IoT Final Deliverable – Arduino Bin Project

Links:

Trello Page :

GitHub Team Page :

Pushing Box:

Google Spreadsheet :

Problem to be Solved

Research

While our initial problem to be solved was primarily to do with climate change, and how our project help reduce our carbon footprint, adding further internet functionality will have a different goal. This will have more to do with maximising efficiency, focusing on the commercial side of this, mainly for waste companies.

"The Irish waste sector is facing unprecedented challenges as new forms of recycling have to be embraced, and old reliable ways of disposing waste are ending, including the easy option of sending it abroad." (Upheaval in Irish Waste Industry Places New Demands on Consumers, 2018)

According to leadpointusa.com, excessive downtime is a major problem in the waste industry, "each employee should be accountable for their time. They should be ready to go to work, not just punching their timecard, when the machinery is first turned on." (The 10 Biggest Problems Facing the Waste/Recycling Industry – And How to Solve Them, 2020).

This glaring problem is most likely due to the set routes that most or all recycling companies use daily. This method is very inefficient and is a waste of fuel for the machinery, as well as the company's and the employees' time.

This leads to some employees doing very little, while others may have to travel long distances to complete their routes meaning they may not return home until late in the evening, perhaps even unpaid for their extra work. This system is not only very damaging for the efficiency of the industry, but also for the morale of its workforce. That is where our project comes in.

Our previous project's spreadsheet internet functionality could be expanded into graphs and other easier ways to view data. Through this, patterns could be predicted, and the most efficient routes can be calculated. Simply, this would mean that instead of collecting bins on a set route, on a set day, the smart bins would be monitored. Full bins would be stated as such, and a dynamic route can be created. This covers the big problems of efficiency and downtime in the recycling industry.

Waste companies may spend less on fuel, for much more efficiency; have less workers out collecting bins, for more waste collected in less time. As some addresses may have a significantly larger amount of waste than others, such as restaurants/retail, a separate system could be set out for them.

In conclusion, I strongly believe our project idea would lead to increased efficiency for the recycling industry, solving some big problems associated with process.

References:

The 10 Biggest Problems Facing the Waste/Recycling Industry – And How to Solve Them, [WWW Document], 2020 .. Lead Point USA URL https://leadpointusa.com/10-biggest-problems-facing-wasterecycling-industry-solve/ (accessed 07/05/2020)

Upheaval in Irish Waste Industry Places New Demands on Consumers 2018 [WWW Document], 2018 .. The Irish Times URL https://www.irishtimes.com/news/environment/upheaval-in-irish-waste-industry-places-new-demands-on-consumers-1.3437178 (accessed 07/05/2020)

Summary of Project 1.

Requirements

Smart Bin should show visual indicator of how full the bin is

This indicator should update when the bin is used

When the bin is full, a spreadsheet should record the bin is ready to be connected

When the bin is full, the system should send an email to the bin collection service

We setup a group on using Trello which made our ideas and development really easy to track. Noting our ideas after carrying out research and developing them throughout the trello page really helped us track through the project and allowed us to assign a role for each group member which made it simple for everyone as they knew what they were assigned and could always reference the Trello page.

We have gone through a few ideas and decided to make a group choice on one that we think is the most appropriate.

We have identified the problems where people would not know when to take out their bin, if its full or empty.

This is where we decided to stop our choice on the idea of a smart bin. A bin that would have sensors that would allow a user to receive notifications of how full the bin is. As our Project 1 idea we decided to build a Low-level prototype using the Arduino Yun.

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Design

Research and testing were carried out to identify the most suitable sensors. We were able to identify that an ultrasonic sensor would be most fitting as an Ultrasonic sensor send waves which bounce back to the sensor allowing for accurate reading to be done and organised into readable data. But due to lack of this equipment, we were forced to stop on an IR distance interrupter.

The IR distance interrupter works on the basis of Infra-Red Light. It shoots a beam of light and when that beam of light is blocked it send back an alternative reading. We were able to adjust the sensitivity of the beam to allow for it to work more accurately.

After identifying the required sensor.

We held a group discussion on how we will transmit the data and display it to the user. A decision was made to use custom code to Pushing box and Google Spread Sheets to output the display as this was only a low-level prototype. We had the idea of displaying this data on a website but due to technical difficulties we had to settle with Google sheets.

