Development of Semi-Automatic Quail Egg Incubator System

Observational Study

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Abstract

An incubator which uses a common microcontroller that becomes an IoT to visualize data whilst hatching quail eggs in the process. The project aims to be the low-cost solution for any hobbyist and increase the chance of eggs hatchability for small or medium-sized amounts of fertile eggs. Factors that were considered into the design of the incubator are the temperature and humidity, which were around 37 degree Celsius for temperature and humidity range of 50-60% for hatching quail eggs during the first two weeks of and was maintained at 37 degree Celsius and humidity of 65-75% until hatching. The temperature and humidity readings from the DHT-22 sensor are filtered with the Kalman filtering algorithm to reduce the reading noise. The status condition of the incubator is visualized on Grafana, which shows the stability of the incubator over time. 4 amounts of clean, healthy, and well-developed quail eggs are successfully being hatched from this incubator design.

Keywords: **Egg Incubator, Kalman Filter, Candling Experiment, Period of Incubation, ESP-32, Grafana, InfluxDB**

Section 1: Introduction

Nowadays, incubators are a well-established technological device that are used in the poultry industry. The increasing use of incubators is to be encouraged, since it has become an important factor in the extensive development of the poultry industry. In incubation, the fundamental objective is to get the largest possible number of chicks that are in proportion to the number of egg sets. However, the result lies between the process of natural and artificial incubation.

The apparent difference between them is that the natural process involves a parent taking care of the eggs through the providing of the right temperature through contact, whereas the artificial process can only imitate nature since it is a sensitive process because certain variables are necessary to be monitored in order to have a successful hatching. In our case of research, it would be an artificial process that entails making the incubation and hatching process a semi-automatic one. With it being a semi-automatic incubator, several important elements could be taken care of such as the temperature, humidity, ventilation, and the cleanliness of the incubator itself are also being managed.

The concept designs that the group built are almost similar to one another, with a plastic box for the incubator, but the other electrical components differ from each individual. Some used more than others, and some used less. Three of the group members decided to store their sensor data to a time-series database called "InfluxDB" that will be sent and shown in an analytics and interactive visualization web application called "Grafana" which allows the researchers the capability to monitor the temperature and humidity of the incubator in real-time. The use of Kalman Filter was also put into effect as a way to keep track of the estimated state of the temperature and humidity and also to reduce noise as much as possible.

