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A CONTROL SYSTEM FOR REMOTE MONITORING AND CONTROL OF THE TEMPERATURE IN CHICKEN EGGS HATCHING USING ARTIFICIAL INCUBATORS

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ABSTRACT

According to OACD/FAO Agricultural Outlook, poultry meat remains the primary driver of growth in total meat production. Its short production cycle allows producers to respond quickly to market needs, as well as rapid improvements in genetics, animal health, feeding practices, breeding conditions and breeding environment. Hatching process needs to be done properly in order to maximize the number of healthy chickens hatched and to minimize their death rate. When using artificial egg incubation, it is important to monitor and control ambient conditions in incubators, to obtain ventilation and egg turning. Ambient conditions are expressed in terms of temperature and humidity, where maintaining and controlling the temperature inside the incubator is of the greatest importance. This paper deals with the description of a control system developed for remote monitoring and control of the temperature in chicken eggs hatching using artificial incubators. The system consists of heater in a form of an incandescent light bulb, temperature sensor, relay, microcontroller, and communication module. For temperature control, a PID (proportional-integral-derivative) controller is designed, which maintains the temperature at 37.8 °C. Temperature readings are available through the web browser and are accessible using wired Internet connection. Proposed system represents a simple, low-cost but very efficient solution which provides the necessary conditions for proper development of chickens while growing inside the egg.

Key words: *temperature control, PID, hatching, artificial incubator, Internet of Things.*

INTRODUCTION

Poultry meat consumption is predicted to increase globally to 145 million of tons by the 2029, with poultry expected to account for 50% of the additional meat consumed. This provides the poultry meat to remain the primary driver of growth in total meat production, accounting for half of all additional meat produced over the next decade. Poultry meat short production cycle, rapid improvements in genetics, animal health, feeding practices, breeding conditions and breeding environment allow producers to respond quickly to market needs (OACD/FAO Agricultural Outlook, 2020).

To achieve the stated predictions, it is necessary to provide optimal conditions for hatching process. This process can either be natural or artificial. In natural hatching, a hen provides all the conditions by sitting on few eggs, turning them regularly and incubating until they hatch. Artificial hatching involves the usage of artificial incubators which maintain necessary conditions for hatching a large number of eggs. During the incubation, the heat is being applied to fertilized eggs to keep them warm and allow proper development of the embryo into a chick. Besides the incubation, eggs collecting, storing and turning need to be done properly when using artificial incubators in order to maximize the number of healthy chickens hatched and to minimize their death rate.

In artificial incubation, successful hatching depends on maintaining proper environment conditions (temperature, humidity, air quality), especially in incubation stage, of which temperature has the strongest influence and is the most critical (Clauer, 2009). Optimal incubation temperatures result in high hatchability of healthy chicks with good post-hatch performance (Boleli et al., 2016). Incubation temperature needs to be set according to requirements of the embryo and fetus in different stages of incubation. Optimal ambient temperature for incubating poultry species should be between 37°C and 38°C (French, 2009). In order to keep eggshell temperature on appropriate level, incubator temperature has to be between 37.5°C and 38°C (Boleli et al., 2016). Smith (2004) states that the best hatching, when using forced-air incubators, is obtained by keeping the temperature at 37.8°C, with fluctuations less than 0.5°C, and when using still-air incubators it should be kept at 38°C. Similarly, Archer and Cartwright (2018) suggest that the incubator temperature should be between 37.5°C and 38°C for chickens during the set stage.

