PALESTINE POLYTECHNIC UNIVERSITY

College of IT and Computer Engineering

Department of Computer System Engineering

"Smart Egg Incubator"

Team members

Fatima Rezq-Abu-Shaikha

Ruba Mahmoud Awawdeh

Supervisor

Dr. Mohammad Al-Dasht

Palestine
2022-2023

ABSTRACT

With the increasing number of people and the increased demand for eggs and birds of various kinds, incubators have been used to hatch large amounts of eggs and preserve some kinds of birds from extinction, but there are several problems with them, such as Egg fertility issues, issues with hatching conditions, such as problems in environmental conditions like heat, humidity, ventilation, and irregularity of turning, need supervision and intervention by the user. If the user wants to monitor what is happening inside the incubator or see if the eggs hatch, he needs to open it. The need arose for a smart incubator that could solve these problems.

Our project seeks to provide a smart system capable of providing a successful hatching process. This system is for hatching various types of eggs and allows the user to choose the suitable kind of egg to be hatched. This incubator should be able to create the perfect environment and conditions for an egg to incubate because it controls factors such as temperature, humidity, and turning the eggs and examining the embryos to exclude rotten eggs. It also provides the possibility of permanently monitoring what is happening inside the incubator remotely for a user and sending him an alert through an application when the process is complete and if any error occurs.

الملخص

مع تزايد أعداد الناس وزيادة الطلب على البيض والطيور بمختلف أنواعها ، تم استخدام الحاضنات لتفريخ أعداد كبيرة من البيض والحفاظ على بعض أنواع الطيور من الانقراض ، ولكن هناك عدة مشاكل معها ، مثل مشاكل خصوبة البيض،والمشاكل المتعلقة بظروف الفقس ، مثل المشاكل في الظروف البيئية مثل الحرارة والرطوبة والتهوية وعدم انتظام الدوران ، تحتاج إلى إشراف وتدخل من قبل المستخدم. إذا أراد المستخدم مراقبة ما يحدث داخل الحاضنة أو معرفة ما إذا كان البيض يفقس ، فعليه فتحها. نشأت الحاجة إلى حاضنة ذكية يمكنها حل هذه المشاكل .

يسعى مشروعنا إلى توفير نظام ذكي قادر على توفير عملية فقس ناجحة. هذا النظام مخصص لتفريخ أنواع مختلفة من البيض ويسمح للمستخدم باختيار النوع المناسب من البيض ليتم تفقيسه. يجب أن تكون هذه الحاضنة قادرة على خلق البيئة والظروف المثالية لاحتضان البويضة لأنها تتحكم في عوامل مثل درجة الحرارة والرطوبة وتقليب البيض وفحص الأجنة لاستبعاد البيض الفاسد. كما يوفر إمكانية المراقبة الدائمة لما يحدث داخل الحاضنة عن بعد للمستخدم وإرسال تنبيه له عبر أحد التطبيقات عند اكتمال العملية وفي حالة حدوث أي خطأ .

ACKNOWLEDGEMENTS

Table of content

List of Tables

List of Figures

Chapter one
Introduction

1.1 Overview

Egg incubator is one of the inventions that provide opportunity, especially for those who want to be excellent farmers. The incubator is a system that simulates the environmental conditions that work to provide the suitable climate and conditions of heat, humidity, and ventilation the bird needs inside the egg to complete its growth and thus the exit of the chicks from the egg without the need for the incubating mother. The egg incubator has become necessary in chicken breeding projects because artificial hatching is much easier, and hatching machines will provide a large, regular, and continuous production. But what makes our project stand out is that it has a small scope, which can accommodate tens of eggs, and anyone can use it. And it is a smart system that detects fertile and infertile eggs, it is characterized by containing more than one system according to the kinds of eggs to be hatched, This is done without human intervention.

1.2 The main idea

Our project is to build a smart hatching system capable of providing the necessary environmental conditions for a successful hatching process. This system is for hatching various types of eggs, which allows the user to choose the suitable kind of eggs to be hatched. This incubator is able to set the perfect environment and condition for an egg to incubate because it controls the factors such as temperature, humidity, and turning the eggs, and also works on examining the embryos to exclude infertile eggs. It also provides the possibility of permanent monitoring of what is happening inside the incubator remotely for a user and sending to him an alert through an application when the process is completed and if any error occurs.

1.3 Project Aims and objectives

We can summarize our objectives for this project as follows:

1. Create a smart egg incubator that provides the necessary environment for egg hatching.
2. Increase the hatching rate.
3. automatic egg turning system.
4. Remote monitoring and control.
5. Examination of egg embryos and exclusion of infertile ones.
6. Providing the ability to choose the type of eggs that the user wants to hatch.

1.4 Problem Statement

In this section, we're going to talk about problem statements that contain problem analysis and the importance of solving this problem.

1.4.1 Problem analysis

Due to the increasing number of people and the increased demand for eggs and birds of various kinds, incubators have been used to hatch large numbers of eggs and preserve some types of birds from extinction, but there are several problems with them, most notably:

1. Egg fertility issues.

2. There are issues with hatching conditions, such as problems in environmental conditions like heat, humidity, ventilation, and irregularity of turning because the eggs from some existing incubators need human intervention to do it, as well as the proximity of the eggs the walls of the incubator.

3. The need for supervision and intervention by the user.

4. If the user wants to monitor what is happening inside the incubator or to see if the eggs hatch, he needs to open it.

Therefore, we need a system that performs several operations to solve these problems in the best way.

1.4.2 The importance of solving this problem

The scope of this system will be small to suit personal use and small farms as it produces tens of eggs, and it can be changed to suit the needs of large farms. The incubator in our project, reduced human time and effort because there is an application, reduced the cost because instead of having an incubator for each kind of bird one incubator was used, and also it can provide high production accuracy thus reducing losses.

As the system examines the embryos to exclude infertile eggs, this solves egg fertility issues. and alerts the user when the hatching process begins, this makes it smart.

1.5 Project Requirements

The requirements of our project are shown below

1.5.1 List of requirements

The system requirements can be summarized as

1. The system asks the user to choose the kind of egg that they want to put in the incubator by using an application.
2. The system provides the appropriate conditions as it maintains a certain temperature by checking it with a special sensor and saves heat by turning on a heat lamp, Providing ventilation through a fan, and Providing the appropriate humidity either through a device that provides humidity using water.
3. The system automatically turns the eggs.
4. Examination of the embryos inside the eggs by shining an intense light on the egg and then taking images of eggs to analyze them to exclude infertile ones.
5. The system displays the value of each environmental condition and the number of days remaining for the egg to hatch. This is done by displaying it on the application.
6. Monitor the system by placing a camera inside it.
7. The system should alarm when the hatching process is completed.

1.5.2 Functional Requirement

The functional requirement in our project is

1. Smart system (egg examination).
2. Selection of the hatching system based on bird kind.
3. Intelligent control of environmental conditions such as temperature and humidity.
4. User-friendly system, alert the user if the process is finished.

1.5.3 Non-functional Requirement

The non-functional requirement in our project is

1. Remote access to the system.
2. Scalability: The ability of the system to deal with the increasing number of eggs without reducing the overall quality of the service provided to any eggs number.
3. Reliability: The system is intended function to do all it's under stated conditions without failure for a given period of time.
4. Response time: the total time it takes from a request until they receive a response in our system is short.
5. Security: To achieve security, we will provide authentication in the application of our project in order to prevent anyone from accessing it except the owner of the incubator.

1.6 System Description

This system works as follows:
This system works on hatching eggs according to the time and conditions required for each kind of bird. First, the eggs should be placed in the right place inside the incubator. After that, the user must choose the type of system based on the kind of eggs he lays. This system is able to hatch three kinds of eggs. The system differs from one type of egg to another due to the different conditions that suit it (such as temperature, humidity, ventilation, the full hatching period, and the number of turns).

The smart egg incubator should have good ventilation so that the oxygen content is 21% (its concentration in normal air), and the carbon dioxide content is not more than 1%.

The system begins to work without the need for any human intervention, and the farmer can monitor the eggs inside the incubator because there is a camera inside, and he is also alerted by sending a notification to him if the process is completed. The system displays the value of each environmental condition and the number of days remaining for the egg to hatch.

This system examines the egg to exclude infertile eggs, because when infertile eggs remain inside the incubator, they cause problems for other fertile eggs.

1.7 Project Limitations and features

In this section we will talk about the constraints and features of our project.

1.7.1 constraints

The system constraints can be summarized as

1. Providing an energy source to operate the incubator, which can't be guaranteed in rural areas or far from residential areas.
2. There is a danger in this process because we can lose one of the conditions necessary for hatching when any malfunction occurs in sensors or other component, and this process is usually applied to many eggs.
3. The presence of fully formed but dead chicks (due to low average humidity in some stages and a rise in other stages).
4. Some eggs hatch early and some late in the same group of eggs (due to high temperatures in the last three days and improper storage of eggs).

1.7.2 Features

1. Adding a camera to enable the user to monitor the inside of the incubator remotely without having to open it.

2. Alert the user when the hatching process is completed.
3. The project can hatch three kinds of eggs. The user can choose the kind of egg that they want to hatch.
4. Examination of the egg to exclude infertile eggs.