1.1 Drawing Concept

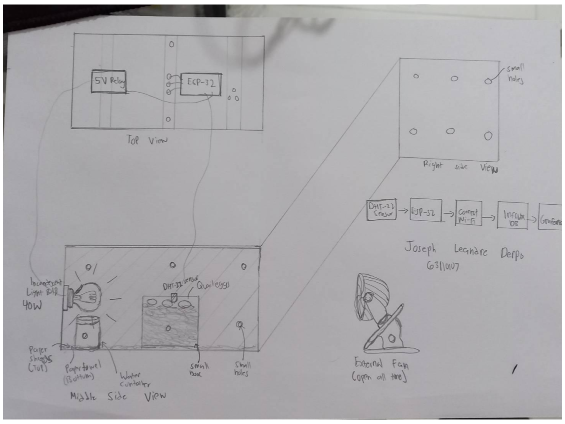

Figure 1: Joseph's Drawing Concept

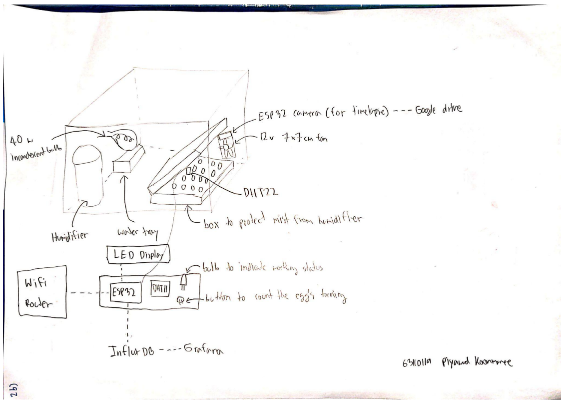

Figure 2: Piyawud's/Micro's Drawing Concept

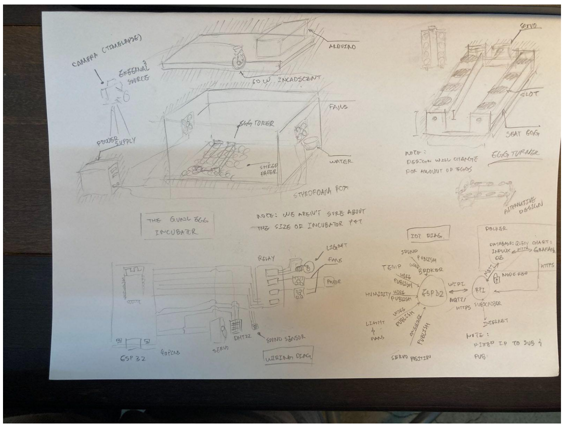

Figure 3: Chern-Tay's/Kevin's Drawing Concept

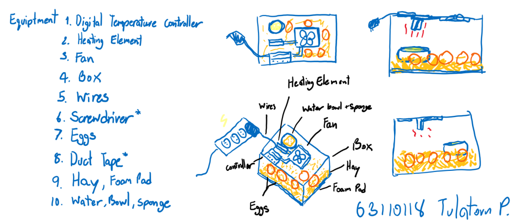

Figure 4: Tulatorn's/Jul's Drawing Concept

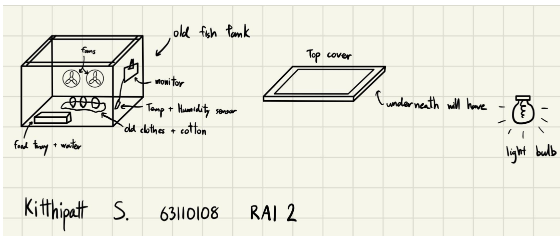

Figure 5: Kitthipat's/Chaaim's Drawing Concept

1.2 Actual Implementation

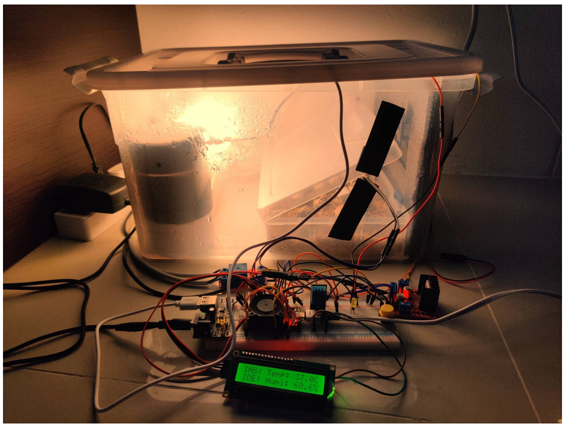

Figure 6: Piyawud's/Micro's Actual Implementation

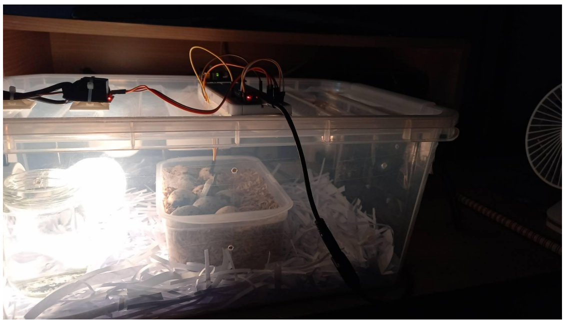

Figure 7: Joseph's Actual Implementation

Figure 8: Kevin's incubator implementation. Weed growth can be seen near the water source.

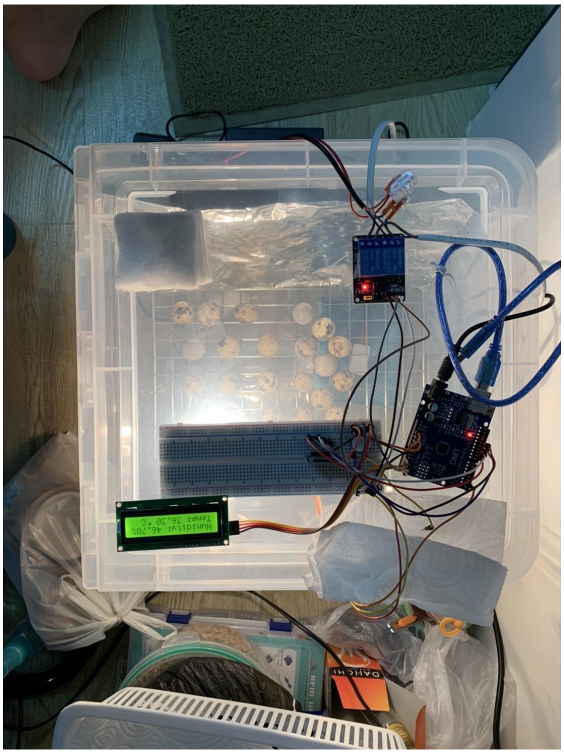

Figure 9: Jul's Actual Implementation

1.3 Considerations of the Incubator

The incubator should be made with readily available materials that common people can get with little to no cost, and the incubator is large enough to be able to hatch different shapes and sizes of eggs. Also, the incubator should have higher capacity compared to the natural methods that mother chickens use and should be simple to operate and maintain by anyone who does not have any formal education regarding taking care of poultry.

1.4 Considerations of the environment

In the development of the smart incubator, sanitation, humidity, temperature, and ventilation are the important environmental factors to be considered in the development of the incubator. The conditions of the surrounding environment around the incubator is equally important, where the temperature and humidity may affect the hatchability of the eggs.

1.5 Materials of the Incubator

The materials used to create each of the incubators of the researchers were carefully chosen and inspected with the intention of not having any implications during the incubation period as well as the hatched period. Some of the electronic components were bought by the researchers, but the microcontroller was given in order to make use of it for IoT.

1.6 Considerations of Factors affecting the Performance of the Incubator

It is also essential to mention that there are factors that were taken into consideration that might affect the performance of the incubator, such as a possible blackout, electronic components' failure, the bought quail eggs being bad. Not to mention, the significant conditions needed to hatch the egg can also markedly affect the performance of the incubator in terms of hatching the quail eggs It is also worth remembering that temperature factor brings a dramatic effect on the hatchability of the fertile eggs (Harb et al, 2009).

