Intelligent Monitoring System of Environmental Biovariables in Poultry Farms

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Abstract. Modern technologies in poultry farming prevail over many limitations of traditional methods; thus they help reducing labor costs and increase productivity. In Ecuador, most poultry farms have modest systems capable of monitoring variations in temperature, humidity and gas concentrations caused by the generation of chicken manure in closed environments, which creates a stressful atmosphere affecting the health of broilers during breeding stage; therefore there is a palpable loss of money and productivity. This project presents an intelligent monitoring system composed of a star type sensor network for environmental monitoring variables in the poultry farm. Long Range Technology (LoRa) is used for the system communication, information is gathered and stored in a cloud database and then processed to be visualized through historical trends storage and alarm reporting creating an affordable and easy interpretable solution.

Keywords: Sensor network · LoRa · Poultry farms · Environmental parameters · Machine learning

1 Introduction

The Food and Agriculture Organization mentions that world population has reached 821 million over the last three years in the world until 2017 [1], which caused a rise in demand for production and consumption of proteins and other foods [2]. In consequence poultry meat has been set to be the be one of the most consumed proteins by humans due to it is a nutrient-dense, high-protein, low- saturated fat and low-cholesterol food [3]. In Ecuador, to satisfy local demand, the commercialization of *Broiler* has had an important growth in the last four years according to the Latin American Poultry Association (ILP) [4], a clear example of this agroindustry, are some poultry farms located in Cotopaxi province, with around 10,000 birds per farm, raised to produce eggs and meat. This production volume has caused the need to measure and monitor relevant variables inside the farm, for a correct growth and development in birds [5].

Normal growth of broilers depends on how the farm is designed, taking into consideration environmental parameters and conditions [6], such as humidity, temperature and gases, which are known as environmental biovariables, this, together with the right amount of food gives as a result healthy broilers with ideal weight. These factors are crucial to increase production [7, 8]. Poor air quality inside the chicken coop is a result of manure produced by chickens and this causes the release of volatile organic compounds (VOCs) to the atmosphere [9, 10] generating the propagation and transmission of pathogenic agents, creating a stressful environment which affects birds health during their breeding stage. Consequently the mortality rate increases [11]. The high cost of implementing a monitoring system capable of recording variations in temperature, humidity and gases is considered as a limitation [12–15].

Modern technologies prevail over these limitations of traditional methods, reducing labor costs and increasing productivity [16, 17]. The monitoring and control of variables in agro industries has been improved thanks to the implementation of point-to-point protocols using technologies such as General Package Radio (GPRS) and the well-known Internet of Things (IoT) [18], supported by microcontrollers and Programmable Logic Controllers (PLC) at distances no longer than 100 m. [19]. On the other hand, the poultry sector, which is considered as one of the most needy sectors, is currently making use of common wireless communication systems such as Bluetooth, GPRS and Global Mobile Communication Systems (GSM) together with the IoT [20, 21] with a range of up to 200 m., to monitor the different conditions of the birds, reducing losses in the production of meat and eggs [22, 23]. For sizeable installations where there is a larger production volume and longer distances 200 m., some solutions might not be enough. Some technologies have come up with solutions to deal with long distances, which allows extending the monitoring of many systems.

This work offers a system that allows a long-range biovariable environmental monitoring inside the chicken coop, using a star-type sensor network based on Long Range Technology (LoRa) for wireless communication of the nodes, the collected information is stored in a cloud database and processed by intelligent algorithms, to be visualized through historical trends and event and predictive alarms. With this intelligent monitoring system, it is expected to measure environmental bio variables in poultry farms with an error of less than 2%, with respect to the standard equipment with a coverage distance of 300 m. round.

This article is made up sections: Section II presents the methodology used to develop the proposed system. In section III the experimentation is carried out and results of the implemented system are presented. Section IV presents conclusions. Finally, section V presents future work.

2 Methodology

Poultry farms are located in areas with sufficient amount of water to meet the needs of broilers in addition to respecting the distances enforced by authorities in relation to other farms, urban centers, swampy areas, garbage dumps, wetlands and lakes. The infrastructure and area must have perimeter enclosure in order to maintain isolation preventing and controlling the access of people and animals outside the farm. The roofs are made of insulating material, which protects broilers from cold, sun and rain. The floor is made of smooth concrete to facilitate the cleaning, disinfection and total hygiene of the surface. In the windows welded wire mesh is used to exclude entry of birds and predators. The walls design depend on the region where the farm is located, if they are located in the Ecuadorian highlands, they must be 3 m. tall to protect broilers from air flow according to the good practice handbook for poultry farms, published in 2016 by the Ministry of Agriculture, Livestock, Aquaculture and Fisheries (MAGAP) [24].

