Introduction

Majority of the people living in the major cities of the world, live alone or everyone in home goes to office regularly. Those who have pet in their home struggle to feed their pet timely. Even if they are able to feed them twice a day, their pet might get hungry at other times throughout the day. To feed these pets timely, the solution is designed in this project which allows to refill the pet feed plate while no one is at home. The owner can also monitor the feed consumption anytime using internet.

Design and Development

The system consists of firstly getting the distance measurements every second from the sonar sensor. The sensor used for this purpose is HC-SR04 which will take vertical height readings. If the pet feed plate is full the vertical height will be shorter. Alternatively, the vertical height will be higher if there is no feed in the plate. The limit of the height is set in the code. If this limit is crossed, it means there is no feed, and the servo motor will rotate roughly 180 degrees to fill the plate. The servo motor is attached with the plastic bottle, cut from top, and filled with feed. The servo used is the 9g SG90 mini servo motor. The ESP32 microcontroller is used to control the servo motor and sonar sensor readings. The ESP32 is a small controller that is embedded with Bluetooth and Wi-Fi modules. The ESP32 in this project is used with Wi-Fi module of the controller. It is flashed with Micropython, which is a lighter version of the Python allowing it write code and run the entire system with only 2MB of usable ROM [22]. To send the data over the internet and visualize it remotely, these two things are made possible using the Thingspeak IOT [16]. The Thingspeak uses the MQTT protocol to connect with ESP32 to send the data to the Thingspeak cloud and visualize, figure 1. When the feed is finished, the value which is now out of limit, will upload to the Thingspeak. The Thingspeak React option allows to send the alert to the IFTTT website [17] [12]. The IFTTT, stands for If This Then That, allows to manage the SMS alert using its Webhooks option, figure 2. The Webhooks option sets up the SMS details with the mobile number and specific event name. Then it will generate a http link which can be run to trigger the event. This trigger event link is added in the React app of the Thingspeak to trigger the SMS alert whenever the plate is empty as shown in figure 3 and figure 4 [1].