Section 2: Theoretical Background

2.1 Period of Incubation

Species	Incubation period (Days)	Incubation Temperature (Celsius)
Chickens	21 (bantams: 20)	37.5
Ducks	28	37.5
Muscovy Ducks	35	37.5
Geese	28-33	37.5
Turkeys	28	37.5
Coturnix Quails (Japanese)	16-18	37.5
Bobwhite Quails	23-24	37.5
Guinea Fowls	27-28	37.5
Lovebirds	23	37.5
Pheasants	24–26	37.5
Peacocks	28	37.5
Ostriches	42	36.1

2.2 Humidity

Eggs have porous structure on its shell where the water evaporated from which the eggs lose water during the incubation period due to the heat and other factors, to overcome the rate of the water loss of the eggs, the incubator must maintain the relative humidity within the reasonable range for each type of eggs — 45% for quail eggs during the first 15 days and maintained at 65% three days prior to the hatching (Lane, 2020). The humidity inside the incubator will be read by the DHT-22 sensor. The farm that the eggs were purchased from specifically stated that the humidity should be 60±7% throughout the incubation and lockdown period

2.3 Temperature

Temperature is an extremely important factor that could determine the life and death of the embryo. Variations of more than one degree from the recommended range will adversely affect the number of eggs that will successfully hatch. In this project, we will use 50-75 watts as the heat source within the incubator. The bulb would be put in the far end of the incubator where it is not hitting directly on the eggs in the close distance for effective heat distribution. The heat supplied through the bulb can be controlled by the relay used in the system, though you could manually turn on or off the bulb. There are at least two fans being used within the incubator for evenly distributing the heated air throughout the incubator.

A DHT-22 sensor was installed within the system to monitor the temperature of the inside air. However, the set temperature was between 37 and 39 degree Celsius during the first 15 days of the incubation period as if there is a fluctuation in temperature within the incubator can affect the hatch rates or hatchability of the eggs, so it is best that the temperature could be maintained at 37.5 degree Celsius until hatching that could potentially provide the best result in hatching the eggs. The farm that the eggs were purchased from specifically stated that the temperature should be maintained throughout the incubation and lockdown period.

2.4 Sanitation

The cleaning of the enclosure needs to be taken care of before and after hatching the eggs. The system and the environment need a proper cleaning before the eggs can be set, in order to avoid pathogens or other infections which can kill off the embryo during the hatching process. After the hatching process is over, the incubator's enclosure must be treated by removing the leftover eggshells, unhatched eggs in the incubator for the next hatching.

2.5 Ventilation (Fans)

Ventilation within the incubator could help decrease the humidity of the incubator and regulate the temperature to be more stable. As well as, exchanging the oxygen and carbon dioxide within the incubator, where oxygen is necessary for embryo development (need to source this) since that the embryo releases carbon dioxide when it receives the oxygen.

If there are more eggs, then there needs to be more fans to exchange air within the incubator. Taking into consideration that each fan can exert a set amount of CFM which, we could calculate how many minutes could the fan exchange the air within the volume entirely — the shorter the time needed to exchange the air, the better.

The better the ventilation inside the incubator is, the faster the moisture on the surface and in the air can be exchanged with drier air from the outside, though it might not be a significant difference since that the fans that used in the ventilation system can only help with humidity as much as the air circulation that the fans could displace. The fans in the ventilation system cannot remove humidity directly, they can only help mitigate the humidity.

The fans that were installed into the incubator was a 5V DC Fan, but there is one case where someone strayed from actually installing it into the incubator, rather putting an external desk 5V DC fan facing towards the incubator. The fan speed was kept as low as possible throughout the incubation and hatching period.

2.6 Turning of Eggs

The embryo will form on top of the egg yolk during development. If the eggs are not turned, they will become stuck to the shell membranes, causing the embryo to die (Brinsea, 2016). To prevent the eggs from sticking to the wall, turn them at least three times a day, while five times is better (Lane, 2020). It is preferred to stop turning the eggs at the 15th day of incubation, since the eggs are nearly fully developed and will position themself inside the eggs to prepare for hatching.

Another advantage of egg turning is that the embryo will be exposed to fresh oxygen and nutrients while the metabolic wastes are moved away from the embryo, resulting in healthy development (Brinsea, 2016). The eggs were turned every 4-6 hours so there would only be 3 rotations at max for each day.

2.7 Handling of Eggs

If we do not have an egg turner, which we may need to handle the eggs by manually turning the eggs by ourselves, there is a factor that needs to be considered when handling the eggs by hand is your sanitation and the heat being dispersed to the room. If your hands are not sanitized, you may introduce infections that could immediately kill off the embryo and fail the hatching. If you handle the eggs too long while the lid of the incubator is open, the heat may be dispersed into the surrounding air, which may lead to longer periods of time to stabilize the temperature of the incubator. It is best practice to slightly lift the lid or at a 45-degree angle at maximum to prevent the heat from dispersing into the air too quickly, or simply that closing the lid while handling the egg is the best way to prevent any heat dispersing into the air entirely.

2.8 DHT-22 Sensor

DHT22 is a temperature and humidity sensor, where the sensing element is connected with an 8-bit or 32 bits microcontroller. It is a small size and low consumption sensor that is suited for both hobbyists and small-scale businesses to use in harsh environments. The sensor uses polymer capacitor to sense the temperature and humidity, its operating range for temperature range from -40~80 degree Celsius with the resolution of 0.1 degree Celsius and accuracy of +/- 0.5 degree Celsius, and humidity ranging from 0-100% RH with resolution of 0.1% RH and accuracy of +/- 2% RH. The sensor can be powered from as low as 3.3 volt to as high as 6 volt DC voltage, which makes this convenient for anyone to use it with IoT or small-scale devices.