The correct growth and development of broilers are important factors for the productivity and profitability of poultry farms. Variables such as temperature, humidity and gas concentration should be monitored 24 hours, 7 days a week, allowing operations staff make decisions based on indicators and historical trends. This work proposes a system that allows monitor environmental bio variables, considering the most important variables the ones inside the chicken coop. The system has several stages: data acquisition, by means of which the bio variable values are collected with the help of sensor nodes, forming a network that allows to get the exact values. The communication system is supported by LoRa, which is responsible for wireless communication between the sensor nodes and send all the information through a physical gateway to a microcomputer to create a cloud database, this database is processed with intelligent algorithms that include filters and classifiers. Data must be displayed in scales of temperature, humidity and gases respectively. The system has a Human Machine Interface for both remote and local access. The remote HMI is available on a web server and the local HMI is installed in the chicken coop. Data is visualized thanks to storage of historical trends and alarm reports so that the operator can access it, as shown in Figure 1.

Data acquisition: According to the temperature, humidity and gas concentration levels indicated in Table 1, the MQ 135 sensor for CO_2 concentration with 2 ppm accuracy, 0.1 ppm resolution and NH_3 with precision is selected 1.5 ppm, resolution 0.1 ppm; the DHT 22 is a digital temperature and humidity sensor with high precision of $0.5°C$, resolution of $0.1°C$ and precision of 2% RH and resolution of 0.1% RH for humidity.

Network topology: Because of the architecture that manages the LoRa protocol, the star-type topology is used, so that the first star is made up of sensor nodes along with a gateway, and the second star is made up of the gateway and a network server that avoids information traffic. It is also possible and easy to add new nodes in case any of the nodes fail, the network continues to work normally.

Communication system: It consists of a LoRa module for IoT networks, with a frequency of 433 MHz, power up to 600 $dmips$ and -148 dBm sensitivity, suitable for working under the standards given by MAGAP for the construction

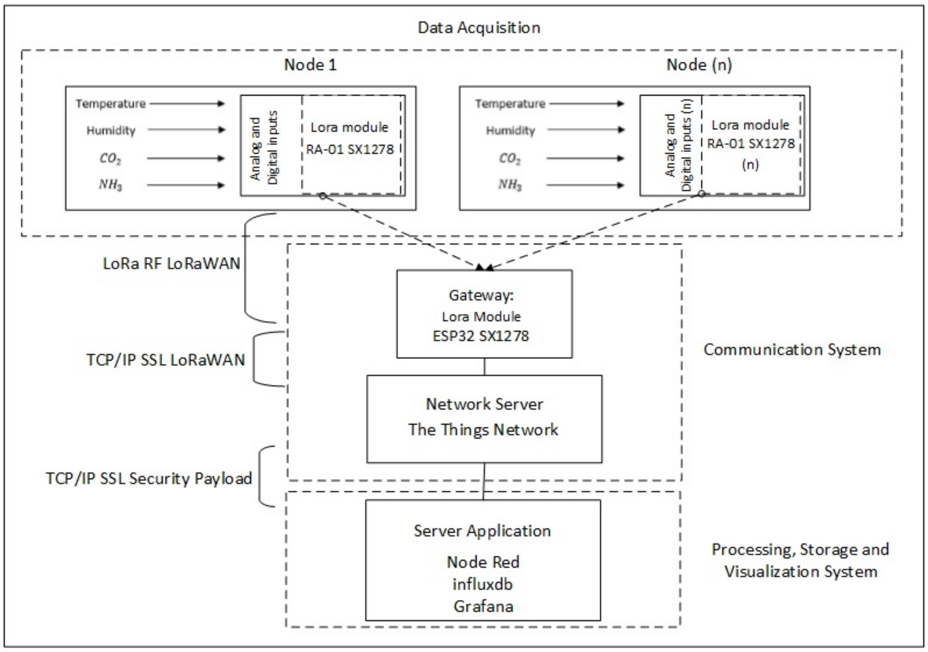

Fig. 1. Network diagram. Data acquisition: composed of sensor nodes; Communication System: LoRa wireless communication that works together with the server network called The Things Network; Storage System: Influx cloud database; Processing: filters to reduce error and classifiers used for machine learning; Visualization: Human Machine Interface (HMI).

Table 1. Biovariable parameters for *Broiler* growth from 1 to 7 weeks.

