Telemetric system implementation for monitoring physical parameters within an entomological greenhouse

Implementación de un sistema telemétrico para el monitoreo de parámetros físicos dentro de un invernadero entomológico

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Abstract

The controlled breeding of *Leptophobia aripa* has become in a sustainable activity in Latin America countries where this species is endemic. Producers interest is establishing predictivity criteria related with the organism and installed infrastructure, in order to cuantify presicely the availability of its host plant and insects for subsequent sale. In this paper is described the implementation of an embedded electronic system designed to read and log the micro-weather parameters inside the enthomological greenhouse and generated models to explain the cicle of life for *Leptophobia aripa*, growing in this environment. The calculated model characterizes the growing rate of *Leptophobia aripa* across its life stages.

***Leptophobia Aripa*, Embedded System, Telemtric System**

Resumen

La cría controlada de *Leptophobia aripa* se ha convertido en una actividad sustentable en países de América Latina donde la especie es endémica. Un interés de los productores es establecer criterios de predictividad asociados con el organismo y la infraestructura instalada, con la finalidad de cuantifiacar con precisión la sensible disponibilidad de la planta hospedera y los organismos para su venta posterior. En el presente trabajo se describe la implementación de un sistema electrónico embebido diseñado para realizar lecturas y registros de los factores microclimáticos dentro del invernador entomológico y los modelos generados para el ciclo de vida de *Leptophobia aripa* cuando se cría en dicho ambiente. El modelo caracteriza la tasa de crecimiento de la *Leptophobia aripa*, en todos sus estadios de vida.

***Leptophobia Aripa*, Sistema Embebido, Sistema Telemétrico**

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1. Introduction

In recent years, new solutions have been proposed for the sustainable exploitation of non-timber biological resources in different countries of Latin America (Peña 2015). The telemonitoring and analysis of physical parameters such as temperature, relative humidity, insolation, fluid level, etc., applicable to industrial, biotechnological, agricultural, and other processes (Montesinos-Patiño 2002); It has been resolved through electronic devices and expert systems that centralize information by computer means, allowing to analyze the relationship between physical parameters with the development and production of *Leptophobia aripa* and Lepidum savitium (Bustillo 1975), which has facilitated the analysis of data to establish a growth model of the *Leptophobia aripa*, presented in this work.

2. Development

The proposed telemetric system design (Solarte 2011) and its subsequent implementation is shown as a scheme in Figure1, and was developed in four stages:

- Stage 1. Technological development.
- Stage 2. Acquisition of data.
- Stage 3. Data transmission.
- Stage 4. Monitoring and visualization of data.

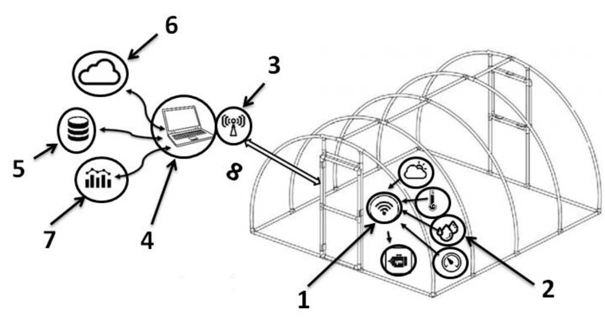

Figure 1 Diagram of the designed telemetric system

Components	
1	Electronic telemetry prototype
2	Physical parameters inside the greenhouse
3	Communication module
4	Embedded system
5	Database
6	Access from the internet
7	Web service
8	Wireless data transmission

Table 1 Components of the telemetric system designed

2.1 Technological development

For the development of the prototype the evolutionary process methodology was used (Sommerville 2005) which consists of 5 steps for the development of the prototype which will allow the acquisition of data.

Step 1. Communication

The objective of what the developed prototype has to do is defined, which consists of "Developing a telemetric system that allows compiling the physical parameters of the entomological / agricultural greenhouse, which allows consultation through a web service in real time"

Step 2. Quick plan

The needs and variables to be measured are identified, such as insolation, temperature and relative humidity, as well as implementing the appropriate wireless communication protocol for the transmission of information.