2.9 ESP-32

The ESP-32 is a powerful microcontroller that is low-cost and uses a low-power system with built-in Wi-Fi and Bluetooth. Since the device itself is equipped with a dual-core system in which the microcontroller structure operates under various protocols — TCP/IP, full 802.11 b/g/n/e/i WLAN MAC, and Wi-Fi Direct specification or a Wi-Fi P2p Protocol that can act as a station and be connected to the internet or server and access point in order for user interface to be provided (Maier et al., 2017). On the ESP-32 microcontroller, the practical implementation of many applications such as communication, data visualization, and processing of measured data from IoT sensors can be achieved (Babiuch et al. 2019).

2.10 ESP-32 Cam

ESP-32 Cam is a low power consumption camera module based on ESP-32. The camera comes with a field of view of 66°, with the ability to connect to Wi-Fi and Bluetooth. It also comes with a microSD card slot for storing pictures and other data. For this project, it is used to take the picture every minute and upload it to Google Drive to monitor the process and make a time-lapse video. However, with the field of view of 66° being too narrow, changing the module lens to a field of view of 160° is better since it has more viewing angle.

Aside from sending the picture to Google Drive, it can also send to the Line messaging application or even make a real-time video live-streaming on a webpage. But it might consume too much power and overheat itself, therefore, it will not be implemented in this project.

2.11 Relay & Stepper Motor

A relay is a programmable electrical switch that can be turned on or off by any microcontroller — even the ESP32, which has a 3.3V output voltage. A common relay can operate any AC voltage between 5 and 220 volts, allowing us to control any household item, including an incandescent bulb that functions as a heat source for our incubator.

2.12 Candling Test Experiment

Candling test is a method where we candle the incubated eggs to determine whether the incubated eggs are fertile and that the embryo is healthy and growing. Every different type of poultry eggs have different periods where we should first candle the eggs to determine if the embryo is alive or dead.
Holding any light source near the egg that could shine through the eggs to see the inner contents of

the eggs. If you candle the egg where the egg shows no embryo, very rough blood ring, ruptured air cell, detached air cell, or cracked shell, then the eggs are bad and not hatchable anymore.

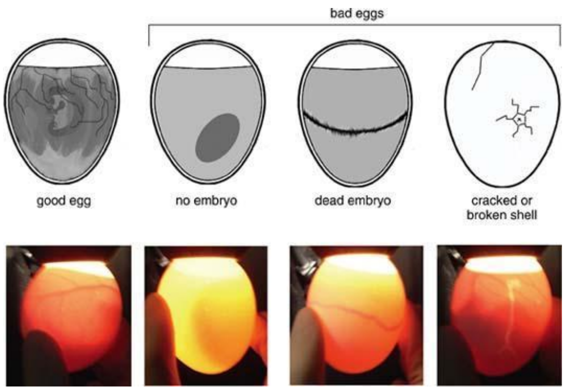

Figure 10: The difference between the good egg and bad eggs during the incubation period using the candling test.

You do not need to candle the incubated eggs every single day other than doing research where you may need to record the progress of the embryo's development since you may want to reduce the chance of exposing harmful infections that could kill the embryo during its development.

2.13 Kalman Filter Algorithm

The Kalman filter algorithm would be the best possible choice to reduce the signal reading from the DHT-22 sensor, which keeps track of the estimated state of the system. Assuming the worst for the quality of the temperature and humidity sensor that the reading fluctuates. Since the incubator's temperature and humidity are continuously changing, it would be suitable for Kalman Filter to be put to use since it is well suited for real-time monitoring.

From the Kalman filter formula in 1 dimensional system:

$$KG = \frac{E^{err}_{est}}{E^{err}_{est} + E_{mea}}$$

$$EST_{k+1} = EST_k + KG(MEA - EST_k)$$

$$E^{err}_{est_{k+1}} = E^{err}_{est_k}(1 - KG)$$

We applied these equations into our program using the measured error (E_{mea}) and estimated error (E^{err}_{est}) from the DHT22's specification page, and we acquired the initial estimated value (EST_k) by measuring 50 data samples and averaging it out during the ESP32 startup procedure. Those values are then going to be changed into the previous measured/calculated values at the end of every programming loop.

2.14 Networking (Network Configuration)

A) Local Database and Visualization Server

On the ESP-32, the ESP-32 will connect to the local network via wifi. The ESP-32 will connect to the MQTT server which is being specified in the program, if the connection is successful, the ESP-32 will start publishing formatted data in JSON format to the server. The MQTT Server will be the gateway to publish the data to other services.

