Principles and Design of IoT Systems

[INFR11239 (UG)/INFR11150 (PG)]

School of Informatics, University of Edinburgh

Coursework 1 – Released on 18 Sept. '24, Deadline: 1 Oct. '24

Coursework 2 – Released on 18 Sept. '24; Deadline: 25 Oct. '24

Coursework 3 – Released on 18 Sept. '24; Demonstration on 20 Nov. '24; Final report: 17 Jan. '25

All submission deadlines are at 12 noon on the days indicated.
Please contact Professor D K Arvind (dka@inf.ed.ac.uk) if you have any questions.
Version 1.6, updated 24 Oct. 2024.

Summary

The course is concerned with the emerging discipline of digitising the physical world with networks of wireless sensors, analysing the sensor data using machine learning techniques to extract concise actionable information, and influencing the physical world via actuators, with an optional human in the loop.

The course imparts foundational concepts in IoT through personal research distilled in the form of one research paper on foundational topics in IoT, and students working in pairs gain hands-on experience by realising a healthcare application idea as a demonstrable IoT system using wearable sensors by the end of the semester.

Course Description

The course aims to deliver a sound understanding of the design and analysis of Internet of Things systems through personal research and practice. The research in selected topics in IoT provides the foundational knowledge distilled in the form of a 3000-word research paper.

The students conduct a major piece of coursework working in groups to develop an IoT application using wearable sensors. Students will experience all the stages in the design and implementation of a complex system, from its specification to the demonstration of a working prototype. They will be exposed to aspects of embedded systems programming, sensor data analytics using machine learning methods, user interface design, system integration and testing. Each pair will demonstrate a working prototype at the end of Semester 1 and deliver a written report at the start of Semester 2.

Each student team is given two Inertial Measurement Units (IMU), with 3-axis accelerometer and gyroscope sensors, and an Android app for data collection. The task will be to design, implement and demonstrate a system for human activity recognition in real-time using the wearable sensor which interfaces to an Android app.

Organisation

The course has tutorial and lab sessions. Attendance is compulsory and will be noted.

Students registered for this course or wishing to take this course should attend the introductory meeting at 10:00 on Wednesday, 18 September 2024 in the PDIoT lab in Appleton Tower, room 3.09. During the first meeting you will form groups and take delivery of the hardware. A locker will be provided for storing equipment safely in the lab.

Tutorials

Tutorial meetings will take place in weeks 2-5 to present progress on your research for the Research Paper due as part of Coursework 2. Please come prepared with 2-3 slides describing your research for each tutorial session.

The tutorials on Tuesdays at 10:00 and 11:00 will start on 24 September and run until 15 October, 2024; the ones on Thursdays at 10:00 and 11:10 will start on 26 September and end on 17 October, 2024. All tutorials take place in Appleton Tower, room 2.11.

Lab sessions

Weekly lab sessions in the PDIOT Lab (AT3.09) take place on Wednesdays, starting on 18 September 2024 and running for 10 weeks. Student groups should sign up for **one** of the 1-hour sessions at 10:00, 11:00 or 12:00 noon. The whole group must attend the chosen session every week.

Feedback

There will be opportunity to demonstrate progress and receive written formative feedback in week 5 (16 October, 2024) and in week 10 after the demonstration.

Coursework [100% of course marks]

This course is assessed purely on three coursework assignments; there are no lectures or examinations. Coursework 1 and 2 are individual assignments, whereas coursework 3 is group work. The data collection, research and implementation deliverables are described in more detail below, along with their allocation of marks.

Coursework 1: Data Collection [10%]

Release date: 18 September 2024
- ✓ **Submission date**: 1 October 2024
- ✓ **Feedback return**: 15 October 2024

The first coursework assignment is to collect sensor data for a defined set of activities. Each student will wear the Respeck monitor, worn as a plaster on the chest, and the Thingy placed snugly inside a right-hand pocket of your clothing. The sensor data from all students will be combined to produce a labelled dataset for training and testing your ML models.

Coursework 2: Research paper [20%]

- ✓ **Release date**: 18 September 2024
- ✓ **Submission date**: 25 October 2024
- ✓ **Feedback return**: 8 November 2024

Compose a technical Research Paper (max. 3,000 words) in **one** of the following topics, that will be assigned to students:

- Comparison of encryption algorithms for wearable devices in IoT systems
- Comparison of data fusion methods for estimating orientation in 3-D space using inertial motion sensors
- IoT for the management of Long COVID
- IoT for healthcare of the elderly
- IoT in mental health
- IoT for clean environment (air pollution and global warming)

The Research Paper should be divided into sections, with the following mark weightings:

- A brief introduction which sets the context [10%]
- The main body of the essay, divided into subsections [60%]
- Conclusions [20%]
- Bibliography (not included in the word count) [10%]

Please include diagrams, graphs and images to communicate your findings.

The 60% of marks for the body section are shared as follows: breadth of research - 20%; distillation of essential features in a scholarly manner - 40%.

