Principles and Design of IoT Systems

[INFR11239 (UG)/INFR11150 (PG)]

School of Informatics, University of Edinburgh

Coursework 1 – Released on 20 Sept. '23, Deadline: 3 Oct. '23

Coursework 2 – Released on 20 Sept. '23; Deadline: 27 Oct. '23

Coursework 3 – Released on 20 Sept. '23; Demonstration on 22 Nov. '23; Peer Review by 1 Dec, '23; Final report: 19 Jan. '24

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 1.1, updated 18 Sept. 2023

Course Overview

Welcome to the Principles and Design of IoT Systems (PDIoT) course!

You will experience the different facets of designing and implementing a complex IoT system, from specification to demonstration of a prototype, over the course of 10 weeks (Coursework 3). Working in small groups, you will produce a real-time human activity recognition system, using wireless Inertial Motion Unit (IMU) sensors and machine learning techniques.

The practical work will be complemented by knowledge gained through personal research on foundational topics in Internet of Things and distilled in a 3,000-word essay (Coursework 2).

Each student will also collect labelled motion data, for a set of prescribed physical and breathing activities. This will contribute towards a common dataset, to be used for training and testing their implementation (Coursework 1).

Each group will be provided with the following hardware:

- **Respeck**: A compact Inertial Motion Unit (IMU) device, designed in-house, with a 3-axis accelerometer and gyroscope sensor for physical activity monitoring
- **Thingy:** An off-the-shelf IMU prototyping platform produced by Nordic Semiconductor with 3-axis accelerometer, gyroscope and magnetometer sensors

Both devices use the Nordic NRF52 System on Chip (SoC), containing a low-power Arm Cortex processor and Bluetooth Low Energy (BLE) radio for wireless communication.

Coursework [100% of course marks]

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

Coursework 1: Data Collection [15%]

- ✓ **Release date**: 20 September 2023
- ✓ **Submission date**: 3 October 2023
- ✓ **Feedback return**: 17 October 2023

The first coursework assignment is to collect motion 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 their clothing.

Coursework 2: Research [15%]

- ✓ **Release date**: 20 October 2023
- ✓ **Submission date**: 27 October 2023
- ✓ **Feedback return**: 11 November 2023

Research and compose a technical Survey 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 Survey 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

- ✓ **Release date**: 20 September 2023
- ✓ **Progress demonstration/feedback**: 18 October 2023
- ✓ **Final Demonstration date**: 22 November 2023 (10:00 – 13:00)
- ✓ **Peer testing completion date**: 1 December 2023
- ✓ **Final report submission date**: 19 January 2024
- ✓ **Feedback return**:13 March 2024

This coursework involves the development, demonstration, and final written report (max. 10,000 words) for the human activity and breathing recognition and classification system.

Implementation

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

Category 1: Physical activity (breathing normally)

1.1 sitting
1.2 standing

1.3 lying down (1.31 facing left; 1.32 facing right; 1.33 on the back (supine); 1.34 on the front (prone))
1.4 normal walking
1.5 stairs (1.51 ascending stairs and 1.52 descending stairs)
1.7 shuffle walking
1.8 running/jogging
1.9 miscellaneous movement (sudden turns, bending down, getting up from chairs, or anything else not listed above)

Category 2: Stationary activity (with respiratory symptoms)

2.1 sitting down + [2.1.1 coughing; 2.1.2 hyperventilating]
2.2 standing + [2.2.1 coughing; 2.2.2 hyperventilating]
2.3 lying down on your left side + [2.3.1 coughing; 2.3.2 hyperventilating]
2.4 lying down on your right side + [2.4.1 coughing; 2.4.2 hyperventilating]
2.5 lying down on your back + [2.5.1 coughing; 2.5.2 hyperventilating]
2.6 lying down on your front + [2.6.1 coughing; 2.6.2 hyperventilating]

Category 3: Stationary activity (with other behaviours)

3.1 sitting down + [3.1.1 talking; 3.1.2 eating; 3.1.3 singing; 3.1.4 laughing]
3.2 standing + [3.2.1 talking; 3.2.2 eating; 3.2.3 singing; 3.2.4 laughing]
3.3 lying down on your left side + [3.3.1 talking; 3.3.2 singing; 3.3.3 laughing]
3.4 lying down on your right side + [3.4.1 talking; 3.4.2 singing; 3.4.3 laughing]
3.5 lying down on your back + [3.5.1 talking; 3.5.2 singing; 3.5.3 laughing]
3.6 lying down on your stomach + [3.6.1 talking; 3.6.2 singing; 3.6.3 laughing]

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.