A group member set out to create code for the Arduino Yun that will allow the Arduino Transmit the data to Pushing box and then into Google Sheets.

Implementation

The First Prototype was set out to be made of a cardboard box with Sensors attached to the sides.

A development was made throughout our setting up stage that using a PIR monitor sensor, we could reduce the workload on all devices by programming it to Activate the IR Distance interrupters when movement was detected.

See Implementation Plan below

Testing

Finally, we could start our testing.

Using the Arduino Yun, we wired up all the required sensors according to our plans. We connected the Arduino to a wireless connection using wireless sketch code provided by Arduino.

After we could successfully ping the Yun, we knew it was successfully connected to the internet.

Now, We Placed our sensors on the box in a convenient way to cover the area and for the PIR monitor sensor to transmit successfully.

After setting everything up, Executing the custom code that will be the base function of our project went successful.

All the required software and websites were opened up on the PC and were monitored.

As we placed objects into the box under the immersion that this was someone filling up their bin, Small indicator lights flashed on the IR sensors indicating a disrupt signal.

As we monitored the Google Sheets page, Data started to get injected. We previously formatted the Sheet which made it easy to read the data collected. We received Reading of the bin being either Empty, Half-full or Full.

Some of the problems we encountered were: Inconsistency of Data and connectivity to Pushing box. We fixed the Inconsistency by adjusting the IR sensors and Pushing box was fixed by adjusting the Connectivity part of it in the code.

Conclusion

The testing went successful and a lot of valuable information was gathered. It showed us that this concept could really be developed further on as a full-fledged project. All group members were happy with the successful testing and the working of our concept. It was a great experience through the tasks and challenges we faced.

We are looking forward to developing this Project into its second stage.

Requirements for next stages of development

For the next stages of the project, we would like to use multiple bins, and attempt to replicate our project but on a larger, more sophisticated scale. To succeed in this, would be necessary to acquire more advanced equipment.

In project 1 and 2, we use Google Spreadsheets. While they are good, to expand on our project for larger scale development, we would ideally involve using MongoDB Atlas as a database on the cloud. Perhaps storing each individual user in a document. We could then use this information to generate graphs on the website. MongoDB would allow us to store more detailed information on location, the user, ID, timestamp. It is quick, flexible and is very easily scalable to accommodate changes and growths as our project moves further in stages.

A dedicated server is also needed for the next stages of development. Currently, our website is local. Because of this, our website generates the value from the front-end. A dedicated server allows for access anywhere with an internet connection, and allows you to use better security, hiding the API keys to the user, and allows the generation of graphs using the servers.

The website also had a very basic layout. In the next stages we would expand the CSS.

Liberg et al. (2018) show that in order to decrease power consumption, two solutions are to select better hardware, and to improve network operating efficiency. In the next stages the processing of the data may be sent directly to the cloud, or to a gateway or MQTT broker.

The Arduino Yun is not optimal hardware for this project on a larger scale. The Arduino Yun is not designed with battery efficiency in mind. There is no need for the additional processer, the Atheros AR9331. We do not need to use Linux to send the sensor data to the cloud. Therefore, a device that is more compact and has a lower power consumption should be used (Arduino, No Date).

References:

Liberg, O., Sundberg, M., Wang, E., Bergman, J., Sachs, J. (2018) NB-IoT Performance, *Cellular Internet of Things*. Cambridge: Academic Press.

Arduino (No Date) *Getting Started with the Arduino Yún.* Available at: https://www.arduino.cc/en/Guide/ArduinoYun (Accessed: 14 May 2020).

Implementation Plan

EQUIPMENT NEEDED

In project 1, we only had access to IR distance sensors. These sensors were digital and had an extremely limited distance when monitoring. This led to us putting the IR sensors at different heights on the bin, and limiting our readings based off their relative height (50% and 100%).

However, in project 2 we would use four ultrasonic sensors placed at the top of the bin, under the lid, facing towards the bottom of the bin. The ultrasonic sensors give an analogue reading, allowing us to compare the distance given from each of the four sensors, and compare it to the bin's empty height. This would allow us to get an accurate reading of the bin's fullness, as opposed to the 0%, 50%, and %100 we previously were limited to with the IR distance monitors.

We ideally would also need to power the Arduino using a battery or power bank, as if the bin is outside, the Arduino cannot feasibly connect to a dedicated power supply. This brings battery life issues.

