ISSN 2444-4995

Journal of Technological Prototypes

Volume 9, Issue 24 — July — December — 2023

ECORFAN®

Journal of Technological Prototypes, Volume 9, Issue 24, July – December 2023, is a journal edited sixmonthly by ECORFAN-Spain. 38 Matacerquillas street, Postcode: 28411. Moralzarzal – Madrid WEB: www.ecorfan.org/spain, journal@ecorfan.org. Editor in Chief: QUINTANILLA - CÓNDOR, Cerapio. PhD, ISSN On line: 2444-4995. Responsible for the latest update of this number ECORFAN Computer Unit. ESCAMILLA-BOUCHÁN, Imelda. PhD, LUNA-SOTO, Vladimir. PhD, 38 Matacerquillas street, Postcode: 28411. Moralzarzal – Madrid, last updated December 31, 2023.

Journal of Technological Prototypes

Definition of Journal

Scientific Objectives

Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines of technological development, digitized technology, technological impact, computer aided teaching, computers reliability, heuristics, computing, machine arithmetic instructions, artificial intelligence, algorithmic languages, programming languages.

ECORFAN-Mexico SC is a Scientific and Technological Company in contribution to the Human Resource training focused on the continuity in the critical analysis of International Research and is attached to CONAHCYT-RENIECYT number 1702902, its commitment is to disseminate research and contributions of the International Scientific Community, academic institutions, agencies and entities of the public and private sectors and contribute to the linking of researchers who carry out scientific activities, technological developments and training of specialized human resources with governments, companies and social organizations.

Encourage the interlocution of the International Scientific Community with other Study Centers in Mexico and abroad and promote a wide incorporation of academics, specialists and researchers to the publication in Science Structures of Autonomous Universities - State Public Universities - Federal IES - Polytechnic Universities - Technological Universities - Federal Technological Institutes - Normal Schools - Decentralized Technological Institutes - Intercultural Universities - S & T Councils - CONAHCYT Research Centers.

Scope, Coverage and Audience

Journal of Technological Prototypes is a Journal edited by ECORFAN-Mexico S.C in its Holding with repository in Spain, is a scientific publication arbitrated and indexed with semester periods. It supports a wide range of contents that are evaluated by academic peers by the Double-Blind method, around subjects related to the theory and practice of technological development, digitized technology, technological impact, computer aided teaching, computers reliability, heuristics, computing, machine arithmetic instructions, artificial intelligence, algorithmic languages, programming languages with diverse approaches and perspectives, that contribute to the diffusion of the development of Science Technology and Innovation that allow the arguments related to the decision making and influence in the formulation of international policies in the Field of Engineering and Technology. The editorial horizon of ECORFAN-Mexico® extends beyond the academy and integrates other segments of research and analysis outside the scope, as long as they meet the requirements of rigorous argumentative and scientific, as well as addressing issues of general and current interest of the International Scientific Society.

Editorial Board

Arbitration Committee

Assignment of Rights

The sending of an Article to Journal of Technological Prototypes emanates the commitment of the author not to submit it simultaneously to the consideration of other series publications for it must complement the Originality Format for its Article.

The authors sign the Authorization Format for their Article to be disseminated by means that ECORFAN-Mexico, S.C. In its Holding Spain considers pertinent for disclosure and diffusion of its Article its Rights of Work.

Declaration of Authorship

Indicate the Name of Author and Coauthors at most in the participation of the Article and indicate in extensive the Institutional Affiliation indicating the Department.

Identify the Name of Author and Coauthors at most with the CVU Scholarship Number-PNPC or SNI-CONAHCYT- Indicating the Researcher Level and their Google Scholar Profile to verify their Citation Level and H index.

Identify the Name of Author and Coauthors at most in the Science and Technology Profiles widely accepted by the International Scientific Community ORC ID - Researcher ID Thomson - arXiv Author ID - PubMed Author ID - Open ID respectively.

Indicate the contact for correspondence to the Author (Mail and Telephone) and indicate the Researcher who contributes as the first Author of the Article.

Plagiarism Detection

All Articles will be tested by plagiarism software PLAGSCAN if a plagiarism level is detected Positive will not be sent to arbitration and will be rescinded of the reception of the Article notifying the Authors responsible, claiming that academic plagiarism is criminalized in the Penal Code.

Arbitration Process

All Articles will be evaluated by academic peers by the Double Blind method, the Arbitration Approval is a requirement for the Editorial Board to make a final decision that will be final in all cases. MARVID® is a derivative brand of ECORFAN® specialized in providing the expert evaluators all of them with Doctorate degree and distinction of International Researchers in the respective Councils of Science and Technology the counterpart of CONAHCYT for the chapters of America-Europe-Asia- Africa and Oceania. The identification of the authorship should only appear on a first removable page, in order to ensure that the Arbitration process is anonymous and covers the following stages: Identification of the Journal with its author occupation rate - Identification of Authors and Coauthors - Detection of plagiarism PLAGSCAN - Review of Formats of Authorization and Originality-Allocation to the Editorial Board-Allocation of the pair of Expert Arbitrators-Notification of Arbitration -Declaration of observations to the Author-Verification of Article Modified for Editing-Publication.

Instructions for Scientific, Technological and Innovation Publication

Knowledge Area

The works must be unpublished and refer to topics of technological development, digitized technology, technological impact, computer aided teaching, computers reliability, heuristics, computing, machine arithmetic instructions, artificial intelligence, algorithmic languages, programming languages and other topics related to Engineering and Technology.

Presentation of Content

In the first article we present, *System implementation for gait gratification for analysis with a low-cost development board and a real-time application* by VERA-NIÑO, Carlos, GUTIERREZ-VILLALOBOS José Marcelino, TALAVERA-VELÁZQUEZ Dimas and JIMÉNEZ-GONZÁLEZ, María de Jesús, with adscription in the Universidad Autónoma de Querétaro and Universidad de Guanajuato Campus Celaya-Salvatierra, as the next article we present, *Design of a WiFi sensor network to identify transmission zones of respiratory diseases through air quality indicators* by FIGUEROA-MILLÁN, Patricia Elizabeth, BRICIO-BARRIOS, Elena Elsa, LUA-MADRIGAL, Olimpo and ARCEO-DÍAZ, Santiago, with adscription in the Tecnológico Nacional de México/I.T Colima, as the next article we present, *Development of a prototype of a low-cost basic climatological study station using the Arduino platform* by ECHANDI-PACHECO Rodolfo with adscription in the Universidad Fidélitas, as the last article we present, *Gas detector as a technological alternative for home security* by BRIONES, Alexis, JASSO-JASSO, Ángel Erasmo, ORTEGA-GOVEA, Jacobo Neri and CORTÉS-SEGURA, Juan Pablo, with adscription in the Tecnológico Nacional de México, Instituto Tecnológico de San Luis Potosí.

Content

Article **Journal of Technological Prototypes**
December 2023 Vol.9 No.24 1-6

System implementation for gait gratification for analysis with a low-cost development board and a real-time application

Implementación de sistema para gratificación de la marcha para análisis con una placa de desarrollo de bajo costo y una aplicación en tiempo real

VERA-NIÑO, Carlos†, GUTIERREZ-VILLALOBOS José Marcelino*, TALAVERA-VELÁZQUEZ Dimas and JIMÉNEZ-GONZÁLEZ, María de Jesús

Universidad Autónoma de Querétaro, Cerro de las Campanas s/n, C.P. 76010, Querétaro, Querétaro, México.
Universidad de Guanajuato Campus Celaya-Salvatierra, Av. Javier Barrios Sierra 201 Col. Ejido de Santa María del Refugio C.P. 38140 Celaya, -Gto. México.

ID 1st Author: *Carlos, Vera-Niño* /**ORC ID**: 0009-9316-079X

ID 1st Co-author: *José Marcelino, Gutierrez-Villalobos* / **ORC ID**: 0000-0001-5947-1489, **Research ID Thomson**: S-7666-2018, **CVU CONAHCYT ID**: 173461

ID 2nd Co-author: *Dimas, Talavera-Velázquez* /**ORC ID**: 0000-0002-8074-1647, **CVU CONAHCYT ID**: 85034

ID 3rd Co-author: *María de Jesús, Jiménez -González* /**ORC ID**: 0000-0003-3806-0714, **CVU CONAHCYT ID**: 177299

DOI: 10.35429/JTP.2023.24.9.1.6 Received July 12, 2023; Accepted December 15, 2023

Abstract

Gait analysis is important to detect abnormal patterns caused by disease or injury in human body parts such legs, ankles, arms, elbows, back, and hips. Suitable treatments and routines can be established from this analysis, and it is possible to determine what may be appropriate for each patient according to the walking pattern and body movements presented by them. In this project, a wearable system with accelerometers and low-cost effective development board is implemented, which can be a practical tool for health professionals for measuring spatiotemporal gait characteristics and assign a proper treatment. Finally, it can be concluded that the system presented has a reliable performance.

Spatiotemporal analysis, Gait, Sensor technology, Accelerometer, Wearable sensors

Resumen

El análisis de la marcha es importante para detectar patrones anormales causados por enfermedades o lesiones en partes del cuerpo como piernas, tobillos, brazos, codos, espalda y cadera. A partir de este análisis se pueden establecer tratamientos y rutinas adecuadas, así como determinar cuál puede ser la más acorde para cada paciente según el patrón de marcha y movimientos corporales que presenta. En este trabajo se implementa un sistema portátil con acelerómetros y una placa de desarrollo de bajo costo, que puede ser una herramienta práctica para que los profesionales de la salud midan las características espaciotemporales de la marcha y asigne un tratamiento adecuado. Finalmente se puede concluir que el sistema presentado tiene un desempeño confiable.

Análisis espacio temporal, Marcha humana, Tecnología de sensores, Acelerómetro, Sensores portátiles

Citation: VERA-NIÑO, Carlos, GUTIERREZ-VILLALOBOS José Marcelino, TALAVERA-VELÁZQUEZ Dimas and JIMÉNEZ-GONZÁLEZ, María de Jesús. System implementation for gait gratification for analysis with a low-cost development board and a real-time application. Journal of Technological Prototypes. 2023. 9-24: 1-6

* Correspondence to Author (e-mail: jmgutierrez@ugto.mx)
† Researcher contributing first author

Introduction

Gait analysis is an important activity to observe human motion to find abnormalities in locomotion. Wearable systems using accelerometers are a common practice to perform these tests. However, sometimes the main electronic board to integrate the entire system is expensive; they need to have some features to obtain advantages of the portability. Nowadays, these implementation boards must have wireless communication, handling capacity for several tasks, communication for several devices and the most important goal, low power consumption.

There have been several alternatives for gait studies as described by Zani 2022. On one side, the image processing systems, and on the other hand the accelerometer sensor systems. Starting with image processing, these gadgets demand bigger spaces and budget, depending on the human disclaimants required to be measured. Contrary to accelerometer sensor wearable systems, which tend to be smaller and suitable for tasks where these tests must be performed in sport, training session and physical activities.

There have been several accelerometer sensor systems such Vertens 2015, Cardou 2008, Cardou 2009, Tao 2012, Muro-de-la-Herran 2014, Kavanagh 2005 and Fourati 2011. In these works, there have been other uses for the gait measurement, a different approach. Nevertheless, some other works using wearable systems were presented by Liu 2009, Donath 2016, Kluge 2017, Mayagoitia 2002, and Verheul 2019. Finally, there are published thesis such as Adkins 2023 and Chanda 2023, where gait systems took place for treatment design and patient treatment with a motion disorder.

Wearable System

The main goal is to build a reliable tool to accomplish a human gait study at low-cost. Therefore, a fast development board which reduces implementation time, because sensors and the board are pin-connected, makes its construction easier. The system is formed by an ESP32-WROOM-32, five AXL345 accelerometer sensors with SPI communication, a DS3231 RTC to set the time and day of each test, a microSD memory module to save a data backup when wireless communication fails and a battery for power supply. System components and their connections are shown in picture 1.

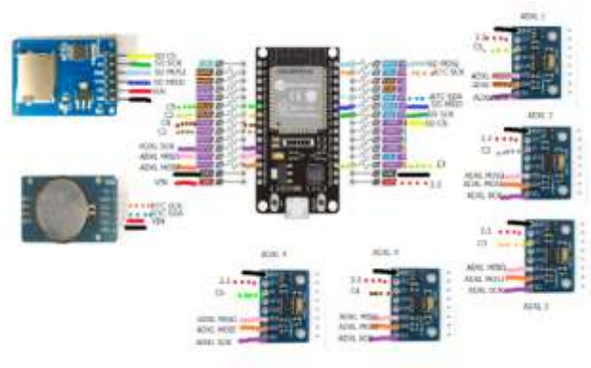


Figure 1 System elements and pin-connections

In this section, the way the system works is explained. First, The ESP32-WROOM-32 is turned on, and as soon as it happens the sensors and microSD memory are initialized reading their direction by the SPI protocol. Secondly, an IP direction file, previously loaded, with the name and password of the Wi-Fi network is read by the ESP32-WROOM-32, and Wi-Fi communication starts. Then, the board initializes working as a server with an HTML webpage, where data will be shown. Finally, I2C is only used by the RTC, so there is no problem to communicate with the ESP32 board. It must be mentioned that the ESP32 pin-port must be set as SPIMODE3 linked to the 1 MHz SPI Clock. Now, SD serial communication is set to 115200 bauds.

