Lecture Notes in Networks and Systems 1040

Marcelo Zambrano Vizuete · Miguel Botto-Tobar · Sonia Casillas · Carina Gonzalez · Carlos Sánchez · Gabriel Gomes · Benjamin Durakovic *Editors*

Innovation and Research – Smart Technologies & Systems

Proceedings of the CI3 2023, Volume 1

Springer

Lecture Notes in Networks and Systems 1040

The series "Lecture Notes in Networks and Systems" publishes the latest developments in Networks and Systems—quickly, informally and with high quality. Original research reported in proceedings and post-proceedings represents the core of LNNS.

Volumes published in LNNS embrace all aspects and subfields of, as well as new challenges in, Networks and Systems.

The series contains proceedings and edited volumes in systems and networks, spanning the areas of Cyber-Physical Systems, Autonomous Systems, Sensor Networks, Control Systems, Energy Systems, Automotive Systems, Biological Systems, Vehicular Networking and Connected Vehicles, Aerospace Systems, Automation, Manufacturing, Smart Grids, Nonlinear Systems, Power Systems, Robotics, Social Systems, Economic Systems and other. Of particular value to both the contributors and the readership are the short publication timeframe and the world-wide distribution and exposure which enable both a wide and rapid dissemination of research output.

The series covers the theory, applications, and perspectives on the state of the art and future developments relevant to systems and networks, decision making, control, complex processes and related areas, as embedded in the fields of interdisciplinary and applied sciences, engineering, computer science, physics, economics, social, and life sciences, as well as the paradigms and methodologies behind them.

Indexed by SCOPUS, INSPEC, WTI Frankfurt eG, zbMATH, SCImago.

All books published in the series are submitted for consideration in Web of Science.

For proposals from Asia please contact Aninda Bose (aninda.bose@springer.com).

Marcelo Zambrano Vizuete ·
Miguel Botto-Tobar · Sonia Casillas ·
Carina Gonzalez · Carlos Sánchez ·
Gabriel Gomes · Benjamin Durakovic
Editors

Innovation and Research – Smart Technologies & Systems

Proceedings of the CI3 2023, Volume 1

Springer

Editors
Marcelo Zambrano Vizuete
Instituto Tecnológico Superior Rumiñahui
Sangolquí, Ecuador

Miguel Botto-Tobar
Eindhoven University of Technology
Eindhoven, The Netherlands

Sonia Casillas
universidad de salamanca
Salamanca, Spain

Carina Gonzalez
Universidad de La Laguna
Tenerife, Spain

Carlos Sánchez
Universidad de Zaragoza
Zaragoza, Spain

Gabriel Gomes
Universidad Estatal de Campinas
Campinas, Brazil

Benjamin Durakovic
International University of Sarajevo
Sarajevo, Bosnia and Herzegovina

ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-3-031-63433-8 ISBN 978-3-031-63434-5 (eBook)
https://doi.org/10.1007/978-3-031-63434-5

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The 4th edition of the International Research and Innovation Congress – Smart Technologies and Systems, CI3 2023, took place from August 30 to September 1, 2023, at the facilities of the Instituto Tecnológico Universitario Rumiñahui, located in the city of SangolquÍ, Pichincha, Ecuador.

The conference was organized by the Red de Investigación, Innovación y Transferencia de Tecnología RIT2, made up of the most relevant university institutes in Ecuador, among which are ITCA, BOLIVARIANO, ARGOS, VIDA NUEVA, ESPÍRITU SANTO, SUDAMERICANO, ISMAC, SAN ISIDRO, ARTES GRÁFICAS, ORIENTE, HUMANE, SUCRE, CENTRAL TÉCNICO, POLICÍA NACIONAL and RUMIÑAHUI.

Additionally, the event is sponsored by the Secretaría de Educación Superior, Ciencia, Tecnología e Innovación SENESCYT, Labortorio de Comunicación Visual de la Universidad Estatal de Campinas—Brazil, Universidad Ana G. Méndez—Puerto Rico, Centro de Investigaciones Psicopedagógicas y Sociológicas—Cuba, Instituto Superior de Diseño de la Universidad de La Habana—Cuba, GDEON and the Corporación Ecuatoriana para el Desarrollo de la Investigación y la Academia—CEDIA.

The main objective of CI3 2023 is to generate a space for dissemination and collaboration, where academia, industry and government can share their ideas, experiences and results of their projects and research.

"Research as a pillar of higher education and business improvement" is the motto of the Conference and suggests how research, innovation and academia must coincide with the productive sector to leverage social and economic development.

CI3 2023 had 145 papers submitted, of which 52 were accepted for publication and presentation. To guarantee the quality of the publications, the event has a staff of more than 70 experts, from different countries such as Spain, Argentina, Chile, Mexico, Peru, Brazil, Ecuador, among others, who carry out an exhaustive review of each proposal sent.

Likewise, during the event a series of keynote conferences were held, given by both national and international experts, allowing attendees to get in touch with the latest trends and technological advances around the world. Keynote speakers included: Ph.D. Carina González, University of La Laguna, Spain; Ph.D. Gabriel Gómez, State University of Campinas, Brazil; Ph.D. Carlos Sanchez, University of Zaragoza, Spain; Ph.D. Juan Minango, Instituto Tecnológico Superior Rumiñahui; Dr. Iván Cherrez, Universidad Espíritu Santo, Ecuador; and Ph.D. Nela Paustizaca, Escuela Politécnica del Litoral, Ecuador.