Modern automated artificial incubators are equipped with heating and cooling units, humidifiers, ventilation system and eggs turning mechanism (French, 2009). Large scale industrial incubators can store hundreds to thousands of eggs, while small hatcheries, intended for home production, usually store a couple of tens of eggs in artificial incubators. Small hatchery owners can build artificial incubators on their own, instead of purchasing commercial ones which are usually expensive, considering their specific requirements and needs, and control all the necessary incubation and hatching conditions. Some examples of such incubators and temperature control techniques are given as follows. Thermoelectric egg incubator is proposed in (Suriwong et al., 2016), while automatic temperature closed-loop control system for egg incubation is designed in (Lawal et al., 2014). The rapid development of Internet of Things (IoT) paradigm over the last decade enabled the production of smart egg incubators. These incubators are very easy and efficient to use in small hatcheries and provide controlling and monitoring incubation environment parameters easily. Besides this, they are provided with Internet connection, which is not the case with traditional incubators, so they enable chicken breeders to monitor these parameters anytime from anywhere. The most important parts of a smart incubator are microcontroller and various sensors. IoT prototyping boards are very suitable to be used in eggs incubators, so Raspberry Pi was used in (Adnyana et al., 2018; Purwanti et al., 2021) and Arduino in (Shafiudin and Kholis, 2018; Bacalso and Sobejana, 2021, Gutierrez et al., 2019). When controlling the temperature, different control systems theory techniques can be used, such as PID (proportional-integral-derivative) control and fuzzy logic control. For example, PID control is used in (Ohpagu and Nwosu, 2016; Shafiudin and Kholis, 2018) and fuzzy logic control is used in (Alimuddin et al., 2012, Aborisade and Oladipo, 2014; Rakhmawati et al., 2019). Islam Juel and Ahmad (2019) proposed a smart auto-balanced system for incubation process with Android application and Bluetooth module for wireless communication, while Bacalso and Sobejana, (2021) developed temperature and humidity controller with GSM module and SMS notification.

This paper deals with the description of a control system developed for remotely monitoring and controlling the temperature in chicken eggs hatching using artificial incubator. For temperature control, a PID controller is designed, which maintains the temperature at 37.8 °C. Temperature readings are available through the web browser and are accessible using Internet connection. Proposed system represents a simple, low-cost but very efficient solution which provides the necessary conditions for proper development of chickens while growing inside the egg.

MATERIAL AND METHODS

The developed control system for remotely monitoring and controlling the temperature, given in figure1, consists of heater in a form of an incandescent light bulb, Arduino Uno board, digital temperature sensor module, relay, potentiometer, and communication module. The system reads and maintains the temperature values inside the incubator, stores these values in a database and enables the users to monitor them through the web browser, as shown in figure2. The Arduino Uno board (Arduino, n. d.) belongs to Internet of Things microcontroller-based devices. It provides power to the sensor module, reads temperature values generated at its output and generates a digital signal that turns the relay (heater) on and off. For reading the incubator temperature, a DS18B20 (Digital sensor, n. d.) digital sensor module was used. The role of the used SSR-25DA relay (Solid-state relay, n. d.) is to instantly switch the heater on and off, by which the temperature is changed and controlled. Connection between Arduino Uno and Internet is obtained by Arduino Ethernet shield. Potentiometer enables setting the reference temperature at the desired value manually. The reference temperature is, according to literature, chosen to be 37.8 °C. The software part of the system is written in Arduino IDE software tool. For maintaining the temperature at reference value, a PID controller is designed in Arduino IDE.

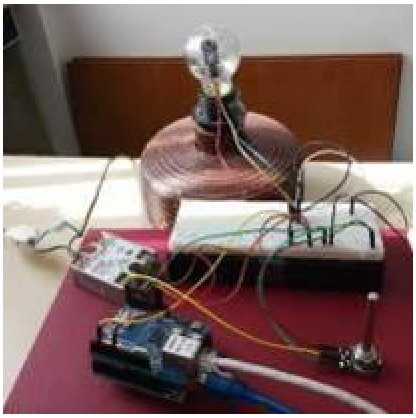


Figure 1: Experimental setup of a system for reading and controlling the temperature in egg incubator