The index file loaded on the microSD is taken by the Wi-Fi module (ESP32), with the HTML code is executed so real-time interface begins to plot the signals of the accelerometer sensors. Since the board code is asynchronous to the sensor date collecting, the embedded server on the chip demands data update of every sensor every 200ms to show the data graphic at all time.

During main code execution, a loop is performed, which calls a function to read all the 5 sensors one by one. Information for each axis is saved into a two bytes variable, so the tree axis information is saved into a six-space array (two for each axis). Then, a shift is done to obtain the complete data of each axis in form of a three-space array. An RTC update is asked by the code to have the date, hour, minute and second of the sensors reading. Information is turned to a string and then concatenated to the sensor value, to be stored in the SD card. As mentioned before, this action is performed every 200 mS.

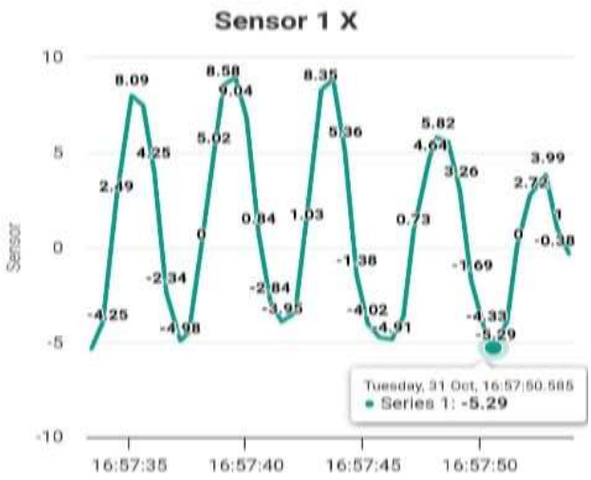
ISSN 2444-4995

System tests

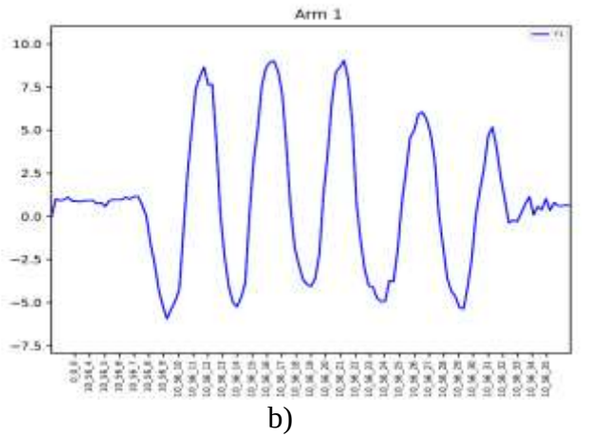
Tests took place on a regular person with no locomotion problem at that moment. However, there is an agreement with another educational nursing program, where there are physical rehabilitation classes, and professional practices with real patients' participation.

Results

On this section, graphics of arms and legs movement measures are presented. There is a comparison between the data in the real time application on the website and the date stored on the microSD, as shown in graph 1, where right arm graphics are compared. On the next figures, comparisons are shown between raw data coming from the server and graphed on the wireless application; and the graphic obtained using an off-line Python-based data processing script, from the data collected in the microSD during a preformed test.



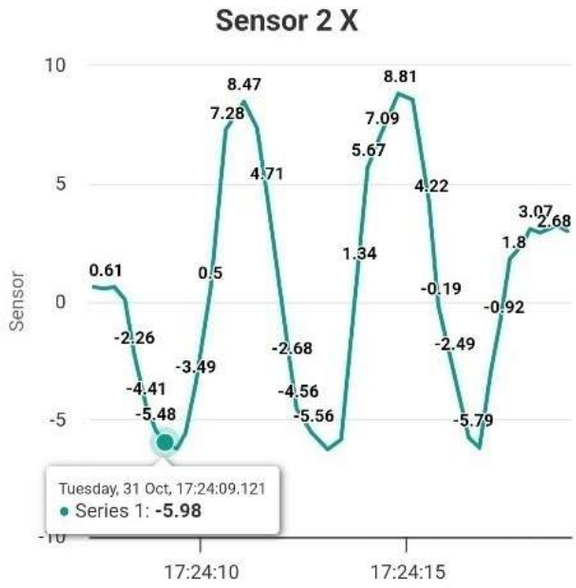
a)



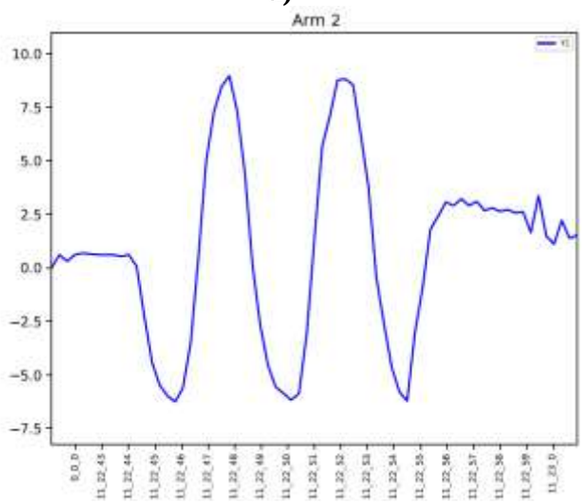
b)

Graph 1 a) Real-time application graphic shown on the website (right arm) vs b) Data storage in the microSD module graphed with Python

In the next figure, the graphics of the left arm are presented as well. The same comparison is done between the real time application on the website and the data written on the microSD, as shown in graph 2 (left arm).



a)

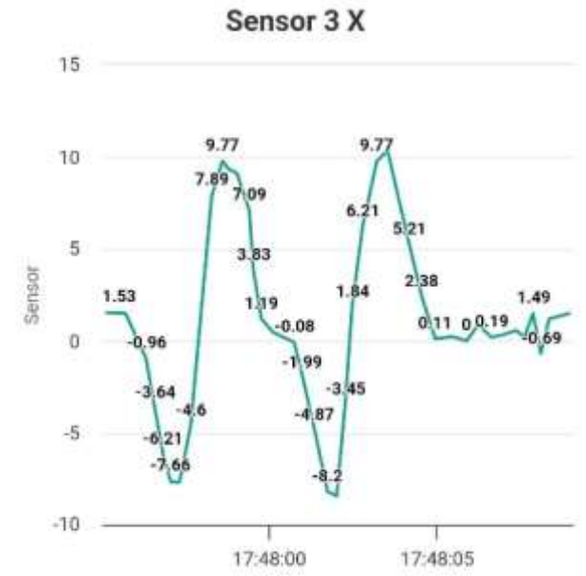


b)

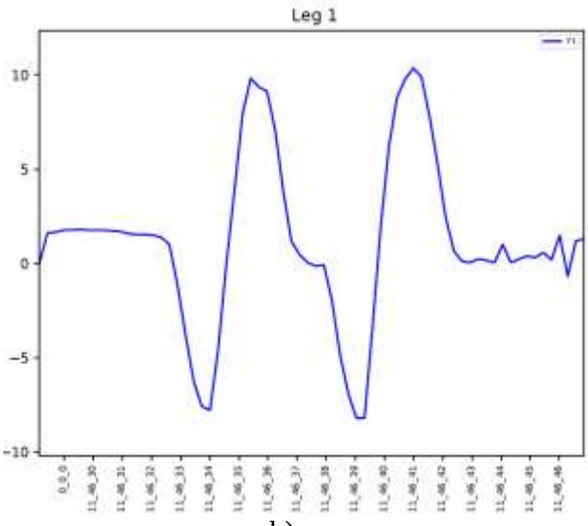
Graph 2 a) Real-time application graphic shown on the website (left arm) Vs b) Data storage in the microSD module

Now, leg graphics are presented. In the Graph 3, the right leg is tested, also comparing the real-time graphic and the one obtained from the Python interface.

ISSN 2444-4995



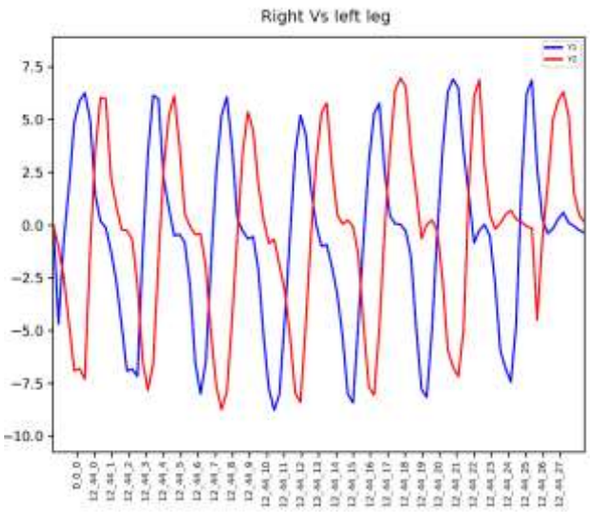
a)



b)

Graph 3 a) Real-time application graphic shown on the website (right leg) Vs b) Data storage in the microSD module

Finally, it is necessary to show both legs in Graph 4, walking at the same time, presenting a diphase with every step the subject person has performed.



Graph 4 Right leg and left leg are moving with a diphase between both movements

Conclusions

The data and graphics presented in this work show the system results for a test done on a person gait walking, on a plane surface area and collecting the data to be plotted after the tests. Moreover, the design time for this diagnostic tool was about three months, where the hardest part was the main script coding stage, because implementation, connections and test were short-time covered.

Acknowledgments

The authors acknowledge the financial support of the University of Guanajuato to publish this work 2023 and PRODEP support 2023. Authors also recognize the facilities and the support received by Autonomous University of Queretaro to accomplish this work in 2023.

References

Adkins, T. (2023). "Auto instrucción en adolescentes con trastorno del espectro autista: uso de modelos en vivo y refuerzos auditivos condicionados (Dissertation for thesis, Universidad de Capella)". Capella University ProQuest Dissertations Publishing August, 2023. https://www.proquest.com/openview/2a88f513a55d6535aea4235ace9404af/1?pq-origsite=gscholar&cbl=18750&diss=y

ISSN 2444-4995

Alvaro Muro-de-la-Herran, Begonya Garcia-Zapirain, Amaia Mendez-Zorrilla, "Gait Analysis Methods: An Overview of Wearable and Non-Wearable Systems, Highlighting Clinical Applications", Sensors (Basel). 2014 Feb; 14(2): 3362–3394. Published online 2014 Feb 19. https://www.mdpi.com/1424-8220/14/2/3362, DOI: 10.3390/s140203362

Chanda, A., Sidhu, SS y Singh, G. "Materiales para Simulación Biomédica: Diseño, Desarrollo y Caracterización". Naturaleza Springer. September, 2023. 191. DOI: 10.1007/978-981-99-5064-5

Felix Kluge, Heiko Gaßner, Julius Hannink, Cristian Pasluosta, Jochen Klucken, Björn M Eskofier, "Towards Mobile Gait Analysis: Concurrent Validity and Test-Retest Reliability of an Inertial Measurement System for the Assessment of Spatio-Temporal Gait Parameters", Sensors (Basel). 2017 Jun 28; 17(7):1522. https://www.mdpi.com/1424-8220/17/7/1522 DOI: 10.3390/s17071522

Hassen Fourati, Noureddine Manamanni, LissanAfilal, Yves Handrich, "A Nonlinear Filtering Approach for the Attitude and Dynamic Body Acceleration Estimation Based on Inertial and Magnetic Sensors: Bio-Logging Application", IEEE Sensors Journal, Vol. 11, Issue: 1, January 2011,https://hal.science/hal-00624142/document, DOI: 10.1109/JSEN.2010.2053353

Jasper Verheul, Warren Gregson, Paulo Lisboa, Jos Vanrenterghem, Mark A Robinson, "Whole-body biomechanical load in running-based sports: The validity of estimating ground reaction forces from segmental accelerations", Sci Med Sport. 2019 Jun; Vol. 22, issue 6, pp: 716-722. https://www.sciencedirect.com/science/article/abs/pii/S1440244018303529 DOI: 10.1016/j.jsams.2018.12.007

Johan Vertens, Fabian Fischer, Christian Heyde, Fabian Hoeflinger, Rui Zhang, Leonhard Reindl and Albert Gollhofer, "Measuring Respiration and Heart Rate using Two Acceleration Sensors on a Fully Embedded Platform", Proceedings of the 3rd International Congress on Sport Sciences Research and Technology Support At: Lisboa, Portugal Vol. 1, (2015).http://www2.informatik.uni-freiburg.de/~vertensj/publications/icSPORTS_2015_25.pdf, DOI: 10.5220/0005604000150023

Justin J Kavanagh, Steven Morrison, Daniel A James, Rod Barrett, "Reliability of segmental accelerations measured using a new wireless gait analysis system", Biomech. 2006; 39(15):2863-72, Epub 2005 Oct 25, https://www.sciencedirect.com/science/article/abs/pii/S0021929005004288?via%3Dihub, DOI: 10.1016/j.jbiomech.2005.09.012.

