Applied Machine Learning - Laboratory & Devices

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Electrical and Electronics Engineering
Imperial College London

AML Lab and Devices

The AML Laboratory aims to expose you to:

- ML on **embedded** systems.
- **Real-world** applications.

You will do this by working on a **group project** with your fellow Applied Machine Learners

AML

- AML Lab (Autumn term)
- AML Devices (Spring term)

AML Lab (Part 1)

Laboratory exercises (Week 3-7)

- Done individually with AML Lab box
- Connecting sensors to Arduino
- Collecting data

AML Devices (Part 2)

A **self-proposed project**

- Something realizable in about 20 weeks of work.
- Within a budget ($\sim$ £300).
- Using ML on real embedded hardware!

A few examples of possible projects:

Motion Capture

Purity Classifier

Smart Garden

AML - Lab/Devices - Intended Learning Outcomes

- **Apply** the process of developing a machine learning approach to an EEE problem.
- **Design** and implement ML algorithms for embedded systems.
- **Prepare** data for typical learning tasks such as classification and regression.
- **Train** a model from a given data
- **Evaluate** the performance of the developed model
- **Analyse** the results and draw appropriate conclusions

Background & Prerequisites

Desirable Skills

- Undergraduate Level Engineering Knowledge
  - Linear algebra, calculus,
  - Electronics, circuits
  - Signal processing,
  - etc.
- Machine Learning (don't worry if you are new to ML. You will learn this during the course)

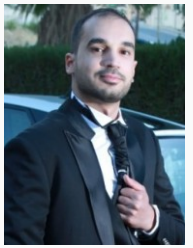
Course Organization

- **Class meetings:**
  - Progress presentations (Room 407A, every 2 weeks, Thursdays 11am),
- **Systematic work:**
  - Work on your project with your group!
  - MSc Labs (Level 1, 114b)
  - MSc common room (305 - **no lab work!**)
- **Assessment:**
  - Project design & Milestones completion.
  - Collaboration.
  - Final report, Presentation & Hardware.

Supervisors

Abdalrahman M. Abu Ebayyeh

- a.abu-ebayyeh@imperial.ac.uk



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Krystian Mikolajczyk

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Supervision and Contact

- **Meetings**
  - Groups are expected to hold their meetings on a weekly basis to discuss progress, problems and solutions.
  - All groups, module supervisors meet every odd week (eg. W2,W4,...)
- **Questions** can be posted online in Teams channels
- **Meetings** with lab/project supervisors during office hours.
  - Upon request (register your interest with them)

Rules of Engagement

Supervisors are available for helping and giving you feedback **BUT**:

- Please make an appointment to meet.
- **Post your questions** on Teams.

AML Lab - Individual Exercises (Part 1, Week 1-7)

AML Lab - Individual exercises

Preparation (Week 1-2)

- Access to Level 1 lab, 114b
- Collect locker key (from lab managers)
- Collecting AML Lab box
  - Arduino
  - Breadboard, jumper wires, tactile buttons
  - Sensors: IMU, FSR, Flex.
  - Display: OLED 0.91in.

AML Lab - Individual exercises

Practical exercises (Week 3-7)

- Lab hours 9am-5pm (No timetabled sessions, unsupervised)
- Connecting sensors to Arduino

  https://docs.arduino.cc/hardware/uno-rev3/

  https://learn.sparkfun.com/tutorials/i2c/all

  FSR 402, Flex, IMU 9DOF (Icm20600+AK09918)
- Streaming data via USB, use tactile buttons to start/stop recording.
- Visualising using OLED display and computer screen
- Recording and editing a demo video

AML Lab - Assessment

- (Week 7) 30%, 2min video submitted by each student, showing the circuit connected to a laptop, showing data streaming from multiple sensors, reacting to changes.
  - Criteria 1. 'neatness' of the circuit & setup
  - Criteria 2. Clear data variations as changes are applied to each sensor.
  - Criteria 3. Presentation of the statistics of the data being collected live (time series figure).
- (Week 9) 70%, Submit a report of project design, including: intro, review of existing solutions, design of the proposed AML device (diagram, circuit, parts), detailed plan of what, when and how (10 pages, from intro to conclusions) - to be extended for your final report for AML Devices.