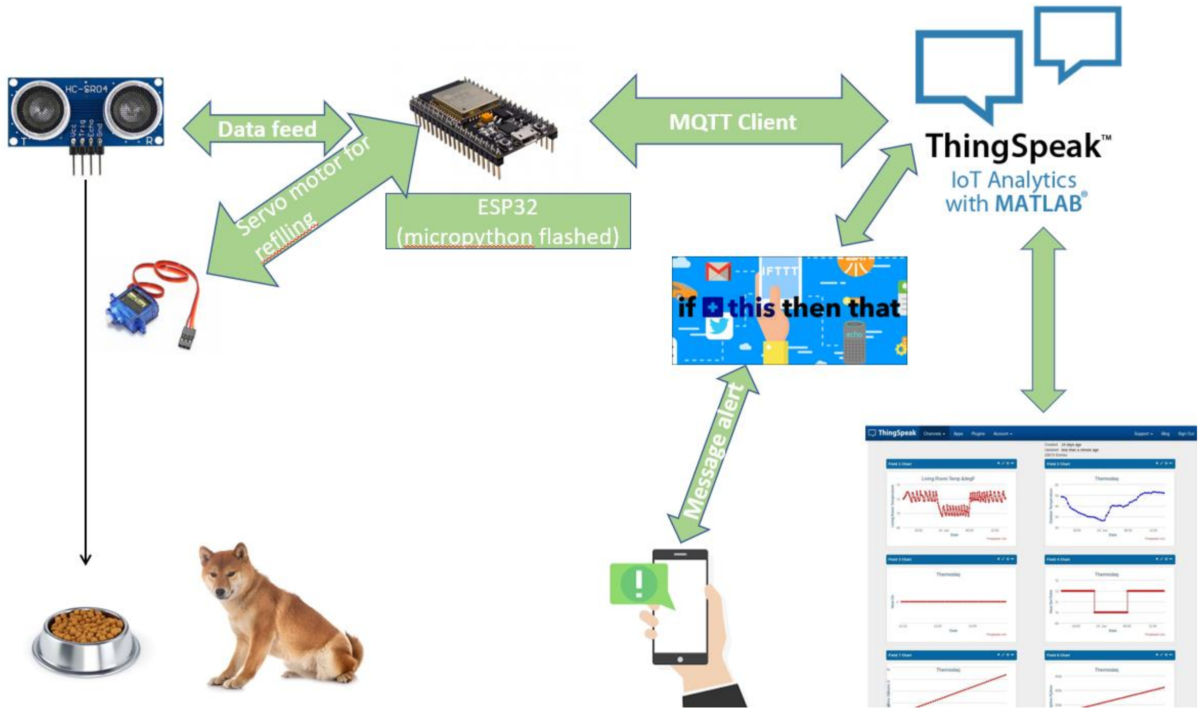

Figure 1: System design for automatic dog feed

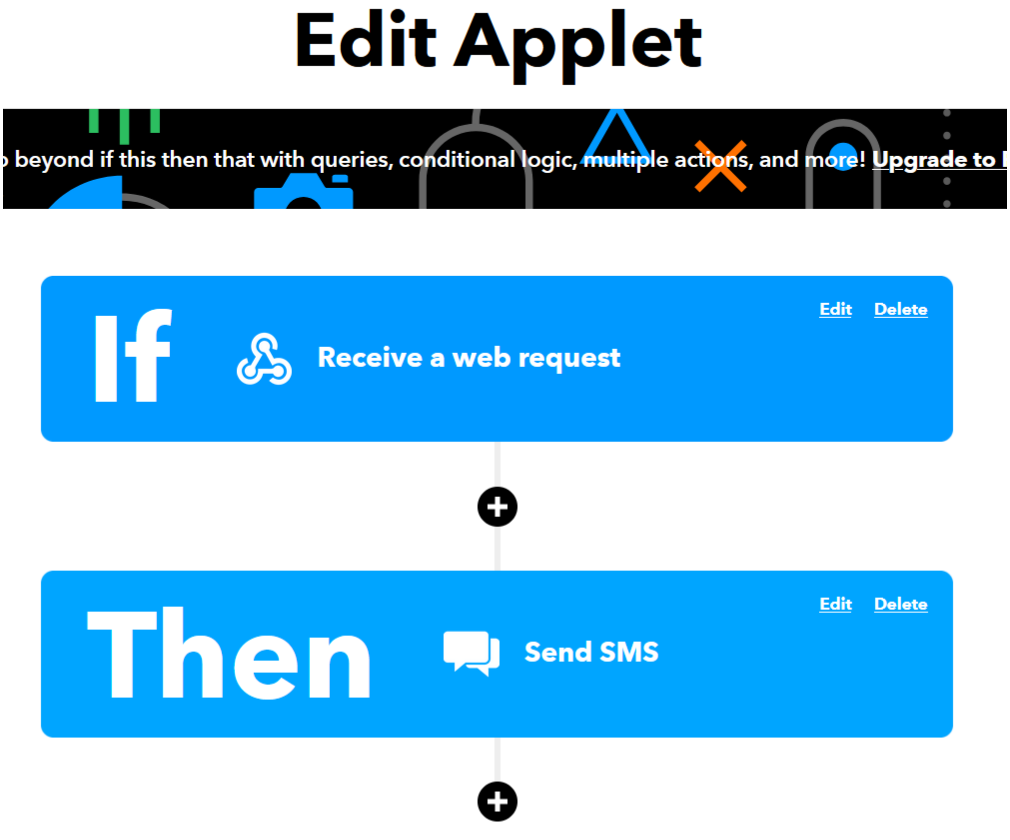

Figure 2: IFTTT SMS Alert setting UI

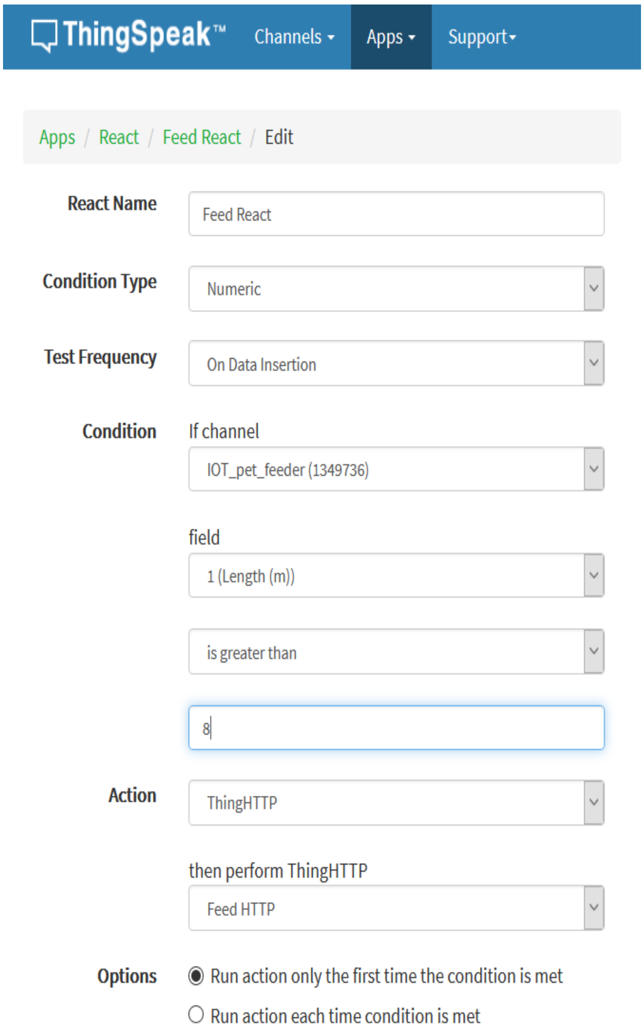

Figure 3: Thingspeak React App

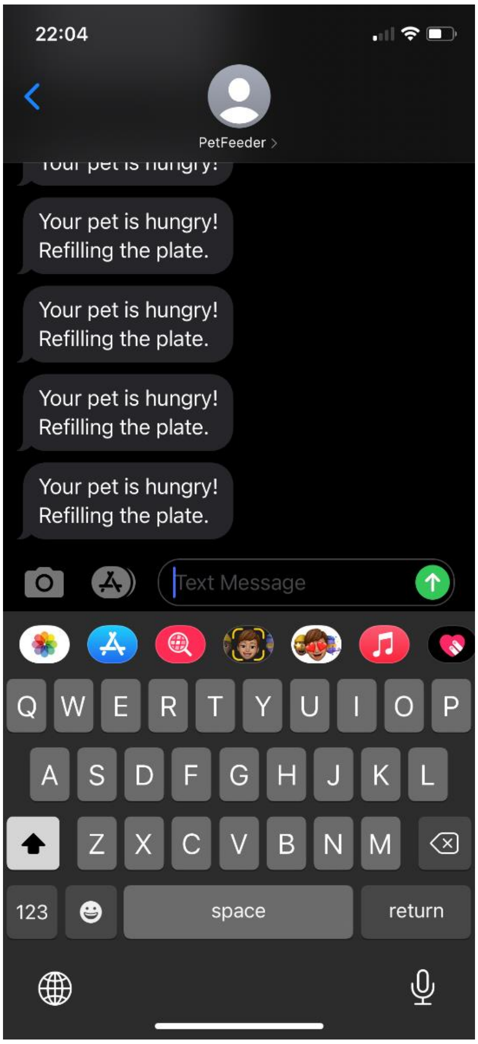

Figure 4: SMS Alert on Phone

The MQTT, Message Queuing Telemetry Transport, is a lightweight messaging or communication protocol that is commonly used for IOT applications. Its small code makes it possible to use in small microprocessors where memory is a major constraint. It consists of three main roles. The Client, who send the data to the server. Secondly, the Broker, which is responsible to receive all the messages from all the clients and sends them to those Brokers, the third role, who have subscribed to specific clients, will receive the data [23]. In the pet feeder application, the client is the ESP32 who is publishing the sonar distance values to the Thingspeak server. The Broker is the Thingspeak server which is managing all the data. The subscriber is the persons' Thingspeak account through which one can see the data which he has subscribed to.