Variable	Levels	Weeks
Temperature	$32°C$ a $34°C$	1-2
	$26°C$ a $30°C$	3-4
	$18°C$ a $24°C$	5-7
Humidity	50% a 70%	1-7
CO_2 Gas	<5000 *ppm.*	1-2
	<4000 *ppm.*	3-4
	<3000 *ppm.*	5-7
NH_3 Gas	<55 *ppm.*	1-2
	<40 *ppm.*	3-4
	<10 *ppm.*	5-7

of poultry farms [24]. The module works with an open platform network server, called The Things Network used as a bridge to build an IoT application. This tool delivers a data frame shown in Figure 2.

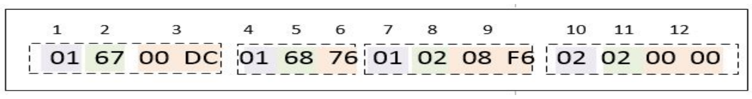

Fig. 2. Data frame obtained from node 1: 1 device number, 2 type of variable (67: temperature), 3 variable value, 4 device number, 5 variable type (68: humidity), 6 variable value, 7 device number, 8 variable type (02: analogical), 9 variable value, 10 device number, 11 variable type (02: analogical), 12 value of the variable.

Storage system: All information obtained by the communication system is collected by the Node RED editor set up in the browser in which nodes are added or deleted, to write and query in the database which is based on time Influx series where the data to be monitored is stored.

Processing: Filtration techniques, statistical processing and Machine Learning are used to process the data collected from temperature, humidity and gases sensors:

- FIR filters, are designed to have linear phase and greater stability and also to be compared with IR filters designed to have a feedback from the output signal and greater efficiency.
- Statistical processing through which parameters such as the statistical mean, correlation and Pearson correlation with the aim of getting features that are used for the Machine Learning deployment.
- Machine learning through Fisher's linear discriminant, consists in giving all the artificial elements or computer systems the ability to learn from examples [25].

Visualization system: Grafana its a tool to visualize temporal time data. A local Human Machine Interface (HMI) is designed inside the chicken coop and the remote HMI is designed with the help of a web page which connects to the database to present indicators, historical trends and alarm reports of temperature, humidity and gases.
In Figure 3, it is possible to observe the interface made with Grafana in both modes local and remote.

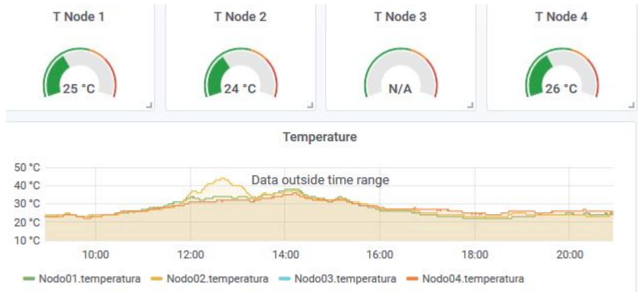

Fig. 3. Local and remote HMI, the upper panel displays the instantaneous temperature of the nodes and the lower panel displays the historical trends of the last hour.

3 Experimentation

For verifying this methodology, the monitoring system is installed inside a farm whose dimensions are 160 m. length, 12 m. width, 3 m. height and a capacity for 18,000 broilers and a distance of 300 m. between the chicken coop and the remote installation.

Communication: Due to the characteristics of the experimentation environment, the area to be covered is 160 m. length and 12 m. width as explained in the previous paragraph.

- **Coverage inside the chicken coop:** With the purpose of locating the optimal points to set the sensors inside the chicken coop, it is necessary to determine the coverage generated by the Gateway node installed in the center of the chicken coop at a height of 2.5 m., the signal power is measured at different distances. For this, the Agilent Field Fox model N9912a of the factory is used. After these measurements are made, the power distribution of radiation of the sensor node is displayed in Figure 4 where it may be determined that the sensor nodes receive maximum power when the sensor nodes are placed at a height of 30 cm. above the ground and they are located near the Gateway, whereas the power falls exponentially as it moves away from the center as observed in Figure 4(a). Through the propagation chart with the Gateway in the center of the chicken coop, it is determined that the nodes can be located in anywhere because they have good radiation power as seen in Figure 4(b).
- **Outdoors coverage:** As mentioned, the distance between the chicken coop and the monitoring center is 300 m. away. For this reason communication between these two points must be ensured. To reach this objective it is crucial to measure the quality of propagation versus measuring range for which a

repeater node is installed; the power of the signal is measured by the same device mentioned in the previous section. A modified node gateway is installed which has a range coverage of up to 400 m. The procedure consists of taking 20 samples every 50 m. as walking away from the repeater node. Within this measurement two important parameters are considered: Received Signal Strength Indicator. (RSSI) that reaches the receiver in dBm and the Signal to Noise Ratio (SNR) of the power radiated by the transmitter and receiver antenna gain.
This experiment is seen in Figure 5, with line of sight in testing area having as a result a significant signal in terms of RSSI, SNR and number of packages received up to 350 m., with measurements made beyond this distance there is no an acceptable power intensity producing noisy signals and data loss.