1.8 Project Schedule

Table 1.1: TimeTable

Task	Time (each cell represent 2 week)													
	First Semester							Second Semester						
Planning	▓	▓												
Project requirement		▓	▓	▓										
Analyzing and design				▓	▓	▓	▓							
Project development								▓	▓	▓				
Project test and maintenance											▓	▓	▓	▓

1.9 Report Outline

The rest of the report is organized as follows: Chapter 1 presents the main idea, aims and objectives, problem statement, and functional and nonfunctional requirements of our project. We describe the system and how it works and finally project limitations. Chapter 2 presents a theoretical background of the project, and a description of the hardware and software components is discussed in addition to the system specification and design constraints. Chapter 3 detailed design block diagrams, and flowcharts.

Chapter two

Background

2.1 Overview

This chapter introduces the theoretical background of the system, a literature review of the project, and a summary of the topics we discussed in this chapter.

2.2 Theoretical background

In the theoretical background, we will talk about the definition of a smart egg incubator, the Types of incubators, and biological factors.

2.2.1 Definition of smart egg incubator

The smart egg incubator is based on a microcontroller that can automatically help with the generation of chicks for birds. The controller's primary responsibility during the incubation process is to monitor and regulate the entire environment, including temperature, humidity, and ventilation, turn eggs automatically, also detect if the egg is fertile or infertile, and alert the user for some issues [1] [2].

2.2.2 Types of Incubators

There is a different type of egg incubator, from the control side there is Auto and manual egg incubator. An autonomous egg incubator's ability to spin the eggs without your assistance. The eggs are placed on a tray with sections. Then an automated motor turns the tray, which causes the eggs to rotate. In a manual egg, you must manually turn the eggs at least three times per day [3]. The system in our project will be automatically controlled for various egg kinds and be made to integrate IoT technology with smartphones to improve the user experience for monitoring and using the incubation system more conveniently.

Egg incubators also may be Convectional incubators, still-air incubators, or forced-air incubators. Convectional relies on ventilation apertures in the incubator's top, sides, and bottom.

Air holes are absent from the second type of egg incubator. One of the most well-liked and frequently employed egg incubators is forced air. We shall utilize force air because it distributes heat more evenly inside the incubator. The fan automatically controls the ventilation and is simple to use [4].

Egg incubators consist of a setter and a hatcher. The two main apparatuses in the hatchery are the incubators and the hatcher. The term "setter" is also frequently used to describe the incubator, the eggs will be in the incubator (setter) about 3 days before they hatch, Then they will be transferred to the hatcher, where they will stay for an additional two to three days until the majority of the chicks hatch out [5].

In our project we will use a combined incubator, also called a combo incubator, which is a system that has both the functions of a setter and a hatcher. Because this is the best for small incubators with a capacity of no more than thousands of eggs, it may be less expensive to produce one machine with both functions as opposed to producing two machines [6].
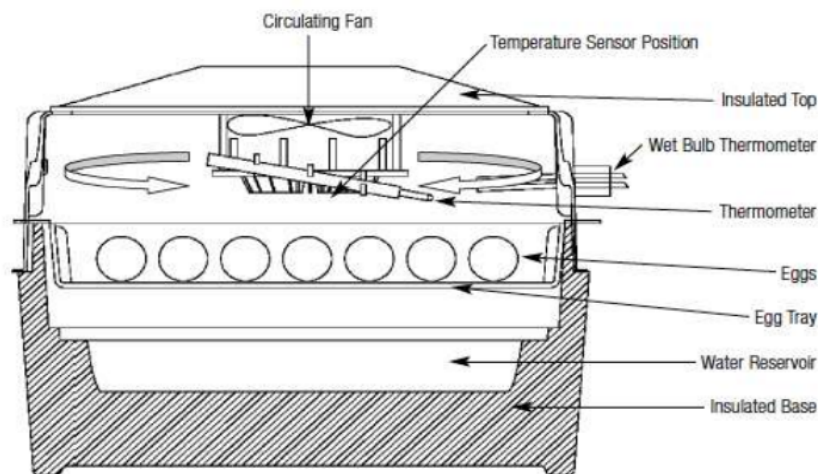

Figure 2.1: Forced Incubator, source [7].

2.2.3 Biological factors

The condition of the incubator is a critical factor, the most common causes of poor results are humidity and/or improper temperature regulation. Inadequate control occurs when the

temperature or humidity is too high or low. This prevents the fetus from growing and developing normally. In addition, improper ventilation and defects in egg turnover lead to substandard results. [2][8].

This system is influenced by Biological factors such as

1. Air quality: An adequate oxygen level should be maintained in the incubator during the incubation process, it must be 21%.

2. Turn the egg: egg turning is the most important step in the incubation process since, during the first week, the embryo lacks a circulatory system. By turning the eggs, new embryonic membranes are developed properly, enabling the chick to peep out without any issues. Additionally, as the egg rotates, the sub-embryonic fluid helps the embryo receive nutrients from the yolk.

   Evaporation and humidity: During incubation, the embryo needs to lose the correct amount of water. If it retains too much water, it will be difficult to perform the internal pipping; if this loss is excessive, this causes a risk of dehydration.
   Depending on the relative humidity of the surroundings, the egg loses moisture through the pores in the shell. Problems with diet and hygiene will undoubtedly impact the quality of the shell and, in turn, the loss of moisture. The best hatching is accomplished with a moisture loss in eggs of between 12 and 14%.

3. Temperature: Without question, the most important aspect of incubation is temperature. Small variations in air temperature have been demonstrated to affect embryo growth, hatchability, and post-hatch performance in a number of experiments and field studies. and The development of the cardiovascular system, muscles, and tendons are all impacted by the temperature during incubation. The temperature needs to be kept at the ideal level for proper embryo growth and hatchability. Embryos kept with the eggshell temperature very high during incubation have been shown to present shorter lengths of the tibia, femur, and metatarsus, lower body length, lower weight, higher residual yolk, and lower stomach, liver, and heart, affect the development of the cardiac muscle and may cause right ventricular hypertrophy and increased mortality. On the other hand, low temperatures also cause great losses in the incubation process. They will prolong the incubation time, increasing the final mortalities, and generating delayed chicks.

4. Disinfection: Before storing the eggs in the incubator, they should be disinfected to stop the growth of fungus, bacteria, yeast, and viruses that could seriously harm the developing embryo.

5. Egg embryo examination: an "infertile" egg looks transparent with the exception of a very faint yolk shadow. A living embryo has a spider-like appearance, with blood arteries extending out like the legs of a spider.[9].
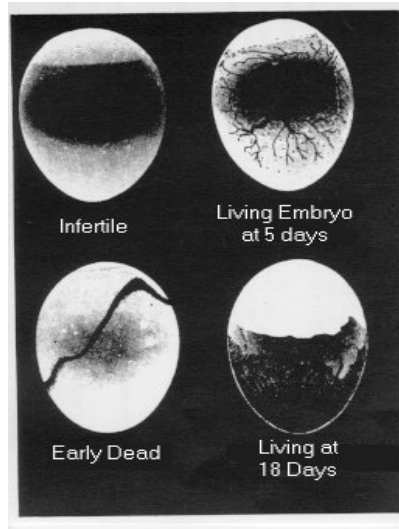
Figure 2.2: Hen embryo development, source[9].

In Table. 2.1, we have described the elements that are essential for each type.

Table 2.1: Conditions needed for each Kind of bird, source [9].

Species	Incubator Period (days)	Temp (F.)[1]	Humidity (F.)[2]	Do not turn after	Humidity Last 3 days[2] (F.)[2]	Open vent more
Hens	21	98.5-99.6	85-87	18th day	90 - 91	18th day
Turkey	28	98.5-99.6	85-86	25th day	90 - 91	25th day
Quail	16-18	98.5-99.6	< 77	15th day	84	15th day

2.3 Literature review

In this section, we will talk about some projects similar to the idea of our project:
After we searched for D space at Palestine Polytechnic University, we did not find any similar project.

Project outside the Palestine Polytechnic University:

- **Smart Egg Incubator**

    This work was done by Rula Salahat and Afeef Moghaiar at Al Najah University in Palestine in"2021." The main idea is based on a smart system that can be used to adjust the humidity and temperature through an application. Inside the incubator, the system provides oxygen and turns the eggs automatically through the microcontroller. incubator based on the Internet Of Things(IoT)[10]. This project hatched just the hen egg but in our one, we hatch various types of eggs. Their system can't detect infertile eggs but our project has the ability to detect them. We help users to monitor the process remotely and alert them when any error occurs against them.

- **SMART EGG INCUBATOR**

This work was done by Susmita M. Chougule, Virashree B. Desai, Pooja S. Gaikwad, Shweta S. Kamble, and Prof. Vishal T. Metkari from India in "2018". "The main idea of this project is to build an incubator that can control the temperature, and humidity and rotate the eggs automatically based on a microcontroller. In addition, the incubator based on the Internet of Things (IoT) system using a PC/smartphone can help the farmers to monitor the smart incubator from a distance" [11].

This project developed an incubator that hatches hen eggs and can automatically control only the temperature, humidity, and turn the eggs, but in our project, we not only control this, but also build the incubator for various egg kinds, this gives the user the ability to choose the system based on the type of eggs that he wants to hatch, examination of egg embryos and exclusion of rotten ones, and when the chicks start to leave the egg, a notification is sent to the user.