The first step for using Thingspeak is to create an account in the Thingspeak website and note its channel ID. Next step is to note the Read API and Write API key. The Read API key allows to read the data and in contrast the write API key is used to write the data. In the code, first thing is the initialization of the SSD1306 LCD screen so that data can be displayed at each step throughout the code. Secondly, the ESP32 is connected to the Wi-Fi network. This is done by importing the network library and creating the object **wlan**. This object is used to enter the network access point (AP) credentials namely username and password of the Wi-Fi network. The next step is to connect to the MQTT server which is **mqtt.thingspeak.com** for connecting to the Thingspeak. The **MQTTClient()** is the function which takes the server address and topic name as inputs. The topic name is always written something unique to avoid any similarities with other topics over the same server. The function also takes another input **ssl=True**. The Secure Sockets Layer (SSL) is an extra layer of security. Although, the code suggests that MQTTClient is using SSL, but it is using TSL (Transport Security Layer) using the old name SSL [21]. This extra layer of security encrypts the data. The TSL handshake will begin by client specifying the TLS version being used, followed by which cipher to use, then authenticating the server identity using the server's public key and the SSL certificate authority's digital signature. Then the data can be transmitted in the encrypted form [19].

Before the TSL can begin, the TCP handshake, transport layer in network model, is established which is a three-way handshake protocol. This starts by client sending the SYN, Synchronize, message with unique synchronize sequence number to the server. The server, then responds with the SYN-ACK, Synchronize-Acknowledge, message to tell the client that it can now start communication. The client sends back the ACK signal to the server to establish a complete path of communication [24]. The SSL and TCP encryption can be seen in figure 5 below.

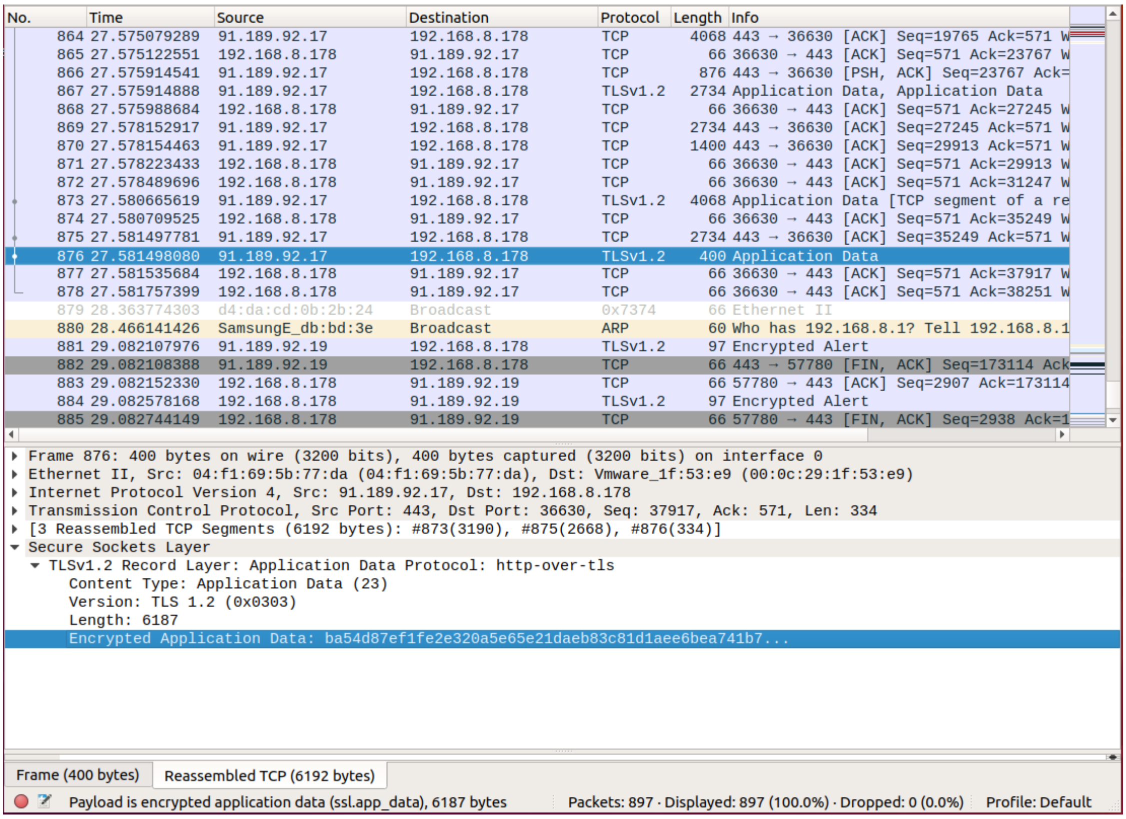

Figure 5: Encryption in SSL layer (last blue highlighted line)