Lab rules

- Lab access only to AML students - don't bring your friends from other degrees
- Soldering and heatgun training (if needed) https://www.youtube.com/watch?v=SlbxNGLIEz4
- Use only the workbenches allocated to AML lab
- Lab managers are in charge
- No project hardware must be left on the tables (use lockers to store hardware)
- Tools must not be taken out or moved between desks
- Workbenches must be left clean and tidy.

AML Lab/Devices - The Project (Part 2, Week 3-20) Continued in AML Devices during Spring term

AML Lab/Devices - The Project

Project specifications:

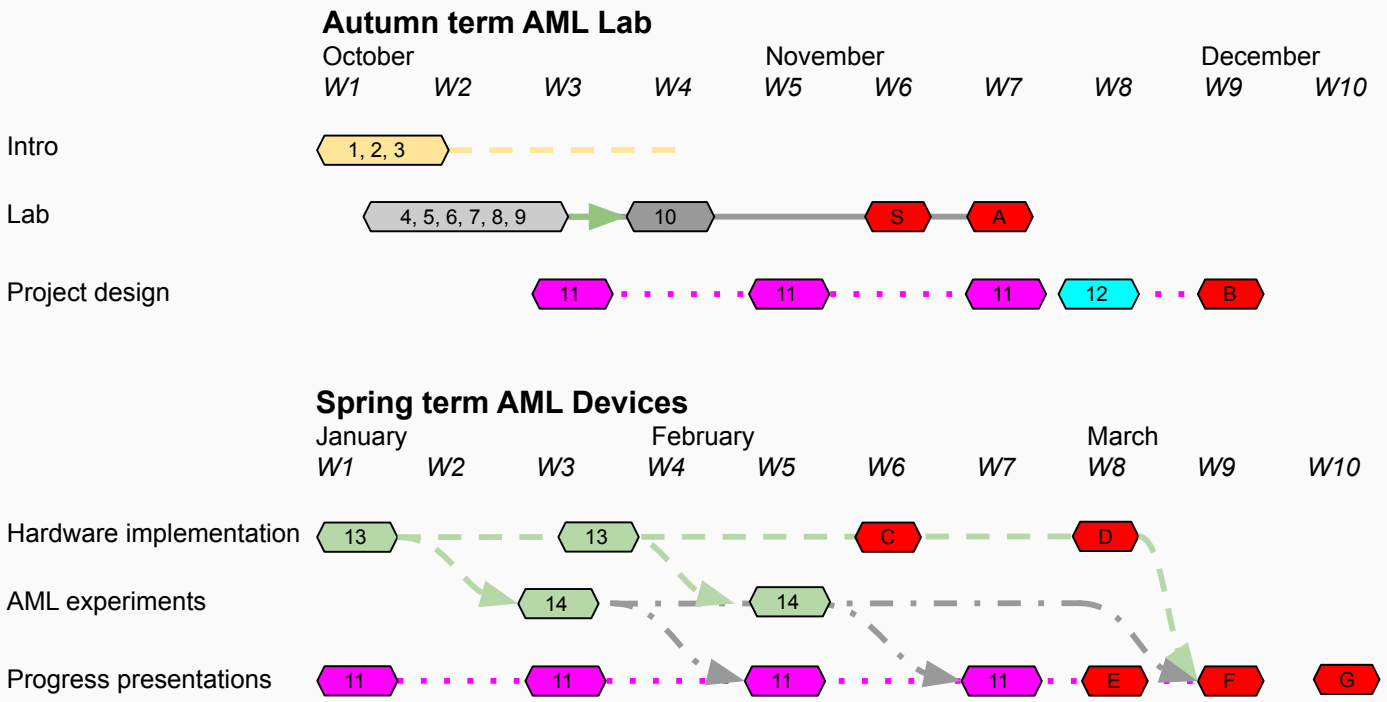
- 3 Students per group (team name - one word $<$10 letters).
- Arduino as hardware platform.
- Project should have a significant component of data collection.
- Each group must build their hardware.
- Hardware budget is £300
- Design, implement and test a ML model on collected data (doesn't have to be embedded).