- **Smart Eggs Incubator System**

This Project was done by Fawziie Omar, H. C. M. Haris, Nabil Hidayat, I. Ismail and nawawi Seroji at Electrical Engineering Universiti Teknologi MARA Malaysia in Malaysia at "2017". The purpose of this project is to design and develop Smart Egg Incubator System. The system provides the temperature and humidity and ventilation automatically based on a microcontroller[12]. This system hatch just hens and in the future, it can develop to hatch other kinds of birds but our project is designed for various kinds. Their system doesn't support the idea of remote monitoring. But it does the process of checking the presence of embryos, as is the case in our project.

We explained the details and differences between them and our project in Table 2.2

Table 2.2: Differences between Projects

Project	Our project	Al-Najah University Project	SMART EGG INCUBATOR from India	Project No 3
Type of bird	Chicken Turkey Quil	Chicken	Chicken	Chicken (but it can develop for other types)
Microcontrooler	Raspberry pi	Arduino	Arduino	Arduino
Remote control	Yes	NO	No	No
Alerting the user	Yes In emergencies, and When the process is complete.	No	No	No
Examination of egg embryos	Yes	No	No	yes

2.4 Summary

In this chapter we define the egg incubator. In theory, we talked about the types of incubators in terms of the ventilation system, in terms of design (combo or consists of two parts), and auto and manual incubators.

Then we talked about biological procedures that contain the characteristics of the incubation period (time, temperature, humidity, ventilation, and stirring) in terms of science.

In the literature review, we talked about three projects about egg incubators and explained the differences and similarities between each project and our project.

Chapter Three

System Design

3.1 Overview

The following section has a description of the system, detailed design, and necessary information about the design.

3.2 System components

We divide system components into three sections:

3.2.1 Mechanical Design

In this section, we focus on the construction and building of the shape of an incubator.
We will build the incubator with a wooden box covered from the inside with cork material, as it has the ability to retain heat for 3–4 hours, which is essential in the event of a power outage.
One of the sides of this incubator can be opened so that the chicks are taken out after the hatching process is complete. The dimensions of the Smart Egg Incubator are 40 cm in height, 50cm in width, and 50cm long. And it contains an egg tray that can fill up to 30-40 eggs.
From the bottom, there is a designated place covered with a cloth to receive the chicks when they hatch.

Figure 3.1: incubator, source [13].

3.2.2 Hardware components of the system

This section describes the hardware components used in the system.

1. Raspberry pi3 model B+ microcontroller

We use a raspberry pi microcontroller to control all operations in the system.
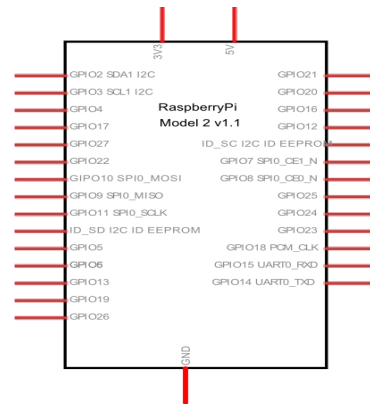
Figure 3.2: Raspberry pi, source [14].

Raspberry pi receiver five different signals from different sources as follows:

- **DHT11 Signal(For Temperature and Humidity)**

    To read temperature and humidity from the DHT11 sensor, We will write code for an Arduino IDE based on the Adafruit DHT library. The library supports DHT22. The Raspberry pi delays 2 seconds, because the DHT11 maximum sampling period is 2 seconds. So, we can only get readings every two seconds.
    The temperature and humidity are returned in float format, then create float variables h, and t, to save the humidity, and temperature in Celsius by using a function from the library, then send the value to the mobile application.

If the value of humidity and temperature does not enable a suitable range, the micro sends pulses to the bulb and pump to turn on or off to increase or decrease these values[15].

- **Ultrasonic Signal(For Water level detection)**

To read the signal from the Ultrasonic sensor, We will write code for the Arduino IDE. There is a variable that saves the velocity of sound in the air at 20ºC. The other variable saves the travel time of the ultrasonic waves (time elapsed since transmission and reception of the pulse wave, then saves the distance to an object in centimeters Define the trigger pin as an output the trigger pin emits the ultrasound. And define the echo pin as an input the echo pin receives the reflected wave and sends a signal to the raspberry pi that is proportional to the travel time.

Then produce a 10uS high pulse on the trigger pin—this means the pin will emit an ultrasound. Note that before sending the pulse, we give a short low pulse to ensure you'll get a clean high pulse. We use the function to get the sound wave travel time, then raspberry pi uses this equation to compute.

Distance in cm = travel time of the ultrasonic waves *velocity of sound in the air /2 [16].

- **Relay signal (For Power Driving)**

We will write code for Arduino IDE to make raspberry pi able to receive relay signals. This code defines the relay as output, then sends a low signal or high signal if we use a closed configuration to let the current flow and light the lamp. To stop the current flow send a high signal to the relay or a low signal if we use a closed configuration to stop the current flow [17].

2. DHT11 temperature-humidity sensor:

It is used to measure temperature and humidity in the system and then send the data to the Raspberry pi. We were prompted to use it with a number of features [18].

Figure 3.3: DHT11 sensor.

In this sensor, the temperature ranges from -40°C to + 80°C, and the humidity range is from 0% to 100%.

The sensor measures the value of temperature and Humidity, and then it represents these values in decimal. After that, it calculates the check-sum through this equation.

Check-sum = 8 integer data bit RH + 8 decimal data bits RH + 8 integer data bits T + 8 decimal data bits T.

After that it calculates the data through this equation :

DATA = 8 integer data bit RH + 8 decimal data bits RH + 8 data bits integer T + 8 decimal data bits T + 8 check-sum bit.

This is the form of data that is sent to the microcontroller. The microcontroller receives 40 bits from the sensor: 16 RH data bits, 16 T data bits, and 8 checksum bits. Where T is Temperature and RH is Humidity [19].

3. BULB

It is used as a heater source to provide the incubator with a suitable temperature. The light turns on when the temperature falls below the ideal level, but when it rises above the required range, it will turn off [20].

Figure 3.4: Bulb.

4. Fan

The fan will act to reduce the temperature if it rises above the ideal level. The fan will turn off when the temperature is at its ideal level [20].
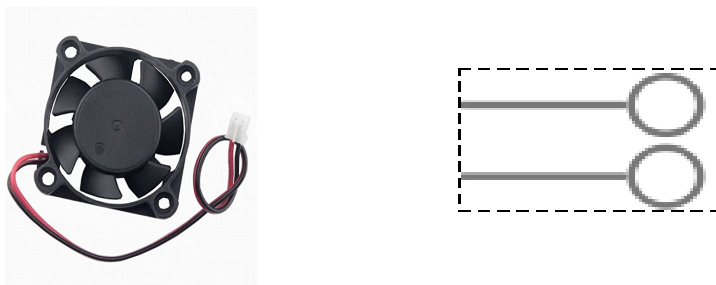

Figure 3.5: Fan.

5. Relay System

A relay is actually a switch that has the ability to turn off and on the power supply. With a little programming, it can function as an automatic switch, it will be used to control the heat source, humidity source, turning motor water pump, and frogger device [20].
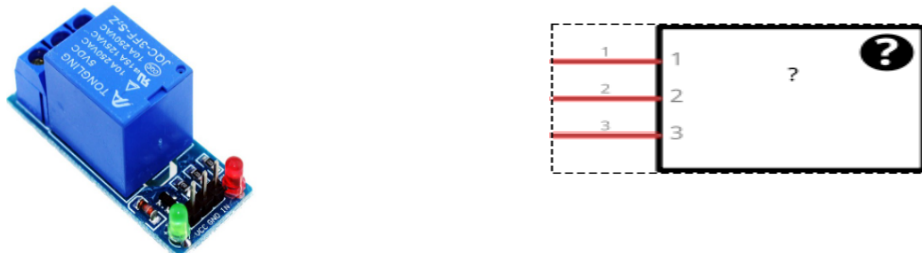
Figure 3.6: Relay.

Relay work

We cannot connect high voltage devices directly to raspberry pi, so we use a relay between this device and raspberry pi.

In our project, the electrical lamp, Fan, Fogger, and servo motor work with high voltage (12v) so we will use a relay to prevent raspberry pi from burning [21].

8. Ultrasonic sensor (HY-SRF05)

The ultrasonic sensor measures distance by using ultrasonic waves [22].

We will use this sensor to calculate the amount of water in the small tank, as we will place it at a point at the top of the tank, and it will measure the distance between it and the level of water to run a pump when the water drops below the required level. This sensor sends the data to the raspberry pi.

Figure 3.7: Ultrasonic sensor.

Ultrasonic work

The TRIG pin on the sensor receives a 10 uSec or wider logic HIGH pulse, which is often supplied by a microcontroller. The ultrasonic sensor will initiate a detection cycle as a result. The module sets its ECHO pin output HIGH and emits eight bursts of 40 kHz sound. Then the ECHO pin is returned to LOW when the module detects the signal being reflected back from an object. The simple formula (Time that ECHO is held HIGH * Speed of sound / 2) can be used to determine the distance to an item by timing how long the ECHO pin is held HIGH. Since we are only interested in the outward distance, we must divide the result by two because sound must travel both forth and backward [23].

11. Camera

It is used to help us with remote monitoring of the inside incubator. And in the process of examining embryos inside eggs.

Figure 3.8: Camera.

12. Pump

We will use the pump to pump water from the tank to the receptacle inside the incubator when it receives a signal from the microcontroller to turn on to increase the humidity value.

