COMP4971C

Website Construction and Data Analysis for Real-time Display of Machine Status

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Section 1: Motivation

With electronic sensor components and software systems developing, the infrastructure of the IoT is influencing and changing our daily lives prevalently. Inspired by the idea of IoT, this project is initiated to improve the place where students spend most time, the campus, to be a smarter one that saves time and energy by displaying useful information through multiple devices. This may enable people to make better decisions, for example, to choose a route without congestion, to departure when less people waiting for buses, to do the laundry when there are available machines.

Section 2: Overview

Firstly, a survey with some possible functions was done to evaluate which were the most needed for students. These functions include bus station queuing monitoring, common room availability checking, remotely air conditioner controlling. And lastly the laundry machine working status monitoring was voted to be the most needed one. Most students tend to do the laundry during around the same time, but when off the peak hour, the washers are idle. Moreover, during the peak hour, all washers and dryers are always occupied. Students who already finished the washing process may have to wait for an available dryer so they leave their clothes occupying the washer, which makes it hard for next person to use.

To select a suitable type of sensors, multiple aspects are considered. Getting the information like the charging system inside the student ID card involves issues related to student’s privacy. Installing any instrument inside the machine, such as a voltage sensor on the electric wire, may influence the working performance of those washing machines. After comparing several monitoring strategies, vibration sensors are chosen, which is not expensive, easy to install and can be functioned efficiently.

If sensors are installed, the working status can be obtained from this information and sent to the website for users. They will be able to remotely monitor the status of washers and dryers simply through a website browser. This reduces the time wasted for students to walk to laundry rooms holding buckets of clothes and the usage of lifts as well. Students can also know when the machine finish current washing will and plan earlier. Therefore, the website encourages students to do the laundry in different time period to avoid the peak hour, so the efficiency of laundry rooms is increased. Greater control of laundry machines no doubt will ease people's life by making right decision and saving time with a browser.

Section 3: Background

Section 3.1 Condition of laundry in campus

The current washers and dryers in most dormitories on campus are located in one laundry room in each residence building. Most people's preferred time to do the laundry is similar. Though enough is the quantity, many people find all machines occupied and have to spend time waiting for others during the peak hour due to the ununiformed distribution of residents' washing time. And during their waiting, people have to walk to the laundry room to check for multiple times.

Section 3.2 Equipment

In the idea of IoT, using sensors for data collection is an essential part. Usually the physical objects that people are interested in will be connected with one or more sensors. These sensors are commonly monitoring the vibration, pressure, temperature, etc. at specific locations during a time period. The monitored status will be send to a system that can analyze and process the data to make it more meaningful, then present the result clearly with a suitable platform, mostly on PCs or mobile phones. As for this project for laundry, the objects supposed to be monitored are washers and dryer. Which kind of physical information is needed and what instrumentations are available and affordable are issues evaluated.

Section 3.3 The main equipment that need to purchase

- Vibration sensors: vibration sensors are chosen based on three concerns. Firstly, vibration sensors don't cost so much. Because the status of each washing machine needs to be collected independently, it is very important to control the cost of sensors so that the total price will be acceptable and attractive to be widely used. Secondly, vibration sensors are mechanically easy to understand so they are user friendly. Users can adjust and repair vibration sensors on their own and little technical knowledge will be needed. Third, vibration sensors can avoid one significant concern of users: privacy. Because no video or photos are collected, the information of each user will be protected.
- Raspberry Pi: it is both functional satisfying and efficient. Raspberry Pi contains a reasonable CPU and both Ethernet and USB ports. Raspberry Pi is also relatively low-cost, around 250 HKD, so it will be cost-efficient, with each hall laundry room share a same Pi.