Lars Donath, Oliver Faude, Eric Lichtenstein, Corina Nüesch, Annegret Mündermann, "Validity and reliability of a portable gait analysis system for measuring spatiotemporal gait characteristics: comparison to an instrumented treadmill", J NeuroengRehabil. 2016; Vol. 13: Issue 6. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4719749/, DOI: 10.1186/s12984-016-0115-z

Massimiliano Zanin, Felipe Olivares, Irene Pulido-Valdeolivas, Estrella Rausell, David Gomez-Andres, "Gait analysis under the lens of statistical physics", Computational and Structural Biotechnology Journal Vol. 20, 2022, Pp: 3257-3267. https://www.sciencedirect.com/science/article/pii/S2001037022002367, DOI: 10.1016/j.csbj.2022.06.022

Philippe Cardou, Jorge Angeles, "Estimating the angular velocity of a rigid body moving in the plane from tangential and centripetal acceleration measurements", Multibody System Dynamics, Vol. 19, pp: 383–406, 2008. https://link.springer.com/article/10.1007/s11044-007-9096-9, DOI: 10.1007/s11044-007-9096-9

Philippe Cardou, Jorge Angeles, "Linear Estimation of the Rigid-Body Acceleration Field From Point-Acceleration Measurements". J. Dyn. Sys., Meas., Control. Jul 2009, 131(4): 041013 (10 pages), https://www.researchgate.net/publication/245372987_Linear_Estimation_of_the_Rigid-Body_Acceleration_Field_From_Point-Acceleration_Measurements, DOI:10.1115/1.3117209

Ruth E. Mayagoitia, Anand V. Nene, Peter H. Veltink, "Accelerometer and rate gyroscope measurement of kinematics: an inexpensive alternative to optical motion analysis systems", Journal of Biomechanics Vol. 35, Issue 4, 2002, pp: 537-542. https://www.sciencedirect.com/science/article/abs/pii/S0021929001002317?via%3Dihub DOI: 10.1016/S0021-9290(01)00231-7

ISSN 2444-4995

Tao Liu, Yoshio Inoue, Kyoko Shibata, "Development of a wearable sensor system for quantitative gait analysis", Measurement Volume 42, Issue 7, August 2009, Pages 978-988, https://www.sciencedirect.com/science/article/abs/pii/S0263224109000372?via%3Dihub DOI: 10.1016/j.measurement.2009.02.002

Weijun Tao, Tao Liu, Rencheng Zheng, Hutian Feng, "Gait Analysis Using Wearable Sensors", Sensors (Basel). 2012; Vol, 12(2): 2255–2283. Published online 2012 Feb 16. https://www.mdpi.com/1424-8220/12/2/2255, DOI: 10.3390/s120202255

ISSN 2444-4995

Article **Journal of Technological Prototypes**
December 2023 Vol.9 No.24 7-15

Design of a WiFi sensor network to identify transmission zones of respiratory diseases through air quality indicators

Diseño de red de sensores WiFi para identificar zonas de transmisión de enfermedades respiratorias mediante indicadores de calidad del aire

FIGUEROA-MILLÁN, Patricia Elizabeth†, BRICIO-BARRIOS, Elena Elsa*, LUA-MADRIGAL, Olimpo and ARCEO-DÍAZ, Santiago

Tecnológico Nacional de México/I.T Colima, México

ID 1st Author: *Patricia Elizabeth, Figueroa-Millán* / **ORC ID:** 0000-0001-7562-7578, **Researcher ID Thomson:** GRX-4871-2022, **SNI CONAHCYT ID:** 237559

ID 1st Co-author: *Elena Elsa, Bricio-Barrios* / **ORC ID:** 0000-0002-1260-9470, **CVU CONAHCYT ID**: 509944

ID 2nd Co-author: *Olimpo, Lua-Madrigal* / **ORC ID:** 0009-0005-9477-3059, **CVU CONAHCYT ID**: 381282

ID 3rd Co-author: *Santiago, Arceo-Díaz* / **ORC ID:** 0000-0002-7085-3653, SNI **CONAHCYT ID**: 231269

DOI: 10.35429/JTP.2023.24.9.7.15 Received August 30, 2023; Accepted December 10, 2023

Abstract

Airborne diseases can pose significant threats, particularly to infants and postoperative patients. While air extraction and droplet filtration systems are effective in containing these viruses, interconnected ventilation ducts can still facilitate virus transmission in areas with lower viral concentration. This study introduces a Wireless Sensor Network based on WiFi technology, designed to monitor crucial environmental variables such as CO_2, TVOC, temperature, and humidity, collectively influencing indoor air quality. Moreover, this network connects to an online server, collaborating with subscribers to store historical data. The stored information aids in identifying patterns and high-risk zones associated with the transmission of respiratory diseases. The outcomes demonstrate a comprehensive, adaptable, and scalable WiFi-based Indoor Air Quality sensor network. Employing the publish-subscribe pattern, the MQTT message transport protocol, and open-access platforms like Streamlit, Supabase, and HiveMQ, along with affordable boards and sensors, this solution offers an innovative, scalable, and cost-effective approach to identifying areas at risk of airborne disease transmission. The system's design prioritizes data precision and reliability, making it a valuable addition to indoor air quality monitoring systems.

WSN, Indoor Air Quality, MQTT

Resumen

Las enfermedades transmitidas por el aire pueden representar amenazas significativas, especialmente para los bebés y pacientes en período postoperatorio. Aunque los sistemas de extracción de aire y filtración de gotas son efectivos para contener estos virus, los conductos de ventilación interconectados aún pueden facilitar la transmisión viral en áreas con concentraciones virales más bajas. Este estudio presenta una red de sensores WiFi, diseñada para monitorear variables ambientales como CO_2, TVOC, temperatura y humedad, que influyen colectivamente en la calidad del aire interior. Ésta red se conecta a un servidor en línea y colabora con suscriptores para almacenar datos históricos. La información almacenada ayuda a identificar patrones y zonas de alto riesgo asociadas con la transmisión de enfermedades respiratorias. Los resultados muestran una red de sensores integral, adaptable y escalable, utilizando el patrón publicista-suscriptor, el protocolo MQTT y plataformas de acceso abierto como Streamlit, Supabase y HiveMQ, junto con placas y sensores económicos, esta solución ofrece un enfoque innovador, escalable y rentable para identificar áreas en riesgo de transmisión de enfermedades transmitidas por el aire. El diseño prioriza la precisión y confiabilidad de los datos, contribuyendo con una valiosa adición a los sistemas de monitoreo de la calidad del aire interior.

Redes inalámbricas de sensores, calidad del aire en interiores, MQTT

Citation: FIGUEROA-MILLÁN, Patricia Elizabeth, BRICIO-BARRIOS, Elena Elsa, LUA-MADRIGAL, Olimpo and ARCEO-DÍAZ, Santiago. Design of a WiFi sensor network to identify transmission zones of respiratory diseases through air quality indicators. Journal of Technological Prototypes. 2023. 9-24: 7-15

* Correspondence to Author (e-mail: elena.bricio@colima.tecnm.mx)
† Researcher contributing first author

Introduction

Globally, respiratory diseases pose a significant threat to public health, with an estimated rate of 35.8 deaths per 100,000 inhabitants (Sailema, 2023). However, diseases such as COVID-19 and Influenza ranked fourth and eighth, respectively, among the top ten causes of mortality in Mexico during the years 2021 and 2022 (Pérez et al. 2023).

Medical and technological advancements have allowed us to determine that these viruses transmit through microdroplets (Martí and Tuma, 2014). Moreover, they remain suspended in the air in open spaces for up to 10 minutes in indoor environments with a relative humidity of 50 to 80% (Lombardero, 2022). Ventilation systems can transport these microdroplets, potentially leading to hospital-acquired infections (Palacios, 2020). Additionally, an illustrative example of this phenomenon is the increased incidence of respiratory diseases observed by Cobos (2008) in patients who underwent organ transplantation at a hospital in Jalisco, Mexico, due to the proliferation of fungal spores. Similarly, a high mortality rate has been reported among newborns in Colombia (Hernández and León, 2008) and Peru (Hernández et al. 2015) due to poor indoor air quality in hospitals.

Alongside the implementation of stringent hygiene and maintenance protocols in patient areas, there is a growing emphasis on the reduction of airborne virus concentration. Consequently, three distinct strategies have emerged:

1. The utilization of natural and mechanical ventilation systems, depending on the availability of windows (Gutierrez, 2011). However, these measures exhibit optimal effectiveness when the occupancy is low, ensuring individuals maintain over 2 meters while minimizing direct interactions (Leung, 2022).

2. The application of chemical disinfectants in enclosed spaces to neutralize viruses (Santos et al. 2020). Nonetheless, their efficacy diminishes in areas with high foot traffic or during aerobic activities, such as those occurring in gyms (Mutsch et al. 2022).

3. The installation of air extraction systems to enhance the air exchange rate (AER) within enclosed spaces (Constantin et al. 2020). Reports have indicated a reduction of up to 50% COVID-19 viral particles in enclosed spaces equipped with 6 AER units (Medscape Pulmonary Medicine, 2022). It is important to note, however, that these technological advancements primarily transfer microdroplets from enclosed areas to open spaces.

It is crucial to recognize that no single strategy is entirely effective on its own, and a combination of these approaches may be necessary to minimise virus transmission.

A complementary strategy to air extraction systems is the use of filters, which serve to capture microdroplets carrying infectious agents on their surfaces, thereby reducing people's exposure to viruses (Ramos, 2015). Furthermore, these measures have been implemented and validated in crowded enclosed spaces such as hospitals (García, 2019), fast-food restaurants and bars (Comunian, 2020), public transportation like subways (López et al. 2020), and university hallways (Brevisa et al. 2021).

Subsequently, sensors were integrated in air extraction devices so that if any variable of interest falls outside a range considered safe or acceptable, corrective action is taken to ensure indoor air quality. This strategy has been assessed and validated in administrative offices (Higuera et al. 2021), hospitals, and shopping centers (Guerrero et al. 2022).

Following the successful implementation of this strategy, the next crucial step is to further enhance the process. For instance, Vega et al. (2019) developed a wireless sensor network to measure and monitor indoor air quality levels in a private hospital in Mexico and Ecuador. Párraga (2022) extended the proposal of Vega et al. (2019) to include a data storage module for online data access (cloud-based). On the other hand, Hernández (2022) reported on the energy sustainability of these optimised systems.

ISSN 2444-4995

Moreover, Edupuganti et al. (2023) proposes a system based on IoT for monitoring air pollution. The system utilizes sensor nodes, a gateway, WiFi module, LCD display, and a cloud server to measure and transmit real-time data (temperature, humidity, gasses, microbes, and light intensity). The collected data are aggregated by the gateway and sent to the cloud server for analysis. The system incorporates a web interface that displays pollution levels and can issue alerts to users in case of poor air quality, enabling timely precautions.

In the same way, Ariyaratne (2023) examines levels of pollutants such as Carbon Monoxide (CO), Nitric Oxide (NO), Ozone (O3), Nitrogen Dioxide (NO2), and Sulfur Dioxide (SO2) on Kandy City. The results indicate that electrochemical sensor networks offer a cost-effective alternative to regulatory monitoring methods, providing higher accuracy and resolution. However, challenges related to sensor calibration, especially concerning temperature and humidity effects were presented.

Pramanagara et al. (2023) propose a smart pollution monitoring system design in Manokwari to address the impact of air pollution on health. They propose the use of IoT utilizing sensors such as MQ 135, MQ2 and dust particles, along with a GPS module and a Raspberry Pi. The system design aims to provide air quality data to users through a smartphone app or text messages.

On the other hand, Truong et al. (2023) propose a system to monitor and collect environmental variables such as light intensity, temperature, humidity, carbon dioxide (CO_2) and fine dust in classrooms based on a LoRA wireless sensor network. They propose a gateway that collects and uploads the data to the Cayenne database for real-time storage, providing users with easy access to visual charts displaying environmental quality indicators in the classroom.