AML Lab/Devices - Groups

Forming groups:

- Prepare 1 slide on yourself and include it in google slide deck (to be sent around via Teams)
- Give a 1 minute flash presentation about yourself.
- Contact people, discuss project ideas, start forming groups
- Enter groups into Google Sheet (to be sent around via Teams)

Timeline



ST- student, LL-lab leader, LT - Lab technicians, S - stores, PS-project supervisors
1. Personal intro slide (ST)
2. Group forming (ST)
3. Forming project ideas (ST->PS)
4. Lab risk assessment (ST->LL)
5. Lab access (LL->LT)
6. Locker storage keys (LL->S->ST)
7. Distribution of lab boxes (LL->ST)
8. Lab training (soldering, heatgun) (LL->LT->ST)
9. Creating accounts for 3D printing and laser cutting, hardware workshop (LL->LT)
10. Learning Arduino, sensors with lab experiments, Lab 114 (ST)
11. Progress presentation (ST->PS)
12. Hardware approvals (PS->ST)

CD-Curse director
13. Hardware assembly and debugging (ST)
14. Data collection and AML experiments, Lab 114 (ST)

Assessment
A. Lab video submission (ST)
B. Project design report submission (ST->PS)
S. AML invited seminar (CD)

C. Return of complete AML Lab box (order missing parts) (ST->LL)
E. Peer assessment forms (ST)
F. Final presentation with hardware (ST->PS)
G. Video and report submission (ST->PS)