Section 4: Methodology

Section 4.1 Overall introduction of methodology

There are two main parts: hardware (electronics) and software (data analysis and website building). The vibration sensors will generate the vibrating frequency, which is the raw data. It will be analyzed to exclude conditions that the washing machine is accidentally moved or other machines besides is vibrating fiercely. To make the result accurate, modeling the whole washing process is needed to find most suitable thresholds. And to show the results, a platform allowing people to access the status and for future implementation of IoT Campus[1] should be built as well. This report will mainly focus on the part I join, the software developing part in data analysis and website building, and demonstrated by two videos done for promotion and crowd fund raising.

Section 4.2 The data flow

Vibration sensors send signals to a single-board computer, Raspberry Pi. The data will be analyzed inside the board computer with a program using Python (Program A). Then the signals will be transformed into a text file for presenting (Program B). The Raspberry Pi then transmits the file to the ihome server website (Program C and D). The website is built using HTML, CSS and JavaScript language. The data flow is presented more clearly in Figure 1.

[1] The detailed information about future implementations of IoT Campus with more function can be view at https://hkust25projects.ust.hk/en/projects/detail/developing_an_iot_campus

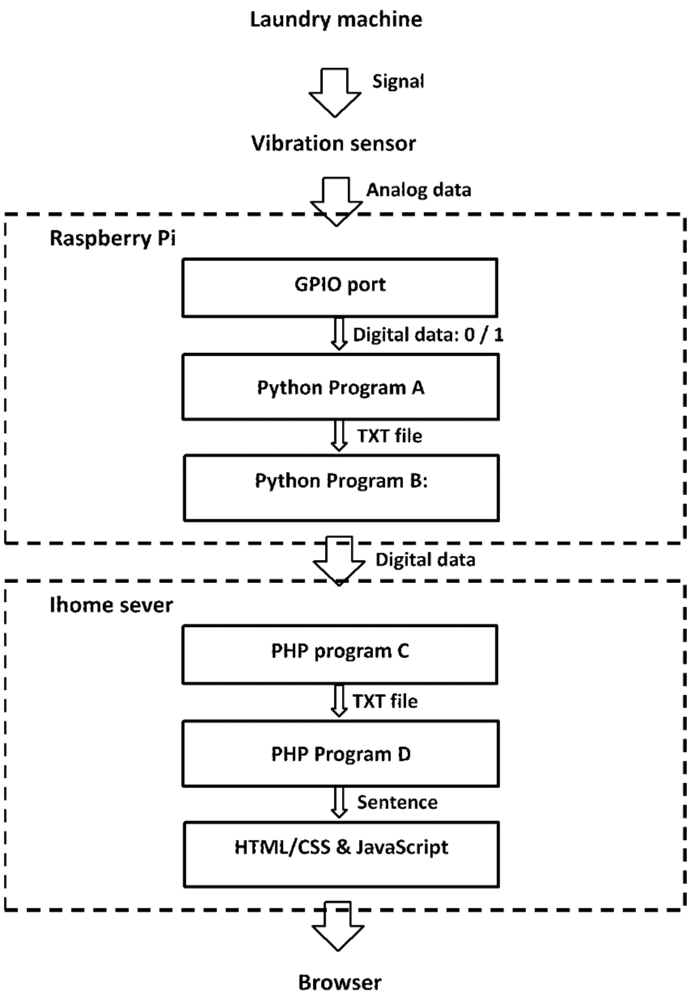

Figure 1 The flow diagram of this project

Section 4.3 Methodology in data analysis

Vibration sensors are stick on the back of the washers, and a raspberry Pi is set to be a local computer to transmit the data into internet and then it can be accessed and analyzed. In the implementation in real life, in case that someone may accidentally kick the machine or influenced by the adjacent machines' motion, the output of the vibration sensor may not be reliable. Therefore, a Python program is written to take the summation of the most recent 100 sample n which is taken every 30 seconds.

A threshold T is set beforehand according to real situation. The Python program will record "No" to a text file when the sample summation is less than the threshold (Sum <= T refers to vibrating) and record “Yes” when the sample summation is larger than the threshold (Sum > T refers to still). Python script set in the Raspberry Pi aims to report the status of a true/false vibration sensor. The output of the vibration sensor is either 0 when still or 1 when vibration.