Henceforth, the present study proposes the design of a Wireless Sensor Network (WSN) based on indoor air quality (IAQ) indicators using WiFi communication technology. This network focuses on monitoring IAQ indicators to identify high-risk areas, ultimately aiming to reduce the risk of airborne disease transmission and contagion.

Its primary objective is to gather data through the continuous monitoring of interconnected indoor air variables. These variables are known contributors to the transmission of airborne diseases and include carbon dioxide (CO2) concentration, total volatile organic compounds (TVOC), as well as indoor temperature and humidity. All the data collected through monitoring is transmitted to an online server, referred to as a "broker." This broker is equipped with a notification mechanism, which allows subscribing clients to access and store the data in a cloud database. This stored record can subsequently be utilized to devise preventive and corrective strategies for areas that pose potential risks.

This paper is organized as follows: the second section presents the research and development methodology, along with the tools needed; the third section showcases the results of the sensor network design; the fourth section describes the conclusions and future work; following that, acknowledgments and references are provided.

Methodology

The present technological development was conceptualized and designed at the Graduate Studies and Research Division, while the elaboration and manufacturing of prototypes were carried out in the Mechatronics Department, both belonging to the Instituto Tecnológico de Colima, México.

Research Methodology

The research methodology employed in this study is based on De la Cruz (2016) technological research methodology in engineering. This approach considers the following phases: problem statement, which addresses the formulation of the problem, objectives, justification; theoretical background to determine background, foundations, and definition of basic terms; hypotheses; methodology for design or development considering the instruments, tools and materials needed; implementation and evaluation. According to the objective of this paper, the phases of implementation and evaluation are outside the scope.

ISSN 2444-4995

Development methodology

Moreover, the methodology for the design of the proposed WSN is based on the spiral model according with Pressman (2020) is an evolutionary model that couples the iterative nature of prototyping with the controlled and systematic aspect of a linear process flow; hence, this model is appropriate for technological developments and fits the requirements of the design of the WSN proposed in this paper.

Using the spiral model, the technological development is performed in a series of evolutionary releases, which in early iterations the release might be a model or prototype. Spiral model involves the systematic progression through its phases: determine objectives, identify risks, plan next iteration, development, and testing. The first circuit around the spiral results in the specification of the WSN design proposed in this paper. Figure 1 illustrates this methodology and its application in the development of the WSN design.

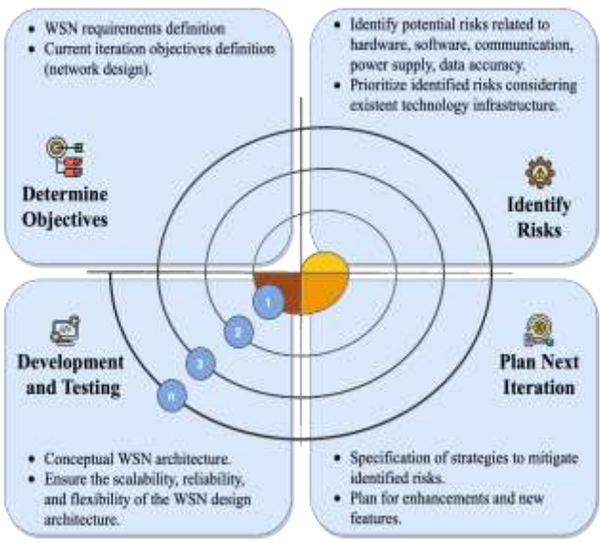


Figure 1 Spiral Model application for the WSN design architecture
Source: Pressman (2020). Own adaptation

As can be seen in Figure 1, during the phase of determining objectives, specific requirements for the proposed WSN were established. These requirements include types of sensors, data collection frequency, network topology, communication model architecture, communication technology, message protocol, content-type format of data transferred and power supply of sensor nodes. Moreover, the objectives of the current iteration were determined.

During the phase of risk identification, potential risks related to hardware, software, communication, and infrastructure factors were identified; additionally, these risks were prioritized based on their impact on the project.

In the phase of planning the next iteration, strategies to mitigate risks were developed. For example, the use of power banks in cases where power supply infrastructure was inaccessible and the inclusion of a data logger in case of signal loss.

Finally, during the development and testing phase, the WSN architectural design was specified, primarily focusing on a communication model that ensures scalability, flexibility, and reliability. This design enables the seamless integration of new sensor nodes and network functionality, utilizing open-source technologies for deployment to ensure future scalability.

It is estimated that eight more iterations will be needed to deploy the proposed WSN. These iterations will include construction of sensor node prototypes, calibration and testing of sensor node prototypes in experimental scenarios, correction of the prototypes, if necessary, replication of the prototypes to ensure indoor infrastructure coverage, communication architecture testing, design and development of the database and web client, and data knowledge acquisition.

Finally, the architectural design of the proposed WSN is based on sensors, microprocessor, power supply, network infrastructure and communication architecture, and user interface. Sensors considered to determine indoor air quality (IAQ) in the proposed WSN design are the CSS811 (CO2 and TVOC) and DHT22 (temperature and humidity). CSS811 is a gas sensor that detects Volatile Organic Compounds (VOCs), returning a Total Volatile Organic Compound (TVOC) reading and an equivalent carbon dioxide reading (eCO2) over I2C interface (Miller, 2023).

The ESP32 DevKit 1 board by Espressif was selected as the microprocessor for its small size and its built-in WiFi capabilities, supporting both 2.4 GHz and 5 GHz bands (Espressif Systems, 2023).

ISSN 2444-4995

Considering that WiFi is the predominant wireless communication technology in indoor infrastructures, the network infrastructure chosen is WiFi. Additionally, the indoor electrical infrastructure was opted for as the power supply due to its accessibility.

Moreover, network architecture was specified following the publish-subscribe pattern and employing the Message Queuing Telemetry Transport (MQTT) protocol to exchange messages between sensor nodes (publishers) and subscribers from the Internet through an online server acting as a broker.

The free public broker HiveMQ was selected for this purpose (HiveMQ, 2023). The exchange of messages follows a JavaScript Object Notation (JSON) format. JSON is a lightweight data interchange format that is easy for machines to parse and generate and it is language independent (JSON, n.d.).

This architecture requires the use of a BaaS for data storage. The Supabase database was chosen for its open-source nature and its set of tools to build scalable and secure web applications. One of the core features of Supabase is its full Postgres database (Supabase, n.d.). Considering this, the Streamlit Python library was included in the WSN architecture design. Strimlit is an open-source library that simplifies the creation and sharing of web apps for machine learning and data science. It provides an API reference for displaying data and optimizing performance. Streamlit also provides a way to connect to Supabase using the Streamlit Supabase Connector (Streamlit, 2023).

In the following section the architectural design of an indoor air quality-based WiFi sensor network for identifying transmission areas in airborne diseases is presented. This architectural design is the result of applying the methodology described earlier.

Results

The design of a WSN based on WiFi was designed to monitor indoor air quality, considering temperature, humidity, CO_2 and TVOC concentration levels as variables of interest. This WSN aims to identify potential indoor areas at risk for the transmission of airborne diseases.

The WSN architecture follows a publish-subscribe model to exchange messages between the wireless sensor nodes located in indoor areas and remote clients acting as subscribers from the Internet.

The publish-subscribe model requires three entities: publishers, subscribers and a broker which specifies topics. Topics are logical channels used to interchange data between publishers and subscribers; because of this, topics need to be previously defined in the broker. Publishers are devices that generate messages and send them to predefined topics. In this case, publishers are sensor nodes inside the WSN which recollect and publish (2) data correlated with levels of CO_2, TVOC, temperature and humidity.

These variables are correlated with indoor air quality (IAQ). Subscribers are devices that express interest in specific topics on the broker through a subscription mechanism. In this case, the subscriber is a Raspberry Pi on the Internet, which will insert received messages into Supabase, part of a backend as a service (Baas) cloud service.

The broker is a central server that acts as intermediary between publishers and subscribers, specifying topics needed. It receives messages from publishers, verifies which subscribers are interested in the topics of those messages and delivers the messages to the appropriate subscribers through a notification mechanism. This architecture is shown in Figure 2 and its design employs the use of the MQTT protocol that adheres to the publish-subscribe model through the implementation of this pattern.

The communication flow, as illustrated in Figure 2, follows the publish-subscribe model. The process begins with an Internet subscriber subscribing (1) to a specific topic in the free HiveMQ broker. In this case, the specified topic is /CO2Net/measurements. Within the sensor network, each sensor node serves as a publisher, generating and publishing (2) messages to the predefined topic on the broker. The broker receives messages (3) in a JSON format from the sensor nodes, verifies which subscribers are interested in the topics of these messages, and delivers the messages to the appropriate subscribers using a notification mechanism (4).

ISSN 2444-4995

The subscriber, the Raspberry Pi in the architecture, is then responsible for inserting the received data in the Supabase database (5) to create a historical record of CO2, TVOC, temperature and humidity measurements. This database, based on PostgreSQL, offers an integrated authentication mechanism and the necessary APIs needed for storage and data access.

Finally, a web client developed using the open-source framework Streamlit will query the data stored in the database, process it and display graphics related to the variables of interest, behavior, historical data, and knowledge acquisition of potential risk areas for airborne disease transmission.

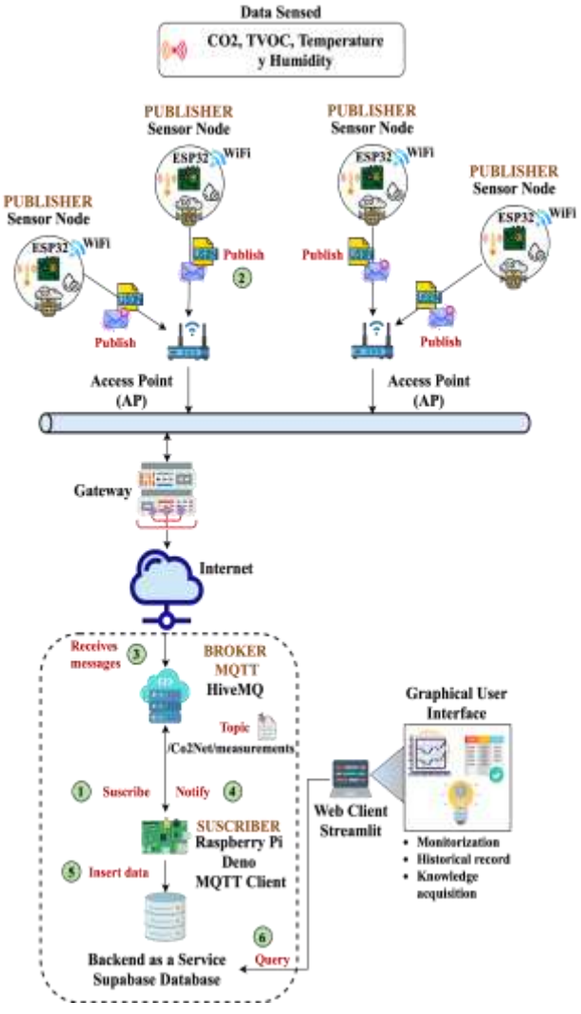


Figure 2 Architectural design of WSN based on WiFi for Indoor Air Quality monitoring
Source: Own Elaboration

A critical part of the WSN design is format exchange of messages because data format significantly impacts on networks performance, interoperability, and ease of integration with other systems. JSON format offers several advantages in WSN like efficient data transmission, flexible data structures, interoperability, and integration with web technologies.

The JSON schema for transfer IAQ involves structuring the data in a clear, concise, and easily interpretable way (see Figure 3). The timestamp represents the date and time when data was sensed; node_mac_id is the unique identifier for the sensor device generating the data; node_name is a human-readable name for that specific sensor device; measurements include all indicators sensed, such as temperature, humidity, CO2 and TVOC assigning each value along with the unit of measurement.

```
{
        "timestamp": 16976515154,
        "node_mac_id":
"C0:49:EF:CC:2C:64",
        "node_name": "Classroom A",
        "measurements": {
          "temperature": {
            "value": 26.89,
            "unit": "°C"
          },
          "humidity": {
            "value": 68.5,
            "unit": "%"
          },
          "CO2": {
            "value": 533,
            "unit": "ppm"
          },
          "tvoc": {
            "value": 20,
            "unit": "ppb"
          }
        }
}
```

Figure 3 JSON format to exchange indoor air quality indicators
Source: Own Elaboration

Conclusions

We have presented the design of an indoor air quality-based WiFi sensor network to identify transmission areas in airborne diseases, considering CO_2, TVOC, temperature and humidity variables. This design integrates free and open-access advanced technologies, low-cost components, representing an innovative contribution to indoor air quality monitoring systems with the potential to facilitate timely interventions based on accurate information and reduce the risk of airborne disease transmission in indoor areas.