Step 3. Modeling and rapid design

The design of the prototype / hardware is quickly planned, the components are identified for the manipulation, communication and collection of physical parameters of the systems.

Step 4. Construction of the prototype

The prototype is developed which allows to take readings of the physical parameters already mentioned, by means of the different sensors, depending on the request that the user requires, this is done from an embedded system, which chooses the transceiver that will respond to reading requests enabling wireless communication implemented with modules under protocol 802.15.4.

Figure 2 Design and prototype assembly

Step 5 Deployment delivery and feedback

The prototype was implemented in an agricultural / entomological production greenhouse of 40 m3, where communication tests were carried out and analog reading sensors were calibrated.

2.2 Data acquisition

For the acquisition of the corresponding data (temperature, relative humidity, insolation), inside the entomological greenhouse was used the DHT22 sensor for temperature and relative humidity (Figure 3) and a solar cell to monitor the insolation (Figure 4). As an embedded system, a Raspbery Pi 3B was used (Figure 5), in addition a software routine was developed which allows making the connection between the telemetric prototype and the system, which makes requests via wireless to obtain the parameters; which are stored in a database, which in turn makes a mirror copy to a web server through the SSH (Secure Shell) protocol, data storage tests were performed on the embedded system and on the server managed through a web page to display neatly the collected data.

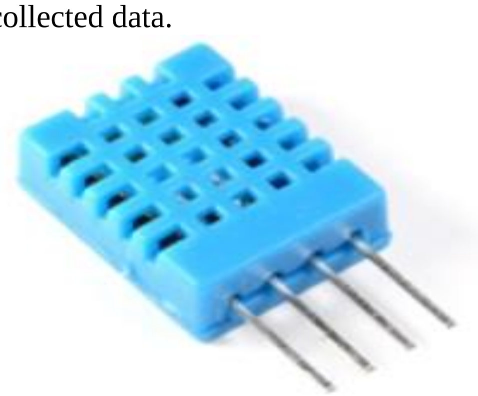

Figure 3 DHT22 sensor

Figure 4 Solar cell

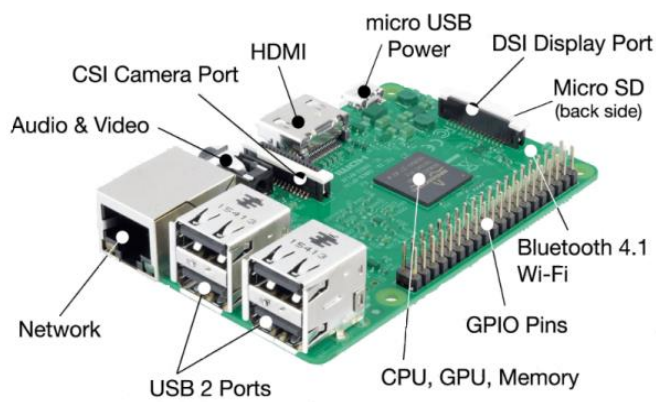

Figure 5 Raspberry PI 3B

2.3 Data transmission

The data transmission system consists of two Xbee S2 modules (Figure 6) that work under the 802.4.15 protocol in the free 2.4 GHz band.

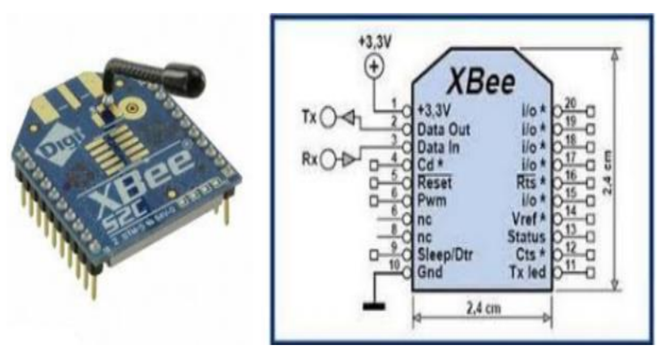

Figure 6 Xbee S2

For the selection of the equipment, the low cost of the equipment was considered and its wide use as a solution to establish point-to-point, point-to-point wireless links that allow a full-duplex communication where a module is configured as a *coordinator*; is in the embedded system and allows requests to each telemetry equipment *end device* of the network, they respond to the request by sending the requested parameters.

