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Development of incubator for the preservation of endemic birds and reptiles of Quintana Roo

Desarrollo de incubadora para la preservación de aves y reptiles endémicos de Quintana Roo

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Abstract

This article presents the design, programming, control and monitoring of the temperature, relative humidity, angular position and aeration of eggs of an artificial incubator prototype for the preservation of birds and reptiles endemic to Quintana Roo. As an example, the incubation parameters of poultry (chicken) and an endemic species (macaw) are presented. A shield card is used to facilitate coupling on the Arduino Mega card with the electronic components. The programming routine performs the automatic incubation, using the LabVIEW software to tune the PID controllers (Proportional Controller - Integral - Derivative) by means of the Ziegler-Nichols first and second method.

PID controller, Temperature, Humidity position

Resumen

En este artículo se presenta el diseño, la programación, el control y monitoreo de la temperatura, humedad relativa, posición angular y la aireación de los huevos de un prototipo de incubadora artificial para la preservación de aves y reptiles endémicos de Quintana Roo. A manera de ejemplo se presentan los parámetros de incubación de un ave de corral (pollo) y una especie endémica (guacamaya). Se emplea una tarjeta shield para faciltar el acoplamiento en la tarjeta Arduino Mega con los componentes electrónicos. La rutina de programación realiza la incubación automática, se utiliza el software LabVIEW para sintonizar los controladores PID (Controlador Proporcional – Integral - Derivativo) por medio del primer y segundo método de Ziegler-Nichols.

Controlador PID, Temperatura, Humedad posición

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Introduction

At present there is a need to incubate eggs of birds and reptiles endemic to the state of Quintana Roo with the intention of preserving the greatest number of endangered species.

The fact that preservation talks are more constant reveals that the current situation is very worrying. The vast biological diversity developed on our planet through evolution over millions of years is in great danger. The rate of disappearance increases rapidly. It is estimated that between 17,000 and 35,000 species extinguish each year worldwide. It is expected that in fifty-one hundred years most species will have disappeared.

Endemic species are those species of flora and fauna typical of a geographical area, considered exclusive to a region, as they do not exist anywhere else in the world and represent one of the greatest riches of the landscape, as well as one of the best indicators of the biological heritage of a country. In general, they are usually classified as vulnerable species, since their restricted location and limited population make them susceptible to threats.

The state of Quintana Roo has a record of 483 bird species including two introduced species, from 71 families, representing 88% of bird species in the Yucatan Peninsula, 44% of birds in Mexico and 4.8% of birds in the world. It holds 23 families, 72 genera and 106 reptile species of the 140 reported for the Yucatan Peninsula 75%, which represents about 13% of the national total and 1.3% of the world. Table 1 shows the common name, genus and species, order and family. For more information see (Valdez, 2012).

Common Name	Genus and species	Order	Family
Birds			
Keel-billed toucan	Ramphastos sulfuratus	Pciciformes	Ramphastidae
Slaty-tailed trogon	Trogon massena	Trogonifor	Trogonidae
⋮	⋮	⋮	⋮
Black-and-white hawk-eagle	Spizaetus melanoleucus	Accipitrifo	Accipitridae
Reptiles			
Boa constrictor	Boa constrictor	Squamata	Boidae
Yucatan banded gecko	Coleonyx elegans	Squamata	Gekkonidae
⋮	⋮	⋮	⋮
Yucatsn white-lipped snake	Symphimus mayae	Squamata	Colubridae

Table 1 Bird and reptile species in Quintana Roo included in NOM 059

The article is organized as follows: Section II contains information regarding artificial incubation, while the development of the prototype is described in section III. In section IV the proposed control system for the artificial incubation variables is presented; finally, in section V we present the conclusions.

Artificial incubation

The incubation regime is defined as the set of physical factors present in the environment surrounding the egg. On the other hand, artificial incubation is a process by which conditions suitable for proper embryonic development are provided.

This type of incubation is possible because of a followed methodology, where the fertilized egg is taken and placed into an enclosure in a controlled environment; after a period of days, the embryo can develop until it hatches. This process involves variables that must be controlled to ensure its success.