This proposal incorporates WiFi technology for seamless wireless communication, enabling an easy deployment and data transmission across interconnected areas. Moreover, it implements the publish-subscribe pattern and MQTT as the message transport protocol to ensure a reliable communication between sensor nodes and data subscribers, using HiveMQ broke as intermediary. It leverages robust data storage and synchronization with Supabase and uses open-access platforms such as Streamlit for user-friendly data visualization, ensuring data accessibility and knowledge acquisition.

As part of our future work, we will develop sensor node prototypes, the database and web client. The sensor network will be deployed in both experimental and operational environments.

Additionally, a model for knowledge acquisition about patterns and identification of risk areas for transmission of airborne diseases will be specified.

Acknowledgments

This work has been funded by the Tecnológico Nacional de Mexico [grant number 17796.23-P] "Red Inalámbrica de Prototipos para el Monitoreo de la Calidad del Aire y la Extracción de CO_2 en Zonas de Riesgo de Contagio de Enfermedades Transmitidas vía Aérea.". The authors wish to thank the resources and installations provided by the Instituto Tecnológico de Colima and its Department of Mechatronics and Graduate Studies and Research Division.

References

Ariyaratne, R. G. R. N. K. (2023). Application of Air Pollution Monitoring Sensor Networks and Modelling Techniques to manage Ambient Air Pollution in Kandy City, Sri Lanka (thesis). Department of Chemical and Process Engineering Faculty of Engineering, Peradeniya, Sri Lanka. doi: http://dx.doi.org/10.13140/RG.2.2.10798.48964

Brevisa, W., Cortésb, S., Duarted, I., Ficad, D., Soledad, F. F., Martínezd, M. R., … & Valdésd, M. (2021). Escuelas Seguras en tiempos del COVID-19. Universidad de Chile. Retrieved from: https://acortar.link/CQDWGg

Cobos López, J. (2008). Gestión de la calidad del aire ambiental en el Hospital Universitario de Guadalajara y su implicación en su infección hospitalaria. Retrieved from: http://www.conama9.conama.org/conama9/download/files/CTs/985744_JCobos.pdf

Comunian, F. (2020). El filtrado y renovación de aire como medida de control de la concentración viral en recintos no sanitarios. Retrieved from: https://acortar.link/WKWcJH

Constantin, J. G., Montesinos, N. V., Santágata, D., Quici, N., Lichtig, P., Espada, R., & Rössler, C. (2021). Transmisión de SARS-CoV-2 por vía aérea (inhalación de aerosoles). Medidas de reducción de exposición. Retrieved from: https://acortar.link/i346dp

De La Cruz, C. (2016). Metodología de la Investigación Tecnológica en Ingeniería. Ingenium, 01(01). doi: http://dx.doi.org/10.18259/ing.2016007

Edupuganti, S., Satwik Tenneti, N. S., Iqbal, M. M., & Rajaram, G. (2023). An IOT implemented Dynamic Air Pollution Monitoring System. EAI Endorsed Transactions on Internet of Things, 9(4). doi: http://dx.doi.org/10.4108/eetiot.v9i4.4316

Espressif Systems. (2023, September 21). ESP32-DevKitC V4 Getting Started Guide. Retrieved from: https://docs.espressif.com/projects/esp-idf/en/latest/esp32/hw-reference/esp32/get-started-devkitc.html

García Portocarrero, A. (2019). Sistema de climatización de aire filtrado para el área de preparación del servicio de farmacia de producción del Hospital Nacional Guillermo Almenara Irigoyen (Tesis de Licenciatura, Universidad Nacional Pedro Ruíz Gallo, Perú). Retrieved from: https://acortar.link/6AI4o9

Guerrero de Luna Villalobos, D. A., & Diaz Yllanes, J. J. (2022). Diseño de sistema de climatización para calidad de aire interior en grandes establecimientos cerrados post COVID-19 (Tesis de Licenciatura, Universidad Cesar Vallejo, Peru). Retrieved from: https://acortar.link/L3apFU

Gutiérrez Muñoz, F. (2011). Ventilación mecánica: Acta médica peruana, 28(2), 87-104. Retrieved from: http://www.scielo.org.pe/pdf/amp/v28n2/a06v28n2.pdf

Hernández Ramírez, M. N., & León Piñeros, S. P. (2008). Determinación de la calidad del aire extramural e intramural en la sala de cirugía del Hospital el Tunal de la ciudad de Bogotá para el desarrollo de mecanismos de control y minimización de riesgo causado por microorganismos potencialmente nosocomiales, Ciencia Unisalle, 1(1). Retrieved from: https://ciencia.lasalle.edu.co/ing_ambiental_sanitaria/393

Hernández Arones, C. G., Matta Purilla, K. M., & Ramos Velarde, P. I. (2015). Factores de riesgo asociados a la mortalidad neonatal temprana en la unidad de cuidados intensivos neonatales. Hospital San José de Chincha, 2013 (Tesis de Licenciatura Universidad San Luis Gonzaga, Perú). Retrieved from: https://acortar.link/nVrpyd

Hernández Quintón, J. O. (2022). Diseño de un prototipo de red de sensores para el monitoreo de la calidad del aire en ambientes interiores del Hospital Básico Durán (Tesis Doctoral, Universidad de Guayaquil. Facultad de Ingeniería Industrial. Carrera de Ingeniería en Teleinformática). Retrieved from: https://repositorioslatinoamericanos.uchile.cl/handle/2250/6093818

Higuera González, A. (2021). Arquitectura frente al COVID 19 en espacios de oficinas. Archivo Digital UPM, España. Retrieved from: https://oa.upm.es/id/eprint/67580

HiveMQ. (2023, October 6). The Free Public MQTT Broker & MQTT Client by HiveMQ. HiveMQ. Retrieved from: https://www.hivemq.com/mqtt/public-mqtt-broker/

JSON. (n.d.). Introducing JSON. JSON. Retrieved from https://www.json.org/json-en.html

Leung NHL. (2021) Transmissibility and transmission of respiratory viruses. Nat Rev Microbiol, 19:528-45. Retrieved from: https://www.nature.com/articles/s41579-021-00535-6

Lombardero M. (2022). COVID-19: más allá de su alta infertilidad. ¿Por qué nos contagiamos tanto?. Retrieved from: https://sisiac.org/Analisis.Acrobiologia Dinamica. y.Carga. Viral.pdf

López-Olmedo, N., Stern, D., Pérez-Ferrer, C., González-Morales, R., Canto-Osorio, F., & Barrientos-Gutiérrez, T. (2020). Revisión rápida: probabilidad de contagio por infecciones respiratorias agudas en el transporte público y medidas para mitigarlo. Salud Pública de México, 1-25. doi: https://doi.org/10.21149/11601

Medscape Pulmonary Medicine. (2022). Italian study shows ventilation can cut school COVID cases by 82% Retrieved from: https://www.medscape.com/viewarticle/970705

Martí, M. C., & Tuma, S. U. (2014). Epidemiología general de las infecciones adquiridas por el personal sanitario. Inmunización del personal sanitario. Enfermedades Infecciosas y Microbiología Clínica, 32(4), 259-265. Retrieved from: https://acortar.link/Fy8gDS

Miller, D. (2023). Adafruit CCS811 Air Quality Sensor. Adafruit Industries. Retrieved from: https://acortar.link/dLBkBP

Mutsch, B., Heiber, M., Grätz, F., Hain, R., Schönfelder, M., Kaps, S., et al. (2022). Aerosol particle emission increases exponentially above moderate exercise intensity resulting in superemission during maximal exercise. Proceedings of the National Academy of Sciences, 119(22), e2202521119. doi: https://doi.org/10.1073/pnas.2202521119

ISSN 2444-4995

Palacios Montenegro, J. D. (2020). Diseño de robot para inspección interna en ductos de aire acondicionado y ventilación en el hospital Almanzor Aguinaga Asenjo (Tesis de Licenciatura, Universidad Nacional Pedro Ruíz Gallo, Perú). Retrieved from: https://acortar.link/Y2hmVq

Pérez, N. M., Vargas-García, L. A., Díaz-Cisneros, F. E., Gutiérrez-Sierra, A., Pérez-Rodríguez, M. A., & Wei, L. (2023). Características clínicas y factores de riesgo para mortalidad durante la 'Primera Ola'de COVID-19 en Reynosa, Tamaulipas. Medicina e Investigación Universidad Autónoma del Estado de México, 11(1), 41-48. doi: https://doi.org/10.36677/medicinainvestigacion.v11i1.20452

Párraga Intriago, T. G. (2020). Diseño y Desarrollo de un Prototipo de Sistema de Monitoreo de Calidad de Aire bajo una Temperatura loT en la Nube para la Detección de los Niveles de Contaminación de Aire en las Salas del Hospital de Niños León Becerra (Tesis de licenciatura, Universidad Nacional Mayor de San Marcos, Ecuador). Retrieved from: https://acortar.link/z1XZwC

Pramanagara, R. O., Suhendra, C. D., & Kolibongso, D. (2023). Smart Air Pollution Monitoring System planning design in Manokwari. *AIP Conference Proceedings*. doi: https://doi.org/10.1063/5.0106306

Pressman R.: Software Engineering: A Practitioner's Approach, (4th ed.), McGraw-Hill, 2020.

Sailema Sailema, E. E. (2023). Secuelas crónicas cardiovasculares post SARS-COV-2. Ciencia Digital, 7(2). Retrieved from: https://acortar.link/RiS15n

Santos-López, M., Jaque-Ulloa, D., & Serrano-Aliste, S. (2020). Métodos de desinfección y reutilización de mascarillas con filtro respirador durante la pandemia de SARS-CoV-2. International Journal of Odontostomatology, 14(3), 310-315. Retrieved from: https://acortar.link/fLFtAV

Streamlit. (2023, September 21). Streamlit Docs. Streamlit. Retrieved from: https://docs.streamlit.io/

Supabase. (n.d.). Supabase. Supabase. Retrieved from: https://supabase.com/

Truong, T. P., Truong, A. T., Le, D. P., Pham, D. T., & Qui, N. C. (2023a). Design and implementation of Classroom Environment Monitoring System towards smart campus. *Proceedings of the 2023 9th International Conference on Frontiers of Educational Technologies*. doi: https://doi.org/10.1145/3606150.3606177

Ramos Garcia, J. M. (2015). Modificación del sistema de extracción y filtración de pelusas para la unidad de lavandería del Hospital Nacional Cayetano Heredia. COCYTEC, Perú Retrieved from: https://acortar.link/Yze4dJ

Vega-Luna, J. I., Lagos-Acosta, M. A., & Salgado-Guzmán, G. (2019). Red monitoreo y alerta por partículas PM2.5 en el área de terapia intensiva de hospital. Revista del Centro de Graduados e Investigación, 28. Retrieved from: https://acortar.link/nU78ER

ISSN 2444-4995

Article **Journal of Technological Prototypes**
December 2023 Vol.9 No.24 16-22

Development of a prototype of a low-cost basic climatological study station using the Arduino platform

Desarrollo de un prototipo de estación básica de estudio climatológico de bajo costo usando la plataforma Arduino

ECHANDI-PACHECO Rodolfo*†

Universidad Fidélitas, San José, Costa Rica.

1st Author: *Rodolfo, Echandi-Pacheco* / **ORC ID**: 0000-0001-6807-0679

DOI: 10.35429/JTP.2023.24.9.16.22 Received September 25, 2023; Accepted December 30, 2023

Abstract

Nowadays most people are not really interested in weather issues or news about it. However, with the constant and abrupt climate changes that are occurring worldwide, it is of great importance to be aware of the valuable information that a small weather station can provide in this regard and thus help the general population to act on climate change. This project is centered on the fundamentals of Arduino, which is an open-source electronic platform that allows you to develop a wide variety of project options without having expert knowledge in programming or electronics. Therefore, from some sensors and a code, a circuit was built capable of generating meteorological data that can be understood and used by anyone to know the state of the weather in a particular location. In short, having an Arduino as the brain for the manufacturing of a project can simplify any day-to-day task and allow the creation of devices that can regulate any process carried out by human beings.

Meteorological, Climatologic, Arduino, Code, Circuit, Weather, Station

Resumen

Hoy en día la mayoría de la gente no está realmente interesada en los temas climatológicos ni en las noticias al respecto. Sin embargo, con los constantes y abruptos cambios climáticos que se vienen presentando a nivel mundial, es de gran importancia estar al tanto de la valiosa información que una pequeña estación climatológica puede brindar al respecto y así ayudar a la población en general a tomar medidas sobre el cambio climático. Este proyecto se centraliza en los fundamentos de Arduino, que es una plataforma electrónica de código abierto que permite a desarrollar una extensa diversidad de opciones de proyectos sin tener un conocimiento experto en programación o electrónica. Por lo tanto, a partir de unos sensores y de un código se construyó un circuito capaz de generar datos meteorológicos que pueden ser entendidos y usados por cualquier persona para conocer el estado del clima en una locación en particular. En definitiva, tener un Arduino como cerebro para la fabricación de un proyecto puede simplificar cualquier tarea del día a día y permitir crear dispositivos que pueden regular cualquier proceso que realicen los seres humanos.