The technical characteristics of the Xbee module are shown in Table 2. The communication tests were performed to verify the efficiency of response between the embedded system and the telemetric prototype, which allows requests to be made every 5 seconds with the Xbee S2 modules.

Xbee modules		
Features	**Xbee S2**	**Xbee Pro**
Power	3.3V	3.3V
Speed	250Kpbs 1mW	250Kpbs 60mW
Power	100m. Local o inalámbrica	1000-1500m Local o inalámbrica

Table 2 Characteristics of Xbee modules *(www.digi.com)*

2.4 Monitoring and visualization of data

The information that is acquired through the telemetric system is stored in a database created in MySQL within the embedded system and, as already mentioned, makes a mirror copy using the SSH protocol to a web server, which allows visualizing the information as it is shown in Figure 7, where the temperature, relative humidity and insolation record is shown in real time, recording the moment of reading, these parameters will allow to analyze ideal conditions for its development, growth and sustainability of the breeding process.

Figure 7 Graphic of the registered physical parameters, consulted from the web service

3. Developed Methodology

The generated model consisted of nine laying sites (nests) of *Leptophobia aripa* within the instrumented greenhouse, monitored at the time of greatest presence of the species in the months of April and May, registering the presence of 338 eggs, which were followed stage by stage until his development as an adult. The data obtained were recorded as shown in Table 3.

With the data obtained, the time for the average development cycle of the *Leptophobia aripa*, which is 24.75 days, was calculated for the present experiment. The modeling was carried out applying the linear least squares regression method, to calculate the growth curve of the *Leptophobia aripa* in the referred conditions.

4. Results

The average length of each nest was recorded per larval stage (Table 4). Sanchez indicates that the average cycle is 27.2 days under controlled conditions in Mesa Cundinamarca in Colombia, this work was done from five nests with a temperature that fluctuates between 16 and 23 ° C, having a percentage of 80% of butterflies successful adults (Sánchez 2004).

While the study of Bustillo and Bertha report that the average development cycle is 21.5 days. In controlled conditions in Colombia with a temperature that goes from 16 and 30 ° C (Bustillo 1975).

With the monitoring of physical parameters within the greenhouse and analyzing the data in Table 3, it was compared with previous studies on the life cycle of the *Leptophobia aripa*, where the temperature does influence its life cycle, since when analyzing the development behavior shown in Table 3 and the percentage of organisms that reach the adult stage, it is concluded that when the temperature is higher the development cycle is shorter otherwise when the temperature is higher The development cycle is shorter (Campos - Nava 1992), this can be known and compared with the studies carried out by Sánchez.

His study indicates that the average temperature of his experiment is 19.5 ° C (Sánchez 2004), this temperature is the lowest of the 3 studies carried out, so the average life cycle is 27.2 days, while in the study de Bustillo records an average temperature of 23 ° C and records that the life cycles are 21.5 days (Bustillo 1975). The average temperature recorded in the present study was 21.28 ° C for the development cycles, taking an average of 24.75 days.

	Nests								
Period	Nest1	Nest2	Nest3	Nest4	Nest5	Nest6	Nest7	Nest8	Nest9
Eggs	42	32	38	41	37	45	39	41	29
Larva	39	30	36	38	36	43	36	38	27
Pupa	32	24	27	33	31	36	26	33	20
Adults	32	24	27	33	31	36	26	33	20
Duration of the cycle (days)	24.65	24.5	24.88	24.5	24.96	24.52	24.76	24.95	25.05
% individuals	76.19%	75 %	71.05 %	80.48 %	83.78 %	80 %	66.66 %	80.48 %	68.96 %
Average temperature during the cycle	20.5°C	19.5°C	18.5°C	24.1°C	25°C	23°C	18°C	24°C	19°C

Table 3 Number of individuals obtained from the nests of "Leptophobia aripa" for the present experiment, by larval stage, duration of the stage and physical parameters recorded