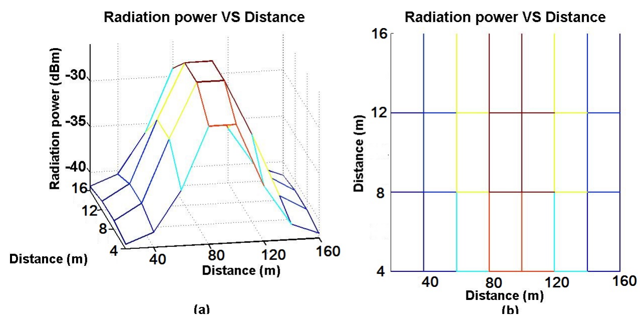

Fig. 4. Radiation power VS Distance: a) 3D view, b) 2D view. -35 dBm. (blue, light blue), -20 dBm. (yellow, red, brown)

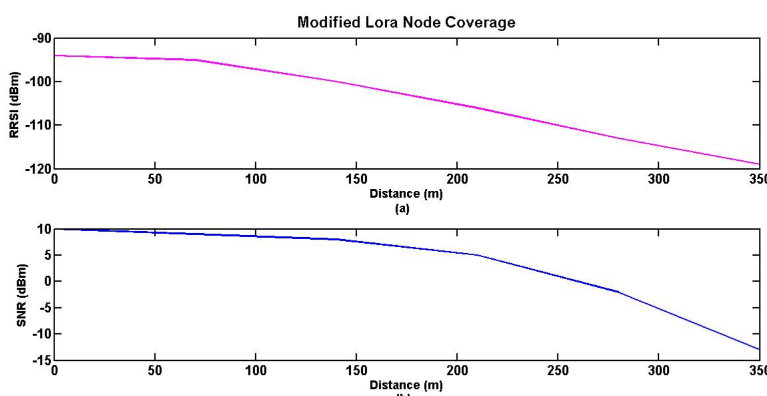

Fig. 5. Outdoors coverage: (a) RSI, (b) SNR.

Sampling Frequency: With the purpose of determining the sampling frequency that best fits the variables to be measured and considering that they have a slow behavior. A sample is taken every 30 *sg.*, 40 *sg.*, 50 *sg.* and 60 *sg.* For this experiment the nodes are placed together in the center of the chicken coop at a height of 30 *cm.* above the ground. Each node measures temperature, humidity, CO_2 and NH_3. This group of measurements is displayed in Figure 6, in a 3-D graph, where the x-axis represents time, y-axis represents measured variation and the z-axis represents sampling period. Panel (a) represents temperature, (b) humidity, (c) CO_2 and (d) NH_3. While the red color represents a sample every 30 *sg.*, green a sample every 40 *sg.*, blue a sample every 50 *sg.* and purple a sample every 60 *sg.*

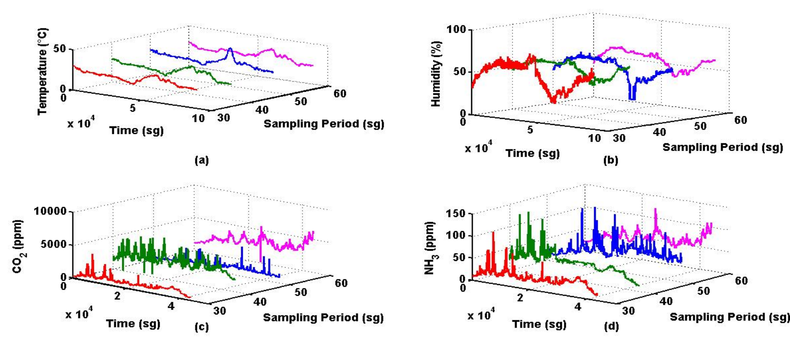

Fig. 6. Representation of (a) Temperature, (b) Humidity, (c) CO_2 and (d) NH_3 in different sampling periods: a sample for every 30 *sg.* (red), a sample for every 40 *sg.* (green), a sample for every 50 *sg.* (blue), a sample for every 60 *sg.* (purple).