N°	Incubation (factors)	Artificial incubation (Variables)	Unit of measurement
1	Temperature	Temperature	$[°C]$
2	Humidity	Relative Humidity	[%]
3	Rotation	Angular position	[°]
4	Aeration	Aeration	[%]

Table 2 Factors and variables of an incubation and artificial incubation with its units of measurement

The efficiency of births is directly related to the control of the variables shown in Table 2. Excessive increase or decrease in temperature and/or humidity for a period of time causes a significant decrease in the number of births. For example, high temperatures can cause the birth of premature offspring and low temperatures a late birth. The angular position of the eggs is the variable which prevents the yolk from adhering to the shell, as it also helps the formation of the Vitelline vesicle membrane and blood vessels, the supply of nutrients to the extra-embryonic organs and to eliminate embryonic heat (Jiménez Rueda, 2008).

Finally, the last important manipulated variable is the air flow, better known as aeration, because while the embryo is developing, there is a constant flow of carbon dioxide and oxygen through the shell.

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Temperature

At the beginning of the incubation, the embryos are not functionally or organically prepared to emit heat. This is why they react like cold-blooded organisms, that is, when the air temperature raises, the metabolism of the embryos increases. If the temperature decreases, the metabolism decreases. Therefore, the increase in temperature favors cell multiplication, the formation of embryonic layers and membranes (allantoids, chorion, amnions and yolk sac are shown in Figure 1), as well as nutrition.

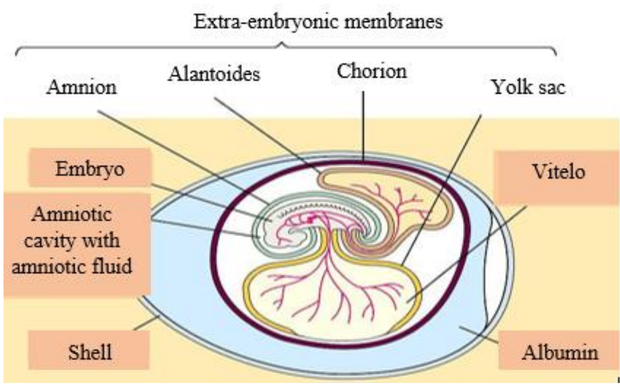


Figure 1 Egg structure

Relative Humidity

The humidity of the environment inside the incubator is lost due to evaporation and because water is absorbed by the embryo through the pores of the shell; therefore, it is necessary to restore that moisture. The highest humidity requirements are in the terminal phase of the incubation cycle, because the embryo needs to rotate in order to break the shell and if the surrounding membranes dry out due to lack of moisture, the embryo dies.

This is measured by evidencing broken eggs with dead embryos inside, due to insufficient humidity in the incubator. Viscous embryos have their lungs stuck due to a high humidity rate; abnormal, weak and small embryos develop due to insufficient humidity at the end of the incubation cycle; and embryos with small lungs form due to low humidity rates.

Angular position

Embryos develop normally only when the eggs are turned, that is, a periodic angular rotation is performed during the first 18 days of incubation (in the case of chickens.) Varying the angular position improves oxygen utilization across the entire shell surface. Both are reflected in better developed offspring.

For this reason, the embryo is exposed to sticking to the inner membranes of the shell, which can cause death, particularly during the first six days of incubation.

In addition to this, the fact that the specific weight of the embryo leads it to remain at the top of the yolk during the first days, below and very close to the shell in the air chamber.

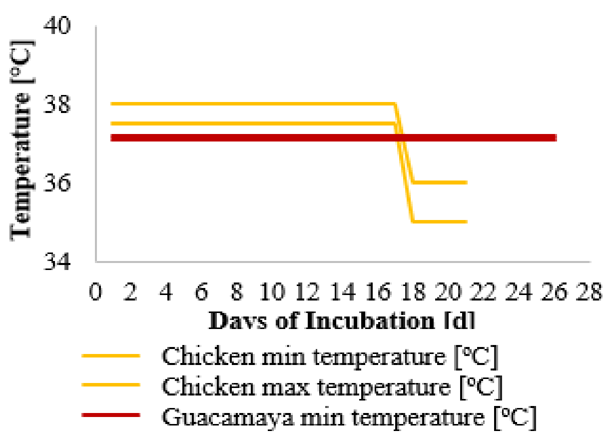
On the other hand, the position of the egg influences the position that the brood will adopt when preparing for hatching; this is of great importance to obtain a high percentage of births.