Coursework 3: Implementation and Final Report [70%]

- ✓ **Release date**: 18 September 2024
- ✓ **Progress demonstration/feedback**: 16 October 2024
- ✓ **Final Demonstration date**: 20 November 2024 (10:00 – 13:00)
- ✓ **Final report submission date**: 17 January 2025
- ✓ **Feedback return**:31 January 2025

This coursework will be undertaken in small groups and involves the development, demonstration, and final written report (max. 10,000 words) for the human activity classification system.

Implementation

Your task will be to implement a human activity recognition system for a set of common physical activities, by applying machine learning techniques on the sensor data and displaying real-time results in an Android app.

You will experience the different stages in the design and implementation of a complex system, from its specification to the demonstration of a working prototype and evaluation of its performance. You will be exposed to aspects of embedded systems programming, sensor data analytics using machine learning techniques, mobile application development, user interface design, and system integration and testing.

Physical activity recognition

Please see the CW3 document for the full list of physical activities that should be detected. You should initially assume that the subject will be breathing normally.

Social signals

During stationary activities, your system should also detect the following social signals, which allow you to monitor the well-being of the subject:

- Coughing
- Hyperventilating
- Eating
- Talking
- Singing
- Laughing

Sleep monitoring

Sensor data will be used to detect sleep cycles, changes in posture and wakeful periods during the night, allowing you to derive sleep quality and efficiency metrics.

Demonstration

Week 10, 10:00 -13:00 on Wednesday, 20 November 2024 in AT6.13

Each group is allocated 5 minutes, which should be roughly allocated as follows:

- 2-minute presentation
- 2-minute demonstration
- 1-minute Q&A

The audience is the entire PDIoT class and the course instructors. You should limit your presentation to around 5 slides and include the following:

- An annotated block diagram showing the architecture of your implementation
- The algorithms/models used for physical activity classification
- The Android app design
- The performance of the implementation:
    - accuracy
    - communication latency
    - power consumption
    - CPU cycles
    - memory usage
- Conclusions and reflections on what you have learnt during the coursework

You should next demonstrate your implementation using a combination of live and recorded data (the latter for activities which would be difficult to demonstrate live, such as climbing stairs). You should share your mobile phone screen, so that it is visible on the projector. Please rehearse your demonstration in advance, so that it works seamlessly on the day and note that time keeping will be strict!

Please upload your slides via Learn, by 09:00 on the morning of the presentation, so that they can be added to the demonstration laptop.

Documentation

A group report describing, testing and evaluating the activity recognition and classification system will be due by 12:00 noon on Friday, 17 January 2025. The final report should not exceed 10,000 words (excluding Bibliography and Appendices) and should be organised into the following chapters:

Title Page

- PDIoT Coursework 3 (2024-25)
- Project title
- Name
- Matriculation number(s)
- Abstract

Introduction

- Project aims
- Brief description of the method adopted
- List the physical activities used in the classification
- Summary of results

Literature survey

- A review of the state-of-the-art for human activity recognition and classification algorithms

Methodology

- A description of the system and its implementation
- Hardware
- Wireless communication
- Algorithm for human activity recognition and classification
- Mobile application
- Software organisation
- Testing

Results

- Critical analysis of the implementation using quantitative methods
- Benchmarks

Conclusions

- Reflection on the project
- How might you wish to extend the project and improve the implementation

Assessment

Students will be awarded individual marks, out of 100, based on the demonstration and the final written report. Criteria for assessment are as follows:

Presentation [5 marks]

Quality of the oral presentation, slides and demonstration.

Analysis [25 marks]

Critical analysis using quantitative methods and performance analysis presented as graphs, with a balanced interpretation of the results.

Technical evaluation [70 marks]

The following factors will be considered when marking the technical merit of the project:

- Completion of the project to produce a working prototype
- Degree of difficulty
- Quality and amount of work undertaken
- Justification of design decisions
- Software design for re-usability

Schedule

Week 1

- Release of Coursework 1, Coursework 2 and Coursework 3
- Introduction and formation of groups (all students meet at 10:00 in AT 3.09)
- How to use IMU sensors and data capture app
- Discuss Coursework 1 and begin data collection

Week 2

- Capture the requirements and use cases for app
- Presentation of sensor data collected in week 1
- Discussion on approaches to data analysis for physical activity recognition and classification
- Start development of your algorithms
- Continue data collection of physical activity

Week 3

- Introduction to Android development
- Development of the app to display real-time recognition of physical activity using TFLite from TensorFlow
- Submission of Coursework 1 by 12:00 on Tuesday, 1 October 2024

Week 4

- Implement end-to-end system
- Continue development of the mobile application

Week 5

- Demonstrate mobile application displaying real-time recognition of physical activity classification and receive written formative feedback
- Receive feedback on Coursework 1

Week 6

- Submit Coursework 2 Research Paper
- Live prediction within your Android app

Week 7

- Continue your work from week 6
- Test the accuracy of your ML models (eg. cross validation, leave-one-out)
- User interface testing

Week 8

- Receive feedback on your Coursework 2 Research Paper

Week 9

- Prepare for the final demonstration in week 10 (20 November, 2024)

Week 10

- Live demonstration

Week 11

- Start working on your final report

The End

We hope that you have enjoyed the course and acquired new skills, which will be useful for future projects!

Final marks and feedback for Coursework 3 will be delivered by Friday, 31 January 2025.