In this case, the data will be sent to the NODE-RED (Fig. 10) to filter the incoming JSON string format data to integer value and publish it to the InfluxDB database server. The InfluxDB will save the data with a retention policy set by the user before the oldest data will be expired and deleted.
Grafana will pull the data from the database that the client user specifies, which will be visualized on the webpage. (Fi 1)

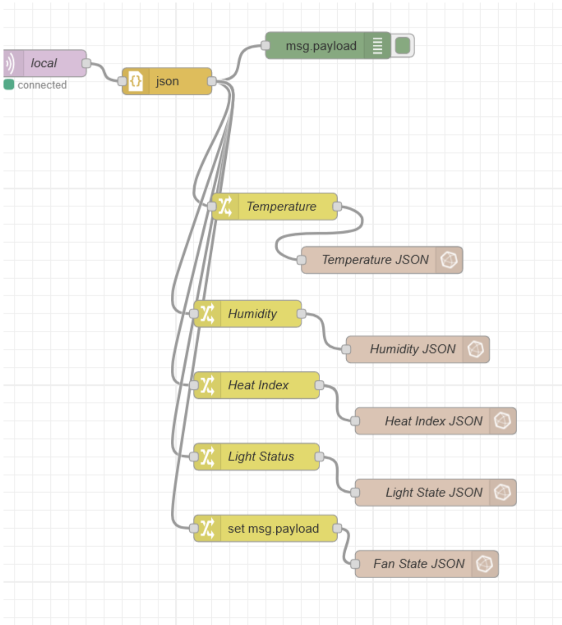

Figure 11: The node design of the NODE RED to filter and convert the data to send the payload to other service

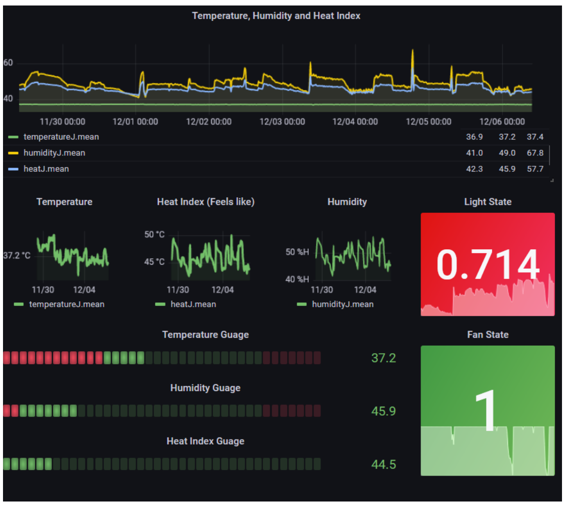

Figure 12a: Grafana Dashboard showing what kind of data can be visualized on the web

B) Cloud Database and Visualization Server

Register accounts on both InfluxDB Cloud and Grafana Cloud service which the InfluxDB website will show the URL for the user to connect to which is specified in the code. ESP-32 will first connect to the WIFI, and then the ESP-32 will connect to the InfluxDB cloud domain that the InfluxDB Cloud provides which the ESP-32 will start publishing the data to the cloud database. The Grafana Cloud will subscribe and pull the data from the InfluxDB cloud to Grafana to visualize the data.

2.15 NODE-RED

NODE-RED is a programming tool for connecting hardware devices, APIs and other services for the Internet of Things. NODE-RED works as a flow-based virtual programming platform, and each function is a node, hence the name. It can be hosted anywhere and provides a browser-based editor that could be easily accessed by anyone and deployed with one click after done. In Kevin's application, his NODE-RED flow talks and subscribes to the MQTT communication protocol to receive the data which the MQTT server is a local server that he has hosted. His nodes (figure 12b) consist of a JSON conversion node where the incoming data will be converted into a JSON format file that is readable for the database server. He also has a debug node where he could locally debug the issues if the data is not coming through. The rest of the flows are to filter which data in the JSON to be published to each different data point where it will push toward the InfluxDB.

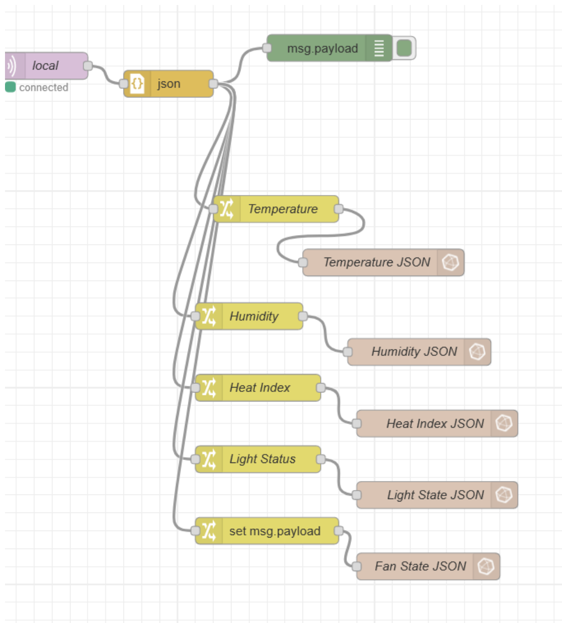

Figure 12b: NODE-RED flow

2.16 Data Logging

Considering that the incubator incorporates Internet of Things (IoT) within the system to be able to let the user monitor the incubator in the distance.

The ESP-32 can send data using MQTT protocol over the internet to a database, where the database can publish the data to a visualization software that users can access to view their real-time data. Using Grafana as the service to visualize the data, the graphical user interface will display as much data as the user set it to display, but in this case, Grafana will primarily visualize temperature and humidity.

Figure 13 shows the graphical user interface of Grafana displaying the temperature and humidity reading. The user could access Grafana via typing down where the Grafana is being hosted locally or if the user wishes to expand the hosting service by setting a domain name that the user could access anywhere around the world.

Figure 13: The Grafana Dashboard displaying all data.

Credit to: Cherntay Shih.

