DEVELOPMENT OF AN EGG INCUBATOR USING RASPBERRY PI FOR PRECISION FARMING

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ABSTRACT

Raspberry Pi is a low-cost ARM-based computer on a small circuit board developed for computer science education. It is a capable credit card sized PC which can be used for various purposes as such a desktop PC can provide; such as spreadsheets, word-processing and games. This paper will explore into the development of such a device which will accommodate the egg-hatching procedure without the broody process. In addition to that, a monitoring system has also been developed so that the user can have seamless accesses to the device. Most importantly, its purpose is to create an environment where the egg incubation process occurs in a more orderly and safe manner. The development of this device also leverages on the Arduino UNO platform, which ultimately has managed to provide an optimum environment for the egg-hatching process.

Key words: Raspberry-Pi, egg incubation, monitoring system, Arduino UNO, egg-hatching.

Introduction

Artificial incubation has been used in the poultry by some farmers to accommodate the eggs hatching. These devices mainly control the heat, moisture and humidity of the incubator. They come is various shapes and sizes and are made from different type of materials. This paper shall describe the development process of a project which will devise a prototype called “PiBator©” also known as Egg-Incubator based on Raspberry Pi. It is a device which simulates an incubator by keeping eggs warm with the appropriate humidity using Raspberry Pi platform for the reason to hatch the eggs. PiBator will allow the fetuses inside the eggs to grow and hatch without the mother (hens) being present. This project is developed for the specific reason which is to assist the small-scale farmers from the technological perspective, so that their productivity can be increased significantly. The PiBator involves the integration between hardware and software elements. It also features a monitoring system that allows the owner to control the incubator’s setting remotely even from a smart phone; over the internet. The monitoring system is developed using Pi Camera Noir. As for the hardware part, Raspberry Pi will act as the microcomputer that can be programmed based on a specific function.

The rest of the paper is organized as follows. The first section shall elaborate the overall motivation of the study. The next section, methodology, shall guide the readers on the selection for the development platform. In the project development’s section, the development processes and the components of the project prototype are described. The experimental results and testing method are further explained in the succeeding section and finally some performance summaries of the prototype and recommendations for future works are presented in the conclusions’s section.

Project Overview

The motivation as well as the overall overview of the project can be described as the following:

i. Objectives

The objectives of this project are threefold:

- To develop a prototype device to hatch an egg without the broody process.
  - This involves manufacturing an incubator whose temperature and humidity will be controlled by a device developed using a Raspberry Pi.
- To develop a monitoring system for the incubator.
  - This element involves developing a web-based system which updates the status of the incubator from the temperature and humidity perspectives.
- To increase the significant of the incubation process.
  - By combining the hardware and software elements of this project, it is hoped that the productivity of the farmers shall increase significantly.

ii. Problem Statement

The egg-hatching process has been a major problem in the field of agriculture especially in small poultry flock. A recent statistic shows that this issue is one of the main factors that cause major loss to farmers (Anon., (2010)). The use of homemade incubator is not so effective to overcome this problem. Breeding chickens is a good way to create a sustainable flock; it should be learned by every chicken farmer.

External threats, for example wild animal such as monkeys or reptiles, could possibly harm the eggs which might cause a major loss for the farmer. This threat not only can damage the eggs, but the breeding process is also stunted.

As stated in the problem statement, it is difficult for the hens to lay eggs again if they are in the breeding process. Farmers can overcome this problem by taking the eggs and put them in the PiBator, which implements a computerized system to control the environment to mimic the normal breeding process. This system is equipped with sensors which monitor the temperature and humidity of the incubator.

iii. Scope

This project shall only address the development of PiBator bounded by the following specifications:

- Temperature, humidity and camera sensor will be used to monitor the breeding process.
- Both Arduino and Raspberry Pi will be communicating with each other.

Methodology

The PiBator development is divided into three sections. There are two elements of hardware designs which are mechanical and electronic; and the third part is comprised of software design. PiBator is an egg incubator that is capable to incubate multiple types of eggs. The incubator will be equipped with the temperature and humidity sensor that can measure the condition of the incubator and automatically change to the suitable condition for the eggs. It is recommended to place the incubator indoor, to avoid any ill-effect from major weather changes. Furthermore, it also can prevent from the threats of wild animals. In addition to that, a well-ventilated area is strongly recommended for fresh air. In short, it is a much easier task for the farmers if this incubator is placed indoor.