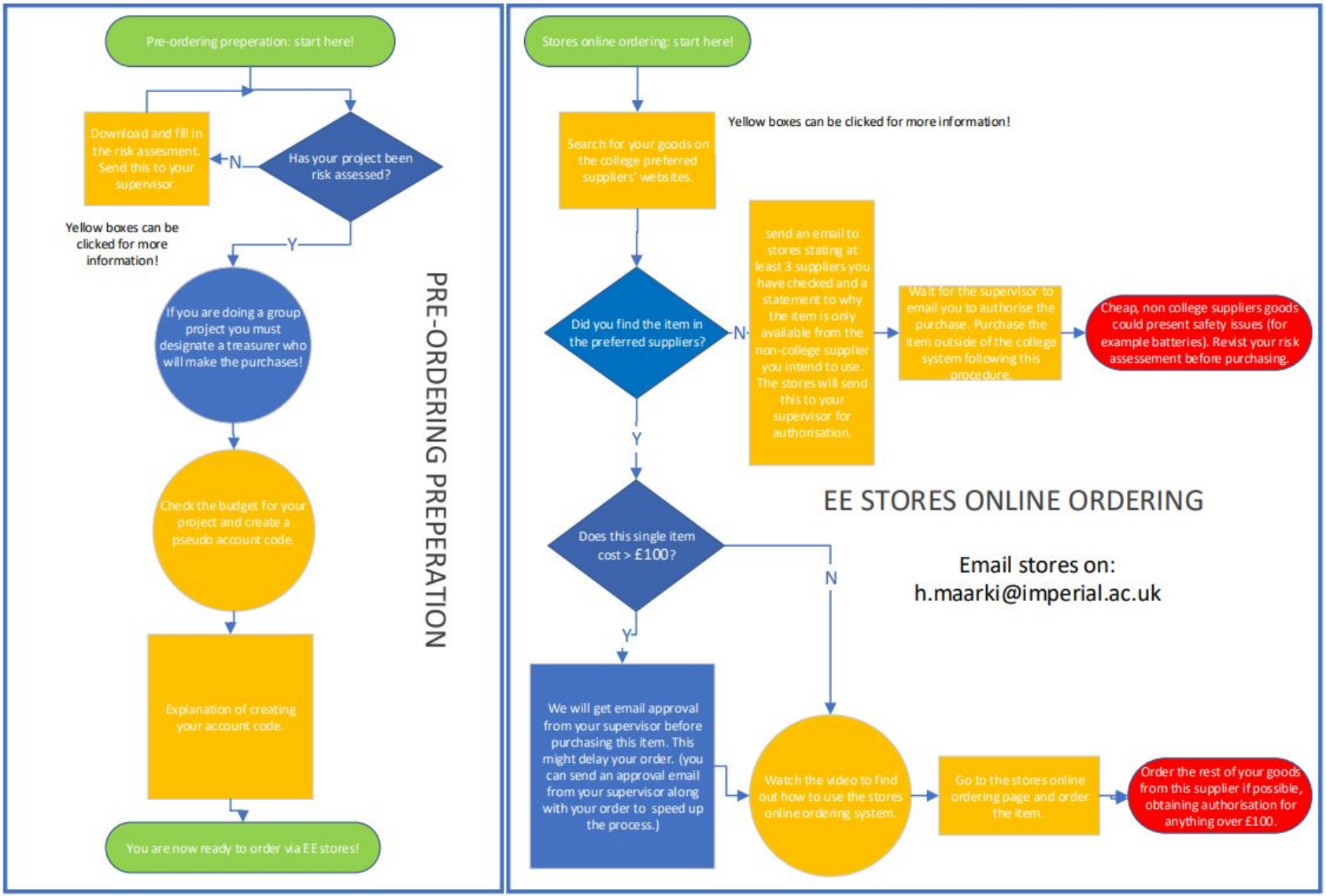
Hardware design

Once the hardware design and components are approved by Lab organizers

- Send the design (slides) to Amine Halimi `m.halimi@imperial.ac.uk` for feedback
- Metal workshop – Phil Jones `p.t.jones@imperial.ac.uk`
- 3D printing – Amine Halimi `m.halimi@imperial.ac.uk`
- Uploading designs to EEE 3D printing & Laser cutter, request online App access from `m.halimi@imperial.ac.uk`

Ordering Hardware (for Project)

(New) Ordering Process



Hardware Purchases

This video explains everything :)

https://www.youtube.com/watch?v=jPgcQitkXAg&ab_channel=DannyHarvey

Hardware Purchases

- All orders recorded on shared spreadsheet
- All ordering is done via EEE Stores (on the 1st Floor)
- Nominate one person from your group who will submit all orders
- Use the following flowchart: https://intranet.ee.ic.ac.uk/scripts2/tsg/studentordering/Process.html
- Try to use only preferred suppliers: https://intranet.ee.ic.ac.uk/scripts2/tsg/studentordering/SupplierList.html
- Use budget code AML24-***** with the stars replaced with the Team Name
- You will be building one piece of hardware per group. This is different to previous years where every group member built their own hardware system. Therefore we expect higher quality than in past years.

Data Collection and Analysis

ML experiments will include:

- Performance metrics,
- Data description,
- List of settings and methods that will be tested/compared.

Assessment

Assessment Criteria

- Project proposal and **design** report (AML Lab)
- Technical progress and achievements – **Milestones** (40%, AML Devices)
- **Collaboration and peer assessment** (20%, AML Devices)
- **Report** (20%, AML Devices)
- **Presentation** (20%, AML Devices)

