SIMULATION OF AN AUTOMATIC INCUBATION SYSTEM FOR POULTRY BUSINESSES

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ABSTRACT
For poultry farmers, one of the activities most integral to a successful endeavor is incubation. Being the primary means by which poultry stock is replenished, it is understandable that the utmost care must be taken to ensure the process is as efficient (in terms of yield) as possible. To this end, this work explores the development of an automatic incubation system, the primary purpose of which is to keep air temperature and humidity within the incubator enclosure within specified limits. The system was built around an ATMega328P microcontroller, DHT11 temperature and humidity sensors and a SIM808 GSM Module enabling remote monitoring. It was found to be capable of monitoring the stated parameters accurately and maintaining them as required.

Keywords: DHT11, GSM, incubation, microcontroller

1.0. INTRODUCTION
Since time immemorial, the practice of keeping chickens and other domestic birds has existed. This initially began as a loose, domestic endeavor ostensibly undertaken for personal or familial consumption of poultry products (Wood-Gush D 1969). As time passed and the demand for poultry products increased, this practice began to transform into a formalized, defined procedure. Initial approaches to poultry practice at this time usually involved the contained rearing of the birds in question within a particular area. Later on, other approaches were discovered, such as the modification of the birds' diet and/or the environment, which went on to have momentous effects on the very nature of poultry practice. With the discovery of empirically-verifiable correlations between some of these parameters and the quantity of yield (meat or eggs) obtained, there was now a valid scientific basis upon which modern poultry practice could be built Hurd (1944).

In poultry farming, there are few processes (if any) as integral as the incubation process. This is on account of the fact that the incubation process is the sole means by which the numbers of birds involved in the poultry farming process can be replenished; Hurd (1944). As a direct implication, the incubation process is required to be as efficient as can possibly be so as to obtain maximum replenishment rates. Traditionally, the incubation process remained largely natural – the birds were effectively in charge of hatching the eggs. Naturally, this process was not completely efficient, as bird attitudes and behaviors led to situations whereby eggs could be physically damaged or eggs would be rendered non-viable. As such, with increasing demand for poultry products, the incubation process was therefore required to become as efficient as possible. Therefore, automatic incubation machines were designed to mimic the natural environment and actions integral to the successful hatching of eggs. The primary variables affecting the viability of an egg are the environmental temperature, the environmental humidity and the degree of physical agitation. Therefore, automatic incubation machines aim to increase hatching yield by maintaining temperature and relative humidity within safe/desirable limits, as well as introduce some degree of physical agitation to the hatching environment.

With the advent of the Transistor in 1947, a new chapter was ushered in the field of Electronics. Amongst the direct benefits of the introduction of this new device was that building logic circuits was now possible using a fraction of power and space required before, while obtaining far better switching speeds and performance. This meant that digital machines could be actively considered as feasible solutions since their implementation could be carried out at such an output/cost ratio that was suitably compelling. For these reasons, digital electronics gained a large boost around that time. Naturally, the need for a general-purpose programmable machine had remained for several years prior to the invention of the Transistor, Betler, *et al.* (1997). With Transistors and manufacturing advancements (LSI, VLSI, etc), such devices could now be reasonably achieved. This eventually led to the introduction of the world's first commercially-available microprocessor, the Intel 4004, Faggin *et al.* (1996). In general, microprocessors required extensive support circuitry, and this characteristic effectively curtailed the adoption of microprocessors in many scenarios due to design constraints. Not long after the advent of the Intel 4004, the world's first microcontroller was introduced. It was called the Texas Instruments TMS1000 and included 4-bit processing core similar to Intel's 4004, G.P. Swann (1985). The integral difference between the two chips was the fact that the TMS1000 included most of the components it required to operate (memory, clock generator, etc) on the chip die, as opposed to the 4004 which required these units to be provided externally. Over the next two decades, several advances were made in storage and processor technology, and microcontrollers became more powerful by leveraging this newer, better technology. In addition, microcontrollers gained new features that lent them more suitability for use in embedded systems. Examples of such features include the presence of general-purpose digital input/output pins, onboard analog-to-digital/digital-to-analog converters, timing and communication peripherals, etc.

