Principles and Design of IoT Systems

[INFR11150]

School of Informatics, University of Edinburgh

Coursework 1 – Released on 21 Sept. ‘22, Deadline: 7 Oct. ‘22

Coursework 2 – Released on 23 Sept. ‘22; Deadline: 28 Oct. ‘22

Coursework 3 – Released on 21 Sept. ’22; Demonstration on 23 Nov. ‘22; Final report: 20 Jan. ‘23

**Please contact Professor D K Arvind (**[**dka@inf.ed.ac.uk**](about:blank)**) if you have any questions**

**Version 1.0, updated 6 September 2022**

# 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 implementation, over the course of 10 weeks). 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 3000-word essay.

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

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, as 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%]

Data collection by each student using the Respeck monitor worn as a plaster on the chest and the Thingy placed snugly inside the right-hand side pocket of their trousers, dress, or any other clothing.

* **Release date**: 21 September 2022
* **Submission date**: 7 October 2022
* **Feedback return**: 21 October 2022

## Coursework 2: Research [15%]

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
* Comparison of networking protocols for edge devices in IoT systems
* IoT for healthcare of the elderly
* IoT in mental health
* IoT for clean environments (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%]

Where possible you should use (in reasonable numbers) tables, diagrams, graphs, images which don’t contribute to the word count.

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%.

* **Release date**: 23 September 2022
* **Submission date**: 28 October 2022
* **Feedback return**: 11 November 2022

## Coursework 3: Implementation and Final Report

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

## Implementation

Your task will be to implement a human activity 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.

* Sitting (straight, bent forward, bent backward)
* Standing
* Lying down (left, right, on the back, on the front)
* Walking
* Running / Jogging
* Ascending and descending stairs
* Desk work
* General movement (sudden turns, bending down, getting up from chairs, anything else that doesn't qualify as an activity)

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.

There will be opportunity to demonstrate progress and receive written formative feedback in Week 5. The final presentation to showcase of your prototype with a live demonstration is scheduled on Wednesday, 23 November 2022. Each group will peer review the App produced by another group and rate it according to a set of criteria. Your final written report will be due on 20 January, 2023.

## Demonstration

Each group should demonstrate their prototype to the entire class on Wednesday, 23 November 2022. Each group’s implementation will then be tested and marked by another group according to a set of criteria, and the results submitted by Friday, 2 December 2022.

## Documentation

An individual report describing the activity recognition system will be due by 16:00 on Friday, 20 January 2023. The final report should not exceed 10,000 words (excluding Bibliography and Appendices) and should be organised into the following chapters:

* Title Page

o PDIoT Coursework 3 (2022-23)

o Project title

o Name

o Matriculation Number

o Abstract

* Introduction

o Project aims

o Brief description of the method adopted

o List the physical activities used in the classification

o Summary of results

* Literature survey

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

* Methodology

o A description of the system and its implementation

o Hardware and firmware

o Wireless communication

o Algorithm for human activity recognition

o Mobile application

o Software organisation

* + Testing
* Results

o Critical analysis of the implementation using quantitative methods

o Benchmarks

* Conclusions
  + Reflection on the project
  + How might you wish to extend the project and improve the implementation
* **Release date**: 21 September 2022
* **Progress demonstration/feedback**: 19 October 2022
* **Final Demonstration date**: 23 November 2022 (10:00 – 13:00)
* **Peer testing completion date**: 2 December 2022
* **Final report submission date**: 20 January 2023 (16:00)
* **Feedback return**: 3 March 2023

**Organisation**

In week 2 – 5 tutorial meetings have been timetabled to present progress (2-3 slides) on your research for the Survey Paper due as part of Coursework 2.

Over the 10 weeks starting on 21st September, 2022, weekly laboratory sessions have been scheduled in AT3.09. Student groups should sign up for one of the 1-hour slots at 10am, 11am or 12 noon. Attendance at these sessions is compulsory.

**Schedule**

**Phase DISCOVER**

**Week 1**

* Students registered for this course or wishing to take this course should attend the first meeting at 10am on Tuesday, 21st September, 2022 for an introduction on the PDIOT course, discuss Coursework 1, form groups and take delivery of the hardware kit and a locker for storing them in the Lab.
* Student groups should sign up for one of the three 1-hour laboratory slots at 10am, 11am or 12 noon on Wednesdays during Week 2 – 10.

**Phase DEFINE**

**Week 2**

* Capture the requirements and use cases for the target application
* Presentation of sensor data collected in Week 1
* Discussion on approaches to data analysis for physical activity recognition
* Start development of the Human Activity Recognition algorithms
* Continue data collection of physical activity

**Phase DEVELOP**

**Week 3**

* Introduction to Android development
* Development of the mobile application displaying real-time recognition of physical activity using TFLite from TensorFlow.
* Submission of Coursework 1 by 4pm, Friday 7 October, 2022.