Project Proposal and Design

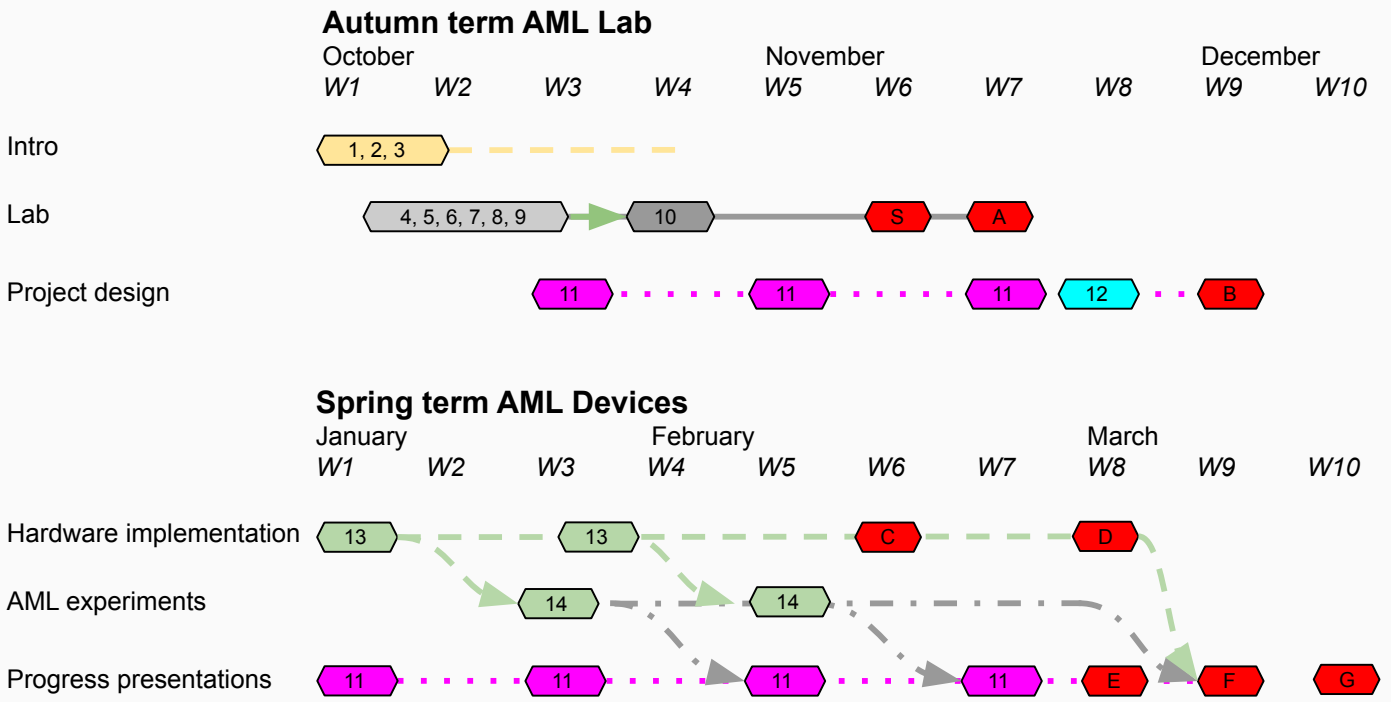
- **Weeks 3, 5 and 7**. Your group will propose a project:
  - Complete a 2-3 slide **proposal** for your project (application, ML problem, required hardware).
  - **Pitch** your idea during the group meeting session.

- Once your project is **approved** you start right away (after **Risk Assessment**!).

- **Otherwise**, based on our feedback, adjust project proposal in the subsequent two weeks.

- If by **week 7** your group does not have a satisfactory proposal **you will be assigned a project.**

AML Timeline



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Collaboration

Collaboration is an important component of AML - Lab.

- Key skill for most jobs.
- Useful experience!

Collaboration will be assessed by (individual):

- Interactions/meetings documented with main points.
- Clear identification of roles/contributions.
- Justified use of budget.
- Peer assessment (self-reflection of your role as part of the team and the team's performance)

Report

You will write a group report detailing the work done:

- 20 pages, from first to last chapter.
- Using a LaTeX template provided by us.

You will create self-contained webpage (zipped package) that will include:

- Brief overview and illustrations/pictures.
- Design files, code, presentation slides and video.

Main assessment criteria:

- Report quality and clarity.
- Experiment design.
- Evaluation, observations and conclusions.

Presentation

Your group will give a live presentation and demo.

Assessment criteria (individual):

- Slides quality and clarity.
- Individual oral narrative.
- Timekeeping.
- Individual question handling.
- Quality of video (2min max).