For demonstration, sensors are installed onto the washer and the data are collected once per 10 seconds. Then two methods are used to demonstrate and explain with these data.

Section 4.3.1 Moving average

The vibration sensors basically give an output 1 and 0, standing for vibrating or still. But errors need to be avoided when the machine is moved by any external forces. If someone accidentally touches or kicks the machine, the influence time is very short. Thus the output can be emerged for several time points to get a final output.

Originally a series of numbers is obtained, which contains ‘1’s and ‘0’s, indicating vibration and still modes. What moving average does is to group adjacent numbers to subsets and calculate the average between every subset. Then the size of subsets is increased for the next cycle.

The following figure (figure 2) shows the results for moving average with cycle from 2-9, and the black line is for 100th cycle (Note that the value is not binary (1 or 0) anymore).

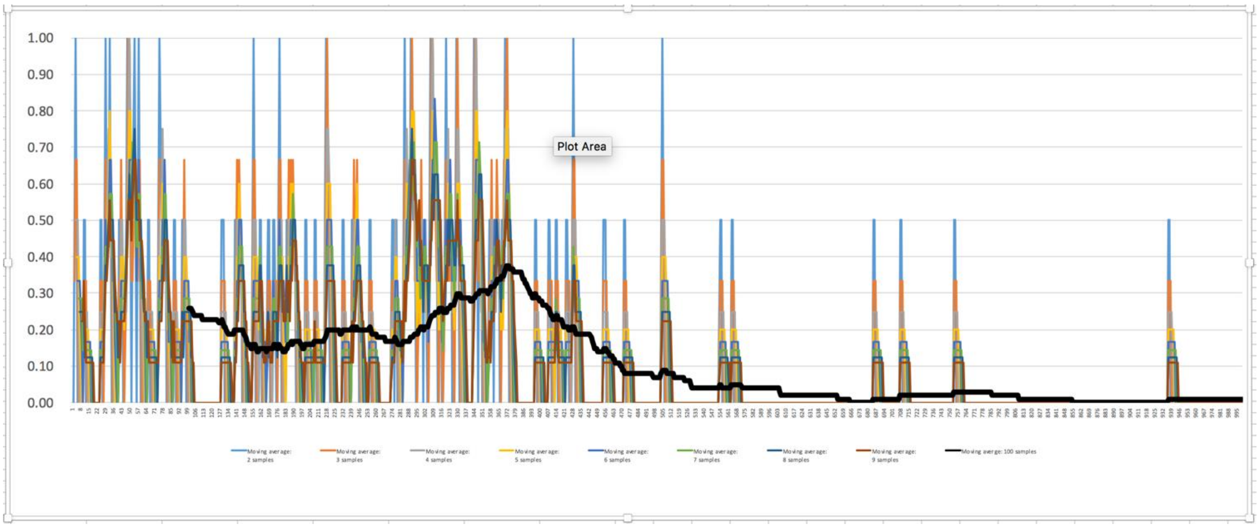

Figure 2 Moving average

As it presents, the black line (moving average every subset of 100 samples) is higher when the washer is working, and it goes down until finish. It is possible to set a threshold and if the line passes it then the machine is working. However, this way is not ideal because the line is not increasing stably, which makes it hard to determine a suitable value for threshold.

Section 4.3.2 Add continuity analysis before counting analysis

The following figure uses state continuity rather than the actual state output. To be clearer, if the state changes, it will get 1, otherwise 0. Thus '…01…' and '…10…' gives '…1…', while '…00…' or '…11…' gives '…0…'. Then in this way, '1' stands for stable state, and '0' indicates state changes.

The idea of counting analysis is also to improve the accuracy of data through calculation. First step is to group the numbers by sequence like the way in moving average. The difference is that, rather than calculate the average within a group, this method counts the occurrence of '1', if the occurrence of '1' exceed a certain threshold, then the result will be set to '1', and it will be passed to the next cycle of grouping and counting. Counting analysis was applied onto the continuity analysis result (figure 3).