The content of this proceeding is related to the following topics:

- Smart Cities
- Innovation and Development
- Applied Technologies
- Economics and Management
- ICT for Educations.

Organization

General Chairs

Marcelo Zambrano Vizuete	Instituto Tecnológico Universitario Rumiñahui, Ecuador

Organizing Committee

Marcelo Zambrano Vizuete	Instituto Tecnológico Universitario Rumiñahui, Ecuador
Miguel Botto-Tobar	Eindhoven University of Technology, The Netherlands
Sonia Casillas	Universidad de Salamanca, Spain
Carina Gonzales	Universidad de La Laguna, Spain
Carlos Sánchez	Universidad de Zaragoza, Spain
Gabriel Gomes	Universidad Estatal de Campinas, Brazil
Benjamin Durakovic	International University of Sarajevo, Bosnia and Herzegovina

Steering Committee

Marcelo Zambrano	Instituto Tecnológico Superior Rumiñahui, Ecuador
Miguel Botto	Eindhoven University of Technology, The Netherlands
Karla Ayala	Instituto Tecnológico Superior Rumiñahui, Ecuador
Xavier Duque	Instituto Tecnológico Superior Rumiñahui, Ecuador
Ernesto Huerta	Instituto Tecnológico Superior Rumiñahui, Ecuador
Carmita Suárez	Instituto Tecnológico Superior Rumiñahui, Ecuador
Maritza Salazar	Instituto Superior Tecnológico Espíritu Santo, Ecuador
Wilfrido Robalino	Instituto Superior Tecnológico Vida Nueva, Ecuador

Roberto Tolozano	Instituto Superior Tecnológico Bolivariano, Ecuador
Carlos Pérez	Instituto Tecnológico Sudamericano, Ecuador
Alicia Soto	Instituto Superior Tecnológico ITCA, Ecuador
Lorena Ávila	Instituto Superior Tecnológico Policía Nacional, Ecuador
Denis Calvache	Instituto Superior Tecnológico ISMAC, Ecuador
Efraín Paredes	Instituto Superior Tecnológico IGAD, Ecuador
Paola Vasconez	Instituto Superior Tecnológico Oriente, Ecuador
Sandra El Khori	Instituto Superior Tecnológico San Isidro, Ecuador
Santiago Illescas	Instituto Superior Tecnológico Sucre, Ecuador
Jorge Calderón	Instituto Superior Tecnológico Argos, Ecuador
Trotsky Corella	Instituto Superior Tecnológico Central Técnico, Ecuador
Javier García	Instituto Superior Tecnológico Humane, Ecuador
Sandra Salazar	Instituto Superior Tecnológico American College, Ecuador
David Flores	Instituto Superior Tecnológico Cordillera, Ecuador
Marcelo Aguilera	Instituto Superior Tecnológico del Azuay, Ecuador

Program Committee

Carina González	Universidad de La Laguna, Spain
Carlos Sánchez	Universidad de Zaragoza, Spain
Sergey Balandin	Universidad de Helsinki, Finland
Silva Ganesh Malla	SKR Engineering College, India
Alberto Ochoa	Universidad Autónoma Ciudad de Juárez, Mexico
Antonio Orizaga	Universidad de Guadalajara, Mexico
Rocío Maciel	Universidad de Guadalajara, Mexico
Víctor Larios	Universidad de Guadalajara, Mexico
Yorberth Montes	Universidad de Zulia, Venezuela
Juan Minango	Universidad Estatal de Campinas, Brazil
Francisco Pérez	Universidad Politécnica de Valencia, Spain
Víctor Garrido	Universidad Politécnica de Valencia, Spain
Alberto García	Universidad Politécnica de Valencia, Spain
Javier Hingant	Universidad Politécnica de Valencia, Spain
Javier Prado	Universidad Técnica Federico Santa María, Chile
Marco Heredia	Universidad Politécnica de Madrid, Spain

Diego Paredes	Universidad de Zaragoza, Spain
Angela Cadena	Universitat de Valencia, Spain
Sonia Casillas	Universidad de Salamanca, Spain
Marco Cabezas	Universidad de Salamanca, Spain
Francesc Wilhelmi	Centre Tecnològic de Telecomunicacions de Catalunya, Spain
Santiago Vidal	Universidad Nacional Del Centro de la Provincia de Buenos Aires, Argentina
Adailton Antônio Galiza Nunes	Universidad Estatal de Campinas, Brazil
Leandro Bezerra De Lima	Universidad Federal de Mato Grosso Do Sul, Brazil
Andrea Carolina Flores	Embraer Defensa y Seguridad, Brazil
Elmer Levano Huamacto	Universidad Federal Do Parana, Brazil
Ari Lazzarotti	Universidad Federal de Goiás, Brazil
Ellen Synthia Fernandes de Oliveira	Universidad Federal de Goiás, Brazil
Fernanda Cruvinel Pimentel	Universidad Federal de Goiás, Brazil
Yuzo Lanoi	Universidad Estatal de Campinas, Brazil
Gabriel Gómez	Universidad Estatal de Campinas, Brazil
Pablo Minango	Universidad Estatal de Campinas, Brazil
Benjamin Durakovic	International University of Sarajevo, Bosnia and Herzegovina
Jhonny Barrera	Universidad Nacional de La Plata, Argentina
Daniel Ripalda	Universidad Nacional de La Plata, Argentina
Alonso Estrada Cuzcano	Universidad Nacional Mayor de San Marcos, Peru
Marcelo Zambrano	Instituto Tecnológico Superior Rumiñahui, Ecuador
Ana Zambrano	Escuela Politécnica Nacional, Ecuador
Angel Jaramillo	Universidad de las Américas, Ecuador
Ángela Cadena	Universidad de Guayaquil, Ecuador
Oscar Leon	Universidad de Guayaquil, Ecuador
Wladimir Paredes	Consejo de Aseguramiento de la Calidad de la Educación Superior, Ecuador
Miguel Angel Zúñiga	Universidad de Cuenca, Ecuador
Alex Santamaría	Universidad Laica Eloy Alfaro, Ecuador
Fabián Sáenz	Universidad de las Fuerzas Armadas ESPE, Ecuador
Darwin Aguilar	Universidad de las Fuerzas Armadas ESPE, Ecuador
Sergio Montes	Universidad de Las Fuerzas Armadas Espe, Ecuador
Jhenny Cayambe	Pontificia Universidad Católica del Ecuador Sede Ibarra, Ecuador