Risk Assessment

During the design you need to consider all aspects of health and safety associated with your project. College policy:

- Step 1. Identify risks/ hazards
- Step 2. Decide who [and what] might be harmed and how
- Step 3. Evaluate the risks & decide on the precautions
- Step 4. Record your findings and record them
- Step 4. Review and revise your assessment if necessary

Risk Assessment Foundation Training (RAFT)

https://www.imperial.ac.uk/staff-development/courses-and-programmes/safety-training/safety-courses/risk-assessment-foundation-training-raft-e-learning/

Time Management

- The Autumn Term (this one) is much less busy than the Spring Term (January onwards).
- It is a good idea to try and get as much work done on the project as possible before Christmas break.
- Aim to have the hardware ready and data collection started early in Spring term.

Example of Previous Projects

Examples of Previous Projects

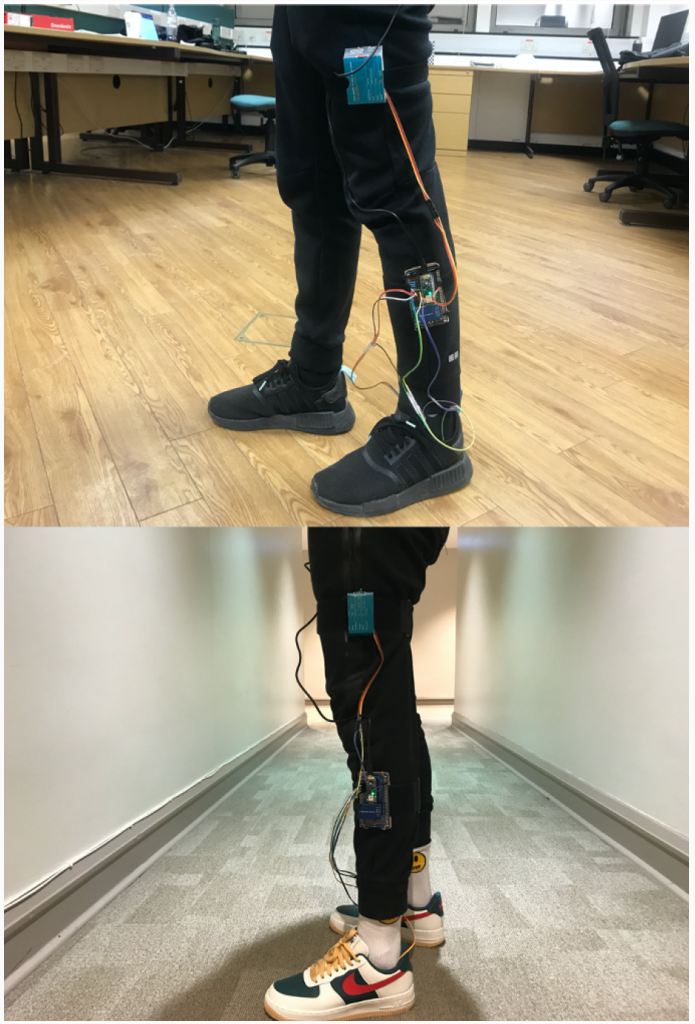
1. Counterfeit Drug Detection

- An Arduino-powered Spectrometer.
- Liquid solutions could be distinguished.
- Cooking oil used instead of actual drugs!