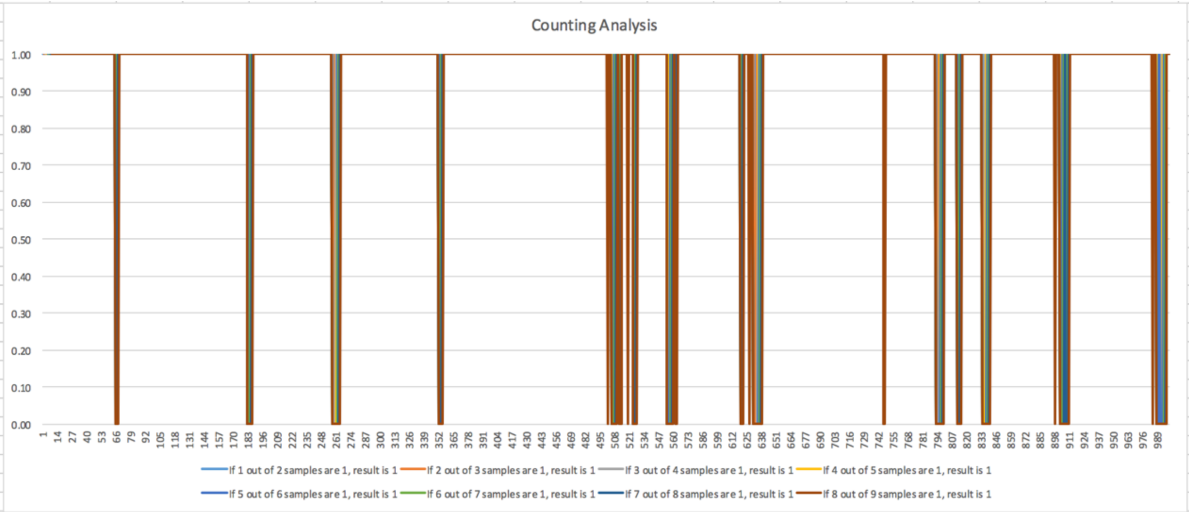

Figure 3 Counting analysis based on continuity

In the figure there are multiple jumps in the value, the value may be 0 sometimes but jump to 1 very quickly, indicating a state changes. This graph tells when the machines start or end vibrating. However, it is hard to make sure whether the washing is finished.

Section 4.3.3 Add continuity analysis before moving average

To stabilize the output of continuity analysis, moving average is used based on the result. Thus the indications of a state change can be more reliable. The following figure shows the final result after moving average calculation:

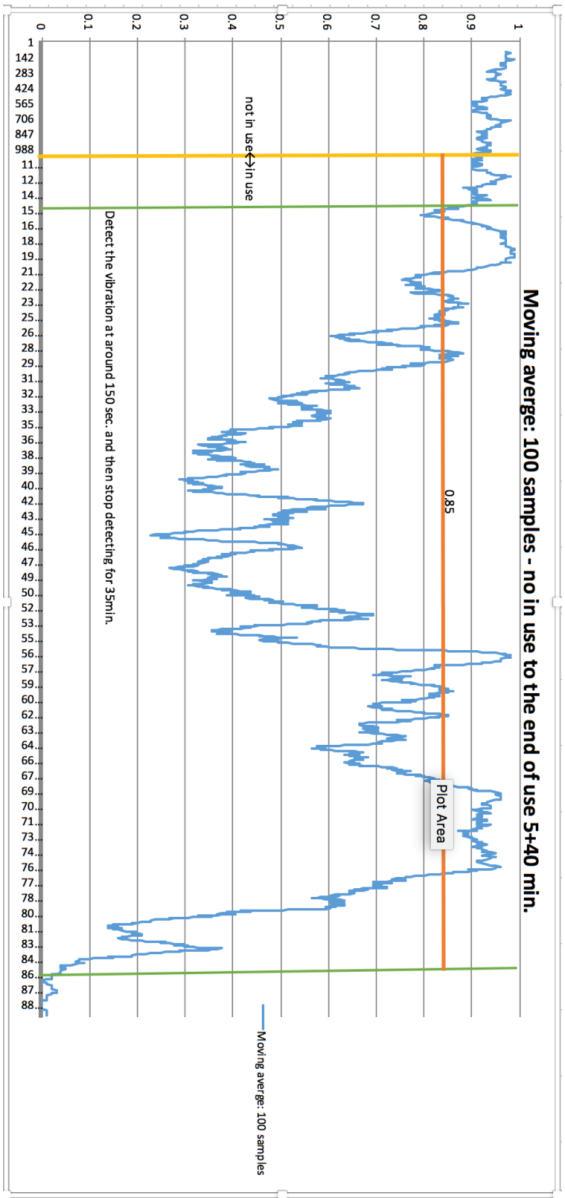

Figure 4 Moving average based on continuity

The threshold is set to be 0.85, if the value goes down below this value, the state is changing. In this figure, at first the machine is idle, then the value goes down, means that the machine starts vibrating. The figure also shows that during the whole cycle of washing, the states keeps changing, which is why the value remains below 0.85. Therefore, another requirement was added that only when the value go up to '>0.85' (stable) for 5 minutes (a certain time period), the program will start to regard the following '<0.85' value to be a valid state change. And this is the final solution used in the project.

The detection sensors will send the data to computer through WI-FI. Then compute whether the machine is working. To reduce unexpected influence by random noise, multiple methods were used. After determine it is working, the time will be recorded. Since the washing process will be 35 minutes, time when the work is finished can be estimated and confirm with the result of our program then choose a reasonable one.

Section 5: Website appearance design

Section 5.1 Web layout and outlook

The website is designed to two separated parts, the home page and subpages. The home page is a directory and introduces users some basic information about the project. Then users can get the laundry availability of the hall they want to know. Then there are nine subpages designed for nine halls. The subpages for data representing is designed to be similar for each laundry. And those website pages are integrated with an index page, asking people to choose the location of residence they are interested in. some pictures about student's residential life and HKUST are used to make the outlook better.

The website can be access at: http://ihome.ust.hk/~ikao/

Section5.2 Cross-device compatibility

When design the webpage, it should be sure that people can conveniently view it with a compatible device around. Devices with a browser are able to access the webpage. Usually users may view the page through laptop, pad, and cell phones. In this case, liquid width pages (or flexible width pages) were used so that the reader can find it easier to get the information they want. To make the page width flexible, simply modifying the width divisions with percentage or ems in the css files will make it possible. By using a property 'max-width', the maximum size of the text will be limited so that it will not be enlarged too much for people to read.

Following are some example pictures showing the outlook with varied screen sizes:

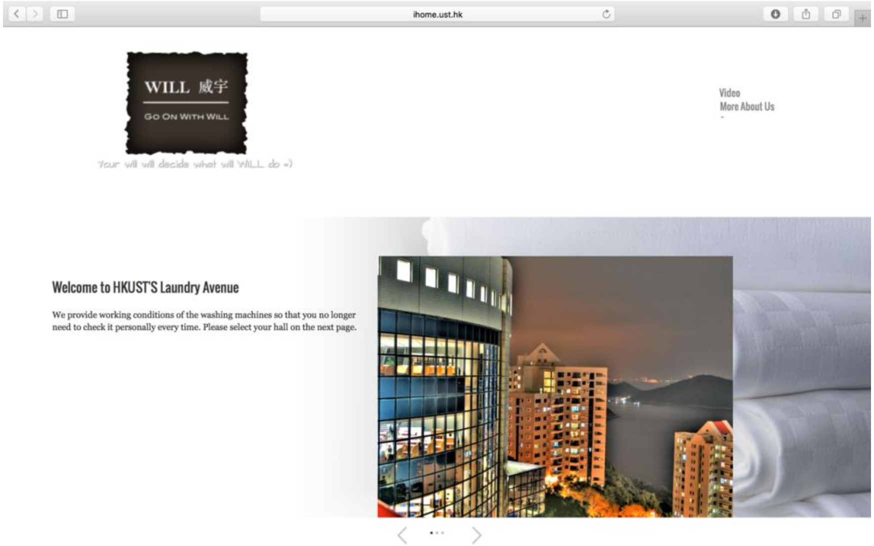

Figure 5 Webpages on laptop (1)

