CS3237: Introduction to Internet of Things Project

CS3237 Group Project will contribute towards 60% of your final grade.

Timeline of the Project:

- Project Release: **9th September**
- Preliminary 2-Page Project Proposal Due: **29th September** [Upload to Canvas]
- Check In 1 / Feedback on Project Proposal: **Week 9**
- Check In 2 / Preliminary Project Assessment (including demo): **Week 11**
- Final Project Presentation and Demo: **14th November**
- Final Project Report Submission: **14th November** [Upload to Canvas]

Grading of the Project (Total 60%):

- Project Proposal: **10%**
- Check In 1 / Feedback on Project Proposal: **5%**
- Check In 2 / Preliminary Project Assessment (including demo): **5%**
- Peer Reviews: **5%**
- Final Project Demo + Presentation: **20%**
- Final Report: **15%**

The project will be assessed based on (a) novelty of the application, (b) difficulty and complexity of the target problem, (c) technical achievements (both in sensing and machine learning), (d) quality of the final solution, and (e) quality of the presentation, demo, and report.

Project Objective:

The objective of the project is to **build a complete IoT system** consisting of your IoT devices, optional gateway (smartphone), and the cloud (laptop or AWS).

A) The focus should be on real-time processing of critical data that requires instant action in the edge device (for example, fall detection, heat ailments detection, or motion sensor-based security) along with long-term analytics in the cloud (for example, the patient's activity trends). Judicious partitioning of the application among the IoT device, gateway and the cloud is expected.

B) You can use a RESTful API and MQTT for communication between the IoT Device and the gateway/cloud.

C) You HAVE to use more than one sensor in the project, and minimally two IoT Devices (ESP32 devices) and use the information from the sensors you choose in a collective fashion.

D) Your ESP32 IoT devices should be powered either using a power bank or directly to the mains/laptop. It is more impressive if it is only connected to a power bank! No communication with a laptop should happen over the USB cable.

E) You may use the sensors/actuators available to you in the kit you were provided with, and the sensors/cameras available on your smartphone and laptop.

F) **Y**ou may purchase additional sensors, actuators, or other devices for your project. (Budget: SGD $60 per group – details on reimbursement will be sent later). **However, you are not permitted to buy a new microcontroller or any other device with more computational power such as a Raspberry Pi.** When in doubt, ask Boyd or Prof Jingxian.

G) You are expected to use some form of machine learning algorithm for the analytics part in the cloud.

H) Some machine learning methods that have been (or will be) covered in the lectures include the following.

   a. Clustering algorithms Kohonen Self-Organizing Maps. These are useful for seeing which datapoints are very close together and are thus likely to be related.

   b. Statistical methods like regression, which is good for predicting values based on past values, and support vector machines, good for doing classification.

   c. Simple backpropagation neural networks, which work well for classifying patterns, and for predicting values, and autoencoders, which map data points to vectors that represent relationships between these points.

d. Recurrent neural networks like LSTMs, very useful for learning patterns over a period of time.

e. Convolutional neural networks, which infer structure from unstructured data.

You may need a fair bit of creativity to combine these diverse techniques to solve your problem.

I) You may use your mobile phone as a gateway device or as part of your IoT System.

J) You can use cloud service providers for collaboration among the team members in the analytics part. You may also use your laptop to emulate the cloud so as avoid complications in connecting the gateway device to commercial cloud services when you are working on your own.

K) The gateway (mobile phone) should be connected to the cloud over WiFi. Be careful to avoid extensive cellular usage charges if you do not have good WiFi coverage.

Setting Up Your Cloud Accounts:

There are numerous providers like Amazon Web Services, Microsoft Azure, Google Cloud and Digital Ocean that you can set use to set up your cloud server. Here are some resources that you can use.

Github Student Pack: https://education.github.com/pack#offers

We recommend the use of Digital Ocean, and there are free credits in the Github Student Pack but you are free to use any service.

Though not recommended, you may also choose to set up your own server at home. In this case you will need knowledge of how to reserve IP addresses on your home router, how to set up a DMZ, or how to remap ports. Please consult the manual for your home router on how to do these. You will also need to enable the SSH server and appropriately set up any firewall settings on your server.

Bonus Points:

You will receive bonus points for introducing real-time operating systems features (e.g., threading, synchronization, timing), bare-metal programming, detailed power management analysis, communication, #D printing, and any other novelty you introduce.

Deliverables:

1. 2-pages preliminary project proposal detailing the application you have in mind and explanation of the feasibility of the project within the constraints of the infrastructure you have access to. In other words, we are looking for creativity within the broad

parameters mentioned earlier; but it cannot be just a dream that is not realizable. Deadline: 29th October 23:59

2. Two check ins in Week 9 and Week 11 respectively (exactly times to be announced). You will be given detailed feedback about the project during this demo session.