2.17 Methodology

A) Method and System Design

- The design is needed to mainly focus on controlling temperature and humidity of the egg incubator. We use a light bulb (25W-40W)/heat element to increase the temperature in the egg incubator — depending on the size of the incubator.
- A fan was used to decrease the temperature and humidity in the egg incubator.
- We used a DHT22 sensor to measure the temperature and humidity in the egg incubator (which can measure a real time temperature and humidity every 2-10 seconds).
- An I2C LCD was used to print the sensor reading of DHT22 in real time.
- A relay was used to control the temperature by turning on the heat source (light bulb/heat element) when the temperature is too low (<37.7degree Celsius) and turning it off when the temperature is too high(>37.7 degree Celsius).
- For the fan control, it will turn on the fan when the humidity is too high (>67% on day 1-13, >75% on day 14 or above) and turn on when the temperature is too high (>37.7 degree Celsius)
- In addition, we can add the active buzzer to alert when the humidity is too low or too high so that we can adjust it manually if the system is having some unfortunate conflict.

B) Incubator Procedure

- Sanitize the incubator with bleach or isopropyl alcohol and let the incubator soak with it for at least 10 minutes
- Alternatively, using warm soap water can work as another sanitizing solution
- Rinse the incubator with water to clean any chemical residue, then let the incubator dry before the next step. Please do not dry the incubator in a dirty area or area where there might be air residues floating to avoid contamination.

- Prepare the incubator like what you design
- Do a dry test run to check if the temperature and humidity is stable
- Put your eggs in the incubator and the DHT22 sensor close to the eggs.
- Turn the eggs at least 3 times per day until the lockdown.
- Add water when the water bowl becomes dry or the incubator relative humidity is too dry (below 45%)
- During lockdown, watch the quails hatch from the eggs and let the newborn quail's feathers dry before moving the newborns to the brooding pen.

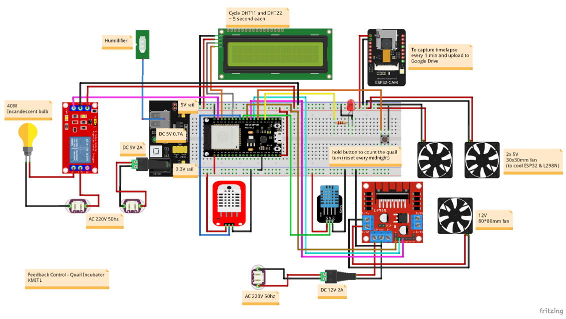

Figure 14: Circuit Diagram of Incubator

Credit to: Piyawud

C) Hardware Design

The container/box shouldn't be too large or too small. For each egg (quail egg) it will need about 3 square centimeters, so the size can depend on how many eggs you want to hatch at the time. The position of the heat source shouldn't be too far to the egg and DHT22 sensor, and shouldn't be too close to the egg and DHT22 as well. The position of DHT22 in the egg incubator should be approximately 1-2 centimeters above the egg. In the egg incubator, you should put a tray containing water and a wet sponge as well. The egg incubator should have holes for air circulation and to intake the oxygen from outside air.

- Tips: the humidity will increase faster if we use warm water instead of room temperature water.
- Tips: Adding fans to regulate the relative humidity is a plus for the incubator, as it disperse the humidity to the atmosphere within the incubator more equally. Though, the duty cycle of the fan should be low if the incubator volume is small.

Locate every electronics device out of all the sides of the incubator and isolate the live wire with electrical tape or heat shrink tube to prevent shock or any danger, or locate the live wire to an area where it is unlikely that the end user will contact the wire.

Not to mention, the incubator boxes that all the researchers have used were made of plastic that were drilled with tiny holes as a way to control the humidity inside.

D) Interface Design

The user interface design that the research is simply done through the visualization of the temperature and humidity in Grafana so that the incubator can be monitored whenever the observers are not present, the convenience of finding out if the temperature and humidity has been stable or gone badly. With Grafana, the temperature and humidity average, maximum, and minimum value could be determined. It also gives the observers a better way to visualize the Kalman filtered temperature/humidity vs raw temperature/humidity on the graph.

Another way is to show the monitoring data displayed on an I2C LCD which shows the temperature, humidity and to warn us of any anomalies in the incubator system.

Figure 15: LCD Display showing a reminder
Credit to: Tulatorn

2.18 Verification and Validation (Static checking, warning, peer reviews, testing and test plan, issue tracking and analysis, run-time error logs)

We tested our system and left it for at least a few hours to ensure that our temperature and humidity would stay within the margins during the incubation process. We then reported the status to the group members, as well as offering assistance to each other when one of us encountered an issue. Furthermore, we also report and seek guidance from someone who has prior experience hatching quail, and we double-check our findings with them.

2.19 Critical System Properties (dependability, security, safety, watchdog timers, and system reset)

For the dependability of the critical system, some of the researchers have little trustworthiness on its incubator since there are some problems that occur during the monitoring of humidity: it's either the humidity source is not working well the humidity has to be manually controlled which is why it leaves us with little to average safety as possible since it can operate decently without a catastrophic failure happening. For the security, some of the wires connected to the various electrical components are located outside of the incubator in order to avoid the spillage of water when changing the water tray on the wires connected to the esp32, relay, and light bulb.