There are three elements in PiBator that must be set and controlled, namely temperature, humidity and movements. In this scenario, a 25W light bulb is used to suitably set the correct temperature for the eggs. The percentage of the humidity in the incubator needs to be consistent. This is achieved by controlling the fan and water running through the incubator. In the same time, it can ensure that the humidity and ventilation of the incubator is in a good condition. In order to ensure that the entire part of the eggs receives heat form the bulb, a stepper motor is used to rotate the egg turner and change the position of the eggs. The status of the condition inside the incubator can be viewed remotely via network connection.

i. Mechanical Design

This part explains the process of crafting the physical aspect of the incubator; which is the chief element of the PiBator project. Firstly, it is highly recommended to use good quality materials, such as plastic casing and hardwood. Use of softwood should be avoided as it will warp during the incubation process (Divoky, Harter, (2010)). Ultimately, this will affect the humidity in the incubator.

ii. Hardware Design

This part will provide an in-depth explanation on the Raspberry Pi microcontroller. It is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. Besides that, it is also capable of doing everything one would expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.

iii. Software Design

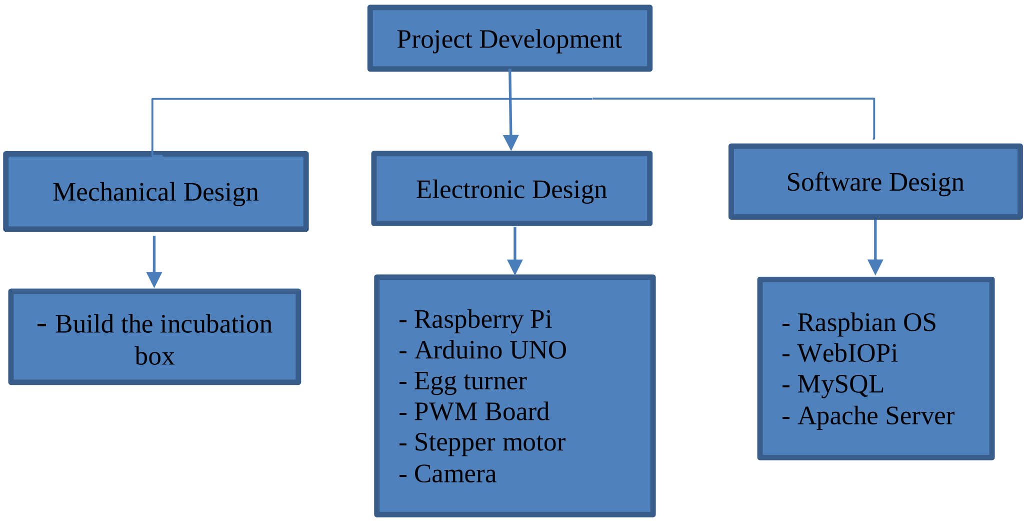
This part involves the required coding and scripting to develop the monitoring system application. This application is designed to work as a completely web-based platform. Google Chrome is used to launch the application. The main page will link several options such as, type of eggs, and administration settings. System settings can be altered remotely using SSH service. This feature emphasize on the possibility of remote administration and monitoring as long as there exist a network connection.

The brain of this incubator resides in the Raspberry Pi microcontroller. It is able to process data received from the sensors, and execute the selected elements so that the condition in the incubator can be changed. All the features including the software are relatively user-friendly and PiBator itself is a portable device.

Project Development

The process of developing the prototype of this project is primarily guided by the description outlined in the methodology section. However, the overall development and implementation can be summed up by the process flow as shown in the Figure 1. This diagram describes the prototype development phases and functionality of the overall connection for this prototype. There are three processes involved in the prototype development; starting with the assembly of the casing, hardware and then the programming for the interface between the sensor circuit and the Raspberry Pi. To satisfy the objective of this project, the interface between Raspberry Pi and the sensor circuit using the GPIO is crucial. To do so, Python programming is used.