3. The final (complete) working project demo and presentation on 14th November. Schedule to be released closer to time.

4. Final project report (at most 20 pages) detailing the high-level idea of project, the techniques employed, the implementation details, the experimental evaluation, and the challenges faced during the project and how you solved those challenges. Deadline: 14th November 23:59

5. A peer review process.

Example Projects from Past Years (for Inspiration):

- IoT for Heat Injury Prevention
- Elderly Health Monitor
- Monitoring Dementia Patients
- Fall Detection and Prediction
- Heat Stroke Detection
- Weather Prediction
- Monitoring Food Stock Levels in Fridge
- Fish Tank Monitoring
- Smart Rubbish Bin
- Driver State Detection
- Smart Baby Monitor

Published Example IOT Projects:

1. Pierleoni, Paola, Alberto Belli, Lorenzo Palma, Marco Pellegrini, Luca Pernini, and Simone Valenti. "A high reliability wearable device for elderly fall detection." IEEE Sensors Journal 15, no. 8 (2015): 4544-4553.

2. Cheng, Yuejiao, Chenglong Jiang, and Jiong Shi. "A Fall detection system based on SensorTag and Windows 10 IoT core." 2015 International Conference on Mechanical Science and Engineering. Atlantis Press, 2016. https://download.atlantis-press.com/article/25851343.pdf

3. McCarthy, Madison, and Petros Spachos. "Using mobile environment sensors for wellness monitoring." 2016 IEEE 21st International Workshop on Computer Aided Modelling and Design of Communication Links and Networks (CAMAD). IEEE, 2016. https://www.researchgate.net/profile/P_Spachos/publication/311897840_Using_mobil

e_environment_sensors_for_wellness_monitoring/links/5ae3f625a6fdcc3bea93d714/Using-mobile-environment-sensors-for-wellness-monitoring.pdf

4. Vamos, Daniel, Stefan Oniga, and Anca Alexan. "Personal data acquisition IOT gateway." Carpathian Journal of Electronic and Computer Engineering 11.1 (2018): 44-47.

   https://content.sciendo.com/downloadpdf/journals/cjece/11/1/article-p44.pdf

5. Monitoring Refrigerator with TI SensorTag
   https://techblog.calvinboey.com/monitoring-refrigerator-with-ti-sensortag/

6. Venkatesan, Chaitra. "Testing Environmental Sensors to Reduce Heat Ailments among First Responders." (2018).
   https://digitalcommons.unomaha.edu/cgi/viewcontent.cgi?article=2370&context=srcaf

7. Motion Security System http://www.blesstags.eu/2017/06/

8. Low Power Home Network Weather Monitoring
   https://embeddedcomputing.weebly.com/low-power-home-network-weather-monitoring.html

Frequently Asked Questions:

Question 1: Do I need to use the cloud or can I use laptop?

We suggest that you use cloud more for your convenience as all of you need to share your data for training. If you can set up your laptop in a way that the data/backend can be shared among the team members, feel free to use the laptop only.

Question 2: Do I need to use all the sensor data for training?

No. We need you to use multiple sensor data for your problem. However, the training can be done using only a subset of the sensors. The remaining sensors can be use directly in your decision making, for example, a decision is influenced by the fact that a sensor data crosses a threshold value.

Question 3: What do we need to show for project Check Ins?

You will need to show a demo of what you have achieved so far and explain your ide and approach. You may use slides to aid your presentation. We do not need a report. These check ins are to ensure that you are making progress in the project and not leaving everything for the last minute. From our experience in previous years, some of the teams managed to improve their projects significantly given the feedback from these reviews.

Question 4: Can I only use data from the web from my training?

No. This is not a machine learning module. The physical aspect, that is, collecting data through the sensor node and performing real-time inference with real data is important and

cornerstone of the project. It cannot be done completely in the virtual world. However, you are welcome to augment the data you have obtained from your sensors with already available data from the web.

Question 5: How will we show the final demo?
The final demo will be in the last week. We hope to do this on Saturday and will let you know soon. You will be expected to show the inferencing capability live. Please note that final project report is due on 14th November.

Question 6: What should I do about power management?
Power management is an important issue for IoT devices. Your project report should minimally include the following:

- Estimate of the lifetime of the device with a LiPo. You need to take multiple readings and estimate the lifetime of the device.
- You should experiment with different internals of sampling and how that impacts battery life.
- If you are using RTOS, make sure that the MCU goes to sleep state between sensor readings.
- Optionally, you can experiment between sending sensor data to gateway/cloud versus inferencing on device itself and measure the impact on battery life.