Figure 3.9: Pump.

14. DC motor

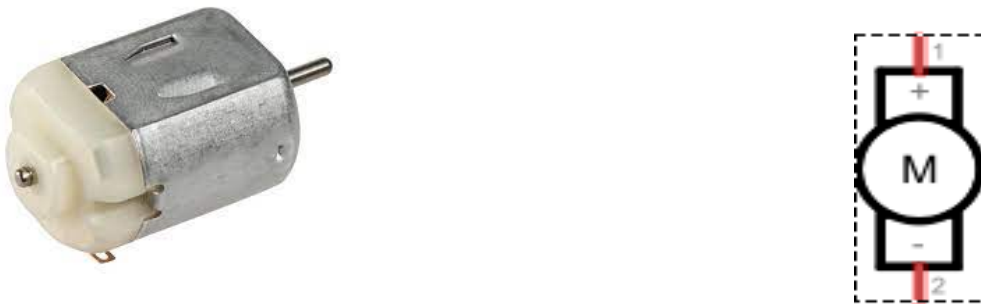It is used to turn the eggs when it receives a pulse from the microcontroller.

Figure 3.10: Dc motor.

15. LED lights

low-power LED light (0.12 Watts) that emits a cool, quiet white light. With this kind of LED, we can image and see the inside of the eggs in great detail to detect fertile eggs.

3.2.3 software of the system

The software of our system includes the following:

1. **python programming language**

   Python is an interpreted, object-oriented, high-level programming language with dynamic semantics. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports modules and packages, which encourages program modularity and code reuse. The Python interpreter and the extensive standard library are available in source or binary form without charge for all major platforms, and can be freely distributed [24].

2. **MIT App Inventor**

   Is an integrated development environment for web applications that was first made available by Google. It enables beginners in computer programming to construct application software (apps) for the Android and iOS operating systems. Users may drag and drop visual items to construct applications that can be tested on Android and iOS devices and created to operate as an Android app using a graphical user interface (GUI) that is very similar to the programming languages Scratch and StarLogo.[25].

   In our project, we will use MIT App Inventor to build a mobile application to display the data that comes from a raspberry pi microcontroller and allow the user to control the system by sending a signal from the app to the microcontroller.

3. **Database**

   A remote database is to be used for storing all needed information about egg hatchings such as temperature, humidity, and remaining days for hatching. This information will be installed on the microcontroller unit to use in the automated controlling process. In our project, we will use the Firebase database since it is a free, easy-to-use database, and supports programming in C++, Java, JavaScript, etc [26].

4. Image processing

Is a technique for applying various procedures to an image in order to improve it or extract some relevant information from it.

We will use image processing in our project as a type of signal processing in which the input is an image of the embryo and the output is the ratio of the number of black pixels to the white ones inside the egg, Black pixels represent the embryo, and its blood veins, while white pixels represent the rest of the image, this ratio used to classify the egg fertile or infertile.

The classification task is performed based on this equation:

$f(x) =$ fertile, $\quad x \geq \beta$

$f(x) =$ infertile, $\quad x < \beta$

where x is the ratio of the number of black pixels to the white ones, and the value of β equal to 7% meets the expected accuracy of the system. This operation is based on the Dynamic threshold finding algorithm shown below [27].

Input :Enhanced grayscale image
Output: Threshold θ

Begin
m ←minimum intensity value of image pixels
M ←maximum intensity value of image pixels

θnew = $\leftarrow \left((m+M)/2\right)$
Repeat
   $\theta \leftarrow \theta$ new
   S1←{image pixels with intensity value less than or equal to θ}
   S2←{image pixels with intensity value above to θ}
   $\theta1 \leftarrow$ mean intensity value of S1
   $\theta2 \leftarrow$ mean intensity value of S2

    θnew $\leftarrow \left((\theta1+\theta2)/2\right)$
Until $\left(|\theta\text{-}\theta \text{ new}| \leq 1\right)$
End

5. OpenCV library

Is a computer vision and machine learning software library available for free use. OpenCV was created to give computer vision applications a uniform framework and to speed up the incorporation of artificial intelligence into products[28].

In our project we will use the opencv library in order to use the camera for egg distinguishing and monitoring.

3.3 Design options

This section is about the components and software we will use in our system and their alternatives and the best option among them.

3.3.1 Microcontroller alternative

This subsection illustrates the alternative for raspberry pi.

1. Raspberry pi

Table 3.1 presents the difference between Raspberry pi and ESP32.

Table 3.1: ESP 32 VS Raspberry Pi 3, source [29].

FEATURE	RASPBERRY PI	ESP 32
Core count	Dual-core	Single/dual
Microcontroller	RP2040	Tensilica Xtensa LX6
Clock frequency	48kHz / 133kHz	160kHz / 240kHz
Internal Flash Memory	2 MB	4 MB
SPI	2	4
ADC	3(12-bits)	18(12-bits)
GPIO(total)	26	34
WiFi Bluetooth	Not Supported	802.11 b/g/n V4.2 (Supports Classic Bluetooth and BLE)

2. Arduino mega

Table 3.2 presents the difference between Arduino and raspberry pi.

Table 3.2: Raspberry pi VS Arduino Uno, source [30].

Specs	Arduino Uno	Raspberry Pi 3 Model B
CPU type	Microcontroller	Microprocessor
Operating System	None	Linux (usually Raspbian) or Win 10
Speed	16 Mhz	1.2Ghz
RAM	2KB	1GB
GPU/Display	None	VideoCore IV GPU
Disk	32KB	Depends on SD card
GPIO pins	14 digital pins (includes 6 analog)	26 digital pins
Other connectivity	None	USB, Ethernet, HDMI, audio
Power consumption	0.25W	6W

In our project we will use raspberry pi because it is a low-cost, Huge processing power in a compact board, Many interfaces (HDMI, multiple USB, Ethernet, onboard Wi-Fi and Bluetooth, many GPIOs, USB powered, etc.), Supports Linux, Python (making it easy to build applications), Developing such an embedded board is going to cost a lot of money and effort, and the main reason we can use the camera with raspberry pi without the need for a camera microcontroller [31].

3.3.2 Software

Alternatives in the software section and the best option.

1. Mobile application

Table 3.3 presents the difference between mobile applications and web apps.

Table 3.3: Difference between mobile apps and web apps.

Development Options	Specification
Web App	• Multiple and NodeJS. • Limited access to OS APTS.
Mobile Application	• Full access to functionalities of underlying mobile OS and device specific capabilities. • Highly complex. • Improved performance and user experience.

In our project, we will chose to develop the mobile application due to its performance in both platforms (Android & IOS)

3.3.3 Sensors

This subsection illustrates the alternative for raspberry pi.
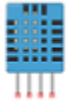
1. DHT11 Alternative

This subsection illustrates the alternative for DHT11:

- **DHT11 VS DHT22**

    The DHT11 and DHT22 (AM2302) are Digital temperature sensors that monitor both temperature and humidity.

    They have varied specifications but have very similar appearances and functions. As it is shown in table 3.4.

Table 3.4: DHT11 VS DHT22, source [32].

DHT11	Specifications	DHT22
Humidity and temperature	Measurement	Humidity and temperature
0 – 50° C / ± 2° C	Temperature Range	-40 – 125° C / ± 0.5° C
20 – 80 / ± 5 %	Humidity Range	0 – 100 / ± 2.5 %
1 wire	Communication Protocol	1 wire
1 Hz one reading every second	Sampling Rate	0.5 Hz one reading every two second
+/- 2ºC (at 0 to 50ºC)	Accuracy	+/- 0.5ºC (at -40 to 80ºC)
15.5 mm × 12 mm × 5.5 mm	Body size	15.1 mm × 25 mm × 7.7 mm
3 – 5 V	Operating Voltage	3 – 5 V
2.5 mA	Minimum current	2.5 mA
$6.99	Price	$10.99

In our project we will use DHT22 because it will provide us with a wide range of measures, and better accuracy. We did not use a temperature sensor and humidity sensor separately to reduce the number of hardware parts inside the system.

3. Ultrasonic sensor

This subsection illustrates the alternative for Ultrasonic Sensor(HY-SRF05)

- **HC-SR04 VS HY-SRF05**

  The HC-SR04 is a particular kind of ultrasonic sensor that uses sonar to determine how far an object is from the sensor.

  Table 3.6 shows the differences between HC-SR04 and HY-SRF05.

Table 3.5: HC-SR04 VS HY-SRF05, source [33].

	HC-SR04	HY-SRF05
Supply voltage, V	+5	+5
Consumption in silent mode, mA	2	2
Consumption at work, mA	15	15
Measurement range, cm	2 - 400	2 - 450
Ultrasound frequency, kHz	40	40
Accuracy, mm	0,3	0,3
Dimensions, mm	45×20×1 5	44×20×1 4

As shown in the above table, the HY-SRF05 is a more flexible sensor that appears to have a better range and a slightly more accurate sensor. so we will use it in our project [34].

3.4 Conceptual system description

In this subsection, diagrams are represented for the understanding of the project concepts and design.