Examples of Previous Projects

2. Gait Phase Detection

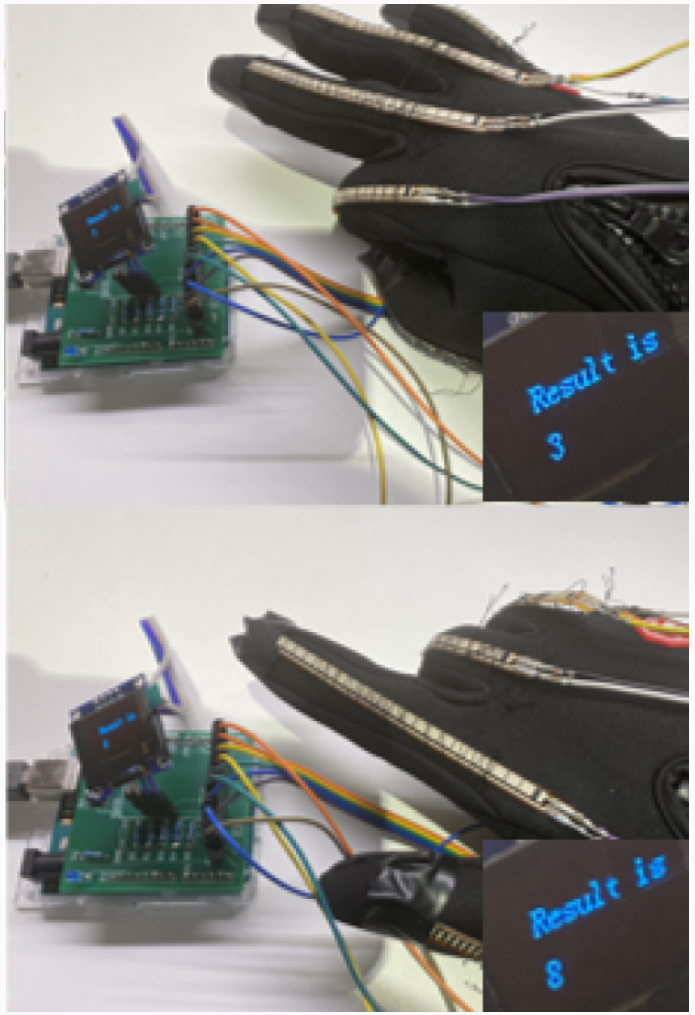
- Wearable Inertial Measurement Units.
- Shoe based Pressure Sensors.
- Automatically label different stages of walking



Examples of Previous Projects

3. Chinese Number Recognition Glove

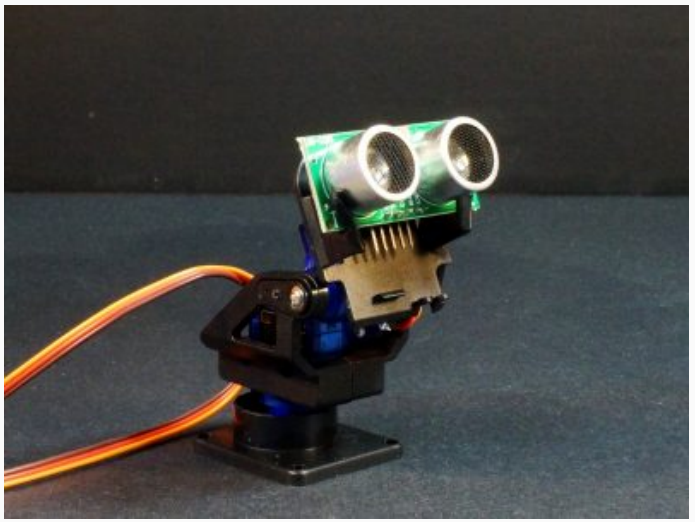
- Custom built data gloves using Flex Sensors
- Trained to recognise sign language numbers
- All machine learning executed on the Arduino



Examples of Previous Projects

4. Classifying Objects with Simple Distance Sensors

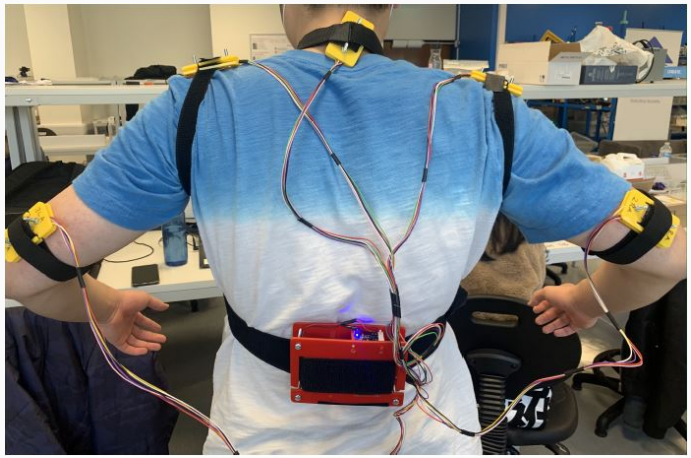
- Three distance sensors mounted on pan/tilt modules
- Recognised household objects with only a few measurements
- Objects in different poses