Fundamentally, a microcontroller is not functionally different from a microprocessor. Therefore, this means that a microcontroller is a general-purpose device whose function is defined by the software running on it. As a result, microcontrollers require a program to function. However, being general-purpose, they lend themselves to virtually every possible problem domain in the context of Electronic device design and control. By utilizing their input/output pins and peripherals, microcontrollers allow for an unprecedented degree of freedom in systems design and implementation.

This work details the design and implementation of an automatic incubator system for a small poultry business. This system is designed to keep the internal temperature of the incubator enclosure between 37.1 and 38.7°C Fresh (1997), and also keep the internal humidity between 50 and 55%. In addition, the system will provide a local display indicating the values of the incubator temperature and humidity. It also incorporates a mechanical agitator to rotate the egg trays periodically. Finally, the system will provide remote monitoring and reporting capability by incorporating a GSM module permitting communication via text message.

2.0 MATERIAL AND METHODS

2.1 COMPONENT SELECTION

A. ATMega328P Microcontroller

The ATMega328P is an 8-bit microcontroller designed and manufactured by Atmel Corporation. It is available in DIL (dual-in-line), QFN (quad flat no leads) and TQFP (thin quad flat package) form factors with 28 and 32 pins respectively. It is capable of running at a maximum clock speed of 20 MHz and has 32Kbytes of flash storage, 2kbytes of RAM and 1Kbyte of EEPROM. It also has an onboard six-input successive- approximation (SAR) analog to digital converter, three timer peripherals, one USART (universal synchronous asynchronous receiver transmitter), one SPI (serial peripheral interface) and one I2C (inter-integrated circuit) peripheral. This microcontroller was chosen for this work due to its wide availability, low cost and easy programmability.

B. DHT22 Temperature and Humidity Sensor

The DHT22 is a low-cost, generic temperature and humidity sensor, capable of measuring temperatures between -40 and 80 °C with an accuracy of ±0.5 °C and relative humidity values between 0% and 100%, accurate to within 2-5% of the actual value. It uses a proprietary one-wire interface to transfer data unidirectionally (sensor to host processor only). It also operates between 3V and 5V.

This sensor was selected for use in this work because it provides both temperature and humidity readings in a single package with acceptable accuracy for both variables.

C. SIM808 GSM Module

The SIM808 GSM module is a quad-band, 2G-only GSM peripheral manufactured by SimCom. It supports the popular Hayes "Attention" instruction set for initiating actions and querying the internal GSM baseband chip. It also supports both text (ASCII) and PDU mode, specifying the input and output data formats used by the module. It also includes an onboard GPS module which was not used in this work.

This module was selected for use in this work due to its wide availability, low cost and high performance.

D. JHD162A LCD Display

The JHD162 display is a 16 character/row, 2 row "positive transflective" LCD display manufactured by Sunrom. It includes a fixed-color green backlight and includes an industry-standard HD44780 interface controller from Hitachi Corporation. Due to the presence of the HD44780 interface controller, this display supports 8-wire mode and 4-wire mode. This display was selected for use in this work due to its wide availability, low cost and suitability for use in the target context.

E. Hitec HS-422 Servo

The HS-422 is a hobby-grade PWM servo from Hitec. It is capable of delivering up to 57 ounce-inch of torque at a rotary speed of 60° / 0.16 s. It operates between 4.8V and 6V, providing nearly 180° of position range. It requires a PWM control pulse train (50Hz nominal frequency) with a mark timing of between 1500 and 1900µS.

This servo was chosen for this purpose due to its wide availability, low cost and holding torque properties.

2.2 METHODOLOGY

Based on the stated goals of this work, the system was implemented using an ATMega328P microcontroller as the main processing element. In order to keep track of the internal incubator conditions, three DHT22 temperature and humidity sensors were used. Due to the fact that the incubator enclosure is not trivially-sized, the sensors were placed at different points within the enclosure. The rationale behind this sort of arrangement is that the actual temperature within the incubator is really the average temperature detected by the sensors. Individual sensors may detect widely varying temperatures depending on their proximity (or lack thereof) to heat sources located within the enclosure itself. However, a circulatory fan is included in the enclosure, the purpose of which is the constant recirculation of air inside the enclosure. As a result, local hot (and cold) zones do not exist in reality.