Santiago Ushiña	Likatelec, Ecuador
Raisa Bernal	Instituto Tecnológico Superior Rumiñahui, Ecuador
Aníbal Altamirano	Universidad de las Fuerzas Armadas ESPE, Ecuador
Moisés Toapanta	Universidad Católica Santiago de Guayaquil, Ecuador
Ricardo Rosero	Instituto Tecnológico Superior Rumiñahui, Ecuador
Danny De La Cruz	Universidad de las Fuerzas Armadas ESPE, Ecuador
Johana Tobar Quevedo	Universidad de las Fuerzas Armadas ESPE, Ecuador
Jhony Caucha	Universidad Nacional de Tumbes, Peru
Mariana Lima Bandeira	Universidad Andina Simón Bolívar, Ecuador
Norma Molina	Universidad Israel, Ecuador
Elfio Pérez	Universidad Indoamérica, Ecuador
Cristian Tasiguano	Instituto Superior San Antonio, Ecuador
Lizbeth Suarez Morales	Instituto Superior Vida Nueva, Ecuador
Carlos Ruiz	Instituto Superior Vida Nueva, Ecuador
Wilfrido Robalino	Instituto Superior Vida Nueva, Ecuador
William Venegas	Escuela Politécnica Nacional, Ecuador
César Ayabaca	Escuela Politécnica Nacional, Ecuador
Dario Morales	Instituto Superior Vida Nueva, Ecuador
Pamela Villareal	Instituto Superior Vida Nueva, Ecuador
Darwin Tituaña	Instituto Superior Vida Nueva, Ecuador
Ismenia Araujo	Instituto Superior José Chiriboga Grijalva, Ecuador
Luz Marina Rodríguez	Instituto Superior José Chiriboga Grijalva, Ecuador
Luis Alzate	Instituto Superior Bolivariano, Ecuador
Noemi Delgado	Instituto Superior Bolivariano, Ecuador
Marítza Salazar	Instituto Superior Espíritu Santo, Ecuador
Martha Fernández	Instituto Superior Espíritu Santo, Ecuador
Néstor Xavier Maya Izurieta	Instituto Superior Central Técnico, Ecuador
Michael Enrique Carrión Garzón	Instituto Superior Central Técnico, Ecuador
Nela Pastuizaca	Escuela Politécnica del Litoral, Ecuador
Marcelo Flores	Universidad Politécnica Salesiana, Ecuador
Diego Vizuete	Instituto Superior Sucre, Ecuador
Edgar Maya	Universidad Técnica del Norte, Ecuador
Mauricio Domínguez	Universidad Técnica del Norte, Ecuador
Fabián Cuzme	Universidad Técnica del Norte, Ecuador

RIT2

Contents

Smart Cities

IoT Applied to Improve Production Controls in the Ecuadorian Floriculture Sector

Claudio Arcos[1](✉), Pablo Calvache[2], and Ricardo Calderón[3]

[1] San Francisco Global Foundation and ISMAC Technological Institute, Quito, Ecuador
claudioarcos@sanfranciscoglobal.org
[2] ISMAC Technological Institute, Quito, Ecuador
[3] World Roses Center Farm, Tabacundo, Ecuador

Abstract. For the development of this study, the internet of things IoT concept was used, in the context of which a network of sensors was deployed within a rose crop that is planted in an area of 30,000 m^2, which are covered under greenhouses. The crop is located at 2,900 m above sea level and, for a year and a half, humidity data, dew point data, temperature data and vapor pressure deficit VPD data were collected with the use of the sensor network. in such a way that a database of more than 49 million data was obtained that was used to contrast and analyze the data collected in the same period related to diseases and pests that can occur in rose production. The results show that there are levels of correlation that allow determining mechanisms for measuring environmental conditions in production to improve efficiency and effectiveness in the decision-making process for better crop management.

Keywords: IoT · Digital transformation · Precision agriculture

1 Introduction

Between the years 2018 and 2022, Ecuador exported 20.46% of a total of USD$15,850′580,000.00 of the fresh cut roses product, thus becoming the second most exporting country of this product during that period, below the Netherlands and above Columbia [1].