The critical system's reliability of the incubator seems to be doing well since it is able to carry out the appropriate temperature and humidity needed to be kept. For the system reset, there is no need to worry about the loss of data since it is all being transferred to InfluxDB and whenever the esp-32 loses connection to the Wi-Fi, it can just be reset.

Kevin's implementation has deep sleep in the code for the ESP-32 to go into a deep sleep state to save some energy, it is required for his system to reset the Wi-Fi connection to the server without any congestion or connection error when trying to connect after waking up. The system has a reset rule where if the ESP-32 is not able to disconnect itself from the network, it will force a reset itself and assign a new ID to prevent a long downtime.

Section 3: Results and Discussion

3.1 Embryo Development

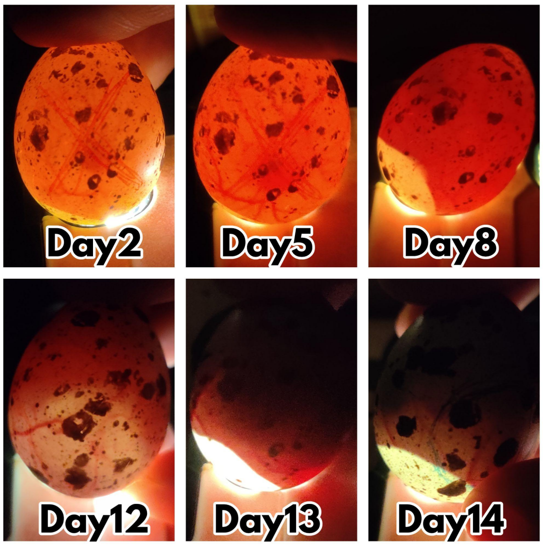

Figure 16a: Embryo Development (Day 2, 5, 8, 12, 13, 14)

Credit to: Piyawud

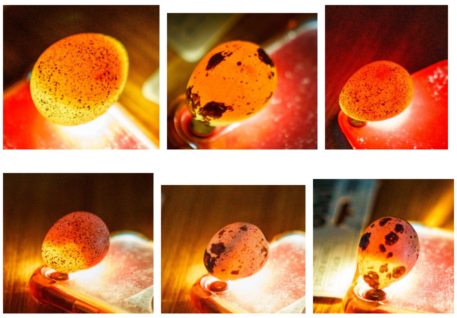

Figure 16b: Embryo Development (Day 3, Day 5, Day 7, Day 10, Day 10, Day 13)

Credit to: Chern-Tay

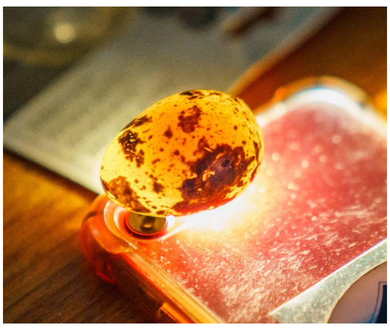

Figure 16c: Unfertilized egg

Credit to: Chern-Tay

Figure 16d: Embryo Development (Day 5, 7, 11, 13)

Credit to: Joseph

3.2 Temperature and Relative Humidity (%RH) Records

Figure 17a: Temperature vs Kalman Filtered Temperature (Day 16)

Credit to: Joseph

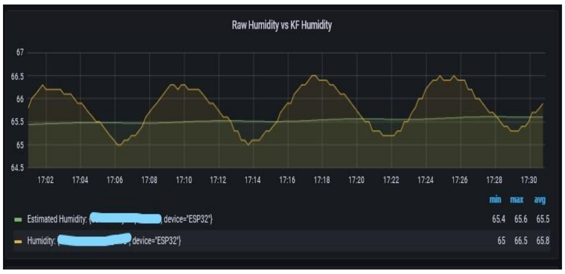

Figure 17b: Humidity vs Kalman Filtered Humidity (Day 16)
Credit to: Joseph

Figure 18: Humidity & Temperature (Day 10)
Credit to: Chern-Tay

Figure 19: Kalman Filtered Temperature & Humidity (Day 1 - 19)
Credit to: Piyawud

3.3 Successful and Failure Results

Figure 20a: Hatched Quail
(From left to right: Ang, Darwin, Emmy)
Credit to: Piyawud
See the video: www.smu.sg/G9Quail

Figure 20b: Fully developed quail but unable to hatch
Credit to: Piyawud

Figure 20c: Soon-to-hatch Quail
Credit to: Piyawud
See the video: www.smu.sg/HatchingSoonMicro

At the time of writing (day 19 of incubation), Piyawud, one of the group members, has hatched 3 of the 12 eggs. Six of them died, either as a result of the excessive humidity or because they matured successfully but were unable to shatter the shell (figure 20b). The rest of them (three) are still alive and trying to crack the shell (figure 20c), which will take them anywhere from a few hours to a day until they hatch (there is an audible sound of the quail poking their beak against the shell). From figure 20a, Emmy came out 12 hours ago, and is still trying to stand since her toes are not fully extended (which can be solved by using a tape). Darwin and Ang, who arrived less than an hour ago, also have them, but with greater or lesser curls. Nonetheless, they all appear to be quite strong and moving nonstop.


Figure 21: Hatched Quail (Big Tweety)
Credit to: Joseph

In the case of Joseph, out of all the 13 quail eggs delivered, only one was successful to get out. Well, there are 2 more eggs, but they still needed a few more days to be developed. It is the almost same case as the first researchers, the quail is nearly developed but its unable to hatch. The hatched chick couldn't stand for a few hours, but it seemed really active. By active, it was kicking its feet and rolling all over the incubator. The chick is still gathering its strength up since it has been recently hatched and that it will be able to move quite well by the next day.