In Figure 6 it is seen that the tendency of measurement in temperature, humidity and gases is similar with different number of samples. With the aim of training the smart system, the shortest sampling period is chosen since it defines the transition trends of the variables better.

Data processing: To generate the database of this experiment the position of the sensor nodes is changed following the scheme of Figure 7, the selected sampling period is 30 *sg.*, the sensors behavior is contrasted with standard laboratory equipment obtaining in temperature and humidity an error of 1% and in CO_2 and NH_3 en error of 2%, this procedure is performed under ISO/IEC 17025-2005 [26].

From data acquired for a period of 7 weeks, corresponding to the *Broiler* breeding stage, they are analyzed in Figure 8 where the signals measured by the four nodes in a period of 2 days are represented and there is some noise in each of them.

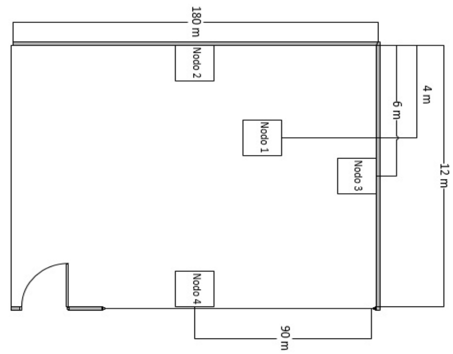

Fig. 7. Node placement inside the chicken coop.

In order to eliminate noise; some tests with 1st, 2nd, 3rd, 4th, 5th IR filter and 2nd, 4th, 8th, 16th, 24th and 32nd FIR filter were carried out. The best results were obtained with the 24th order FIR filter which provides greater stability, eliminates noise, has a stronger signal, it does not affect the rise and falling edge, does not generate offset and does not truncate maximum and minimum values as indicated in Figure 9.

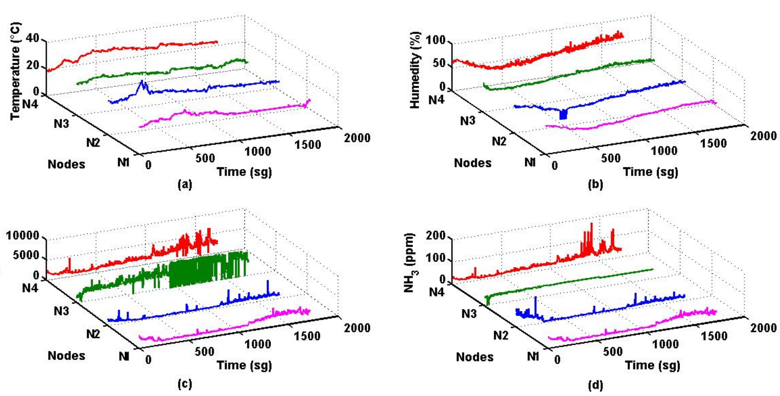

Fig. 8. Samples acquired every 30 *sg*.. Panel (a) temperature, (b) humidity, (c) CO_2 and (d) NH_3, node1 (purple), node2 (blue), node3 (green), and node4 (red).

To verify the same nature of the signals the concept of correlation using the analysis criteria of Bland-Almant is used where it relates two variables of the same nature. Figure 10 is taken as an example of relationship between node 1 and node 2, in panel (a) the temperature is analyzed, in panel (b) humidity is analyzed, in panel (c) CO_2 is analyzed and in panel (d) NH_3 is analyzed.

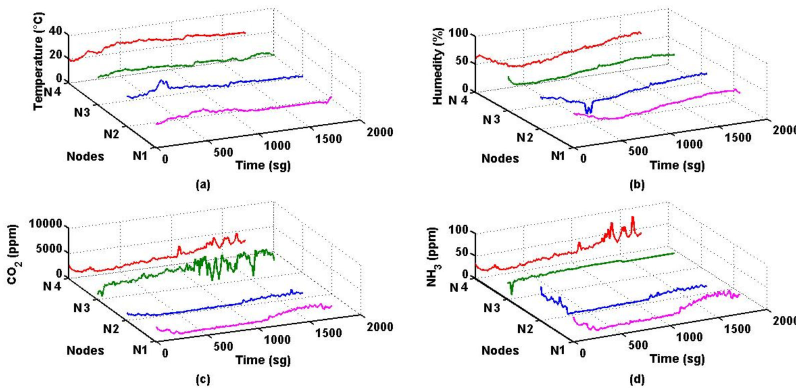

Fig. 9. Signals acquired through 24th FIR filter, a sample for every 30 *sg.*, panel (a) temperature, (b) humidity, (c) CO_2 and (d) NH_3, node1 (purple), node2 (blue), node3 (green), and node4 (red).