In this context, rose crops in Ecuador must implement control technologies in productive management to meet local and international demands in various areas. The phytosanitary field is one of the areas whose management, adequate or not, positively or negatively affects access to international markets, compliance with local controls, quality improvement and waste reduction.

The fact is that damage to the rose plant can occur in different ways. The main damage is caused by pests such as thrips and mites or diseases such as botrytis, powdery mildew and downy.

In this sense, the concept of precision agriculture is transcendental to implement mechanisms that favor the control and management of potential effects on plants. In this context, it is important to first understand what IoT is as a mechanism to promote precision agriculture in rose production, and secondly what are the main diseases and pests that affect the cultivation of roses.

M. Z. Vizuete et al. (Eds.): CI3 2023, LNNS 1040, pp. 3–17, 2024.
https://doi.org/10.1007/978-3-031-63434-5_1

1.1 IoT as a Mechanism to Promote Precision Agriculture in Rose Production

At present, the domain of agriculture results from the application of methods that, by using technological instruments, allow the improvement of traditional cultivation methods in the areas that are possible [2].

The fact is that knowledge-intensive solutions such as the use of sensors, drones, automated irrigation systems, real-time monitoring, timed disinfection, etc., make it possible to enhance the organization's resource and capacity management and favor productivity, efficiency, control of pests and diseases, quality of the final product and competitive access to markets, mainly.

For this reason, farmers are constantly looking for mechanisms to manage the risks of climate change. In this context, the Internet of Things, known as IoT, is a technological evolution that provides access to data, information and services of the activities in which it is applied, through intelligent networks that deliver data in real time [3].

The IoT applied to agriculture can improve several processes, because with better information it is possible to deploy actions to sustain the quality of the product during the production process and thus satisfy customer requirements [4].

In the flower sector, with the application of sensors within the IoT concept, it is possible to know what is happening with the production processes in terms of their incidence environment. In other words, in order to maintain optimal growth and development conditions for rose plants inside a greenhouse, it is necessary to control and manage, among other things, the temperature, humidity, vapor pressure deficit and the dew point within the crop environment [5].

The use of IoT technology can simplify this management by obtaining data from said measurements in real time and, with the analysis of these data, favor decision-making for the good of the production process, as well as the management and control of pests and diseases.

The diffusion of these technologies for the improvement of competitiveness in the flower sector of Ecuador is essential. This is because it has been shown that the presence of innovation activities depends on the execution of various skills within the organization, and its innovative approach is stimulated by mastering a portfolio of technological skills from which they are carried out. R&D activities and, if digital transformation and absorption are not promoted, innovation will not happen [6].

1.2 Diseases and Pests that Affect the Cultivation of Roses

Mainly: the development of cultural practices, adequate air circulation, correct protection of the growing area and irrigation, help prevent and control diseases and pests [7], This, plus the productive capacities of the peasants, which include their traditional and ancestral knowledge on sowing and harvesting mechanisms and practices, have contributed to the development of the flower sector in Ecuador [8].

Additionally, there are organic and chemical treatments to manage pests and diseases, mainly pests such as thrips and mites or diseases such as botrytis, powdery mildew and downy [9–11].

As for pests, thrips are small insects that feed on the petals and cause cosmetic damage to the flower. For their part, the mites that affect roses are sap suckers, therefore, they feed on the sap of the leaves, causing them to turn yellow and dry.

Among the most common diseases are: botrytis, which is a fungal disease that generates brown spots mainly on the petals. Powdery mildew is also a fungal disease that consists of the appearance of a white coating mainly on the leaves and stems, the same that is similar to dust on the leaves, buds and stems. For its part, downy is another fungal disease characterized by the appearance of reddish or orange pustules on the underside of the leaves [12].

The different affectations can cause decomposition of the flower, premature wilting, weakness of the plant, disorder of the growth cycle, deformations, premature fall of the leaves, affectation of the photosynthesis process; all of this decreases the quality of the flowers, reduces their life time in the vase, and therefore decreases the competitiveness of the final product, with the consequent loss of the export market.

The control of environmental conditions inside the greenhouse facilitates decision-making regarding agricultural activities as well as the application of fungicides to protect the health of plants. The fact is that both pests and diseases are the result of poor production management in the face of changing environmental conditions that favor the appearance of pests and diseases, mainly temperature, humidity, vapor pressure deficit and the dew point.

2 Materials and Methods

2.1 Database and Variables

For the development of the study, five sensors were installed on June 25, 2021, the same ones that were distributed in 30,000 m^2 of a rose farm located in Tabacundo - Ecuador, at 2,900 m above sea level.

The sensors used are dataloggers that record and store the data in their internal memory, and transmit it in real time through the internet or it can be downloaded via Bluetooth. For the present study, the data was obtained by the transmission via the internet to a PC.