3.4.1 general block diagram

As illustrated below, the sensor when the system is activated will collect the necessary data and send it to the raspberry. After the raspberry gets it, it will examine the data and process it .when the temperature data obtained from the DH11 sensor is greater than the suitable range of temperature, it will send two signals, one to turn on the fan to reduce and another signal to turn off the lamp, but if the value smaller than rang the raspberry send signal to the fan to turn off and signal to the lamp to turn on. In humidity data from DHT11, if the value is greater the microcontroller will send a signal to the frogger device to turn off, and another signal to the fan to turn on But when the value is smaller it sends a signal to the frogger to turn on. when receiving data from the Ultrasonic sensor (HY-SRF05) if the measured distance is greater than suit values, the ESP32 sends a signal to the pump to turn on to increase the level of water.. This helps the microcontroller to determine when to send a signal to the turning motor to turn eggs , the process of turning on and off the parts is done through a relay system. Figure 3.16 below shows the block diagram of the system.
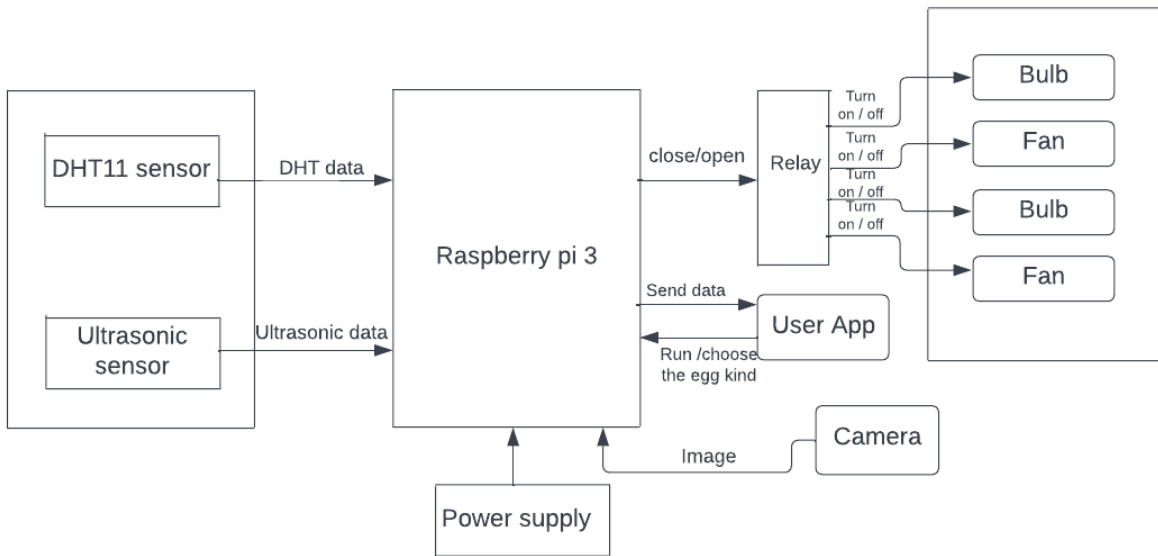
Figure 3.11: general block diagram.

3.4.2 Conceptual Diagram

Figure 3.17 represents the concept of our system.
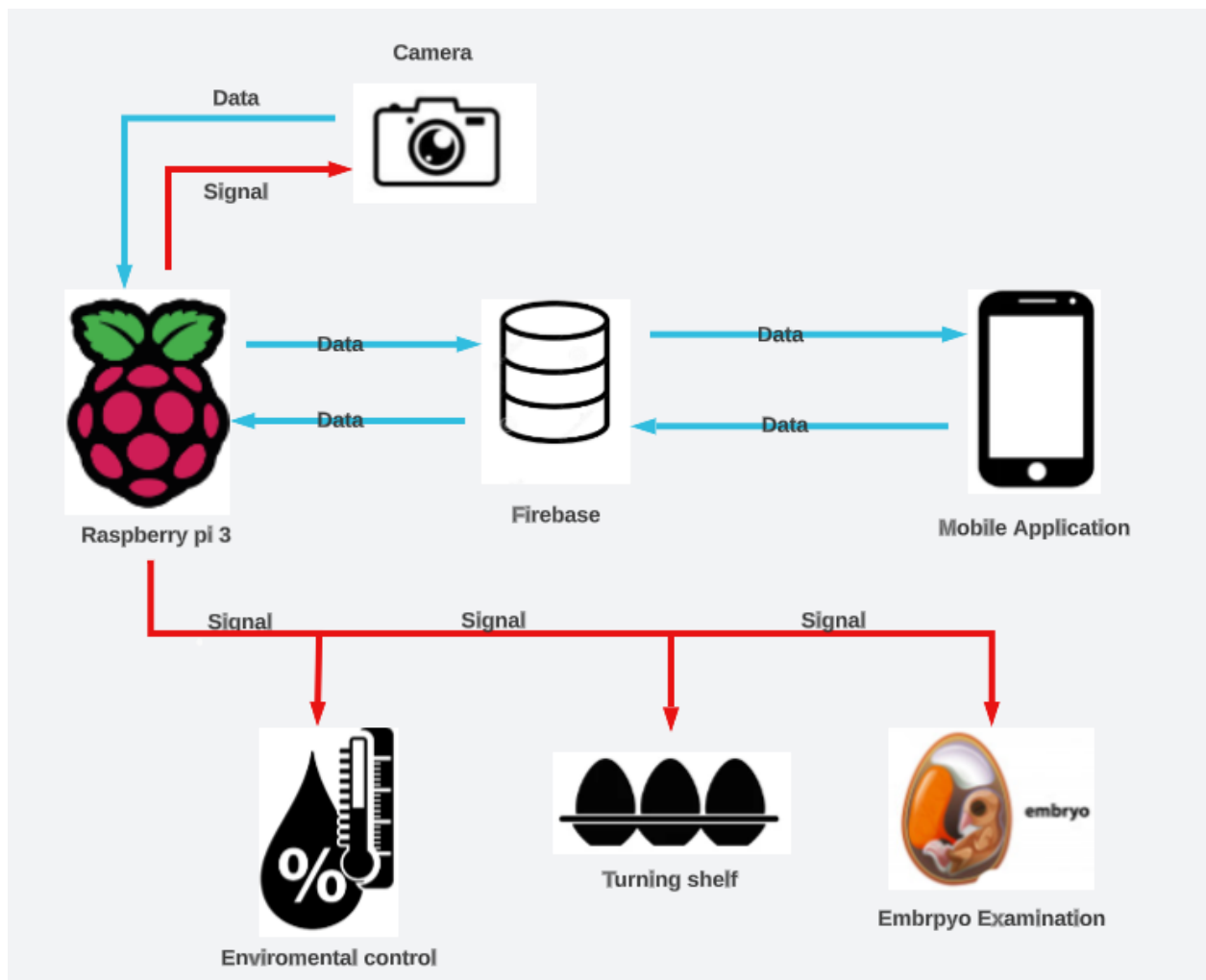
Figure 3.12: Conceptual Diagram of system

3.5 Algorithms and methodologies

In this section, we describe our system work by using a Flow chart.

3.5.1 Flowchart

Figure 3.18 below represents the operation of our system using a flowchart.

Figure 3.13:System Flow chart

To detect if the embryo is fertile or infertile this process is done after 6 days because the blood vessels of the fertilized eggs are visible on the 7th day.

3.6 Schematic diagram

Figure 3.20 represents a schematic diagram, in order for the diagram to be clear, we used more than one source voltage.

Figure 3.14: Schematic diagram.

3.7 Summary

In this chapter we describe mechanical design, hardware design, and software design. In mechanical design, we talk about the shape of the incubator and the materials used to build it. In hardware design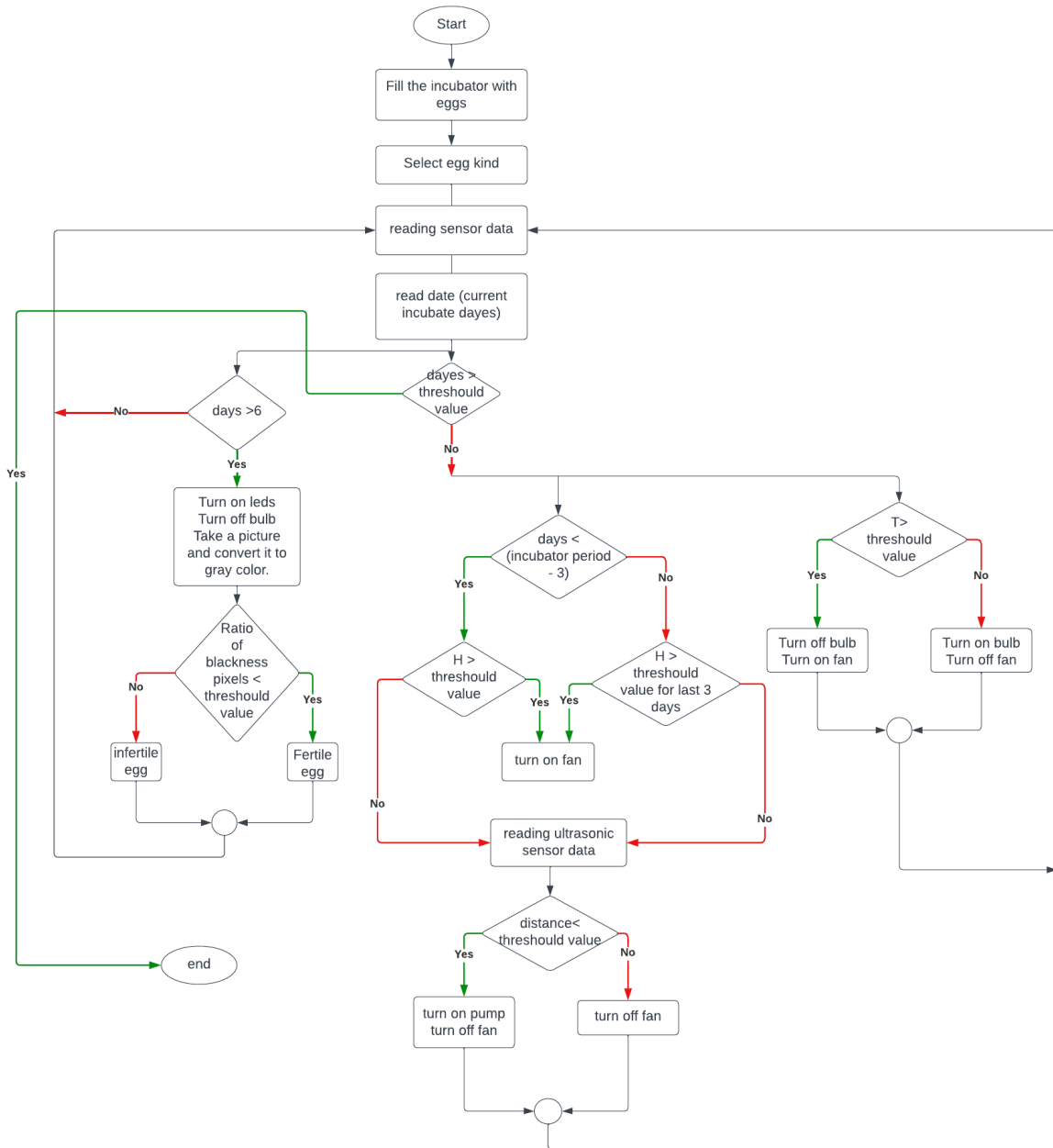, we talk about components that we want to use and how they work together, and finally, we talk about software design such as databases, software development for applications, and Arduino programming language.