**Week 4**

* Introduction to mbed platform and development environment
  + Start programming on the NRF board
  + Establish connection between NRF board and the Android App using BLE
* Continue development of the mobile application displaying real-time recognition of physical activity using TFLite from TensorFlow.
* Start Coursework 2 Survey Paper

**Week 5**

* Demonstrate mobile application displaying real-time recognition of physical activity and receive written formative feedback
* Choose between continuing with the Respeck sensor with emphasis on machine learning based sensor data analytics ,

**OR**

embedded system development of the application in the Thingy sensor

* Receive feedback on Coursework 1

**Week 6**

* Submit Coursework 2 Survey Paper
* Embedded route
  + Algorithm migration to the Cube platform
* ML algorithm route
  + Algorithm tuning
  + Live prediction on the Android App
  + Focus on usability and interface

**OR**

* + Create a backend server where you upload the ML model for generating predictions

**Week 7**

* Continue activity in Week 6
* Test the algorithms:
* validate against off-the shelf models
  + Discuss other methods for validation, e.g. cross-testing the existing models –
* User interface testing for the teams that chose to concentrate on the Android app

**Week 8**

* Second demonstration and feedback
* Receive feedback on Coursework 2 Survey Paper

**Week 9**

Prepare for the final demonstration in Week 10

**Phase DEMONSTRATE**

**Week 10 (Location AT3.01/3.02 10am -1pm, Wednesday 23rd November, 2022)**

Each group is allocated 10 minutes which should be roughly allocated as follows: 4-minute presentation, 4-minute demonstration and 2-minute Q&A. The audience is the entire PDIoT class and the Course Lecturer/Instructor/Demonstrator. [Feedback to students]

You should limit your presentation to around 5 slides to include the following:

* An annotated block diagram of the architecture of your implementation
* The algorithms/models used for physical activity classification
* The App design
* The performance of the implementation: accuracy, communication latency, power consumption, CPU cycles, memory usage.
* Conclusions and reflections on what you have learnt in this coursework

You should next demonstrate your implementation using a combination of live and recorded demonstrations (the latter for activities which would be difficult to demonstrate live, such as climbing up/down stairs, falling). You should share your mobile phone screen using Vysor or similar. Please rehearse your demonstration in advance so that it works seamlessly on the day.

Please upload your slides by 0900 on the morning of the demonstration to the following site:

[https://uoe.sharepoint.com/sites/PDIoT2021/Shared%20Documents/Forms/AllItems.aspx?csf=1&web=1&e=uhuaY0&cid=490f73f1%2D86ba%2D458f%2Dbc89%2Debf9825a0d86&RootFolder=%2Fsites%2FPDIoT2021%2FShared%20Documents%2FGeneral%2FDemo%20Presentations&FolderCTID=0x01200038E7E2AF87B2E949911A6DD76E24855F](about:blank)

The shared space can also be accessed through Microsoft Teams: PDIoT 2021 > General > Files

**Schedule:** The presentations are scheduled to start at 10am in alphabetical order, starting with Group A. The time-keeping will be strict; please rehearse your presentation/demonstration so as not to exceed 8 minutes, leaving at least 2 minutes for discussion.

**Phase PEER REVIEW**

**Week 11**

You should submit your code by 4pm, Friday 25November, 2022 in the advertised format.

Each group will peer review and test the App of another group and evaluate it on a selection of criteria and submit the report by 4pm, Friday 2 December, 2022.

**Assessment**:

Students will be awarded individual marks (out of 100) based on the oral presentation in Week 10, Peer review in Week 11 and the final report.

Criteria for assessment are as follows:

[**Presentation and Peer Review - 20%**]: Quality of the oral presentation and demonstration (5 marks) and the peer review report [15 marks].

[**Analysis - 20%**]: Critical analysis using quantitative methods and performance analysis presented as graphs and balanced interpretation of the results.

[**Technical evaluation - 60%**]: 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.

This section will be evaluated (with range of marks in brackets) according to the conditional presence of the following three types of features :

**Assessment:**  
Students will be awarded individual marks (out of 100) based on the oral presentation in Week 10, Peer review in Week 11 of Semester 1 and the final report due in Week 1 of Semester 2.   
Criteria for assessment are as follows:   
[**Presentation and Peer Review - 20%]**: Quality of the oral presentation and demonstration (5 marks) and the peer review report [15 marks].   
**[Analysis - 20%]**: Critical analysis using quantitative methods and performance analysis presented as graphs and balanced interpretation of the results.  
**[Technical evaluation - 60%]**: 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.  
This section will be evaluated (with range of marks in brackets) according to the conditional presence of the following three types of features :

**Essential features [0-41 marks]**  
o on-device, real-time Human Activity Recognition (ML on the phone or Embedded   
on the Thingy)  
o basic interface for users to view the current activity  
o ability for user to pair a Respeck or a Thingy  
o classification of a subset of activities (Sitting/Standing, Walking, Running, Lying Down, Falling)  
o accuracy of 85-90%

**Desirable features [42 – 54 marks]**  
Accuracy of 91-95% for Essential features, and at least one of the following features:   
o classification of all activities - provide cross validation accuracy  
o use of both sensors for improving accuracy  
o intuitive user interface; user logins and users able to view their past data

**Advanced features [55 – 60 marks]**  
In addition to **Essential** and **Desirable** features, at least one of the following:  
o Enable users to calibrate the sensor to their own body  
o perform live classification in the cloud  
o notifications for reminders to move  
o step counting  
o 96+% accuracy for Essential Features

**Final CW-3 marks and feedback will be delivered by 3rd March, 2023.**