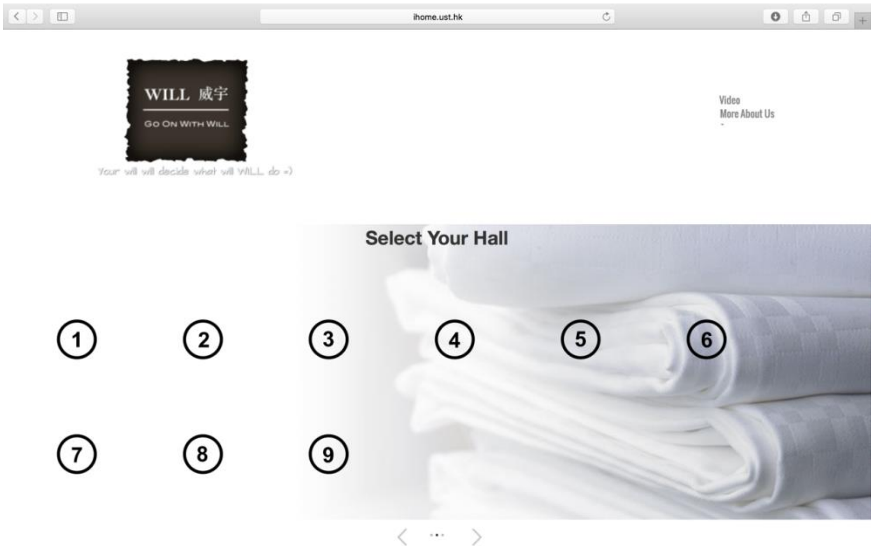

Figure 6 Webpages on laptop (2)

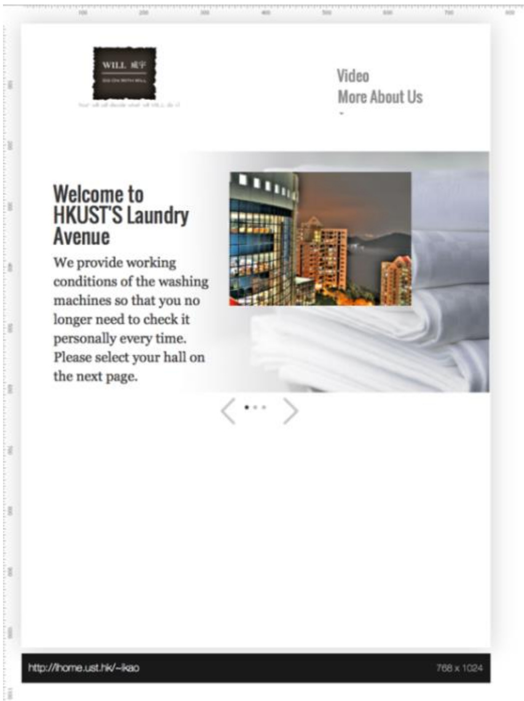

Figure 7 Webpages on smart phone (1)