2.3 DESCRIPTION OF THE INCUBATOR

Since control features were required in this work, a heater, fluid atomizer and extraction grille/vent were included. The heater is a resistive type powered by mains and is controlled by means of a relay connected to the microcontroller via a suitable driver circuit. The atomizer is comprised of an ultrasonic vibrating element and a special driver board for generating signals of the correct magnitude and frequency for the vibrating element. The extractor grille/vent is a simple hatch that is sealed or opened via the agency of a servo-actuated mechanism. These elements were included because the temperature or humidity might require raising/increase, and such a condition would be achieved by enabling the heater or atomizer as required. The lower thresholds that would cause the heater and atomizer to be activated were set at 37.1°C and 50% RH respectively.

However, it must be noted that the converse case(s) must also be catered for i.e the temperature or humidity might require lowering/decrease. By design, this should not occur frequently because the incubator is considered to be a closed system in itself. The direct implication of this is that the temperature and humidity within the incubator enclosure are under direct control of the heater and atomizer, with natural decay occurring over time i.e once the heater is activated and eventually turned off, then the temperature within the incubator is meant to drop off slowly with time – ditto for the humidity. However, external conditions or foreign actors might impinge upon the dynamics of the incubator enclosure, necessitating the inclusion of measures to correct anomalous conditions due to such external factors. To this end, the extraction grille/vent was provided. The actual lowering of the temperature or humidity relies on the microcontroller being able to open the extractor grille when anomalous conditions i.e excessive heat or humidity are detected. The upper thresholds that would cause the extractor grille to be opened/unsealed were set at 39.8°C and 57% RH respectively. These values were set to be slightly above the maximum allowed temperature (38.7°C) and relative humidity (55%) for safe incubation. This way, once the temperature or humidity exceeds either of these limits the extractor grille is immediately opened to minimize risk to the eggs. Once the conditions (temperature and humidity) are both within safe limits (37.1 °C to 38.7°C, 50% to 55% RH) the grille is resealed. In order to provide remote monitoring of the incubator, a SIM808 GSM module was included. It communicates with the microcontroller over a UART/Serial interface at 9600 baud. Specifically, the GSM module comes into play in two instances – the first of these is if the water level in the atomizer's water reservoir is found to be low. Should this be the case, the system will automatically send an SMS to a preprogrammed number notifying the receiver of the condition detected. This message is sent once to avoid becoming a nuisance to the receiver.

The other instance is when the user sends an SMS to the system containing a keyword ("QUERY"). The system will then respond with the current temperature, humidity and atomizer water level.

A servo-actuated tray agitator was also included, as described earlier. Specifically, this is controlled by periodically varying the duty cycle of the PWM signal sent to the Servo, the net effect of which is to cause the tray to be tilted at ±20° alternately to the horizontal/ground plane every 3 s.

The system software was developed using the C++ programming language and compiled using the Arduino platform IDE (integrated development environment) and tools. The resulting machine code file (HEX file) would then be transferred to the microcontroller. A flowchart displaying the execution cycle of the program is shown in Figure 1 below.

3.0 RESULTS AND DISCUSSION

In order to simulate the behavior of the whole system, Labcenter Electronics Proteus ISIS 8 was used. This is a software package supporting real-time simulation of microcontrollers and a host of sensor and actuator devices. By simulating the system and its behavior in response to different conditions, it is possible to rapidly iterate and resolve potential problems, and consequently, validate the correct behavior of the system as a whole.

The system was constructed according to the requirements stated earlier. The simulation environment supported the microcontroller, LCD display, servo motor and the DHT22 sensors. However, there was no direct substitute for the atomizer water level sensor or the SIM808 GSM module. For this reason, a toggle switch was used in place of the water level sensor since its output is binary – high/1 for sufficient water, low/0 for insufficient water, which mirrors the outputs obtainable from the toggle switch. Similarly, light-emitting diodes (LEDs) were used in place of the heater and atomizer circuits since they are controlled by digital (binary) signals, similar to the behavior of LEDs. Thus, for the heater, the corresponding LED would be lit if the microcontroller turned on the heater, and would be unlit if the microcontroller turned the heater off. The same scheme is used for the operation of the atomizer LED.