In the design option, we talked about alternatives to the component that we will use in our project and why we chose them. Then we talk about conceptual system description by using a block diagram and conceptual model, and we use a flow chart in the algorithms and methodologies section.

Chapter Four

System implementation, system testing, and discussion

4.1 Overview

This Chapter introduces a description of the implementation, implementation issues, implementation challenges, description of the method used to validate the system ,validation results include an analysis and discussion about the result and recommendations based on the result .

4.2 Description of the implementation

- We Purchased the necessary sensors for the project , an iron structure was made for the incubator ,and it was coated from the inside with crok .

- We made an animated egg mold, it was attached to a large screw and dc motor to control its movement .

- The necessary pieces and the camera sit in the correct places inside the incubator .

- The sensor power lines (VCC) were connected to the breadboard ,and the necessary voltage was connected to them from the controller,and we did the same for the ground .

- The sensor's signals were directly connected to the microcontroller by wires .

- All pieces were attached to corresponding electric circuits connected to the breadboard ,and then the signal from each circuit was connected to the controller .

- Wires and parts were arranged to do the necessary tests .

4.3 How does the system works

- The Raspberry Pi3 connects to the Internet and then connects to the database .

- The Raspberry Pi3 fetches the previous state of the incubator when an error occurred during work or an interruption of electricity .

- After logging in to the application ,and then selecting the type of eggs ,after that the system will start working by clicking on the start button .

- The suitable value of temperature ,humidity and number of days were stored in the database .

- Get data from sensors,and compare these values with suitable values. If there is any error in value the microcontroller will make the right decision to solve the problem .

- On the 5th day the camera takes a photo, then the image processing is done for it to determine fertile and infertile eggs, and finally upload this image to firebase in order to display it in a mobile application, so the user can see it.

- During the incubation period ,the egg mold moves in two directions.

- The system will continue in this state throughout the incubation period .

- Through the application, it is also possible to display the status of the incubator during the incubation process, like current temperature, humidity, and number of days .

- The user can see inside the incubator everytime during the camera.

- This process continues as long as the Internet connection is not lost .

4.4 Implementation issues and challenges

- We needed to connect a camera to the system ,so we used Raspberry Pi 3 instead of ESP32,because we don't have to work with two microcontrollers.

- While using the servo motor ,it was running at high speed and vibrating the eggs ,so in order not to damage the eggs ,we replaced it with a DC motor .

4.5 Validation result

In this section, we describe our hardware and software system.

4.5.1 Hardware testing

A Raspberry Pi 3 was tested with all sensor and connected directly to the screen as Well as the 24V power supply for the raspberry, 3.3 for the sensors and 12V for the fan and pump.

These images represent the project that was built and we did the test on.

Figure 4.1 : The structure of the incubator.
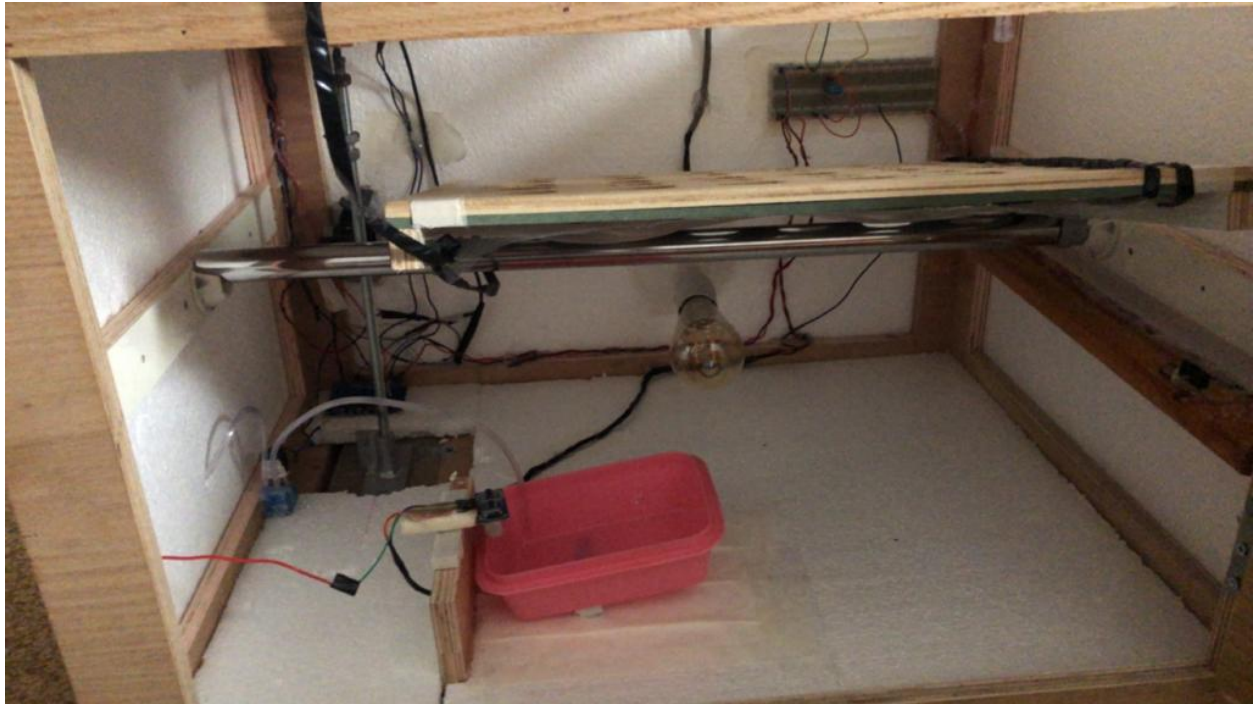
Figure 4.2 : The incubator from the outside.

Figure 4.3 : Hardware component inside the incubator .

The data is stored in the database in the field shown in the following figures on the Firebase Realtime Database website .