The characteristics of the sensors are:

- Wireless access to data.
- The recorded data can be downloaded but cannot be edited.
- It has user-configurable alerts.
- Unlimited number of users that can monitor the same sensor.
- Connection to a portal to monitor in real time through a mobile application that allows the storage and download of data in CSV format.
- Measures temperature ranges from −40 °C to +60 °C.
- Measures relative humidity ranges from 0% to 100% (prolonged exposure to $>$80% can create a lag of up to +3% in readings, this effect gradually reverses after returning to $<$ 80% conditions).
- Temperature accuracy (0 °C to 60 °C): +−0.3 °C typical, +−0.5 °C maximum.
- Temperature Accuracy (full range): +−0.7 °C typical, +−1.2 °C maximum.
- Humidity Accuracy (@25 °C, 20% to 80%): +−3% typical, +−4.5% maximum.
- Humidity Accuracy (@25 ºC, 0% to 100%): +−4.5% typical, +−7.5% maximum.

- Signal range: 100 m in line of sight. It is greater with the use of an amplifying antenna that increases the coverage radius to connect the sensor signal to a router.
- Battery: CR2477 × 1.3 V (duration of one year approximately).
- Dimensions: 40 × 40 × 16.5 mm.
- Weight: 40 gr.
- Compatibility: iOS 8+, Android 4.3+, Bluetooth 4.0+

Each sensor obtains data on temperature, humidity, vapor pressure deficit, and dew point. Sensors are IoT technology that record, store, and transmit data over the Internet in real time to one or more terminals with Android or iOS systems. The network architecture is shown below (see Fig. 1).

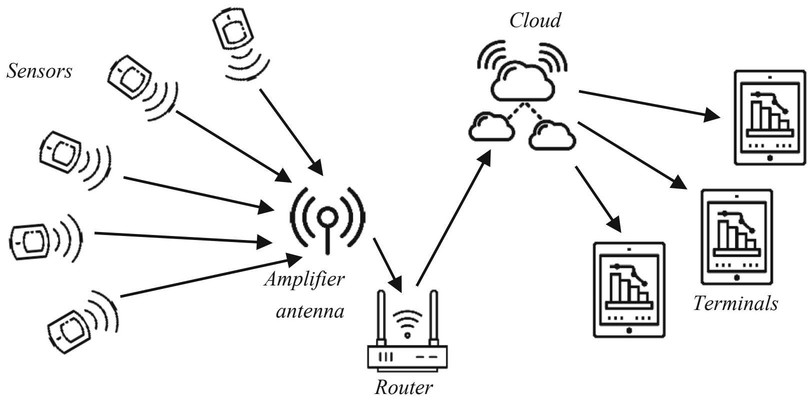

Fig. 1. Network architecture. Source: direct investigation.

Once the sensors were distributed, an amplifying antenna was fixed in the center of the five sensors at a distance of approximately 100 m from each sensor to the antenna. The antenna was connected to a router with internet access via a network cable. The router receives and transmits the data in real time to any terminal that has installed access to the information transmitted by the five sensors.

The data is permanently displayed in the sensors' own software, which allows all the data to be downloaded in CSV format. The databases constitute structured repositories with observations managed by storage systems and software packages of the sensors. In this sense, to obtain the data under study, observations collected from June 25, 2021 at 12:40 p.m. to January 19, 2023 at 5:40 p.m. were considered.

The database consists of minute-by-minute observations of four readings: temperature, relative humidity, vapor pressure deficit (VPD) and dew point, within the crop environment, obtaining the following observations and data:

- Block 1 database: 825,421 observations and 9,905,064 data
- Block 2 database: 825,407 observations and 9,904,884 data
- Block 3 database: 825,411 observations and 9,904,932 data
- Block 4 database: 825,411 observations and 9,904,932 data

- Block 5 database: 825,414 observations and 9,904,968 data

In order to compare the measurements of the five sensors with the state of the plants, the postharvest database of the company participating in the study was used. Said database stores daily information on harvest about production for exporting and discarded production. Discarded production is the number of stems discarded by pests and/or diseases caused in the rose, which go through the composting process because they do not comply with quality parameters for export. Within the discarded production, the different causes analyzed in this study are recorded, such as: in pests: mites and thrips; in diseases: botrytis, downy and powdery mildew. In the same way, the period of time considered for the analysis of the post-harvest database is from June 25, 2021 to January 19, 2023, obtaining the following observations and data:

- Postharvest database: 289,270 observations and 5,785,400 data

Since in Ecuador there are critical points in the productive systems, such as the precariousness of governance and management capacity [13], it is essential to consider that the determining factors of innovation in organizations include the adoption of digital transformation tools, understanding this action as the acquisition or absorption of innovation.

Therefore, demonstrating the application of a system based on IoT to improve production from the implementation of innovation solutions stimulates the mastery of technological skills as determinants of innovation [6].

In this sense, it is understood that the IoT applied acts as a catalyst for innovation, for which the question for this research is: how to improve efficiency in the Ecuadorian floriculture sector using IoT?

3 Results

Prior to the statistical analysis of the databases, these were refined and organized, disaggregating the date and time data as individual variables, to facilitate the grouping of data in intervals by hours, days, weeks, quarters, and years; and the days June 25, 2021 and January 19, 2023 were discarded as they did not have the total number of observations on those days.

To treat the database, a very important criterion for the study was incorporated, such as solar luminosity, so that the observations were grouped considering the sunrise from 6:00 a.m., and the sunset at 6:00 p.m., as well as the highest point (zenith) 12:00 pm. Therefore, a weighted average of four indicators per day was obtained considering the daily luminosity and a simple average was applied for grouping the days per week.