Since the GSM module interfaces with the microcontroller using a standard UART/Serial link, a Serial terminal component was used instead. The Serial terminal component allows for communication (reception and transmission) of ASCII characters via a Serial interface. Hence, any messages emitted by the microcontroller would be displayed in the Serial terminal, and any data to be sent to the microcontroller could be typed/entered via the Serial terminal. A screenshot of the running system in the simulation environment is provided in Figure 2.

During testing, the system was found to operate as designed. By adjusting the temperature and humidity detected by each sensor (via the controls provided by the Proteus ISIS simulator software) it was verified that the heater and atomizer were enabled and disabled under the correct conditions. Similarly, the grille would be actuated when the anomalous conditions (as described earlier) were detected. The monitoring functionality was also found to operate as designed.

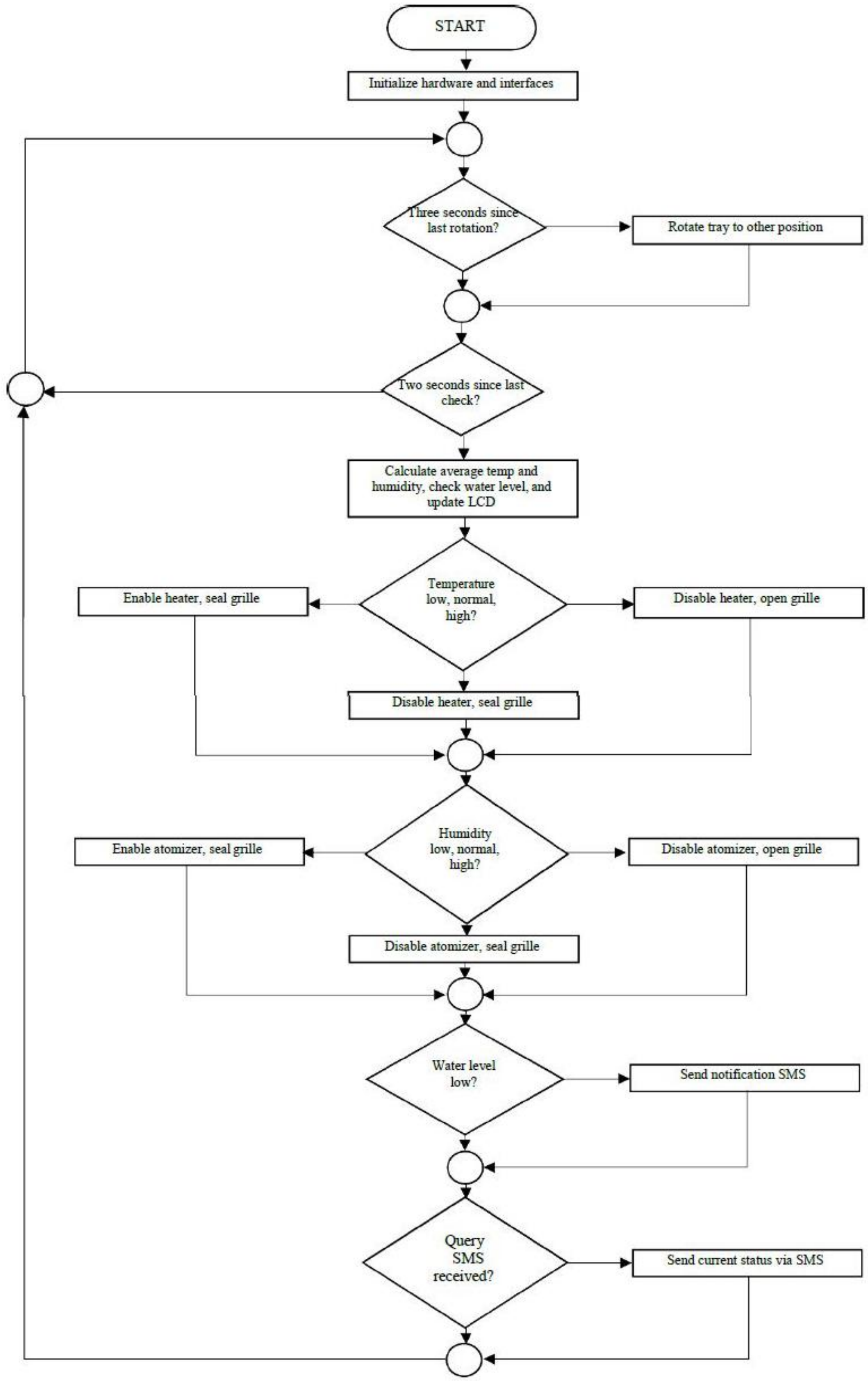

Figure 1: System Simulation in Proteus ISIS Environment

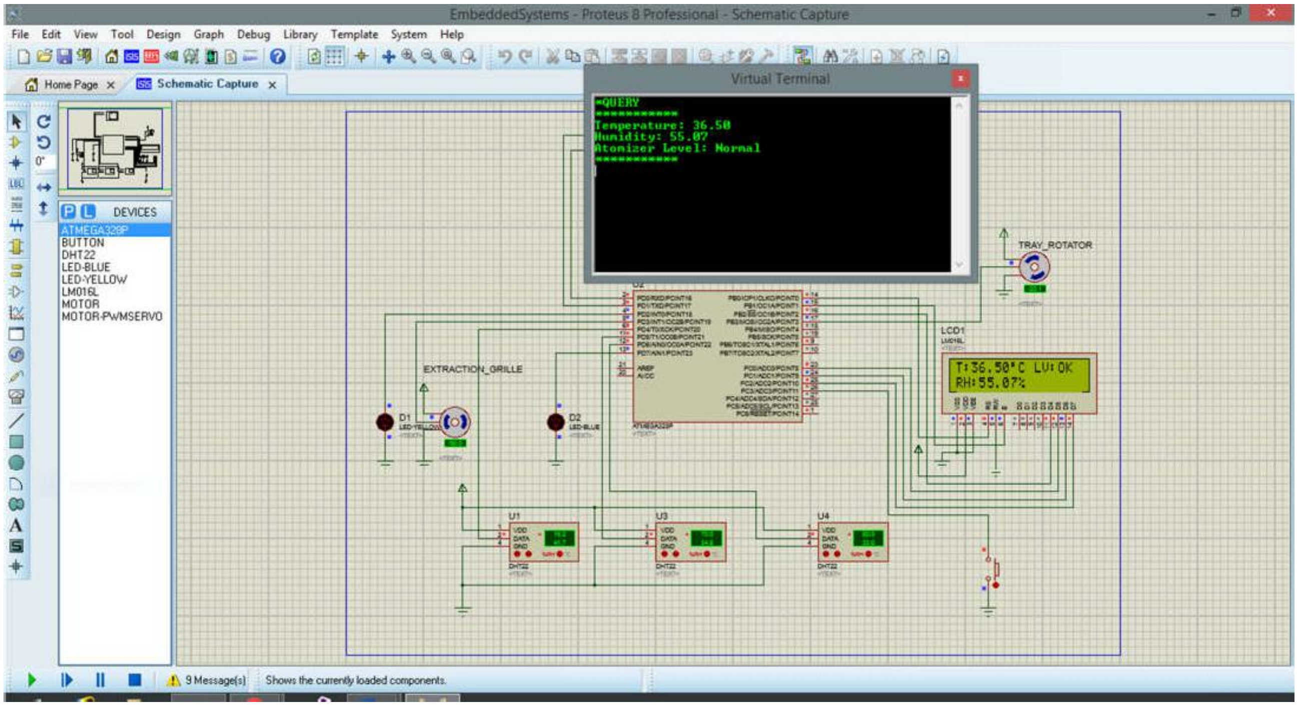

Figure 2: System Simulation in Proteus ISIS Environment

5.0. CONCLUSION

This work explored the design and development of an automatic incubation system for poultry businesses. Target parameters were identified and suitably ranged for optimal operation of the incubator. Design considerations were also discussed regarding component selection and operational behavior and expectations of the system. During simulation and testing, the system was found to meet desired operational objectives as desired.

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