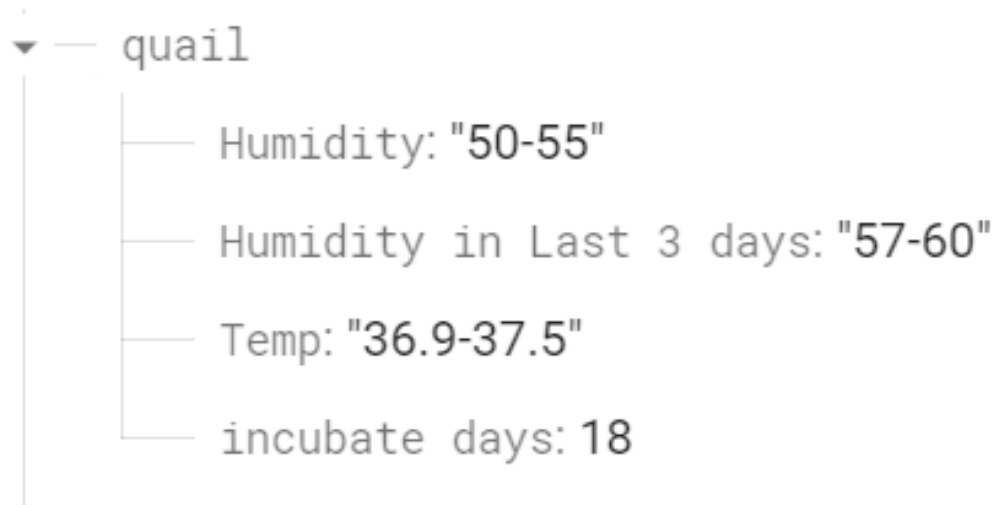Figure 4.5: Data in Firebase about Chicken.
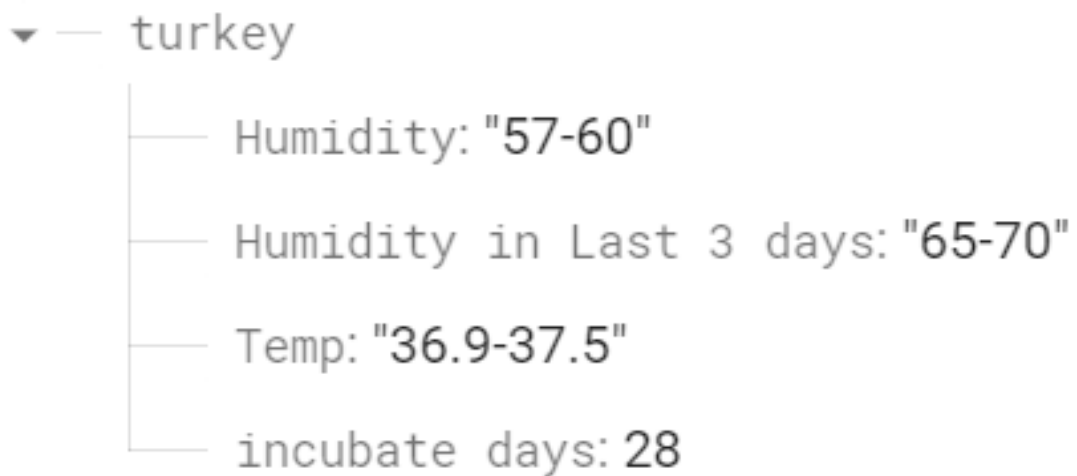
Figure 4.6: Data in Firebase about Quail.

Figure 4.7: Data in Firebase about Turkey.

4.5.2 Software testing

The system was fully checked and ensured how it worked and the results of the Testing were successful ,and the following tables are reviews of some of the tests that we have carried out.

Table.4.1: Unit Test

#	Case	Expected output	Problem while working	Obtained output	Pass/Fail
1	Connect to the internet	Connect to the internet	Problem when we connect raspberry to internet Solving this by writing a set af commands	Connect to the internet successfully	pass
2	Get necessary data from the database	Get data from the DB	Getting API Key by set of steps to solve configuration problem	Get data successfully	pass
3	Get data from sensors	Get data from sensors	Problem in wiring sensors ,solving by fixed it well	Get data successfully	pass
4	Send data to DB	Send data to DB	Getting API Key by set of steps to solve configuration problem	Send data successfully	pass

Table 4.2: System Test

#	Case	Expected output	Problem while working	Obtained output	Pass/Fail
1	The DHT11 sensor start sensing to measure the temperature and humidity in the incubator	The DHT11 sensing to temperature and humidity in the incubator	Problem in wiring sensors ,solving by fixed it well	The DHT11 sensing successfully	pass
2	The lamp start working if temperature less than the threshold	The lamp start working	No problem	The lamp start working successfully	pass

#	case	Expected output	Problem while working	Obtained output	Pass/Fail
3	The lamp stops working if temperature greater than the threshold	The lamp stops working	No problem	The lamp stops working successfully	pass
4	The Pump start working if humidity less than the threshold	The Pump start working	No problem	The Pump start working successfully	pass
5	The Pump stops working if humidity more than the threshold	The Pump stops working	No problem	The Pump stops working successfully	Pass
6	The Fan start working if temperatures or humidity more than threshold	The Fan start working	No problem	The Fan start working Successfully	Pass
7	The dc motor start turning egg per day appropriately for eggs	The egg mold will be turned	The motion of the dc was too small, so we solved this problem by using an adapter with high current.	The egg mold will be turned successfully	pass
8	The system will distinguish between fertilized and unfertilized eggs et	The system will distinguish	There is an algorithm that depends on the appearance of the blood capillaries. We took an image for the egg from the top, the capillaries did not appear,so we used the egg color.	The system will distinguish successfully	pass
9	The camera	The camera	The accuracy of the camera was low, so we replaced it with higher accuracy, and we faced other problems with coding.	The camera capture image in 7th day and monitor successfully	pass

When could not apply the algorithm that we mentioned previously (Dynamic Threshold Finding) because the camera takes the picture from the top, and in this case the capillaries do not appear. When the egg contains the blood veins (fertile), the color of the egg when turn on the leds becomes dark gray or black, the pixel value should be concentrated between 0 to 70. When there are no blood veins inside(infertile), the color of it when turning on the leds becomes white, the pixel value should be concentrated between 200 to 255.

Table 4.3: Application Pages Test

#	Case	Expected output	Obtained output	Pass/Fail
1	Run the incubator	The user can run the incubator by clicking on button start	The user can run the incubator by clicking on button start successfully	pass
2	Select egg kind	The user can select the kind of egg that want to hatch it	The user can select the kind of egg successfully	pass
1	returns data	Show data in a user interface	Show data successfully	pass
2	Show current Incubator status	Show data in the user interface	Show data successfully	pass
3	Start a new incubation period for eggs	Start a new incubation period	Start a new incubation period successfully	pass

The app was developed using MIT App Inventor,it is a good tool for implementing mobile applications,whether for Android or IOS.

When the user opens the application,the program directs the user to the login page,as each user has an account, so that he can enter the system of incubator and this is to enhance security .

After that ,the user is transferred to the next page ,through which he can start a new incubation period for eggs ,and choose it's kinde ,or if there is already an incubation process ,then the user will be shown the current status of the incubator ,including egg kind,temperature,humidity, and number of days.And when examining the embryos, the result will be shown to the user on the application .

These are images of our mobile application pages .

1. In the first the user should create an account by sign up or if have an account he login to it, as shown in the figure.
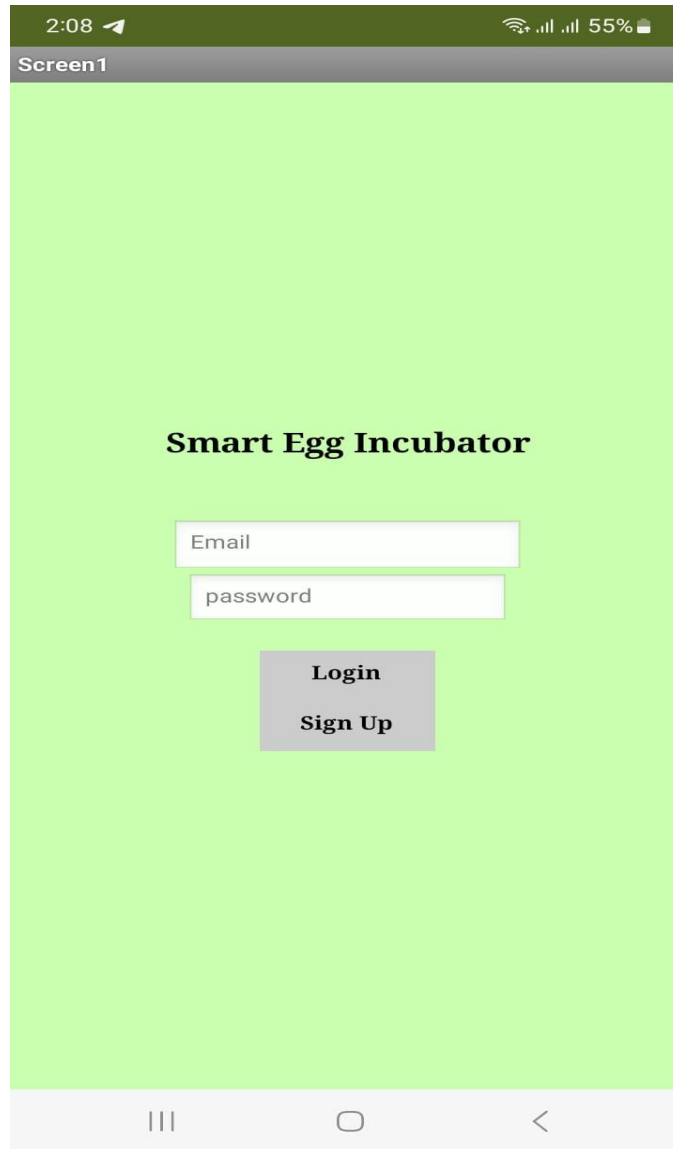
Figure 4.6: login page in mobile app.

2. In the next page the user should be clicked on the start button in order to go to start the process .

3. After that , the application asks the user to choose the kind of eggs from the list on the next page.

4. After the user selects the kind of the egg he runs the incubator by clicking on the switch button. Users can see the status of the process,by clicking on the status button.