The results obtained from Bland-Almant analysis are on Table 2, from which it may be expressed that the temperature correlation values of node 1 with 2 have better stability characteristics in the signal, while the correlation values of the other nodes have a threshold lower than 0.7 due to the distance between them. Regarding humidity it is discussed that correlation values remain stable except between nodes 2 with 3 and 3 with 4 that have a threshold less than 0.7. CO_2 has correlation values between nodes 1 with 2 and 1 with 4 while the other nodes have correlation values below 0.7. The NH_3 has a low correlation due to this variable is easily affected by external disturbances, such as air currents.

Table 2. Correlation values.

Variable	N1-N2	N1-N3	N1-N4	N2-N3	N2-N4	N3-N4
Temperature	0.71	0.56	0.44	0.53	0.22	0.08
Humedity	0.87	0.79	0.91	0.57	0.86	0.59
CO_2 Gas	0.75	0.11	0.72	0.11	0.55	0.19
NH_3 Gas	0.36	0.32	0.68	0.58	0.11	0.11

With the filtered signals, the events are selected in low, medium and high ranges corresponding to the measured variables according to the growth stages of broiler as indicated in Table 1. Under these parameters the intelligent algorithm is trained by Fisher linear discriminant conditions, the database used corresponds to the data acquired by nodes 1 and 2, in the three ranges mentioned previously which are composed of 147 sampled days with a 30 *sg.* period sampling, from which 80% is randomly selected for train the smart algorithm

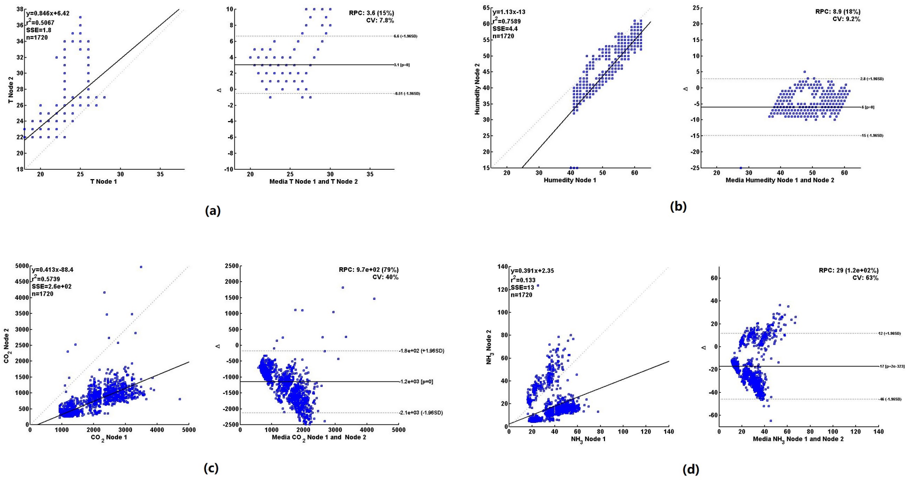

Fig. 10. Bland Almant analysis for biovariables poultry

and 20% for the tests. Table 3, indicates the values of the Area under the Curve (AUC) of each variable in different stages of growth.

Table 3. Fisher Discriminant Method.

	Variable	Low values	Normal values	High values
Phase 1 [1-2] weeks	Temperature	0.69	0.67	0.83
	Humedity	0.72	0.70	0.75
	CO_2 Gas	0.55	0.57	0.61
	NH_3 Gas	0.56	0.58	0.73
Phase 2 [3-4] weeks	Temperature	0.78	0.78	0.87
	Humedity	0.82	0.80	0.85
	CO_2 Gas	0.52	0.60	0.71
	NH_3 Gas	0.51	0.62	0.76
Phase 3 [5-7] weeks	Temperature	0.88	0.89	0.91
	Humedity	0.91	0.89	0.94
	CO_2 Gas	0.49	0.63	0.81
	NH_3 Gas	0.45	0.66	0.79

In the first stage it is observed that the certainty values of the measurement of humidity as well as of temperature exceeds the threshold of 0.7 of certainty, whereas for CO_2 and NH_3 have around 0.5 of certainty. For the second stage both humidity and temperature exceeds 0.75 of certainty, whereas for CO_2 and NH_3 they remain close to 0.55. In the third stage both the temperature and humidity exceeds 0.85 of certainty, whereas CO_2 and NH_3 exceeds 0.6, from these results it is seen that both variables temperature and humidity present similar characteristics during the three stages. It is important to emphasize that these variables are in influenced by environmental conditions such as solar radiation, rain or frost, while CO_2 and NH_3 are much more unstable in his behavior because of their volatility. Factors like movement of broilers, influence of air currents and accumulation of manure causes these variables to vary continuously without registering a consistent pattern. Under these values it is possible to indicate predictive alarms for both of high and low temperature and humidity, but CO_2 and NH_3 increasing level alarms have low certainty at the moment.