			Nidos				
Nests	Egg	Hatching	Status1	Status 2	Status 3	Prepupa	Pupa
Nest 1	1.1	2.0	5.0	11.1	19.0	19.7	19.0
Nest 2	1.3	2.0	5.0	10.9	18.6	19.7	18.4
Nest 3	1.4	1.9	4.9	11.1	19.0	20.1	18.5
Nest 4	1.6	1.9	5.0	11.1	19.1	19.6	19.3
Nest 5	1.4	2.2	4.8	10.9	19.0	19.7	19.4
Nest 6	1.3	2.3	4.7	10.9	19.0	19.2	19.6
Nido7	1.3	2.0	4.9	11.1	18.7	19.3	19.4
Nest 8	1.2	2.0	4.8	11.2	19.3	20.1	19.3
Nest 9	1.8	2.2	5.0	11.0	19.0	20.0	19.3

Table 4 Average length in millimeters per larval stage

	Coefficients of the linear model				Y(X)=A0X0+A1X1+A2X2+…+AnXn					
Grado del polinomio	A0	A1	A2	A3	A4	A5	A6	Error estándar	Coeficiente de correlación	Coeficiente de determinación
Primero	1.1286	3.1821						3.89944	0.888	0.78855
Segundo	-8.6571	9.706	-0.8155					2.24545	0.97155	0.94391
Tercero	0.2429	-0.4302	2.1512	-0.2472				1.52386	0.99027	0.98062
Cuarto	13.2286	-21.0237	12.0708	-2.0836	0.1148			0.7088	0.9986	0.99721
Quinto	1.7571	1.6353	-3.1375	2.4282	-0.4936	0.0304		0.60861	0.99948	0.99897
Sexto	-32.6	80.905	-70.3028	29.8979	-6.3215	0.6471	-0.0257	Error	1	1

Table 5 Coefficients obtained by the linear least squares regression method, for the growth model of "*Leptophobia aripa*"

When analyzing the data of table 5, it can be observed that the polynomial degree of the fifth degree has a percentage of data correlation of almost 100% and has the minimum standard error among the other polynomials, establishing the behavior curve for the growth of the *Leptophobia aripa* as shown in figure 8.

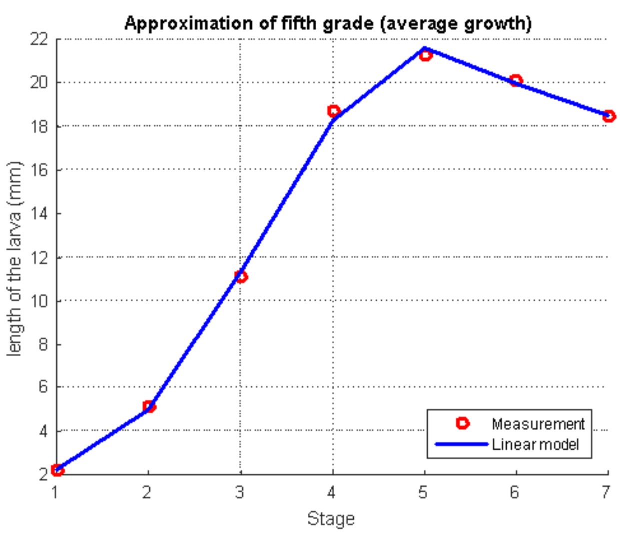

Figure 8 Model that represents the growth behavior of the *Leptophobia aripa*

5. Conclusions

The comparison between the previously published results (Sáncez 2004, Bustillo 1975) and those obtained in this work, it is possible to affirm that the life cycle of Leptophobia aripa has a duration proportional to the temperature of its breeding environment.

The present investigation in comparison to that of Sánchez (Sánchez 2004) and Bustillo and Bertha (Bustillo 1975), allows defining a growth model in this case of the Leptophobia aripa, in addition, it allows real-time monitoring of parameters physical and control of these to have optimal conditions within the greenhouse.

By means of the developed telemetric system, correlation models can be defined between the host plant and the insect to ensure a continuous and sustainable production of both species. It is also possible to propose control models to optimize the production with precision agriculture techniques.