Aireation

The ventilation problem must be addressed in two ways: the circulation of air itself and the renewal or replacement of air. Temperature differences can be used to detect air flow problems.

If the air is not being uniformly distributed throughout the incubator, the result is prenatal death of the embryo. During incubation the egg absorbs oxygen and removes CO_2 in large quantities. Only an adequate air exchange guarantees good incubation results.

Figure 1 shows the temperature range comparison between a poultry (chicken) and an endemic species of Quintana Roo (macaw). On the Y axis the temperature range of each species is plotted, while on the X axis the incubation time is presented. It should be mentioned that the temperature range of the macaw is more precise, it only varies 0.1 °C, while the chicken has a tolerance of 0.5 °C.



Graph 1 Incubation temperature comparison between a chicken and a macaw

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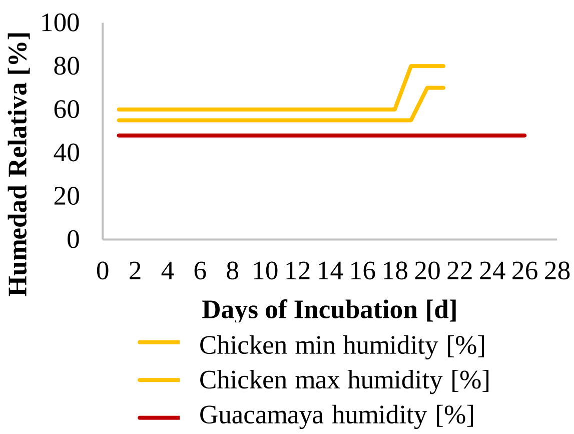
Graph 2 shows the relative humidity variable in comparison between a chicken and a macaw, where the chicken has a range of 5% so that the embryo can develop, while for the macaw the control of relative humidity must be more subtle, since variations in their development are not allowed. The incubation of macaws is very delicate, 2 of 3 tend to die due to slight variations. The incubation period expressed in days is shown on the *x* axis and the relative humidity range on the *y* axis.



Graph 2 Comparison of relative humidity to incubate a chicken and a macaw

Graph 3 shows the incubation time of the 28 days expressed in hours, in order to appreciate the change in the angular position. The rotation of the eggs helps the yolk not to adhere to the shell and thus the embryo develops correctly, even the turning of the eggs improves the distribution of heat and humidity, so the species has a better chance of developing in good conditions.

The *x* axis shows the hours of incubation and the *y* axis the degrees of rotation of the egg ranging from 0° to 180°.

It should be mentioned that the chicken must be rotated 5 times per day, while the macaw requires 6 rotations to ensure a successful incubation.

Prototype development

In order to understand the operation of the proposed artificial incubator, a block diagram has been developed with the general components that have been classified into six sections, in which the Man-Machine interface, the data acquisition system (DAQ), the variable monitoring, the knobs to adjust the control references, the sensors and the actuators shown in Figure 2 stand out.

In order to observe in greater detail the components of the electronic instumentation and the isolation for the power outputs by means of optocouplers, the electronic design of a shield card was made with an Arduino Mega 2560, in which the sensors, actuators and voltage sources are connected, as illustrated in Figure 3. Once the construction of the printed circuit board is completed, the actuators are assembled and the sensors are fixed to the incubator.