In reference to the postharvest database, the data was broken down by dates in format (mm/dd/yy), to facilitate their grouping by days and weeks. The production data were disaggregated to obtain the discarded production due to pests and diseases, and the data from each of the five sensors were grouped to obtain the discarded production and its causes. Sundays and holidays were not considered for not having postharvest records.

For the analysis, the databases were grouped and the observations were structured in years divided into weeks with the readings of the sensors and the causes of national production obtained from the postharvest record.

Once the data of the sensor variables and the causes of discarded production have been organized by years and weeks, the normality test is calculated. The normality test is performed because it is necessary to examine whether the data follows a normal distribution or not. For the normality test we use the Kolmogórov-Smirnov test, which is performed at a 95% confidence level. According to the result of this test, the statistical model should be selected, either for parametric or non-parametric data, and the following hypotheses are proposed:

H1: The data set does not follow the normal distribution
H0: The data set follows the normal distribution

If the result of the Kolmogórov-Smirnov test is less than 0.05, then the H0 hypothesis is rejected, that is, the data set does not follow a normal distribution.

The database was processed with the SPSS software, and the results show that the pest and disease variables obtain significance values less than 0.05 (see Table 1, 2, 3, 4 and 5), therefore the null hypothesis H0 is rejected and the alternative hypothesis H1 is accepted. Consequently, a statistical model for non-parametric data was then applied, it was Spearman Rho correlation coefficient, that is a nonparametric test used when the data does not follow a normal distribution.

Table 1. Normality test with data from sensor #1. Source: direct investigation.

Kolmogórov-Smirnov[a]			
	Stat	df	Sig
Humidity	,079	83	,200*
Dew point	,113	83	,011
Temperature	,058	83	,200*
VPD	,110	83	,015
Botrytis	,305	83	<,001
Powdery mildew	,306	83	<,001
Downy mildew	,308	83	<,001
Thrips	,191	83	<,001
Mites	,197	83	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction.

Table 2. Normality test with data from sensor #2. Source: direct investigation.

Kolmogórov-Smirnov[a]			
	Stat	df	Sig
Humidity	,064	83	,200*
Dew point	,124	83	,003
Temperature	,063	83	,200*
VPD	,096	83	,056
Botrytis	,271	83	<,001
Powdery mildew	,308	83	<,001
Downy mildew	,353	83	<,001
Thrips	,259	83	<,001
Mites	,220	83	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction.

Table 3. Normality test with data from sensor #3. Source: direct investigation.

Kolmogórov-Smirnov a			
	Stat	df	Sig
Humidity	,068	83	,200*
Dew point	,118	83	,006
Temperature	,063	83	,200*
VPD	,111	83	,013
Botrytis	,323	83	<,001
Powdery mildew	,302	83	<,001
Downy mildew	,273	83	<,001
Thrips	,283	83	<,001
Mites	,213	83	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction.

Table 4. Normality test with data from sensor #4. Source: direct investigation.

Kolmogórov-Smirnov a			
	Stat	df	Sig
Humidity	,122	51	,057
Dew point	,139	51	,016
Temperature	,209	51	<,001
VPD	,132	51	,026
Botrytis	,280	51	<,001
Powdery mildew	,260	51	<,001
Downy mildew	,402	51	<,001
Thrips	,346	51	<,001
Mites	,183	51	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction.

Table 5. Normality test with data from sensor sensor #5. Source: direct investigation.

Kolmogórov-Smirnov a			
	Stat	df	Sig
Humidity	,085	82	,200*
Dew point	,117	82	,008
Temperature	,092	82	,085
VPD	,102	82	,033
Botrytis	,291	82	<,001
Powdery mildew	,305	82	<,001
Downy mildew	,299	82	<,001
Thrips	,309	82	<,001
Mites	,204	82	<,001

* This is a lower limit of the true meaning.
a. Lilliefors significance correction.

Once the Spearman correlation coefficient statistical method was applied to the database, the respective correlation coefficient levels were obtained. The interpretation of Spearman's correlation coefficient ranges between -1 and + 1, indicating negative or positive associations respectively; 0 zero means that there is no correlation. The results can be seen in Table 6, 7, 8, 9 and 10.

Table 6. Correlation of pests and diseases with data from sensor #1. Source: direct investigation.

	Humidity				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,122	0,204	0,041	−0,054	0,165
	Dew point				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,081	0,245	−0,021	−0,09	0,097
	Temperature				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	−0,003	0,072	−0,085	−0,034	−0,108
	VPD				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	−0,086	−0,078	−0,057	−0,064	−0,15

Table 7. Correlation of pests and diseases with data from sensor #2. Source: direct investigation.

	Humidity				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,533	0,093	−0,028	−0,434	0,382
	Dew point				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,664	0,3	−0,144	−0,45	0,554
	Temperature				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,251	0,317	−0,174	−0,038	0,267
	VPD				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	−0,284	0,107	−0,024	0,318	−0,165

Table 8. Correlation of pests and diseases with data from sensor #3. Source: direct investigation.

	Humidity				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,573	0,442	−0,014	−0,236	0,377
	Dew point				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,698	0,62	−0,187	−0,128	0,477
	Temperature				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,335	0,391	−0,296	0,118	0,292
	VPD				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	−0,222	0,09	−0,123	0,229	−0,066

Table 9. Correlation of pests and diseases with data from sensor #4. Source: direct investigation.