4 Conclusions

The implementation of a remote sensors network which communicate under LoRa technology allows monitoring environmental bio variables in poultry farms. Measurements obtained have an error of less than 2% with reference to pattern equipment. The environmental biovariables measured with the implemented sensor network in poultry farms are temperature, humidity, CO_2 and NH_3. This network is characterized by placing the nodes in different positions of the environment and allowed registering their values. It is evidenced that both temperature and humidity have a correlation of more than 0.7 regardless of the position of the nodes, while CO_2 and NH_3 which are volatile variables present a correlation below 0.7 showing the need to take samples in different points of the chicken coop as they are affected by external variables, such as air currents and concentration of animals in a single area.

This intelligent system that monitors environmental parameters inside the poultry farm offers historical trends and reports for alarms and events. It has been designed and implemented to facilitate the management of the poultry farm. Each node of the system monitors temperature, humidity and gas concentration with the use of LoRa technology, it stores data in the cloud for easy access from the web. For this type of system,after a study was made, it may be considered reducing the number of sensor nodes of temperature and humidity because they are variables with a stable behavior thus it might be convenient increasing the number of CO_2 and NH_3 sensor nodes which are volatile variables.

5 Future work

To continue with this study, it is proposed to develop a Multivariable Classifier which allows to relate the four variables with their different levels, low, medium and high with reference to the stability of the farm environment. This may allow getting more reliable prediction algorithms.

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References

1. Global hunger continues to rise, new un report says. Technical report, Food and Agriculture Organization of the United Nations (FAO) (2018). Accessed 25 Oct 2019.
2. R. Quintero, R. Romero, M. Sánchez, “Gestion de Inventarios en la industria avicola zuliana”, Vol 17(32), pp. 99-112, (2015).
3. K. Sitaram, K. Ankush, K. Anant and B. Raghunath, ”IoT based Smart Management of Poultry Farm and Electricity Generation,” 2018 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC), Madurai, India, pp. 1-4, (2018).
4. Comercialización del Mercado avícola en Ecuador, reporte por parte de la superintendencia del Control y Poder de Mercado del Ecuador. Technical report, Estudio de Mercado Avícola enfocado a la Comercialización del Pollo en Pie, año 2012-2014 (2014). Accessed 25 Oct 2019.
5. M. Yancha, ” Plan Integral De Manejo, Control Y Aprovechamiento de Residuos Sólidos Orgánicos en La Compañía Productora Avícola Cajamarca Suárez Cavicente Cía. Ltda,”, Thesis, Universidad Técnica de Ambato, Ambato, Ecuador, 2017.
6. K. Sravanth and A. Sudharson, “Internet Based Smart Poultry Farm,” Indian Journal of Science and Technology, Vol 8(19), IPL101, (2015).
7. G. Choukidar and N. Dawande, ”Smart Poultry Farm Automation and Monitoring System,” 2017 International Conference on Computing, Communication, Control and Automation (ICCUBEA), Pune, pp. 1-5, (2017).
8. E. Ávila, J. Carmona, M. Castañeda, A. Cortés, ” Introducción a la zootecnia del pollo y la gallina,” 1era edicion. Vol. 1, Ed. Mexico: LDCV F. Avril Braulio Ortiz, pp. 135-142, (2018).
9. N. Manshor, A. Rahiman and M. Yazed, ”IoT Based Poultry House Monitoring,” 2019 2nd International Conference on Communication Engineering and Technology (ICCET), Nagoya, Japan, pp. 72-75, (2019).
10. M. Islam, A. Islam and M. Islam, ”Variation of biogas production with different factors in poultry farms of Bangladesh,” 2014 3rd International Conference on the Developments in Renewable Energy Technology (ICDRET), Dhaka, pp. 1-6, (2014).
11. R. Vadivel,R. Parthasarathi,A. Navaneethraj,P. Sridhar, K. Muhammad-Nafi and S. Karan, ”Hypaponics - Monitoring and Controlling using Internet of Things and Machine Learning,” 2019 1st International Conference on Innovations in Information and Communication Technology (ICIICT), CHENNAI, India, pp. 1-6, (2019).
12. M. Ammad-uddin, M. Ayaz, E. Aggoune and M. Sajjad, ”Wireless sensor network: A complete solution for poultry farming,” 2014 IEEE 2nd International Symposium on Telecommunication Technologies (ISTT), Langkawi, pp. 321-325, (2014).
13. M. Erazo-Rodas,M. Sandoval-Moreno, S. Muñoz-Romero, M. Huerta, D. Rivas-Lalaleo, C. Naranjo, J. L. Rojo-Álvarez, ”Multiparametric Monitoring in Equatorian Tomato Greenhouses (I): Wireless Sensor Network Benchmarking”, Sensors (Basel, Switzerland), pp.1-22, (2018)