As for Jul's and Kevin's, their eggs are incubated a little bit too late for the schedule which lead to not being able to hatch on time for the deadline though there are still hopes since that the eggs are still alive as of the writing for this report.

3.4 Personal Discussion

Kevin: There are 23 eggs delivered, where one of the eggs have a shell broken probably due to the poor handling of delivery and another one of the eggs is unfertilized after discovering it during the 7th day of incubation. The remaining eggs after the close inspection shows that the embryo is alive and well.

Joseph: There were 13 eggs delivered from the Klaeng Farm in Shopee, but when it first arrived, the researcher took a good look and spent time inspecting each of the eggs only to notice that there was one egg that was broken since the rice husks/hays were sticking to the egg. Throughout the days of incubation, the researcher noticed that two of the quail eggs did not have any movement on the 13th day, perhaps the egg must have died due to it being far from the heat source. Other than that, the 7 remaining eggs either had movements or it's completely dark to see. At the end of the hatching period, it all came down to 1 egg hatched and the chick is a bit weak as well, but it is alive and kicking. Like what was mentioned previously, the chick was still gathering its strength and might be able to move the next day. All of these were possible due to a careful surgery for an emergency rescue as advised by the farm.

Piyawud: There were 23 eggs delivered from the farm; however, the container condition did not appear to be good, since one egg cracked due to a large dent on one of the corners (perhaps caused by the shipping procedure). The researcher noticed that ten of the eggs were not fertilized on day six of candling, causing only 12 of them to continue their journey. On the 14th day of candling, the researcher can see some embryo activity in 9 eggs, while the remainder are too dark to see anything. One of the eggs pipped on day 17, but it remained in the same condition for about 18 hours. The researcher decided to assist it in removing the crust and discovered that it had died, most likely due to a lack of ventilation. On day 19, he decided to execute an emergency rescue on the egg by delicately removing the shell using a tweezer since the expected hatch date had gone. He was able to help three of the alive chicks hatch (section 3.3), while the rest might hatch soon or have died.

Section 4: Conclusion & Recommendation

4.1 Conclusion

To conclude, since that, we are racing against time and have not considered that the eggs will not hatch as what we theorized it to be. We were able to hatch a few eggs, and those fortunate ones had to be saved from the egg since it was going to be past its hatching period. This was all achieved through the development of a quail egg incubator with an ESP-32 connected to a DHT-22. The incubator system was able to control temperature as well as the humidity, but the turning of the eggs was done manually by the researchers.

For the process of monitoring the temperature and humidity, it was all done through the use of an open-source time series database called InfluxDB, which will be monitored and visualized in an analytics and interactive visualization web application called Grafana that allows us to monitor whenever the researchers are not present within the premise. The hatching of the eggs were possible due to the advice given by the farm, the researchers were notified to quickly and gently open the eggs since the chicks are in dire need of being rescued.

4.2 Recommendations

The observational study was done through the building of an incubator that harbors eggs bought online from a farm in Rayong, the study was conducted to monitor the eggs' development throughout a total of 17-18 days. Since some of the eggs were cracked, it would be recommended that total proper care and handling should be given to the eggs.

It would also be worth noting to find a better and longer cable to connect the esp32 into a power supply, so that it won't disrupt the connection to the Wi-Fi since the port of the USB cable is quite loose.

Since the incubator must operate constantly for 17 days, having a backup power supply for the ESP32 would be useful to keep it operating throughout the blackout.

4.3 Impressions and Lessons Learned from the Project

Micro: I'm extremely impressed with the real-world application of the Kalman filter method, which helps in the smoothing of my data and graph. Controlling the temperature is quite simple in this project, but controlling the humidity is a completely different story. I have tried a variety of approaches, including utilizing a water container of various sizes, materials, and surface area, but the humidity can only stay within the desired range for a few hours—the same is true for sponges, hot water, and wet ventilation, it becomes acceptable when I replace them with a humidifier that can maintain the ideal humidity level for the majority of the time. From our research, we discovered that quails take 15-17 days to hatch, but in our situation, it takes 19 to 21 days — which was unexpected, and since few of the quail hatches less than an hour prior to this project submission, we had to rush and finalize everything. I have discovered that the quail will shake its feet and tweet loudly when it encounters cold air, and it cannot sleep properly if the environment is too cold or too bright. In the end, this makes me realize that being a father is really tiring and requires a lot of effort (but the outcome is definitely worth it!).

Kevin: Sanitization is a very essential part of hatching the eggs, since it is often that everyone's first time hatching the eggs have trouble with eggs dying. Feedback system is a hard one to control since everyone's suggestions for hatching the eggs are different, so it is mostly for the end user to get used to and use their best judgment to determine at what conditions are not safe for incubating the eggs. Having a sturdy hand and good handling ethic also further increases the survivability of the eggs, although the system is automatic, but it will not save you from being ignorant care-takers of the eggs if you do not periodically check on the eggs and see what to do next when problems arise.

Joseph: What I feel about this whole experience is that I need to be really careful in handling fragile things and to be patient in certain situations. I also need to be more attentive to the eggs' lack of ventilation, since I did not pay attention to the covering and opening of the holes.

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Works Citation

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