Figure 1: Development phases of PiBator



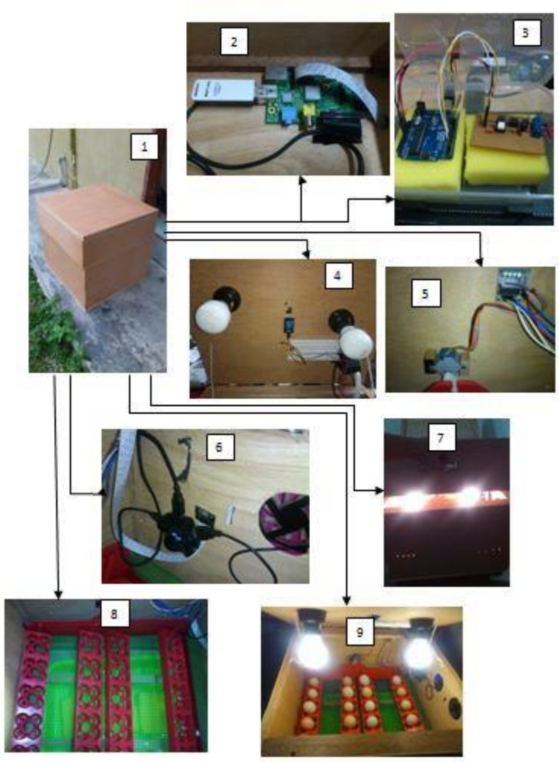
i. Mechanical Design Phase

The physical incubator is divided into two parts. The first part is the upper compartment which is used to place the hardware system of the incubator. And the second part, which is the lower one, is where the incubation process occurred.

Figure 2 shows the overall PiBator prototype and what are inside the incubator. Each of these elements can be described as the following:

1. The physical incubator itself; divided into two layers which is upper and lower layer.
2. The upper compartment; where all the hardware systems are stored, such as Raspberry Pi, Arduino, and PWM board.
3. Physical connectivity between Arduino UNO and PWM board at the upper compartment, to control the light bulb automatically.
4. At lower compartment; two light bulbs are attached with DHT sensor placed in the middle.
5. 5v Servo motor used to control the rotation of egg turner, at the lower compartment.
6. Pi camera board and USB fan whose purpose to keep the air inside the box fresh.
7. The incubator with a maximum frequency of electricity; captured using Pi camera.
8. Egg turner that has been programmed to rotate every four hours. Beneath it is where the water is running to keep the humidity high.
9. An actual illustration of how the incubation process takes place.

Figure 2: The PiBator Prototype and its components



ii. Hardware Integration Phase

This paper will only discuss three elements of hardware integration phase; which are deemed of a highly important aspect of the incubator. The rest of them are available in the project official report (Nizam, (2001)).

- **Egg Turner**

  The positioning aspect of the eggs is critical in order make the incubation process is a successful one. This egg turner is capable to hold up to 36 eggs at a time. It also has a slot for the stepper motor to turn the egg tray from left to right. The position of the egg should be turned at least four to five times daily.

- **Pulse Width Modulation (PWM)**

  Pulse Width Modulation (PWM) signaling is a method for generating an analog signal using a digital source (Octagon (2005)). The PWM board has a direct communication with the Arduino which is used to control the light bulb automatically. The heat sensor will feed certain data to the system which notify on the current status of the temperature inside the incubator. The PWM will adjust accordingly whether to increase or decrease the bulb intensity based on this data.

- **Dimmer Board**

  The main use of this board is to control the DC motors. However, it can also be used to control the voltage, frequency, hydraulic operations, and other mechanical parts.

- **Stepper Motor 5V & ULN2003 Driver Board**

  This stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. The use of this motor is to rotate/spin the egg tray for every six hours (depends on the coding) so the yellow egg will not stick between the egg shell.

Testing and Results

This section will present the testing performed and results obtained. From the conducted testing, every output or result will be carefully analyzed and verified. This testing phase is conducted to make sure the prototype functions accordingly and achieves the goals of this project.

i. Testing Phase

The testing has been done into two phases. During these phases, results are transferred via internet connection and stored at Google docs cloud storage. Testing is conducted to provide results which specifically reflect the performance and quality of the monitoring system. For a local log, the output of the result has also been captured and stored in a MySQL database.

ii. Component Testing

The component testing is conducted on the hardware components to find out whether they are in good conditions before being used in this project. The components are the Raspberry Pi, DHT sensor, stepper motor, Arduino UNO, camera, lamp and switches.

iii. System Testing

This section shows the testing done on the real device. Users are able to control the system remotely. The system can support any device that have web browser installed, such as computers or smartphones.

iv. Testing Objectives

Two testing have been conducted. Each test and analysis takes up to twenty one days, which makes it 42 days to gather and analyze the data for both tests.

- **First batch – Incubation Process**
  For the first batch, the exact environment as shown in Figure 3 is used. 12 eggs are placed on the turner. For the eggs, on 18th day, the turner should be removed, and the humidity should be kept between 70 and 80 degree Celsius. This must remain from 18 days until hatching phase completes.