14. M. Erazo-Rodas,M. Sandoval-Moreno, S. Muñoz-Romero, M. Huerta, D. Rivas-Lalaleo, J. L. Rojo-Álvarez, "Multiparametric Monitoring in Equatorian Tomato Greenhouses (II): Energy Consumption Dynamics", Sensors (Basel, Switzerland), pp.1-36, (2018)
15. M. Erazo-Rodas,M. Sandoval-Moreno, S. Muñoz-Romero, M. Huerta, D. Rivas-Lalaleo, J. L. Rojo-Álvarez, "Multiparametric Monitoring in Equatorian Tomato Greenhouses (III): Environmental Measurement Dynamics", Sensors (Basel, Switzerland), pp.1-36, (2018)
16. A. Raj and J.Jayanthi, "IoT-based real-time poultry monitoring and health status identification," 2018 11th International Symposium on Mechatronics and its Applications (ISMA), Sharjah, pp. 1-7, (2018).
17. J. Guillermo, A. García-Cedeño, D. Rivas-Lalaleo, M. Huerta and R. Clotet, "IoT Architecture Based on Wireless Sensor Network Applied to Agricultural Monitoring: A Case of Study of Cacao Crops in Ecuador", Advances in Intelligent Systems and Computing, pp. 42-57, (2018).
18. J. Abad, J. Farez, P. Chasi, J. Guillermo, A. Garcıa-Cedeño, R. Clotet and M. Huerta, "Coffee Crops Variables Monitoring: A Case of Study in Ecuadorian Andes", Advances in Intelligent Systems and Computing, pp. 202-217, (2018).
19. J. Kalezhi, J. Mbale and L. Ndovi, "Microcontroller-Based Monitoring and Controlling of Environmental Conditions in Farming," 2018 IEEE PES/IAS PowerAfrica, Cape Town, pp. 284-288, (2018)
20. C. González, R. Pardo, J. Fariña, M. Valdés, J. Rodríguez-Andina and M. Portela, "Real-time monitoring of poultry activity in breeding farms," IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society, Beijing, pp. 3574-3579, (2017).
21. W. Sarachai, P. Ratnapinda and P. Khumwichai, "Smart Notification System for Detecting Fan Failure in Evaporative Cooling System of a Poultry Farm," 2019 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT-NCON), Nan, Thailand, pp. 296-299, (2019).
22. Y. Qun, Y. Zhang, X. Wang, Z. Zhou, P. Xian and F. Zhang, "Research on Master-Slave Distributed Large-Scale Poultry Farming Measurement and Control System," 2019 International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), Atlanta, GA, USA, pp. 552-557, (2019).
23. A. Dottavio, R. Di-Masson and P. Khumwichai, "Mejoramiento avicola para sistemas productivos semi-intensos que preservan el binestar animal," BAG. Journal of basic and applied genectics, pp. 1-10, (2015).
24. Ministerio de Agricultura, Ganadería, Acuacultura y Pesca (MAGAP). "Manual de aplicabilidad de buenas prácticas avícolas", (2016). Accessed 25 Oct 2019.
25. D. Rivas-Lalaleo, S. Muñoz-Romero, M. Huerta , M. Erazo-Rodas,M. Sandoval-Moreno, J. L. Rojo-Álvarez, et. all, "Force Trends and Pulsatility for Catheter Contact Identification in Intracardiac Electrograms during Arrhythmia Ablation", Sensors (Basel, Switzerland), pp.1-22, (2018)
26. Organización Internacional de Normalización. "Norma Internacional ISO/IEC 17025: Requisitos generales para la competencia de los laboratorios de ensayo y de calibración", (2005). Accessed 25 Oct 2019.