Demonstration

There will be opportunity to demonstrate progress and receive written formative feedback in Week 5 (18 October, 2023). The final presentation to showcase of your prototype with a live demonstration is scheduled on Wednesday, 22 November 2023. Each group will peer review the app produced by another group and rate it according to a set of criteria no later than 1 December 2023. Your final written group report will be due on 19 January 2024.

Documentation

A group report describing, testing and evaluating the activity and breathing recognition and classification system will be due by 12:00 noon on Friday, 19 January 2024. 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 (2023-24)
- Project title
- Name
- Matriculation number(s)
- Abstract

Introduction

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

Literature survey

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

Methodology

- A description of the system and its implementation
- Hardware and firmware
- Wireless communication
- Algorithm for human activity and breathing 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

Organisation

The course has tutorial and lab sessions. Attendance is compulsory.

Students registered for this course or wishing to take this course should attend the introductory meeting at 10:00 on Wednesday, 20 September 2022 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 Survey 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 (AT2.07) and 11:00 (AT_2.04) will start on 26 September until 17 October, 2023; the ones on Thursdays at 10:00 (AT_2.04) and 11:10 (AT_2.05) will start on 28 September and end on 19 October, 2023.

Lab sessions

Weekly lab sessions in the PDIOT Lab (AT3.09) take place on Wednesdays, starting on 20 September 2023 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.

Schedule

Week 1

- Release of Coursework 1, Coursework 2 and Coursework 3
- Introduction and formation of groups
- 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 and breathing recognition and classification
- Start development of your algorithms
- Continue data collection of physical and breathing 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, 3 October 2023

Week 4

- Introduction to firmware development for the Nordic NRF52
- How to set up the build environment
- Flashing firmware onto the Thingy and reading the debug log
- Continue development of the mobile application

Week 5

- Demonstrate mobile application displaying real-time recognition of physical activity and breathing classification and receive written formative feedback
- Choose **one** of the following options:
    - **Embedded route**: Modify the Thingy stock firmware to perform on-device activity recognition

      OR
    - **ML route**: Further enhance the ML-based sensor data analytics within your Android app
- Receive feedback on Coursework 1

Week 6

- Submit Coursework 2 Survey Paper
- **Embedded route**:
    - Algorithm migration to the Cube platform
- **ML route**:
    - Algorithm tuning
- Live prediction within your Android app

Week 7

- Continue your work from Week 6

- Test the algorithms:
  - Validate against off-the shelf models
  - Discuss other methods for validation (e.g., cross testing the existing models)
- Firmware or user interface testing, as appropriate

Week 8

- Receive feedback on your Coursework 2 Survey Paper

Week 9

- Prepare for the final demonstration in Week 10 (22 November, 2023)

Week 10

- Live demonstration
- Prepare for peer review

Week 11

- Review another group's implementation and submit your before no later than 1 December, 2023
- Start working on your final report

Demonstration

Week 10, 10:00 -13:00 on Wednesday, 22 November 2023 in Location TBA

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 to the PDIoT 2023 sharepoint site, by 09:00 on the morning of the presentation.

https://uoe.sharepoint.com/sites/PDIoT2023

Peer Review

Peer reviewing is an important part of academic research and during the course you will have the opportunity to peer review the work of a fellow group.

You should submit your code for review by 12:00 on Friday, 24 November 2023 in the advertised format.

Each group will review/test the app of another group and evaluate it according to a set of criteria. The review must be submitted by 12:00 on Friday, 1 December 2023.

Assessment

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

Presentation [5 marks]

Quality of the oral presentation, slides and demonstration.

Peer Review [15 marks]

Marks are awarded for thorough testing and the quality of the submitted review.

Analysis [20 marks]

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

Technical evaluation [60 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 reusability

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, 1 March 2024.