The next part of code is to configure the pins of the sensor and servo motor. Then the code goes into the while loop which will run forever until the main power to ESP32 is not cut. At the beginning of the loop, the current sonar reading is taken and displayed on the screen. Then the if condition is applied to check weather the distance is higher than the limit or not. If the distance has crossed the limit, it means the plate is empty and the servo motor is rotated anti-clockwise and back again to refill the plate. This distance is then published on the Thingspeak server. The publish function takes the topic name and the distance value as a string in the input. The topic name structure should be **"channels/" + CHANNEL_ID + "/publish/" + API_KEY** where channel ID and write API key are written from the Thingspeak account as explained above.

Testing

The testing of the code is carried out in the Micropython flashed in ESP32 using Thonny IDE on Linux Bionic Beaver Virtual Machine [5][16]. In the code, the data is only being published to the server but not being read from it. The code to subscribe is also written in the commented section for demonstration only. There were many ways to encrypt the data in order to improve the security but most of them can be hacked given their decoding algorithms are already available on the internet. The best way to secure the transmission is either use SSL certification as used in this project or to use AES cryptography method to encrypt the data. The AES could be implemented using the ucryptolib but it caused the variable size to increase beyond its limit when publishing data [6]. The error says **pyaes is 49kb but could not allocate 136 bytes**. The information on the internet was not very helpful to provide the solid reason for this error. Further, given the potential threat to the system, using the AES to encrypt the data will not be necessary since it is only the sonar distance that is being published.

The Thingspeak gives the option to make bespoke plots by reading the values and using them in the plot functions with the MATLAB coding syntax. This flexibility allows to manipulate the data, if there is any need to evaluate mean, median, or etc. The monitoring is done using four plots. The first plot is the default line plot, figure 6, which shows the sonar distance values for last 24 hrs. The second plot, figure 7, is the same plot, but it was coded manually and with proper axis headings. This plot is created with intention to manipulate later for mean visualization. The third plot, figure 8, shows the current distance value of the sonar sensor. This plot is created to calculate the time it takes to upload the data on the Thingspeak. The fourth plot, figure 9, is the meter that can be used to visualize the amount of feed left in the plate. If the meter is pointing near the red region, it means that there is very small amount of feed left in the plate.