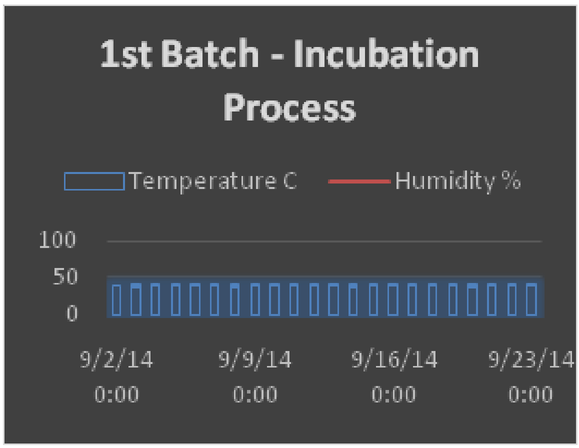
Figure 3: The monitoring system user interface

Type	Incubation Period	Temperature *C	Humidity %	Stop turn after	Humidity last 3 days	Open if more than
Chicken	21	38	25-60	18th day	+20	18th day

Start?

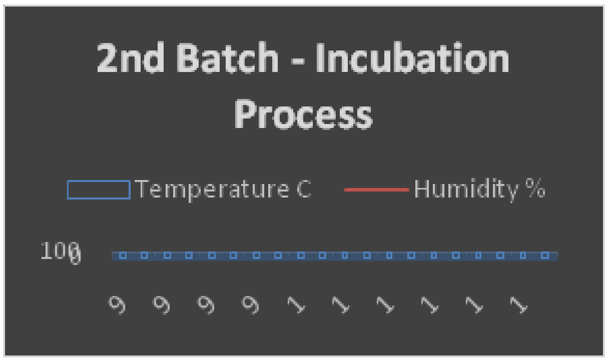
- **First Batch – Result**
  Between the final three days, the user should be aware and keep on monitoring what is happening inside the box. Figure 4 shows such readings from the monitoring made. However, newborn chicks can live without a water and food up to 72 hours (Incubator Warehouse, (2012)). On the 20th day, one of the eggs starts to crack. It is not advisable to help the chicks, because if the egg membrane breaks, and the chick is not ready to come out, it can bleed to death.

Figure 4: Reading from the system for 1st batch incubation



- **Second Batch – Incubation Process**
  For the second process, the scenario set up tries to mimic how a hen would act to hatch the eggs. This is done by incubating the eggs with high temperature, without water inside the box. At the same time, high humidity is applied and the fan is turned off and on inconsistently. Figure 5 shows a snapshot of reading made from the system.

Figure 5: Reading from the system for 2nd batch incubation



- **Second Batch – Result**
  For the first two weeks, the eggs look normal. After two days later, it starts to rot and gives bad smell. There are no movements inside the shell (yolk). It is one of the symptoms that they have died inside the shell. Most of them died because of bacteria, due to lack of fresh air.

  This issue can actually be addressed the auto dimmer board which has been incorporated to this prototype. The bulb can automatically be adjusted to control the heat/frequency based on its environment temperature. With real time auto log/insert into database, they can view it with any device that support web browser. For detail view, it needs to be connected on the local network, and for a minor view, they can view it via Google Docs to check the current temperature and humidity. With piNoir camera, they can monitor it remotely and see what is happening inside the incubator.

v. Testing Results Analysis

Based on both testing that have been done, with the correct or exact temperature, and humidity, the percentage of egg to hatch is high. False temperature and humidity can affect the eggs and can lead it to fail hatch. High temperature can cause injury or death depends on how hot it gets and how long it is hot. Air flow within an egg incubator is important and most vital towards the end of the incubating period. Proper ventilation also removes the carbon dioxide within the incubator for the eggs.

Conclusion

Generally, this project has been successful and the objective of this project has been achieved. This section will focus on the conclusion and the future recommendation of this project.

After a lot of research and observations made, it can be concluded that the prototype of Egg Incubator using Raspberry Pi is successfully developed and functioning perfectly. The objective and requirements of this project have also been achieved. Based on incubation process experiments, it could be found that piBator had contributed into advancing the incubation process. The average of the egg-hatching recorded 83.33% success rate. The accuracy of measuring instruments are determined by using DHT11 sensor and the error of temperature and humidity sensor was less than 5%, which means that measure sensor used in the piBator was acceptable instrument.

Some ideas have been thought of in order to enhance this project and make it better. The recommendations for future development are listed as below:

- Add new sensor such as motion sensor, automatically email to admin if there any motion detected between last three days of hatching.
- Converting circuit from breadboard into the real PCB or Protoshield. Breadboard only suitable for prototype device.
- Register the Raspberry Pi to a webserver so that the detail information can be accessed through internet.

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