Meteorológico, Climatológico, Arduino, Código, Circuito, Tiempo, Estación

Citation: ECHANDI-PACHECO Rodolfo. Development of a prototype of a low-cost basic climatological study station using the Arduino platform. Journal of Technological Prototypes. 2023. 9-24: 16-22

* Correspondence to Author (e-mail: rechandi60580@ufide.ac.cr)
† Researcher contributing first author

Introduction

Meteorology and climatology are areas that encompass the study of a very important and dynamic aspect of the human environment such as climate.

As indicated by the National Institute of Ecology and Climate Change of Mexico (2018) "climate is the most frequent state of the atmosphere of a place on the earth's surface", i.e., it refers to the average pattern of atmospheric conditions in an area during a period of time, where factors such as temperature, precipitation, winds and humidity stand out, thus determining the climate of a place.

There are a large number of weather stations throughout Costa Rica, each station must have different elements that help to carry out an exhaustive analysis of climatological data from the various cities in which they are located and thus learn about the climate. This project seeks to model on a smaller scale a climatological study station like those created by the IMN (National Meteorological Institute of Costa Rica), with the aim of making known, not only the meteorological data obtained from a place, but also the importance of these data for the general population in aspects such as planning, agriculture and health, among others.

The main problem that this project seeks to solve is the lack of interest of the population in knowing about climatological data or events at the national level. With the constant and abrupt climatological changes that have been occurring worldwide, it is of great importance to be aware of the valuable information that a project like this can provide. Likewise, the aim is to develop a low-cost prototype that uses the Arduino platform as a base and is accessible to anyone.

Theoretical development

The 20th century was characterised by a great advance in all the fields where human beings have developed. This era has been described in many different ways: the atomic era, the television era, the computer era, the space era and the computer era. This shows that the human species has come a long way in just a few years, and there is no doubt that in this progress, informatics, computing and electronics have played a fundamental role.

Today, electronics and computers play a key role in climatology, facilitating the accurate acquisition of climate data, weather prediction, climate research and decision making using available climate information. In the following, some concepts in the climatological context that are important to understand will be explained.

The first of these is temperature, which according to Fisicalab (2023) is defined as: "the thermal energy of a body", i.e. it is a physical magnitude that indicates the internal energy of a body, an object or the environment in general, and whose measuring instrument is a thermometer. It is important to know the difference between temperature, heat and thermal sensation as these concepts are often confused.

According to IQR (2021) "heat is energy that is transiting through a system", therefore, it is the total energy of the movement of the particles in a body and depends on the speed of the particles, number, size and type, while temperature is the magnitude that measures this energy. On the other hand, wind chill according to National Geographic (2023): "describes the coldness produced by the combination of air and wind temperature" being the reaction of the human body to various conditions determined by the environment.

Consequently, the normal environmental temperature in warm places is usually taken as 20 to 25 degrees Celsius while in a place with colder climates it can range from -3 to -57 degrees Celsius.

Another concept is air humidity, which according to Areaciencias (2023) "is the amount of water vapour contained in the air" and this is generated due to the evaporation of water from seas, rivers, lagoons and plants, among others. The warmer the environment, the more vapour will be produced. A favourable environment should have a humidity of 50-60% and 40% to 70% is considered acceptable. An environment that is too humid can encourage the growth of harmful germs and fungi which are harmful to health and in some cases negatively affect daily activities. The next concept is the UV index (UVI) which according to the National Meteorological Institute of Costa Rica (2023) "is the measure of the intensity of ultraviolet radiation on the earth's surface".

ISSN 2444-4995

This index is expressed as a value greater than zero, and the higher it is, the more harmful it becomes and can cause lesions and damage to people's skin.

Finally, there is the concept of wind, which Clima Argentina (2023) defines as "a flow of air", i.e. the movement of air with respect to the earth's surface, which originates due to the difference in pressure between two points, which causes an imbalance, causing air masses to travel to points of lower pressure. The wind direction is never fixed, but rather oscillates around an average direction which is used as a reference. Therefore, the eight-directional wind rose will be considered for accuracy.

Having clear the concepts about climate, we will explain what is the heart of the project that was developed, that is, the Arduino.

Figure 1 Arduino UNO R3
Source: https://www.rabtron.co.za/arduino/8382-arduino-uno-r3.html

The Arduino, as shown in Figure 1, is one of the most popular boards in the world when it comes to building electronic circuits. Another quite similar board on the market is the Raspberry Pi, but the Arduino differs in that it offers an open hardware base so that other manufacturers can make their own boards.

In general terms, the Arduino is a platform for building electronic circuits that is based on free, flexible and easy-to-use hardware and software (Torrente, O., 2013).

This platform makes possible the creation of different types of circuits by means of a single board with which different applications can be developed according to the use that is needed.

As mentioned above, Arduino is a free platform, since at the hardware level it is a device whose specifications or diagrams are publicly available, so any person or company can duplicate them. This means that Arduino explicitly offers the basis for anyone to create their own boards, all of them being different from each other, but created from a base that is the same.

With regard to free software, we are talking about programmes whose code can be modified, used and distributed by anyone who needs it, without having any problem with the original author (Zamora, 2016).

Likewise, Arduino has the Arduino IDE platform, through which there is access to a programming environment that makes it possible for anyone who wants to create programmes for Arduino boards, so that they can be given all kinds of utilities.

Methodology

In order to create the prototype of a basic low-cost weather station, the following electronic elements were necessary and were used as primary inputs or instruments in the construction of the circuit:

- 1 Arduino UNO board
- 1 protoboard
- 1 DHT22 temperature and humidity sensor
- 1 anemometer
- 1 UV sensor SI1145
- Battery holders
- LCD display
- Cables and resistors

This prototype presents the proposed creation of a basic weather station that allows the measurement of climatological data such as temperature, humidity, UV index and wind speed, so that anyone can keep more informed about the various weather changes that occur during the day in a specific place. The collected data can be stored and used for reporting, various climate studies, statistics and monitoring among others.

ISSN 2444-4995

As mentioned above, during the operation of the station, basic data on the current and real-time weather condition will be obtained in the following units of measurement: the ambient temperature displayed in degrees Celsius, the humidity displayed in g/m3 (grams per cubic metre), the UV index in IUV and the wind speed in metres per second (m/s).

It is important to note that for a good performance of the weather equipment there must be optimal conditions, such as, a place with good lighting, direct contact with sunlight for the correct measurement of UV rays and good access to the wind stream, this in order to obtain more accurate data.

The main objective of obtaining data through a basic low-cost weather survey station with Arduino is that it can be a beneficial tool to improve daily life by providing up-to-date and relevant information about the weather, allowing people to make more informed decisions and adapt their actions in a better way, for example, in optimising irrigation and gardening or in having a better environmental awareness. The complete prototype of the circuit is detailed in figure 2.

Figure 2 Developed circuit
Source: Own Elaboration

Next, it is specified how the prototype was assembled and an explanation of each of the elements used:

Firstly, since the aim is to make a portable device, two 9V batteries must be used in their respective supports.

One of them will be used to power the Arduino directly and the other will be used to power the anemometer (element that will be explained later), as it needs a current of between 7V and 24V for its operation. Figure 3 shows an example of the battery holders.

Figure 3 9 V Battery Support Boxes
Source: https://www.amazon.com/-/es/almacenamiento-pl%C3%A1stico-duradero-interruptor-encendido/dp/B07N2NW5SM

Also, among the components, a 20x4 LCD display was used, which has the i2c technology, which means Inter Integrated Circuit that facilitates the connection of multiple chips, their communication and coupling. Therefore, this LCD display must be connected to the SCL, SDA, 5v power and finally to ground. Additionally, the "LiquidCrystal_I2C" library will be used in the Arduino code to manage the display.

Also, because multiple connections will be made to the aforementioned ports, a breadboard was used to manage these lines. This means that wires were taken from the Arduino directly to the breadboard and from there a distribution will be made to the different elements used.

For temperature and humidity, the DHT22 sensor was used and specifically a variant of this that is designed for connection to the Arduino and does not need an additional resistor. This sensor has three pins, 3.3 to 6v current, ground and digital data output. This data pin is connected directly to the Arduino via one of the digital terminals. To read and understand the data, the "DHT" library will be used, which extracts the information in different functions, facilitating programming.

ISSN 2444-4995

For the project we also used a UV sensor SI1145 Digital, manufactured by Adafruit, which measures the UV index that allows us to know the intensity of ultraviolet radiation derived from the sun on the earth's surface, which has the same technology as the LCD screen, therefore, this will be connected in the same way as the screen. Taking advantage of the use of the breadboard, the pins of this sensor are connected to the corresponding lines on the same breadboard. Unlike the other sensors, this one requires 3.3V of current and will not be connected to 5V to avoid overheating or possible damage to the chip. Also, this chip has extra pins that will not be used in the project.

Finally, an anemometer was used to measure wind speed. This requires a 9V input to operate, so it will be connected directly to a battery. It has two more wires, a ground which must be connected to the battery ground and also to the ground of the Arduino so that it can get the data correctly and an analog data output that will be connected to one of the analog pins on the Arduino, this works according to the voltage of the anemometer and will be the wind speed at the moment. For this conversion from voltage to m/s a mathematical formula will be used directly in the programming of the Arduino.

Once the meteorological data has been obtained and processed by the Arduino through the programming, it will be displayed on the LCD screen so that the user can visualise it properly.

Results

The results obtained with the three sensors used within the system reflected an optimal performance within the system and this was of great benefit for the good performance of the entire circuit.

Thanks to the development of the project, a functional prototype was obtained that meets the proposed objectives. The prototype shows the different data collected by the sensors, making their respective conversions so that the user can understand them. In addition, an LCD screen was used to display this data, which facilitates the use and interaction with the user.

The first results that were observed were obtained through the use of the UV index sensor, which has detection elements that can measure almost any type of light allowing a very precise UV index to be calculated, as shown in figure 3.

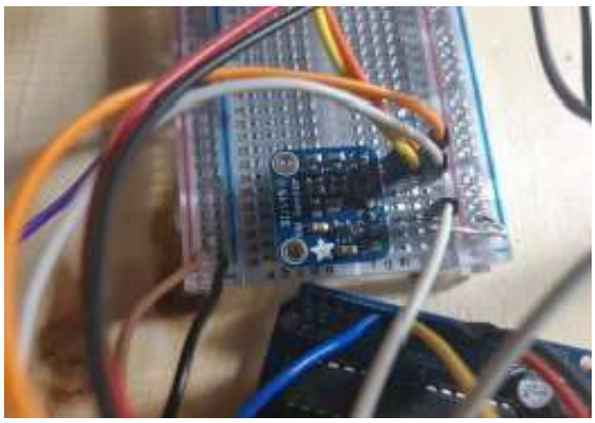


Figure 3 Use of the UV index sensor
Source: Own Elaboration

With regard to the temperature and humidity sensor, it should be noted that it is a very versatile and precise sensor, as it has a very compact design and internally has a small integrated circuit, as well as a capacitive sensor that allows humidity and temperature measurements to be taken, as shown in figure 4.

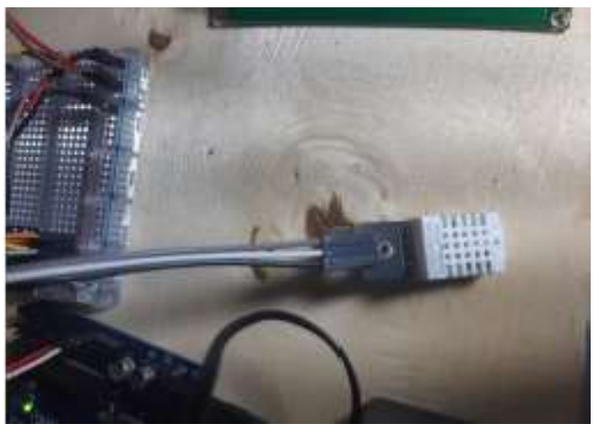


Figure 4 Use of temperature and humidity sensor
Source: Own Elaboration

On the other hand, an anemometer was used to measure the wind speed, which generates the necessary information so that the wind speed can be calculated by programming the Arduino. Figure 5 shows the anemometer used.

ISSN 2444-4995

Figure 5 Use of temperature and humidity sensor
Source: Own Elaboration

Finally, on the LCD screen and after making the necessary calculations in the Arduino programming, all the data measured by the basic weather station were displayed in a simple way for the user, as shown in figure 6.