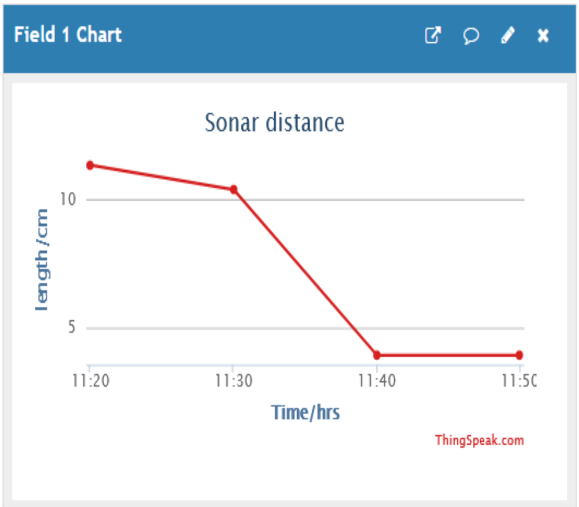

Figure 6: Default line plot

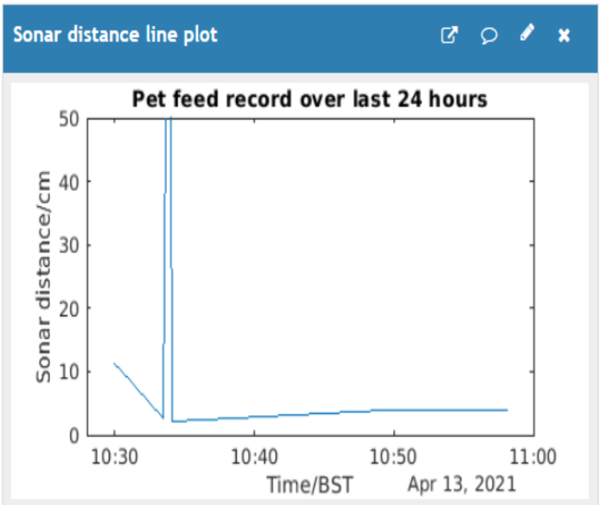

Figure 7: Coded line plot

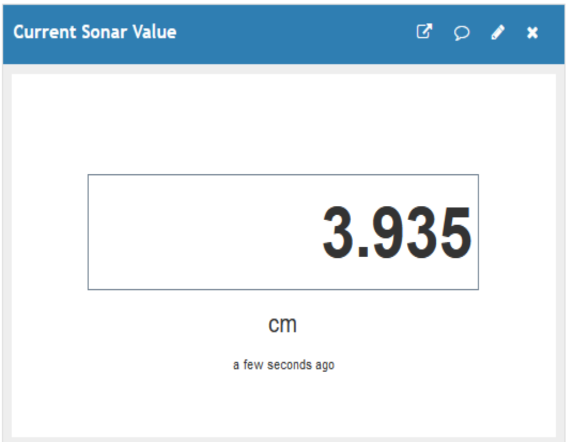

Figure 8: Sensor current vertical distance

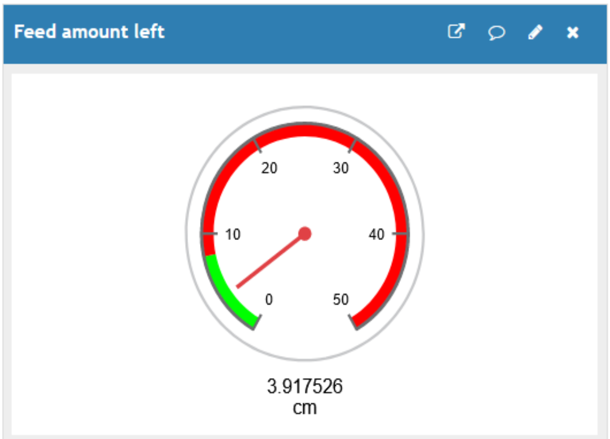

Figure 9: Amount of feed left in plate meter

One practical issue that was experienced during the testing was that the servo motor used is small for the purpose. The easiest solution is to use a bigger motor. Another possible solution is to use vertical bottle shaped container full of feed which is cut from the bottom so that whenever the plate is empty it can fill it by rotating the flaps attached to its outlet. This can be done using the cereal dispenser as shown in the figure 10 below.

Figure 10: Alternative solution to using bottle

Evaluation

The main cost of the system consists of:

- ESP32 microcontroller costs 7.7£ [2]
- HC-SR04 sonar sensor costs 3.26£ [9]
- SSD1306 OLED screen costs 5.5£ [3]
- SG90 mini servo motor costs 3£ [11]
- Connecting wires costs 8£ [8]
- Breadboard costs 9£ [4]

The above listed items are those used in the system. The additional cost of Thingspeak yearly subscription can also be considered if the upload time is to be reduced to 1 second. The minimum subscription costs 65£ per year [10]. The messaging service costs 0.0284£ per SMS. If there are roughly three alerts per day this would make 1095 days which makes 31.3£ per year for messaging service [15]. The total will, therefore, be 132.8£ out of which 36.46£ is for initial setup. Although the need for short upload time is not a necessity in this project therefore, the yearly total will be only for message alert costing 31.3£. The below are some of those items that can be used to improve the sophistication of the system.

- Cereal dispenser (19 ounces) costs 9£ [7]
- High torque servo motor costs 18.4£ [14]

The entire system does not seem very essential part of the daily routine, but when installed it is an extremely practical solution especially for those who have rotational duties throughout the week. The feed can be filled in the container attached above so it can fill the plate in small amounts timely. One further advancement in the system will be to use time setting so that plate is automatically filled at specific times of the day and it schedule can be set through the Thingspeak UI. The Wi-Fi at home uses 2.4 GHz band which allows range of 75-100 ft with 11Mbps download and 2 Mbps upload speed, the 802.11b standard same specifications as the ESP32 [20]. On this speed, the data is published between 15-25 seconds. To reduce the power usage to the system, ESP32 hibernation mode can be used which can be set to hibernate during the night times [13]. The system is powered with the mobile charger power brick which provides the 5V and up-to 1A of current to power the ESP32. The controller worked fine with no heat ups for hours.

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