	Humidity				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,452	−0,009	−0,248	−0,142	0,22
	Dew point				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,689	0,295	−0,233	−0,03	0,384
	Temperature				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,455	0,393	−0,018	0,168	0,236
	VPD				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	−0,071	0,18	0,181	0,178	−0,02

Table 10. Correlation of pests and diseases with data from sensor #4. Source: direct investigation.

	Humidity				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,524	0,299	0,106	−0,298	0,405
	Dew point				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,713	0,373	−0,081	−0,079	0,425
	Temperature				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	0,449	0,227	−0,276	0,234	0,144
	VPD				
	Botrytis	Powdery mildew	Downy mildew	Thrips	Mites
Rho =	−0,116	−0,054	−0,219	0,348	−0,195

According to the statistical analysis of the data and its correlation, the following can be noted:

Humidity. It is verified that there is a positive correlation between the relative humidity variable with the presence of botrytis. The relationship is directly proportional with values of Rho min = 0.122 in sensor #1 and Rho max = 0.573 in sensor #3.

It is verified that there is a positive correlation between the relative humidity variable with the presence of powdery mildew. The relationship is directly proportional with values of Rho min = 0.093 in sensor #2 and Rho max = 0.442 in sensor #3. In this relationship, sensor #4 is the only one with a negative correlation with Rho = −0.009, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

There is not enough significance to prove a correlation between the variable relative humidity with downy. The values shown are negative Rho max = −0.248 in sensor #4 and positive Rho max = 0.106 in sensor #5.

It is verified that there is a negative correlation between the relative humidity variable with the presence of thrips. The relationship is inversely proportional with values of Rho min = −0.054 in sensor #1 and Rho max = −0.434 in sensor #2.

It is verified that there is a positive correlation between the relative humidity variable with the presence of mites. The relationship is directly proportional with values of Rho min = 0.165 in sensor #1 and Rho max = 0.405 in sensor #5.

Dew Point. It is verified that there is a positive correlation between the dew point variable with the presence of botrytis. The relationship is directly proportional with values of Rho min = 0.081 in sensor #1 and Rho max = 0.713 in sensor #5.

It is verified that there is a positive correlation between the dew point variable with the presence of powdery mildew. The relationship is directly proportional with values of Rho min = 0.245 in sensor #1 and Rho max = 0.620 in sensor #3.

It is verified that there is a negative correlation between the variable dew point with the presence of downy. The relationship is inversely proportional with values of Rho min = −0.021 in sensor #1 and Rho max = −0.233 in sensor #4.

It is verified that there is a negative correlation between the dew point variable with the presence of thrips. The relationship is inversely proportional with values of Rho min = −0.030 in sensor #4 and Rho max = −0.450 in sensor #2.

It is verified that there is a positive correlation between the dew point variable with the presence of mites. The relationship is directly proportional with values of Rho min = 0.097 in sensor #1 and Rho max = 0.554 in sensor #2.

Temperature. It is verified that there is a positive correlation between the temperature variable with the presence of botrytis. The relationship is directly proportional with values of Rho min = 0.251 in sensor #2 and Rho max = 0.449 in sensor #5. In this relationship, sensor #1 is the only one with a negative correlation with Rho = −0.003, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

It is verified that there is a positive correlation between the temperature variable with the presence of powdery mildew. The relationship is directly proportional with values of Rho min = 0.072 in sensor #1 and Rho max = 0.391 in sensor #3.

It is verified that there is a negative correlation between the variable temperature with the presence of downy. The relationship is inversely proportional with values of Rho min = −0.085 in sensor #1 and Rho max = −0.296 in sensor #3.

There is not enough significance to prove a correlation between the variable temperature with thrips. The values shown are negative Rho max = −0.038 in sensor #2 and positive Rho max = 0.234 in sensor #5.

It is verified that there is a positive correlation between the temperature variable with the presence of mites. The relationship is directly proportional with values of Rho min = 0.236 in sensor #4 and Rho max = 0.292 in sensor #3. In this relationship, sensor #1 is the only one with a negative correlation with Rho = −0.108, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

VPD. It is verified that there is a negative correlation between the VPD variable with the presence of botrytis. The relationship is inversely proportional with values of Rho min = −0.086 in sensor #1 and Rho max = −0.284 in sensor #2.

There is not enough significance to prove a correlation between the variable VPD with powdery mildew. The values shown are negative Rho max = −0.078 in sensor #1 and positive Rho max = 0.078 in sensor #2.

There is not enough significance to prove a correlation between the variable VPD with downy. The values shown are negative Rho max = −0.219 in sensor #5 and positive Rho max = 0.181 in sensor #4.

It is verified that there is a positive correlation between the VPD variable with the presence of thrips. The relationship is directly proportional with values of Rho min = 0.178 in sensor #4 and Rho max = 0.348 in sensor #5. In this relationship, sensor #1 is the only one with a negative correlation with Rho = −0.064, so the possibility of an investigation by rose variety is opened considering the types of roses existing in the analysis radius measured by this sensor.

It is verified that there is a negative correlation between the VPD variable with the presence of mites. The relationship is inversely proportional with values of Rho min = −0.020 in sensor #4 and Rho max = −0.195 in sensor #5.

4 Discussion

The use of IoT technology helps to obtain data in real time so a farm is able to take decisions also in real time looking to improve the production process, as well as the management and control of pests and diseases.