PARTS LIST

Arduino Yun

Grove Shield

4x Ultrasonic sensors

Power bank

APIS USED

For project 2 we would once again use Pushing Box. We configured the Pushing Box scenario to instead send a single value, which is how full the bin is in a decimal format. To get the percentage you would simply multiply it by 100. The Pushing Box then sends it to the Google Spreadsheet.

Google Spreadsheets API v4

We use the Spreadsheet API v4. In our project 1, we used a temporary key, which are used for the purposes of testing. It expires after one hour, however. Now we use the official key, using OAuth 2.0

This gives our Arduino an extra level of security, as to access the spreadsheet you need to provide an authorization token.

We also use this for our website, as we use JavaScript to make a fetch request to the google spreadsheet, and then display it on the website.

Google Apps Script

We use a script to enter the data by using a GET method.

CODE SAMPLES

This is the main Arduino code, adjusted for the multiple sensors and changed values. It does simple data processing before sending the result to Pushing Box

```
void loop() {

  HttpClient client;

  if (digitalRead(MOTION_SENSOR) == 1)
  {
    delay(10000);
    double result1 = analogRead(ULTRASONIC_SENSOR_1);
    double result2 = analogRead(ULTRASONIC_SENSOR_2);
    double result3 = analogRead(ULTRASONIC_SENSOR_3);
    double result4 = analogRead(ULTRASONIC_SENSOR_4);

    double binFullness = (result1 + result2 + result3 + result4) / (4 * BIN_DEPTH);

    String currentTime = GetDate();

    // Make a HTTP request:
    String APIRequest;
    APIRequest = String(serverName) + "/pushingbox?devid=" + String(devid) + "&TimeStamp=50&fullness=" + binFullness;
    client.get (APIRequest);

    // if there are incoming bytes available
    // from the server, read them and print them:
    while (client.available())
    {
      char c = client.read();
    }

    Serial.println(currentTime);
    Serial.println("Sent values: ");
    Serial.println("fullness: " + String(binFullness) + "\nPercentage full: " + String(binFullness * 100));
  }
```

Here are example entries entered from the edited JScript and Pushing Box. It gives you the percentage full in decimal, and percent.

11/5/2020 15:53:03

A	B	C	D
Time	ID	Fullness (dec)	Percent
11. 5. 2020 15:53:03	1589208784241	0.5	50
11. 5. 2020 15:52:56	1589208777041	0.25	25
11. 5. 2020 15:52:50	1589208770558	0	0
11. 5. 2020 15:52:46	1589208767004	1	100
11. 5. 2020 15:52:41	1589208762196	0.7	70
11. 5. 2020 15:52:35	1589208755896	0.4	40
11. 5. 2020 15:52:17	1589208737172	0.52	52

This is part of the JScript that adds the data to each row. This code sample parses the sent value.

```
var sheet = SpreadsheetApp.openById(id).getActiveSheet();
var newRow = sheet.getLastRow() + 1;
var lc = sheet.getLastColumn();
var rowData = [];
var waktu = new Date();

rowData[0] = waktu.toLocaleDateString() + " " + waktu.toLocaleTimeString(); // Timestamp in column A
rowData[1] = Date.now();

for (var param in e.parameter) {
  Logger.log('In for loop, param='+param);
  var value = stripQuotes(e.parameter[param]);
  //Logger.log(param + ':' + e.parameter[param]);
  switch (param) {
    case 'binFullness':
      rowData[2] = value;
      rowData[3] = value * 100;
      break;
    default:
      result = "unsupported parameter";
  }
}
Logger.log(JSON.stringify(rowData));
```

Analysis of Security Holes

Protection against Physical Tampering

Since there are millions of IoT devices installed within hand's reach it opens a new opportunity for security breaches of those devices.

We can take our Project as an example. Someone could easily reset the Yun and erase all the code by pressing the physical reset button.

Physical tampering can be done is a lot of different way. Such as connecting to exposed ports, interrupting device power or even device theft.