Figure 6 LCD display with measured values
Source: Own Elaboration

Consequently, quite a few lines of code were used in this system, as it had to control electronics elements that not only have programming, but also mathematical formulas for precise calculations. All the code was written in the C++ language, which is very similar and contains many of the same functionalities as the Java programming language. In general terms, it can be said that all the proposed objectives were met, as the whole system worked satisfactorily.

The use of this type of circuitry for the construction of a basic weather station with Arduino can help people now that climate change has become a global concern.

These basic stations allow the collection of accurate data on temperature, humidity and wind among other climate parameters, thus contributing to easy environmental monitoring. They also raise awareness about the importance of understanding and addressing climate challenges, empowering individuals and communities to take informed and responsible action to preserve our planet.

Conclusions

It can be concluded that the prototype obtained from the implementation of the different knowledge acquired meets the expectations. The development of this led to the creation of a device that can be of great help for remote places, where more accurate instruments are required for climate measurement or to educate and arouse the curiosity of different people who are unaware of these two areas and how a device intertwines them.

As for the device itself, more people are urged to improve the prototype so that it can be more efficient or get more functionalities. The room for expansion of the project is quite large as ingenuity can lead to better prototypes with the addition of new sensors.

By automating a weather station with Arduino, the collection of weather data is significantly improved, facilitating research, informed decision-making and efficiency in a wide variety of weather-related applications. Furthermore, it is important to keep in mind that the use of this technology is a great help to work better anywhere, or in case you want to implement a system that helps to perform different tasks at home in a simpler way, as its use is growing more and more.

Acknowledgements

The author would like to thank the Facultad de Ingeniería en Sistema of the Universidad Fidélitas campus San Pedro de San José, Costa Rica. In addition, deep gratitude is extended to the students Karina Montero, Christopher Montero and Carlos Morales for their contribution.

References

Amazon. (2023). *Caja de almacenamiento de batería de 9 V*. https://www.amazon.com/-/es/almacenamiento-pl%C3%A1stico-duradero-interruptor-encendido/dp/B07N2NW5SM

Areaciencias. (2023). *La Humedad y Tipos de Humedad.* https://www.areaciencias.com/meteorologia/humedad/#%C2%BFQue_es_la_Humedad

Clima Argentina. (2023). *Viento.* https://www.clima.com/meteopedia/viento

Fisicalab. (2023). *Temperatura.* https://www.fisicalab.com/apartado/temperatura

Instituto Nacional de Ecología y Cambio Climático de México. (2018). *¿Qué es el clima?* https://www.gob.mx/inecc/acciones-y-programas/que-es-el-clima#:~:text=El%20clima%20es%20el%20estado,periodo%20de%20tiempo%20(2)

Instituto Meteorológico Nacional de Costa Rica. (2023). *Índice ultravioleta.* https://www.imn.ac.cr/indice-ultravioleta

IQR Ingeniería Química. (2021) *¿Qué es el calor?* https://www.ingenieriaquimicareviews.com/2021/01/que-es-calor-y-su-definicion.html

National Geographic. (2023) *¿Qué es la sensación térmica y cómo afecta a tu cuerpo?* https://www.nationalgeographic.es/medio-ambiente/sensacion-termica-que-es-como-afecta-cuerpo

Rabtron. (2013). *Arduino Uno R3*. https://www.rabtron.co.za/arduino/8382-arduino-uno-r3.html

Torrente, O. (2013). *Arduino. Curso práctico de formación*. Alfaomega Grupo Editor, S.A.

Zamora, J. (2016). *Hardware libre: la evolución al software libre.* Diario El Español. https://www.elespanol.com/elandroidelibre/20160408/hardware-libre-evolucion-software/115738780_0.html

Article **Journal of Technological Prototypes**
December 2023 Vol.9 No.24 23-29

Gas detector as a technological alternative for home security

Detector de gas como alternativa tecnológica de seguridad en el hogar

BRIONES, Alexis†*, JASSO-JASSO, Ángel Erasmo, ORTEGA-GOVEA, Jacobo Neri and CORTÉS-SEGURA, Juan Pablo

Tecnológico Nacional de México, Instituto Tecnológico de San Luis Potosí, Ingeniería Mecatrónica

ID 1st Author: *Alexis, Briones* / **ORC ID**: 0009-0004-1919-2193

ID 1st Co-author: *Ángel Erasmo, Jasso-Jasso* / **ORC ID**: 0009-0000-1806-3120

ID 2nd Co-author: *Jacobo Neri, Ortega-Govea* / **ORC ID**: 0009-0003-6944-075x

ID 3rd Co-author: *Juan Pablo, Cortés-Segura* / **ORC ID**: 0009-0008-1721-4298

DOI: 10.35429/JTP.2023.24.9.23.29 Received September 17, 2023; Accepted December 15, 2023

Abstract

As petroleum derivatives, products formed by butane and propane gases require special handling in their industrial and residential use. The accidents linked to these pose potential threats to health and in general to users as a result of fires, explosions, burns and poisoning that can gradually represent death. The leakage or escape of these gases represents the greatest indicator for some type of event to occur; Due to this, the technological development of a device that integrates home security elements with a mechatronic system capable of detecting the concentrations of various gases through the reading of an Arduino software, considering as factors, the composition parameters of propane, methane, alcohol and hydrogen, as well as concentration and toxicity for humans in a given space, is presented. Its integration is based on the research of various theoretical and scientific resources to improve the quality of life, with the purpose of guaranteeing the health and safety of the inhabitants and users of devices linked to the use of gases.

Home Automation, Technological Development, Housing Security, Gas

Resumen

Como derivados del petróleo, los productos formados por gases butano y propano, requieren manipulación especial en su uso industrial y residencial. Los accidentes vinculados a estos, suponen amenzas potenciales para la salud y en general para usuarios por consecuencia de incendios, explosiones, quemaduras e intoxicaciones que pueden en niveles graduales, representar la muerte. La fuga o escape de estos gases, representa el mayor indicador para que se geste algún tipo de evento; debido a esto, se presenta el desarrollo tecnológico de un dispositivo que integra elementos de seguridad en el hogar con un sistema mecatrónico capaz de detectar mediante la lectura de un software Arduino, las concentraciones de diversos gases, considerando como factores, los parámetros de composición de propano, metano, alcohol e hidrógeno, así como concentración y toxicidad para el ser humano en un espacio determinado. Su integración se basa en la investigación de diversos recursos teóricos y científicos para mejorar la calidad de vida, teniendo como propósito garantizar la salud y seguridad de los habitantes y usuarios de dispositivos vinculados al uso de gases.

Domótica, Desarrollo Tecnológico, Sistemas digitales, Seguridad habitacional, Intoxicación por gases

Citation: BRIONES, Alexis, JASSO-JASSO, Ángel Erasmo, ORTEGA-GOVEA, Jacobo Neri and CORTÉS-SEGURA, Juan Pablo. Gas detector as a technological alternative for home security. Journal of Technological Prototypes. 2023. 9-24: 23-29

*Correspondence to Author (e-mail: L21181108@slp.tecnm.mx)
†Researcher contributing first author

Introduction

The areas of home automation combine technical fields related to sensors and measurement, actuation and actuation systems, as well as systems with microprocessors, allowing the analysis of systems and operations with the purpose of controlling and modifying the environment, providing comfort and security so that it is stable, the latter being that which allows living in a pleasant, quality environment (Bolton, 2017).

One of the fundamental elements of home automation is security, with which it is possible to protect the well-being of the person and all their personal property by applying electronic systems that act as receivers of a signal through sensors that cause a response through actuators, such as a warning, an alarm or a text message to the user that notifies changes in a space that may be dangerous, such as the presence of chemicals or temperature changes (CENAPRED, 2021).

The security system is integrated by means of sensing devices. A sensor is a device capable of detecting different types of materials in order to send a signal and allow a process to continue or detect a change depending on the case. The use of sensors is essential for the development of systems, as any system requires an interface with the real world that may require users to enter data, measure variables or perform certain actions with the help of programming and electronics (Abarca, Corona, Mares, 2014).

Statistics linked to accidents resulting from gas leaks show that between 2003 and 2011, 142 disasters occurred in Mexico, with an average of at least 15 accidents per year. Considering that between 2012 and 2017, 399 events were recorded with an average of 66 accidents per year, the increase is 280% compared to the previous period. Between 2018 and 2021, another increase in the number of accidents is recorded, reaching 813 events, an average of at least 203 accidents per year, which represents an increase of 203% over the previous time interval (CENAPRED, 2021).

Technological development, shown as a proposed solution that is aligned with Sustainable Development Goal 9, denotes innovation as necessary to generate projects that impact society and promote the development of nations (UN, 2016); in this way, the construction of a mechatronic device is considered, which involves sensors to detect dangerous and emit a signal to alert users to the leak, it is also considered to send an instruction to automatically close the flow of this, avoiding possible accidents, environmental damage or human and economic losses.

Theoretical Basis

Programming

Considered the main tool to carry out actions in the operation of actuators, programming consists of precise and detailed instructions in a coded language, so that a computer or a microcontroller can perform a specific task. It is stored in a microcontroller that is responsible for executing the indications assigned to it, an example of microcontroller is the Arduino UNO (Juganaru, 2014). This microcontroller is made up of a reprogrammable board that has a series of female pins (inputs and outputs) that allow connections to be established with different sensors and actuator modules that are compatible, such as the MQ2 gas sensor, efficient in establishing connections in Arduino (Diaz, 2019).

Digital systems

A digital system has diverse applications, such as monitoring sensors in real time, providing greater security by alerting users about the designated space to be monitored, control of variables such as temperature, humidity or air quality. The HC-05 module is a component that can be used in circuits and systems to send signals remotely via Bluetooth; it is used in a master and slave configuration, which means that different Bluetooth modules or devices can be interlinked with each other in order to communicate and send information to each other (Flores, Pérez, Villalvazo and Yepez, 2019).

The device is responsible for sending the data received by the sensor through the HC-05 module and is received by the application with which the previous module was previously linked, resulting in accurate monitoring at a current time.

ISSN: 2444-4995

Housing security

Security, understood as the possibility of protecting the welfare of people and all their personal property, can be applied through home automation, which is characterised by the ability to provide security in the home by monitoring in real time a designated area of a space, room or the entire space, as this by performing automation processes, executes specific instructions such as on, off, cut or open flow leading to the neutralisation of detected risks, such as gas leaks, which would lead to a closure of the source or deal dissipation.

In this context, the problems that may arise depend on the time of exposure to the gas and the percentage of oxygen being breathed, with respect to 20-40% representing danger with consequences such as vomiting or nausea, above that percentage, 50-60%, much more severe problems are determined, such as coma, convulsions and irregular breathing; above those percentages, the consequence is death.

Methodological basis

The general objective presented for this technological development is to build an automation system that autonomously detects different concentrations of gases through the reading of an Arduino software which allows to increase the levels of safety in the home in the event of poisoning.

This device integrates different branches of mechatronic engineering, which is a discipline that combines the principles and methodologies of mechanical engineering, electronic engineering and computer engineering to design, develop and control complex systems that involve mechanical, electronic and computational components.

The technological development is based on a methodology of its own creation, based on mechatronic knowledge; it presents a mixed research approach and explanatory information management (Hernández, 2014), which involves programming a gas detector alarm using the HC-05 module, as well as its implementation in an electronic design software such as Proteus and integrating this circuit into a security system that allows the user to see the status of the sensor in real time.

Methodology

The systematically implemented methodology is expressed in nine phases, which individually pursue specific scopes. The first phase deals with the design of the prototype where it is proposed to create a preliminary model of the security device. The second phase explains how to simulate the prototype in software, obtaining detailed images of the device by designing a technical drawing.

The third phase involves making the electrical connections, in this phase the electrical circuit is developed, and phase four covers the analysis of the logical sequence of the code to be designed and its programming. Phase five proposes adapting the device with an application that allows the gas detector to be linked to the user's mobile phone. Phase six involves carrying out an analysis in order to determine the most suitable materials with respect to the simulation developed.

In phase seven, the assembly of the electronic circuit and the housing acquired in the previous phase is determined in order to physically identify the device to be built. In phases eight and nine, the activities concentrate on the necessary tests with the assembled device, so that it is possible to find faults that compromise the operation of the detector, with the purpose of improving it and making final adjustments, so that it is optimal and works correctly.

In summary, it is about designing the gas detector device through the use of electronics, programming and control, determining the best components so that its operation is optimal and adequate when used in a hazardous situation in multiple environments.

Development

The design of the gas detector was simulated using AutoCAD software, which also allowed the selection of electronic components, tools and materials for manufacturing, specific measurements were calculated, greater precision in the traces and aesthetic details were established.