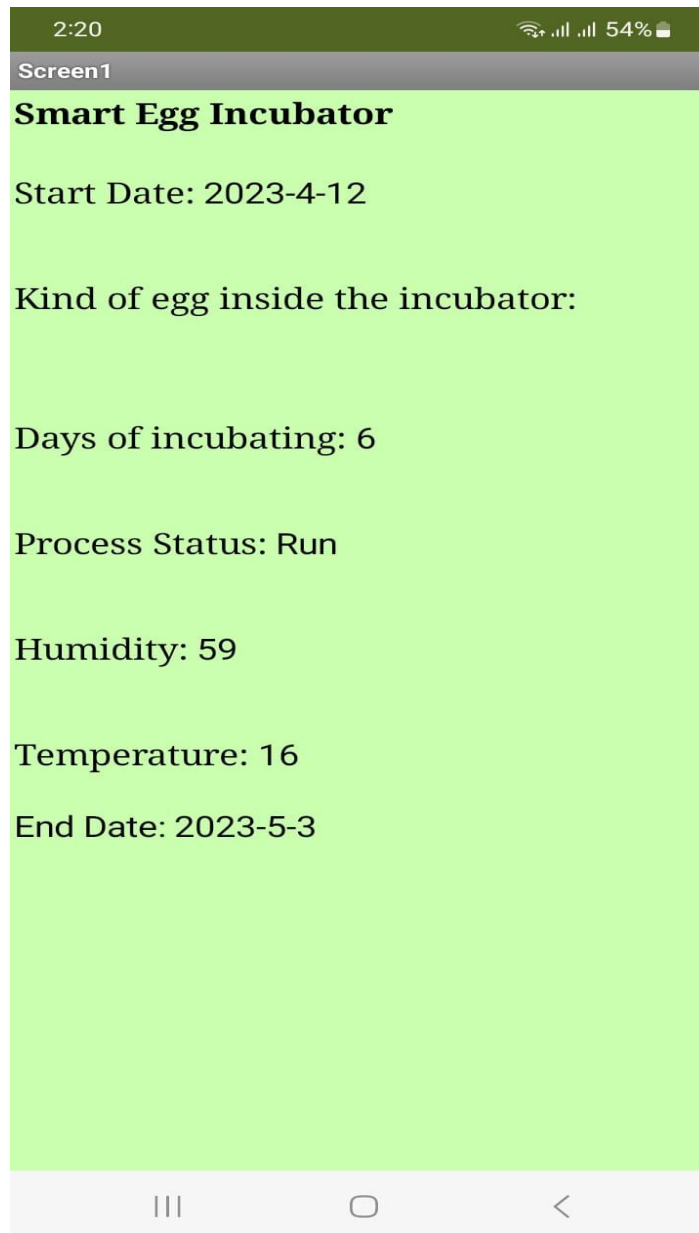5. This screen displays the status of the process, after the user clicks the button.

Figure 4.7: status page in mobile app.

6. On the 7th day, the user can click on the see image button to see the fertile and infertile eggs.

4.6 Discussion

In the beginning, there were several goals in this project to solve many problems. Work has been done to achieve this through this system, which consists of many sensors and pieces. Where these components have been programmed to achieve the requirements of this system, and after building this system and doing the necessary tests to ensure that it works in the required manner and whether it achieves the goals of its construction or not, we can say that it achieved the desired goals and that it worked as required for a simple system.

As this system took the data from the sensors correctly and the microcontroller controlled the incubator environment based on the suitable values for each kind of eggs, turning eggs as needed, distinguishing fertile and infertile eggs and allowing the user to observe inside the incubator. The process of sending and receiving data from the database was done correctly, and it was displayed as required from the mobile application.

Chapter Five

Conclusion

5.1 Overview

Talk in this part about the summary of all parts, future directions, and future work.

5.2 Conclusion

Egg incubator system can solve many of the problems , such as egg fertility issues, issues with hatching conditions, such as problems in environmental conditions like heat, humidity, ventilation, and irregularity of turning, and need supervision and intervention by the user.
In This system ,users can choose the kind of eggs, know the current situation inside the incubator through the mobile application ,also they can start a new experience of incubating eggs ,and monitor inside the incubator through a camera.

This system was built and verified to work as required to achieve the requirements of the project, it was found to work as required and meet necessary needs.

5.3 Future work

In the future, we look forward to adding important features to the system ,the most important of which are :

- Develop the system to contain more than one shelf .
- Develop the system to contain a backup voltage source .
- Develop the system to monitor the process of egg growth .

References

[1] O. Fredrick, etc, "Design and Implementation of a Remotely Monitored Smart Egg Incubator", Journal of Scientific & Engineering Research, vol.12, Nov. 2021, accessed (Oct 2022).

[2] L. Niranjan, etc, "Design and implementation of chicken egg incubator for hatching using IoT" Computational Science and Engineering, vol. 24, No. 4, 2021, accessed (Oct 2022).

[3] FreeWay Poultry, link " https://www.freewaypoultry.ie/manual-v-automatic-egg-incubator/", accessed (Oct 2022).

[4] Livestocking, link: " https://www.livestocking.net/incubator/types-egg-incubators", accessed (Oct 2022).

[5] Yanshan xu, link:

"https://www.linkedin.com/pulse/differences-between-incubator-setter-hatcher-yanshan-xu", accessed (Oct 2022).

[6] Z. Rahman and F. Hussain, " Smart Incubator Based on PID Controller" Journal of Engineering and Technology, vol. 4, Mar. 2017, accessed (Oct 2022).

[7] Idoco E, etc, " Design and Implementation of automatic fixed factors egg incubator", Journal for innovative research in the multidisciplinary field, vol.5, June. 2019, accessed (Oct 2022).

[8] P. Bhosale, etc, "Development of Smart Egg Incubator System Using Arduino" Research Article, vol. 8, Nov. 2018, accessed (Oct 2022).

[9] MISSISSIPPI STATE UNIVERSITY EXTENSION, link:

"http://extension.msstate.edu/content/testing-incubated-eggs-for-embryo-development", accessed (Oct 2022).

[10] Rula Salahat and Afeef Moghaiar, link:

"https://repository.najah.edu/handle/20.500.11888/17172", accessed (Oct 2022).

[11] S. Chougule, etc, "SMART EGG INCUBATOR", Journal of Advance scientific research and engineering trends, vol. 6, 2021, accessed (Oct 2022).

[12] M. Omar, H.C.Harris, M.. Hidayat 3, I. Ismail and M. Seroji, "Smart Eggs Incubator System", 2017, accessed (Oct 2022).

[13] ResearchGate, link:

"https://www.researchgate.net/figure/The-loaded-wooden-incubator-Source-29_fig6_355256045 ", accessed (NOV 2022).

[14] Components101, link:

"https://components101.com/microcontrollers/raspberry-pi-3-pinout-features-datasheet", accessed (NOV 2022).

[15] Freva, link:

"https://www.freva.com/dht11-temperature-and-humidity-sensor-on-raspberry-pi/", accessed (NOV 2022).

[16] Thepihut, link:

"https://thepihut.com/blogs/raspberry-pi-tutorials/hc-sr04-ultrasonic-range-sensor-on-the-raspberry-pi ", accessed (NOV 2022).

[17] Electronicshub, link: "https://www.electronicshub.org/control-a-relay-using-raspberry-pi/ ", accessed (NOV 2022).

[18] adafruit, link: "https://www.adafruit.com/product/385", accessed (NOV 2022).

[19] Sciendo, link: "https://sciendo.com/downloadpdf/journals/aucts/68/1/article-p22.pd", accessed (NOV 2022).

[20] M. Omar, H.C.Harris , M.. Hidayat 3, I. Ismail and M. Seroji, "Smart Eggs Incubator System", 2017, accessed (DEC 2022).

[21] Tutorials-raspberry pi, link:

 "https://tutorials-raspberrypi.com/raspberry-pi-control-relay-switch-via-gpio/ ", accessed (DEC 2022).

[22] Fierce Electronics, link:

"https://www.fierceelectronics.com/sensors/what-ultrasonic-sensor#:~:text=An%20ultrasonic%20sensor% 20is%20an,sound%20that%20humans%20can%20hear ". accessed (NOV 2022).

[23] Proto Supplies, link:

"https://protosupplies.com/product/hy-srf05-ultrasonic-range-finder-module/", accessed (NOV 2022).

[24] python, link: "https://www.python.org/doc/essays/blurb/", accessed (NOV 2022).

[25] Wikipedia, link: "https://en.wikipedia.org/wiki/MIT_App_Inventor" accessed (DEC 2022)

[26] TechTarget, link: "https://www.techtarget.com/searchdatamanagement/definition/database", accessed (DEC 2022).

[27] M Hashemzadeh, Farajzadeh, "A Machine Vision System for Detecting Fertile Eggs in the Incubation Industry", May.8.2016. accessed (NOV 2022).

[28] OpenCV, link: " https://opencv.org/about/", accessed (DEC 2022).

[29] Slant, link:

"https://www.slant.co/versus/25795/36414/~raspberry-pi-3-model-b_vs_esp32 ", accessed (NOV 2022).

[30]Retromania, link:

 "https://retromania.cz/arduino-board-vs-raspberry-pi-k.html ", accessed (DEC 2022).

[31]allaboutcircuits, link:

"https://www.allaboutcircuits.com/technical-articles/10-reasons-raspberry-pi-isnt-a-good-choice-for-commercial-products/ ", accessed (NOV 2022).

[32] Electronic Clinic, link:

"https://www.electroniclinic.com/dht11-vs-dht22-lm35-and-ds18b20-arduino-interfacing-and-programming/", accessed (NOV 2022).

[33] V Zhmud, "Application of ultrasonic sensor for measuring distances in robotics", Journal of Physics, 2018, accessed (DEC 2022).

[34] HY-SRF05 Precision Ultrasonic Sensor, link:

"https://wiki.hshl.de/wiki/images/2/23/HY-SRF05-ETC.pdf ", accessed (DEC 2022).