Controlling affectations that cause damage of the flower can help to get a better competitive level with the consequent increase of the possibilities for exporting.

As a result of the present study, the control of environmental conditions inside the greenhouse can help decision-making regarding agricultural activities as well as the application of fungicides to protect the health of plants. In this sense, this research proposes a data sheet that combines both, pests and diseases, to show when the farm should be alert about the changing environmental conditions that favor the appearance of pests and diseases, considering temperature, humidity, vapor pressure deficit and the dew point, to deploy actions to prevent the damage of the roses.

Table 11 shows a set of indicators that consider the conditions of temperature, humidity, dew point and VPD, which when combined, resulted in the 20% of highest presence and incidence of diseases and pests. These indicators represent the possibility of improving production control through the IoT applied to the production of roses, and mean a guide for daily work on a farm that decides to implement digital transformation tools such as IoT and data analytics.

Table 11. Data sheet of estimated conditions for the prevention of pests and diseases in the production of roses. Source: direct investigation.

Estimated conditions for the incidence of botrytis				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	49.20	6.95	16.57	0.54
MAX:	77.50	14.77	22.02	1.66
Estimated conditions for the incidence of powdery mildew				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	57.72	9.80	16.03	0.59
MAX:	77.50	12.89	23.60	1.95
Estimated conditions for the incidence of downy mildew				

(*continued*)

Table 11. (*continued*)

Estimated conditions for the incidence of botrytis				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	55.57	7.11	13.82	0.36
MAX:	79.40	12.95	20.16	1.39
Estimated conditions for the incidence of thrips				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	48.90	8.36	16.56	0.66
MAX:	71.69	12.83	21.30	1.86
Estimated conditions for the incidence of mites				
Range	*Humidity*	*Dew point*	*Temperature*	*VPD*
MIN:	49.20	6.95	14.73	0.45
MAX:	79.10	14.02	21.27	1.71

5 Conclusions

In all cases it was evidenced that the incidence of pests and diseases has different levels of correlation with the environmental conditions inside the greenhouses. This information is useful to establish a data sheet with a set of indicators that allow the producer to know when it must be carried out preventive and even corrective actions due to the effect of knowledge about environmental conditions in real time.

The present study demonstrates the importance of the IoT applied to control production in the floriculture production sector, however, this study does not cover the economic impact and administrative management due to the fact of handling data on environmental conditions that could affect the crop. Nevertheless, the data sheet of estimated conditions for the prevention of pests and diseases in the production of roses is an important advance for this agricultural sector, the same one that should be measured in a new study.

The possibility of deepening the current study and developing decision-making methods based on statistical information built from the IoT applied to the flower sector remains open.

References

1. Trade Map: Trade Map, 21 05 2023. [En línea]. www.trademap.org
2. Tamoghna, O., Sudip, M., Narendra, S.R.: Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges. Comp. Electron. Agric. **118**, 66–84 (2015)
3. Want, R., Schilit, B., Jenson, S.: Enabling the Internet of Things. Computer **48**, 28–35 (2015)
4. Alagarsamy, G., Gowthaman, N.: Intelligent IoT (IIoT)-based food supply monitoring system with alert messages in transmission and distribution environment. In: de Technology, Business, Innovation, and Entrepreneurship in Industry 4.0, Gewerbestrasse, EAI/Springer Innovations in Communication and Computing, pp. 353–368 (2023)

5. Grower Talks: Grower Talks, 01 11 2018. [En línea]. www.growertalks.com
6. Arcos, C., Padilla, A.: Model of technological competencies as determinants of innovation: a comparative intersectoral study in Ecuador. In: de Trends in Artificial Intelligence and Computer Engineering. ICAETT 2022. Lecture Notes in Networks and Systems, vol. 619. Springer, Cham, pp. 561–574 (2023)
7. Gostinchar, J.: Cultivo del rosal. Cofisa, Madrid (1954)
8. Arcos, C.: Obstacles to innovative activities: case of the floriculture sector in Ecuador. In: de Technology, Business, Innovation, and Entrepreneurship in Industry 4.0, Gewerbestrasse. EAI/Springer Innovations in Communication and Computing, pp. 67–94 (2023)
9. Calvache, Á.: Elaboración de un manual técnico-práctico del cultivo de rosas para exportación. Researchgate (2010)
10. Messelink, G., Kruidhof, M.: Advances in pest and disease management in greenhouse cultivation. In: de Achieving sustainable greenhouse cultivation, London, Burleigh Dodds Science Publishing, p. 46 (2019)
11. Yong, A.: El cultivo del rosal y su propagación. Cultivos Tropicales **25**(2), 53–67 (2004)
12. Daughtrey, M., Buitenhuis, R.: Integrated pest and disease management in greenhouse ornamentals. In: de Integrated Pest and Disease Management in Greenhouse Crops, Berna, Plant Pathology in the 21st Century book series (ICPP, vol. 9), pp. 625–679 (2020)
13. Heredia, M., Falconí, V., Silva, J.H., Amores, K., Endara, C., Ausay, K.F.: Technological innovation for the sustainability of knowledge and natural resources: case of the Choco Andino biosphere reserve,» de innovation and research: a driving force for socio-econo-technological development. In: Botto-Tobar, M., Zambrano Vizuete, M., Díaz Cadena, A. (eds.). Springer, Cham, pp. 464–476 (2021)