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7. References

Bustillo, A., De Gutierrez, B. (1975), “CICLO DE VIDA DEL *Leptophobia aripa* (Boisduval) (Lepdoptera: Pieridae) PLAGA DEL REPOLLO Y LA COL”. Revista colombiana de entomológica. Vol. 1 (4). pp. 1-5.

Campos Rodriguez, F., Stanford Camargo, S., Ibarra González, M., Cruz Miranda, S., (2004), “EFECTO DE LA TEMPERATURA EN TIEMPO DE ECLOSION DE HUEVOS EN *Leptophobia aripa*”. Disponible en: http://www.entomologia.socmexent.org/revista/entomologia/2009/BHN/332-336.pdf.

Cegarra Sánchez J., (2004), “Metodología de la investigación científica y tecnológica” pp. 95-124

Franco, A., J. E. Llorente y A. M. Shapiro. (1988), "ABUNDANCIA RELATIVA DE *Artogeia rapae* (L.), *Pontia protodice* (Boisd. & Lec.) y *Leptophobia aripa elodia* (Boisduval.) (Lepidoptera: Pieridae) EVALUADA MEDIANTE EL MÉTODO DE MOORE MODIFICADO POR POLLARD, EN XOCHIMILCO, D.F.". Folia Entomologica Mexicana 76(11): pp.107-128.

Garcia, L. J. (1992). "*Hymenoptera* PARASÍTICOS DE *Leptophobia aripa* (Boisduval), (Lepidoptera: Pieridae), EN LA ESTACIÓN EXPERIMENTAL CATAURITO, MUNICIPIO ZAMORA, ESTADO ARAGUA". Bol Entomol., Venez. N. S. Vol 7(2). Pp 127-131.

Sommerville I., (2005), "Ingeniería del software"

Montesinos-Patiño, E. (2002). "INTRODUCCIÓN AL CONOCIMIENTO Y MONITOREO DE MARIPOSAS. MEMORIAS DE TALLER DE CAPACITACIÓN: MONITOREO AMBIENTAL PARTICIPATIVO DE MARIPOSAS". Gobierno del Distrito Federal, REMUCEAC, México, D.F. pp 110.

Moreno, R. (1988). "ANÁLISIS ECONÓMICO DEL PROYECTO DE FAUNA: CRÍA DE MARIPOSAS". Instituto Von Humboldt. Colombia. pp. 25.

Nava del Castillo, C. A. (1992). "UNIDADES CALOR E INTERACCIONES DE FACTORES DE MORTALIDAD EN *Leptophobia aripa* (BOISD.) (Lepidoptera: Pieridae)." Tesis de Maestría. Colegio de Posgraduados Estado de México. pp 70.

Peña Bermudez, Y., Rodriguez Aguilar, D. (2015). "ALGUNOS ASPECTOS SOBRE LA CRÍA CONTROLADA DE *Ascia monuste* (Lepoptera: Pieridae: Pierinae) EN EL MUNICIPIO DE ARBELAÉZ". Revista de la facultad de Medicina Veterinaria y Zootecnica. Vol 62 (3).

Solarte Varney, P., Agredo Mendez, G. (2011). "IMPLEMENTACIÓN DE UN SISTEMA DE TELEMETRÍA PARA LA DETECCIÓN TEMPRANA DE EVENTOS TSUNAMIGÉNICOS ASOCIADOS CON LA VARIACIÓN EXTREMA DEL NIVEL DE LA MAREA EN LA COSTA PACÍFICA COLOMBIANA". Gerenc. Tecnol. Inform. Vol. 10(26). pp. 25-34.

Sanchez Lopez, R. (2004). "PROTOCOLO DE CRÍA PARA DOS ESPECIES DE MARIPOSAS, *Ascia monuste* y *Leptophobia aripa* (LEPIDOPTER: PIERIDAE) BAJO CONDICIONES CONTROLADAS EN EL MUNICIPIO DE LA MESA, CUNDIAMARCA". (Tesis de pregrado). Pontificia Universidad Javeriana, Facultad de Ciencias, Bogota.