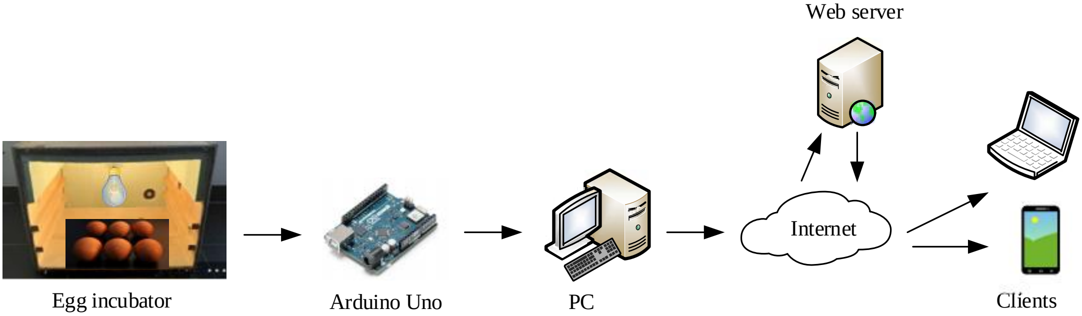


Figure 2: Functional diagram of remotely monitoring and controlling the egg incubator temperature

To make the system work properly, a database was created using MySQL (MySQL, n. d.) system. Within the database, a table was created in which relevant parameters are stored (reference temperature, incubator temperature, PID controller parameters). Several .php files were created to enable Arduino board to establish a connection with the database, to communicate with the database and send data to it, and for displayig the parameter values from the database in a web browser. The Apache HTTP server (Apache, n. d.) was used as a web server.

RESULTS AND DISCUSSION

Developed system was created and tested in Digital control systems laboratory at the Faculty of Electrical Engineering in East Sarajevo. The most important objective was to determine whether the system maintains the reference temperature in a proper way. Through the running the experiment many times, it was observed that the designed PID controller, with the parameters K_p=10, K_i=3 and K_d=1, maintained the temperature on the set value. Furthermore, in a case of presence of disturbances in the system, which violated temperature inside the incubator, the controller was able to regulate the temperature value and achieve the reference quickly and very efficiently. Figure 3 shows the step response of developed system which, from the control systems theory point of view, means that designed system behaves in a desired manner. This response is generated based on the values of the parameters from the database.

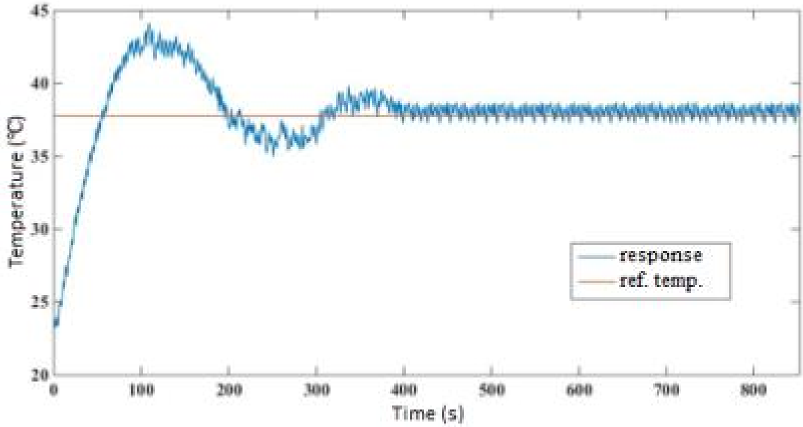
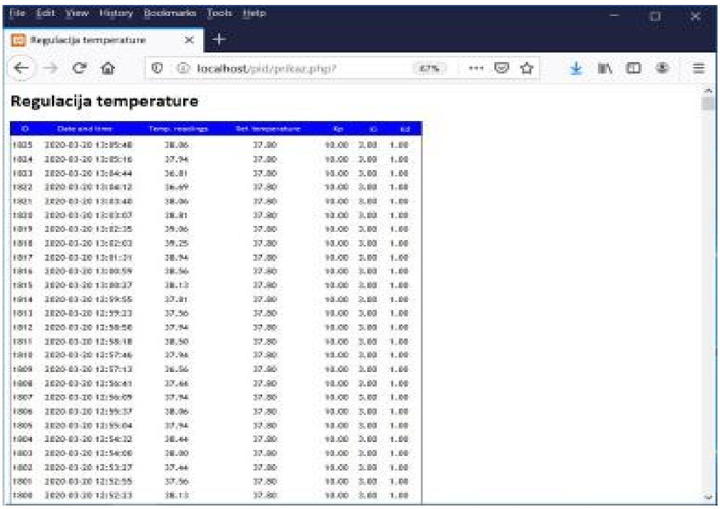


