset; for that you might use the test set directly provided in the links above, already separated from the training data. Provide arguments for the choice and design of your final model(s). Provide arguments for the assessment and validation procedure of your final model(s).

Note for task 1: if you decide to extract explicit features from your spectrograms (remember you can treat them as images, or as a matrix of data), possible ideas and inspiration can come from the following papers.

1. M. G. Amin, Z. Zeng and T. Shan, "Hand Gesture Recognition based on Radar Micro-Doppler Signature Envelopes," 2019 IEEE Radar Conference (RadarConf), 2019, pp. 1-6, (https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8835661). This paper proposes to derive features from the envelopes of the spectrograms.
2. Fioranelli, F., Ritchie, M. and Griffiths, H. (2016), Centroid features for classification of armed/unarmed multiple personnel using multistatic human micro-Doppler. IET Radar Sonar Navig., 10: 1702-1710 (https://ietresearch.onlinelibrary.wiley.com/doi/epdf/10.1049/iet-rsn.2015.0493). This paper proposed to define two quantities, centroid and bandwidth and use their statistical moments as features (section 3.2); note that these features were proposed for a different classification task than hand gestures.
3. L. Pallotta, M. Cauli, C. Clemente, F. Fioranelli, G. Giunta and A. Farina, "Classification of micro-Doppler radar hand-gesture signatures by means of Chebyshev moments," 2021 IEEE 8th International Workshop on Metrology for AeroSpace (MetroAeroSpace), 2021, pp. 182-187 (https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9511751). This paper proposes to use special moments, Chebyshev moments, extracted from the spectrograms as the relevant features.

Other instructions

- You will work in pairs.
- Decisions need to be made together, but tasks can be done individually.
- We recommend splitting the tasks. Any member must be capable of arguing any decision made.
- At least one of the models must be a *deep neural network (Lecture 5)*.
- One report per pair. The report must follow the proposed structure with a maximum number of pages of 10.
- Deadline: Week 8.

Deliverables

1. Final Project Report (see instructions below)
2. Project Assignment Python code

Suggested Report Structure

- Members, emails, student numbers.
- Summary (less than 200 words)
- Detailed ML pipeline (include workflow figure).
- Task 1: selected options for pre-processing and possible feature extraction, argumentation for the selection, results.
- Task 2: argumentations for the model(s) developed, validations, results, comparisons.
- Conclusions (less than 200 words)

Assessment Criteria

You will be evaluated based on a predefined rubric. Check the course Brightspace page to get access to the rubric.

The Project Final Report can be considered *inadmissible*, which will render a FAIL grade for the group, if

- English is not understandable (e.g., full of typos).
- Deep neural networks were not used (as one of the tested models).
- Figures are not legible.
- The report does not follow the proposed structure.

If the report is considered *admissible*:

- English will *not* render extra points.
- Quality of the Python code will *not* render extra points.

Submission Instructions

Please submit your Final Project Report in a PDF format and your Python code in Brightspace before the deadline.