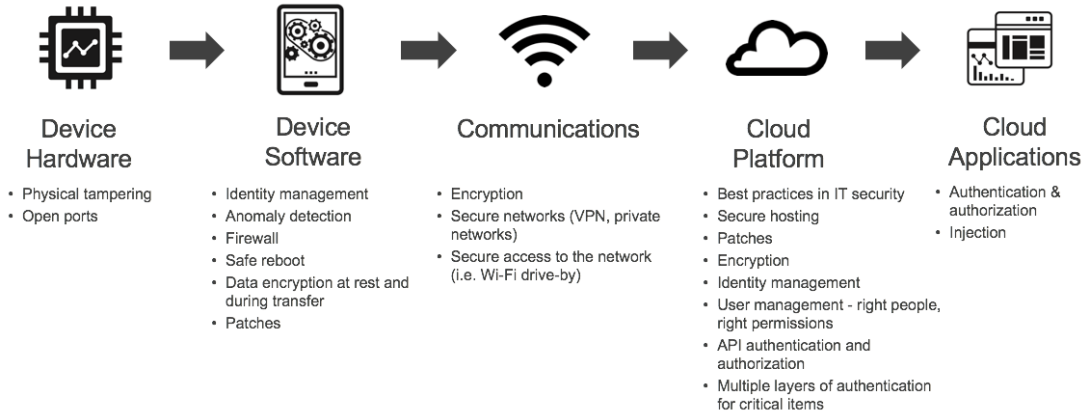
To prevent this, we can Ensure that the device has no exposed ports, Passwords to only authorized people and Placing Product outside normal reach.

Protect Against Cybersecurity attacks.

Cybersecurity practices apply to all the remaining layers of IoT security. As IoT is a very online based infrastructure, this is a very important layer.

Cybersecurity has many methods of protection, ranging from encryption to identity management, authentication, and authorization.

You should outline the steps you need to take to protect each layer stack of cybersecurity.



Improvements Planned and Potential Next Steps in Developing the Idea Further

If we had plans to develop this project to a much larger scale, one major problem we would face is how to power them. As we know from our original hands-on experience with the Arduino Yun, it must be powered via USB cable. Of course, in a MAC lab like the one we were making use of, this was not a problem. However, in a real-world scenario, this could prove challenging. I will outline some potential steps in solving this problem.

The first solution we came up with was using rechargeable power banks, like those used for charging phones. If the Arduino was attached to the bin in some way, the power bank could simply be plugged into it, and the Arduino would function for however long the battery of the power bank lasts. This is where the problem lies. For making smart-bins on a large-scale, the users frequently having to recharge their power bank and reattaching it to the Arduino is highly inefficient. To combat this, we have come up with another solution to compliment this.

The obvious problem is that the Arduino is using too much power continuously, draining the battery of the power bank rather quickly, with some extra code in our Arduino scripts, this could be somewhat resolved.

We would program the Arduino so that only the motion sensor is active. Once the bin is opened, the motion sensor triggers, signalling all the other functions too turn on such as the Wi-Fi and the ultrasonic sensors. A timeout would be set, once ended, all these functions would turn back off excluding the motion sensor.

Though this is not a final solution to the problem. It would greatly decrease the amount of power being used by the Arduino at any given time.

A more obvious solution would be solar power. It is more practical, and many cities are already putting this plan into place. “Dublin city centre is to get 800 solar-powered “compactor” bins, which could reduce the number of on-street rubbish bins by 20 per cent, according to Dublin City Council.” (Dublin City Centre to get 800 Solar-Powered Bins, 2019).

A solar battery could easily be hooked up to the Arduino, the panel can then be placed on top of the lid to source the power. Two problems associated with this are price, and reliability. Everyone has a place for their bins: although some of these places may not be ideal for solar powering the Arduinos, leading to lacklustre energy to power it. Installing this infrastructure could also be pricey, though I believe it is the most practical solution.

“However, to scale in emerging markets such as Colombia, Ecube Labs understood it would have to bring the prices down. That meant finding a solution which didn’t involve replacing a city’s entire existing infrastructure with its $2,000-$3,000 (£1,400-£2,000) Clean Cube smart bins.” (Internet of bins: smart, solar powered trashcans in Colombian cities, 2016).

References:

Dublin City Centre to get 800 Solar-Powered Bins [WWW Document], 2019 .. The Irish Times URL https://www.irishtimes.com/news/environment/dublin-city-centre-to-get-800-solar-powered-bins-1.3510543 (accessed 13/05/2020)

Internet of Bins: smart, solar powered trashcans in Colombian cities [WWW Document], 2016 .. The Guardian URL https://www.theguardian.com/sustainable-business/2016/jun/14/internet-of-bins-smart-solar-powered-trashcans-in-colombian-cities (accessed 13/05/2020)