Figure 3: Step response of developed system

Temperature readings are available through the web browser and are accessible using wired Internet connection. A part of these readings is shown in Figure 4. It can be observed that when the incubator temperature is slightly less or more then the set one, PID controller, giving the command to the relay to switch the heater on or off, regulates the temperature and brings it on the desired value. This figure also shows that the temperature inside the incubator, when there are no disturbances, is within the limits found in literature.



Regulacija temperature

ID	Date and time	Temp. readings	Set temperature	Kp	Ki	Kd
1825	2020-03-20 13:05:48	38.06	37.80	10.00	3.00	1.00
1824	2020-03-20 13:05:16	37.94	37.80	10.00	3.00	1.00
1823	2020-03-20 13:04:44	36.81	37.80	10.00	3.00	1.00
1822	2020-03-20 13:04:12	36.69	37.80	10.00	3.00	1.00
1821	2020-03-20 13:03:40	38.06	37.80	10.00	3.00	1.00
1820	2020-03-20 13:03:07	38.81	37.80	10.00	3.00	1.00
1819	2020-03-20 13:02:35	39.06	37.80	10.00	3.00	1.00
1818	2020-03-20 13:02:03	39.25	37.80	10.00	3.00	1.00
1817	2020-03-20 13:01:31	38.94	37.80	10.00	3.00	1.00
1816	2020-03-20 13:00:59	38.56	37.80	10.00	3.00	1.00
1815	2020-03-20 13:00:27	38.13	37.80	10.00	3.00	1.00
1814	2020-03-20 12:59:55	37.81	37.80	10.00	3.00	1.00
1813	2020-03-20 12:59:23	37.56	37.80	10.00	3.00	1.00
1812	2020-03-20 12:58:50	37.94	37.80	10.00	3.00	1.00
1811	2020-03-20 12:58:18	38.50	37.80	10.00	3.00	1.00
1810	2020-03-20 12:57:46	37.94	37.80	10.00	3.00	1.00
1809	2020-03-20 12:57:13	36.56	37.80	10.00	3.00	1.00
1808	2020-03-20 12:56:41	37.44	37.80	10.00	3.00	1.00
1807	2020-03-20 12:56:09	37.94	37.80	10.00	3.00	1.00
1806	2020-03-20 12:55:37	38.06	37.80	10.00	3.00	1.00
1805	2020-03-20 12:55:04	37.94	37.80	10.00	3.00	1.00
1804	2020-03-20 12:54:32	38.44	37.80	10.00	3.00	1.00
1803	2020-03-20 12:54:00	38.00	37.80	10.00	3.00	1.00
1802	2020-03-20 12:53:27	37.44	37.80	10.00	3.00	1.00
1801	2020-03-20 12:52:55	37.56	37.80	10.00	3.00	1.00
1800	2020-03-20 12:52:23	38.13	37.80	10.00	3.00	1.00

Figure 4: Temperature readings available through the web browser

CONCLUSIONS

Among various incubation conditions, temperature conditions are of the greatest importance and need to be satisfied to obtain maximum chicken production. Described control system for remotely monitoring and controlling the temperature in chicken eggs incubator represents a simple, low-cost, and efficient IoT based solution intended for use in small chicken farms. The system is based on IoT hardware components and uses Internet connection for monitoring the temperature values inside the incubator. The system users can access the temperature sensor readings through the web browser. The functionality of proposed system can be extended by adding humidity and air quality sensors, as well as Wi-Fi module which will be the subject of future research. Besides this, slight modifications of developed system can be performed with the aim of using it in another agricultural applications of interest (greenhouses, different warehouses, grain tanks, stables, etc.).

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