Examples of Previous Projects

5. Classifying Correct Exercise Technique

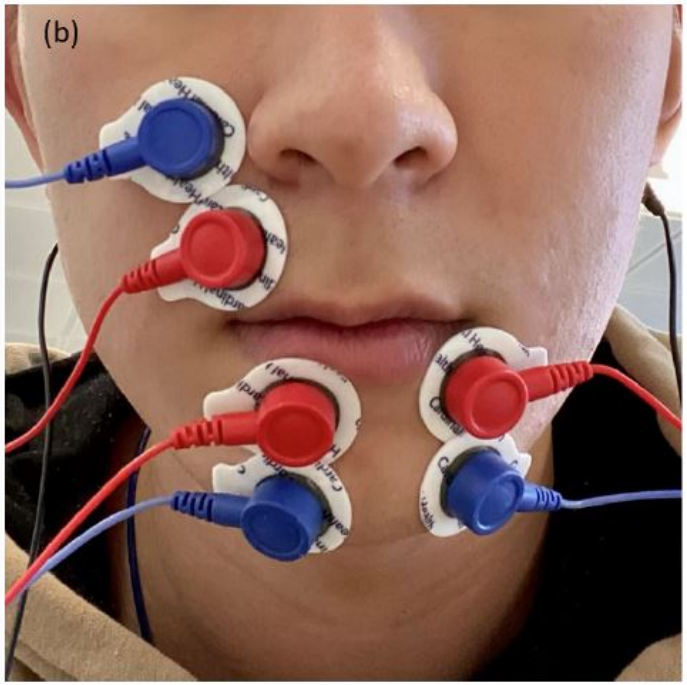
- 5 Inertial Measurement Units
- Record Data during Push-ups
- Video



Examples of Previous Projects

6. Classifying Speech via Muscle Signals

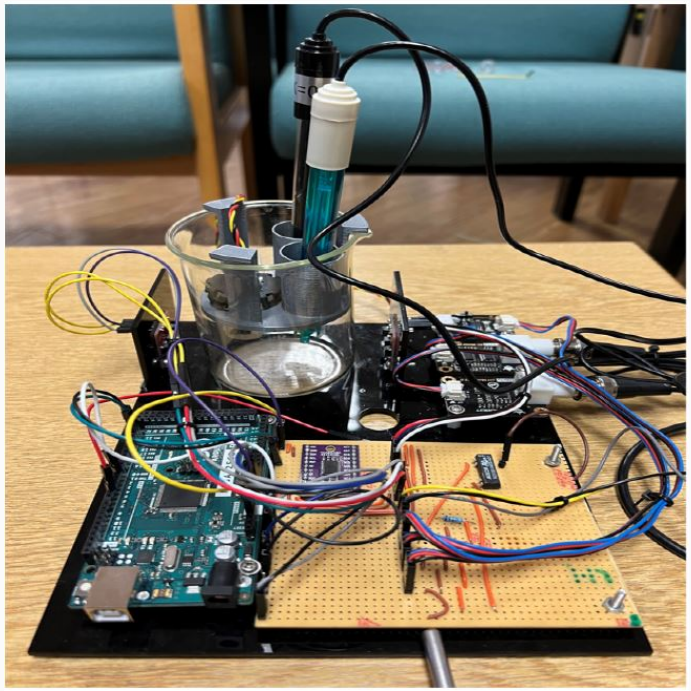
- ElectroMyoGraphy (EMG) Sensors placed on facial muscles
- Recognised a number of different words, even when spoken silently
- Video



Examples of Previous Projects

7. Liquid Classification

- An ensemble of different sensors
- Used to classify different types of coffee
- Video



Video Demos AML 2022-2023

- Gesture Controlled Drumkit
- Tennis Serve Predictor
- Smart Recycling Bins
- Hand Writing Recognision

Choosing A Project

- Check out available sensors (Adafruit.com)
- Read about crazy projects (Hackaday.com) Example
- Be realistic. Sensors are noisy and ML can't solve everything (it isn't magic)