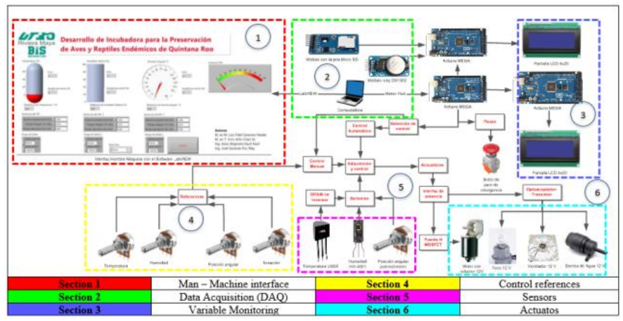


Figure 2 Block diagram of incubator components

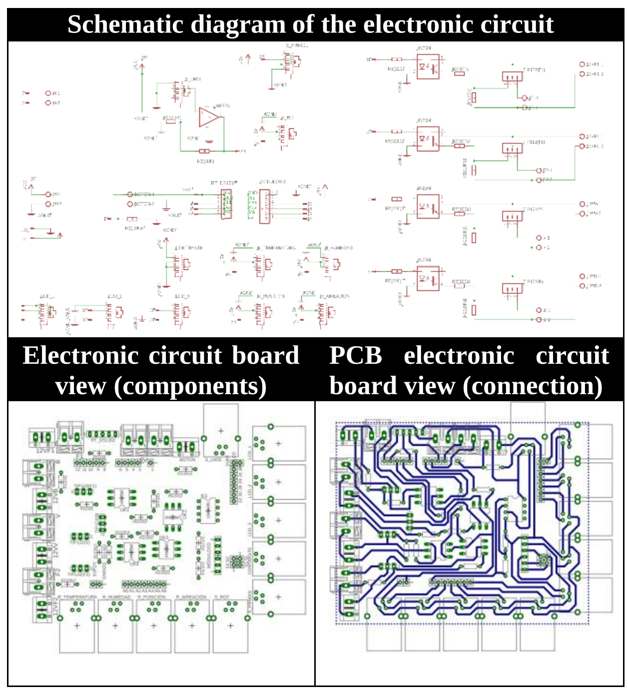


Figure 3 Schematic diagram of the electronic circuit with two board views

Proposed Control System

To maintain the artificial incubation parameters of the prototype shown in Figure 4, a control system is proposed, which is composed of three PID controllers (Ogata, 2010), (Ziegler, 1942) and a conditioning controller.

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Figure 4 Prototype of the artificial incubator

The first controller serves to regulate the incubation temperature, where it is possible to vary the power of the actuator (four lights) to evenly increase the heat, the reading of this variable is done by means of an analog temperature sensor LM35DZ. The proposed structure of the PID controller to regulate the temperature using a bulb and a fan has been implemented for a closed thermal system, with experimental results in (Cerecero, Puc, Ceme, Kauil, & Chan, 2019).

The second controller serves to regulate the humidity of incubation, where it is possible to vary the power of the actuator (water pump with mist sprinkler) to increase the relative humidity inside the incubator, the reading of this variable is done by means of an HIH-4000-001 analog humidity sensor. The proposed structure of the PID controller to regulate humidity is based on the first controller, only the sensor and the actuator are modified.

The third controller serves to regulate the rotation of the egg, where it is possible to vary the angular position of the actuator (the axis of a CD motor) to turn the egg evenly as necessary for the incubation time, the reading of this variable is done by means of a logarithmic potentiometer configured as a voltage divider.

The proposed structure of the PID controller to regulate the angular position where a permanent magnet direct current motor is used has been implemented and compared in (Cerecero, Campos, Ramos, Marquéz, & Chan, 2017).

The conditioned regulator serves to induce forced aeration inside the incubator, as a secondary function, it controls the fan that serves to remove excess temperature or excess humidity in case any of these controllers exceeds the defined incubation parameters.

The visualization of the variables in the LabVIEW environment is very similar to that of the work shown in (Duran, Ramos, Cerecero, & Teran, SIMCI 2014).

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Conclusions

It was possible to design and build a shield-type electronic card that integrates temperature, relative humidity and angular position sensors, signal conditioners, variable monitoring by means of 4X20 liquid crystal displays (LCD), the interface of power with optocouplers and transistors to manipulate the actuators which integrate the prototype of the artificial incubator.

Three PID controllers were implemented through the LabVIEW software using the Control Design & Simulation module, to send the data through the serial communication interface to the Arduino MEGA 2560 development card using the Maker Hub library. In the same way, a graphic programming interface was created with which it is possible to visualize, assign and control the artificial incubation parameters of temperature, humidity, position of the egg and aeration. So far it is possible to visualize and/or store the variables in a Datalogger for offline processing.

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