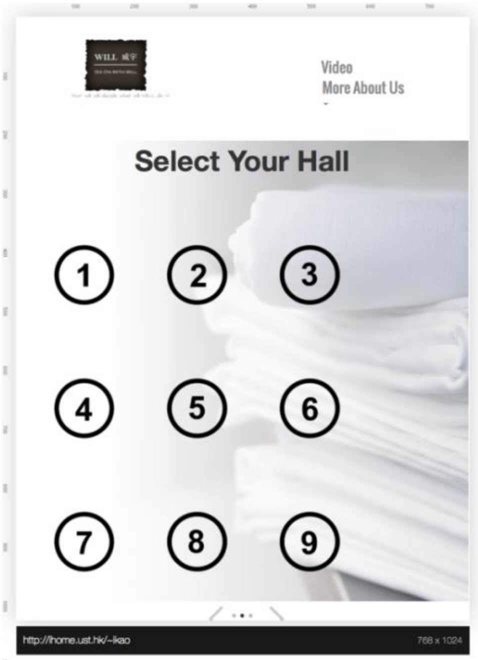

Figure 8 Webpages on smart phone (2)

Section 6: Demonstrations

The first promotion video is to let more students know more about this project and support or gives some advice. This video contains introduction of methodology, hardware installation and user interface demonstration. To shoot the video, our team went to one of the laundry rooms on campus and recorded the whole process from installation to accessing the status change on the website. Some comments from the head of the Student Residential Life Department is also included in the video.

The first video for promotion of the laundry project:

https://www.youtube.com/watch?v=NiQhVp9j0nY (Real-time Display of Laundry Machine Status)

After the first video helped us gaining more attention from people, another video focused on the future development in other functions possible for the IoT campus[2].

The second video for crowd funding

https://www.youtube.com/watch?v=mtitZ8qrsmE (HKUST 25 projects – Developing IoT Campus)

Section 7: Future improvement

Section 7.1 Responsive website design

The website can be more readable and informative if it will be used when more functions of IoT campus project come into being. The webpage may be improved to present various sources of information without forcing users with small screen to scroll un and down. It can be done if the style of the website can respond to users when they arrived. An example for a responsible website is when the screens size is small, users will see less columns while the contents are kept the same.

Section 7.2 More modes separation

Specifically, for laundry, there are at most four conditions: 'available', 'in use', 'ready for picking', 'maintenance needed'. But now this laundry project can only detect of the machine is working or not, which are 'available' and 'in use'. 'Maintenance needed' means that some problems exist in the

[2] This project is one of the participants in HKUST 25Projects, details can be found at https://hkust25projects.ust.hk/en/home .

machine. It can be manually set onto the webpage. For the 'ready for picking' condition, it is assumed that the machine is available. The next person can use the machine, although he may need to get the washed clothes out of the machine for the picker. But it will be better if the condition to be "ready for picking" firstly then change it to "available" after detecting whether the door is opened after the last cycle.

Section 7.3 Usage report for users' information

A usage report shows users how busy the laundry rooms are. It can help people to avoid the peak hour for laundry and make plans earlier.

Section 7.4 A reminder system

A reminder system will be useful for people, which will send messages of emails to the users, making the status checking convenient and efficient. The reminder contains following two kinds:

- If a room is busy, people can request to be notified when a washer or a dryer finishes a laundry cycle.
- If people have laundry in a washer or dryer, they can request a reminder asking them to pick up their clothes when finishes.

Section 8: Conclusion

The example, the idea of remotely monitoring washing machines is supported by many students because it is a real problem people encounter in daily life. Therefore, the IoT project was divided into several parts, started with a system named the real time display of machine status. Monitoring the laundry machine is one of those functions, i.e. this system of detecting and displaying can be utilized into parking lot, bus station queue, canteen seat availability, etc. To complete this project, extra programming, webpage forming and database building skills are challenges, which meanwhile encourage every participant in this project to improve.

Overall, this project benefits residents and students, makes the campus more convenient. After hearing people complained about the insufficiency of campus laundry machines. Instead of purchasing more machines, increase the efficiency is better. This whole system is cheap in cost and is easy for administrators' operation and fixing. No reassembling of machines is needed and this system can also be implemented to suit other functions. The sensor together with a local computer is possible to be made into products, which may also be put into market and widely used in other public areas such as common study rooms, parking lots and so on. Lastly, I hope this project can inspire more people to find solutions to every inconvenience in campus and make it to be a smarter and more environmental friendly place.