ISSN: 2444-4995

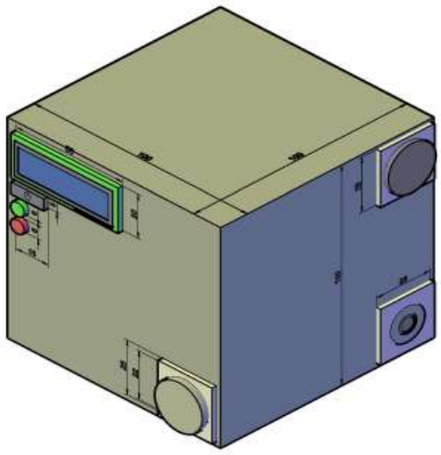


Figure 1 3D design of the gas detection device
Source: Own Elaboration

With the electronic components a diagram of connections was made to show continuity, with the simulation software Proteus, also simulated the operation of the circuit to make physical connections and assemble the components that were selected, a key element for the operation of the gas detector was the Arduino UNO microcontroller.

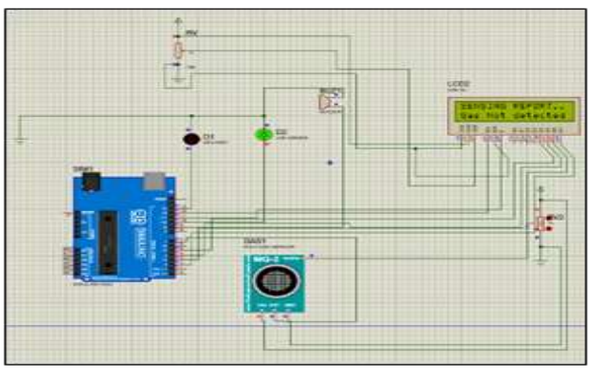


Figure 2 Gas detector circuit implemented in Proteus
Source: Own Elaboration

Once the connections were ready, a logic analysis was carried out to establish parameters and assign outputs and inputs of the microcontroller in the programming used to carry out the operation of the detector. Once the analysis was finished, the programming began, based on and taking into account what was established in the logical analysis, simultaneously the behaviour of the programming was tested to verify and correct any errors; the microcontroller was entered with the circuit already assembled, which allowed testing and verifying that the parameters to detect the gas were correct, finally only some changes were made to the parameters to detect the gas, making it more sensitive and allowing better operation.

With the programming ready, a compatible application was generated and it was ensured that its operation was via Bluetooth, to link it with the circuit of the gas detector and perform tests to verify that the operation of the application and the circuit were correct.

Assembling the device, based on the designs made in AutoCAD, was considered in the final stages; the assembly was made with resistant materials to avoid any damage to the gas detector, tests were carried out to verify that it did not present any fault with the operation of the detector.

Finally, some adjustments were made to the sensor and the final design, where all the selected electrical components were distributed and some aesthetic details were given to the product, resulting in a gas detector capable of operating via Bluetooth that provides greater security in the user's home.

The alarm system is based on the MQ2 sensor which is made of tin dioxide, and works as a variable resistor that changes its resistance depending on the amount of gas it is exposed to because the conductivity of the sensor is higher along with the concentration of gas which is interpreted by the microcontroller to determine if the amount of gas has exceeded the set limit, it executes a series of commands: change the colour of the LED to red, display a hazard warning in the application as well as on the LCD of the device, additionally starts an audible alert and the switching on of the ventilation system. (Correa y Zavala, 2020)

Figure 3 Device functioning properly
Source: Own Elaboration

ISSN: 2444-4995

Figure 4 Rear of gas detector device, buzzer and fan
Source: Own Elaboration

Results

The results showed that the sensor should be left to calibrate for the first few seconds in order to obtain sufficient temperature to take better gas readings. Once this time has elapsed, the sensor works as described above, which consists of having the measurement on the front of the sensor, as well as a text indicating that everything is correct, and a green LED that helps to visualise that everything is in order.

Figure 5 Actuators of the device when no gas is detected in the environment
Source: Own Elaboration

When the gas concentration increases the red led lights up, the sensor screen shows a danger alert, as well as the application, and a buzzer starts to be heard to alert audibly, also starts the ventilation system that is responsible for evacuating the gas, and when the concentration of chemicals decreases, the sensor returns to its initial state.

Figure 6 Actuators of the device when gas is detected in the environment
Source: Own Elaboration

Conclusions

The creation of the device was done with the purpose of innovating an electronic device that detects different concentrations of gases using C++ programming language, implemented in Arduino as the software in charge of the interpretation of data according to the MQ2 gas sensor. Several searches were carried out on the properties and characteristics of the sensor to use its maximum detection capacity, in such a way that it was possible to analyse different gases found in the environment, thus alerting the user about the imminent danger that these gas concentrations represent, avoiding intoxication and increasing safety levels in the home.

The use and application of a gas detector sensor is essential in different environments, whether domestic or industrial, as it reduces the risk of poisoning, poisoning or explosions that endanger the integrity of people and infrastructure exposed to flammable or toxic chemicals, as the gas detector alarm provides greater security, energy efficiency, automation, comfort, through the system installed inside a home or building, integrating the implementation of microcontrollers as a system of purification of gases in the environment, since this sensor has a LCD screen (Liquid Crystal Display) that its function is to quantify the concentration of gas, which when exceeding the preset parameters starts with an alarm that can be displayed on the LCD also starts a sound signal and the lighting of a warning LED that has increased the reading of chemical agents.

ISSN: 2444-4995

Also linked the gas sensor with an application that can be synchronized by standard radio frequency wireless communication of 2. 4 GHz wireless communication, as well as the control of a brushless ventilation system to avoid the presence of a spark that could generate an ignition of the chemical substance suspended in the air.

For this innovation we sought to introduce innovations, improvements and significant changes to improve the efficiency of the sensor, which is why we chose to implement an application that by means of Bluetooth communication to the serial communication terminal, which allowed real-time data transmission of the variation in the reading of the concentration of the gases that were captured in the environment where the gas detector was placed, In addition, this alarm can be synchronised with the appropriate programming to a Wifi module (Wireless Fidelity) to increase the scope of gas concentration reading, this with the intention of warning in advance of any disaster or accident that may claim the lives of people or property, seeking to minimise the dangers that this represents, thus allowing preventive measures to be taken.

The characteristics of this device is that it uses an Arduino Uno microcontroller, a Bluetooth HC-05 module, a buzzer and two LED diodes, the latter two protruding from the box containing the microprocessor. It also has a 16x2 LCD, an MQ-2 sensor capable of detecting smoke, hydrogen, alcohol and propane, as well as a power cable that is placed in the area to be inspected.

The problem to be solved is based on safeguarding the lives of people and their surroundings, whether in a domestic or industrial environment, since the accumulation of certain gases can cause poisoning, fires or even explosions that mean human as well as economic losses. The leaks that the sensor can detect, such as butane, represent great risks for people and industry. The central hypothesis is that the prototype will demonstrate certain sensitivity and precision in the detection of specific gases in the environment, providing a rapid response to the presence of dangerous concentrations or outside the established limits, which will contribute to the safety and prevention of risks in different environments.

The gas detector was developed in order to provide greater safety in the user's home by avoiding any type of poisoning or any dangerous situation that will be caused by a gas leak.

The continuity of this technological development, establishes the protection and implementation in pilot space within the facilities of the Technological Institute of San Luis Potosi.

Acknowledgements

To our house of studies, the Instituto Tecnológico de San Luis Potosí, for the opportunity to grow professionally, to our advisor, Dr. Rosa Elia Martínez Torres, who gave us academic support in terms of ideas, feedback and general help in the realization of this project.

References

Abarca S., Corona G., Mares J., (2019). Sensores y actuadores: aplicaciones con Arduino (Callejas, Ed.; segunda edición.). Grupo Editorial Patria.

Bolton W., (2017). Mecatrónica, Sistemas de control electrónico en la Ingeniería mecánica y eléctrica, un enfoque multidisciplinario, 6ta edición. México: Alfaomega.

Centro nacional de prevencion de desastres. (2021). Análisis de accidentes con Gas LP. Secretaría de Protección Civil.

Correa J., Zavala I., (2020). Diseño e implementación de un sistema de detección y monitoreo de gas metano en una maqueta de planta de tratamiento de aguas. Ecuador: Universidad Politécnica Salesiana.

Díaz A., (2019). Sistema de sensado mediante Arduino y matriz de sensores de gases industriales. Universitat Politécnica de València.

Flores R., Pérez M., Villalvazo E., Yepez I., (2019). Activación de cargas eléctricas a través de comandos de voz vía módulo HC–05 y Arduino. México: Instituto Tecnológico de Aguascalientes

ISSN: 2444-4995

Hernández, R., (2014). Metodología de la Investigación, 6ta edición. México: McGrawHill.

Juganaru M., (2013). Introducción a la programación (1a. ed.). México: Patria.

Organización de las Naciones Unidas, (2016). Agenda 2030 para el Desarrollo Sostenible. ONU.

ISSN: 2444-4995

[Title in Times New Roman and Bold No. 14 in English and Spanish]

Surname (IN UPPERCASE), Name 1st Author†*, Surname (IN UPPERCASE), Name 1st Coauthor, Surname (IN UPPERCASE), Name 2nd Coauthor and Surname (IN UPPERCASE), Name 3rd Coauthor

Institutional Affiliation of Author including Dependency (No.10 Times New Roman and Italic)

International Identification of Science - Technology and Innovation

ID 1st Author: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 1st author: (Scholar-PNPC or SNI-CONAHCYT) (No.10 Times New Roman)

ID 1st Coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 1st coauthor: (Scholar or SNI) (No.10 Times New Roman)

ID 2nd Coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 2nd coauthor: (Scholar or SNI) (No.10 Times New Roman)

ID 3rd Coauthor: (ORC ID - Researcher ID Thomson, arXiv Author ID - PubMed Author ID - Open ID) and CVU 3rd coauthor: (Scholar or SNI) (No.10 Times New Roman)

(Report Submission Date: Month, Day, and Year); Accepted (Insert date of Acceptance: Use Only ECORFAN)

Abstract (In English, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In English)

Indicate 3 keywords in Times New Roman and Bold No. 10

Abstract (In Spanish, 150-200 words)

Objectives
Methodology
Contribution

Keywords (In Spanish)

Indicate 3 keywords in Times New Roman and Bold No. 10

Citation: Surname (IN UPPERCASE), Name 1st Author, Surname (IN UPPERCASE), Name 1st Coauthor, Surname (IN UPPERCASE), Name 2nd Coauthor and Surname (IN UPPERCASE), Name 3rd Coauthor. Paper Title. Journal of Technological Prototypes. Year 1-1: 1-11 [Times New Roman No.10]

* Correspondence to Author (example@example.org)
† Researcher contributing as first author.

Introduction

Text in Times New Roman No.12, single space.

General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Article.

Development of headings and subheadings of the article with subsequent numbers

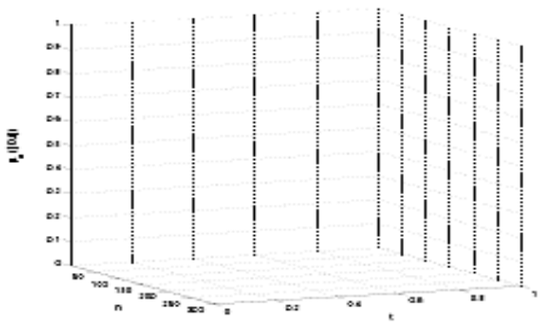
[Title No.12 in Times New Roman, single spaced and bold]

Products in development No.12 Times New Roman, single spaced.

Including graphs, figures and tables-Editable

In the article content any graphic, table and figure should be editable formats that can change size, type and number of letter, for the purposes of edition, these must be high quality, not pixelated and should be noticeable even reducing image scale.

[Indicating the title at the bottom with No.10 and Times New Roman Bold]



Graphic 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

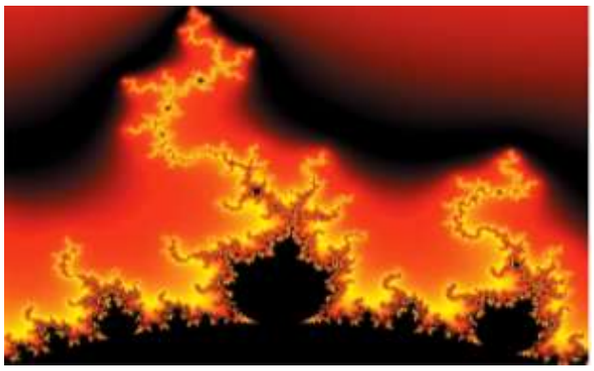


Figure 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

Table 1 Title and *Source (in italics)*

Should not be images-everything must be editable.

Each article shall present separately in **3 folders**: a) Figures, b) Charts and c) Tables in .JPG format, indicating the number and sequential Bold Title.

For the use of equations, noted as follows:

$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \quad (1)$$

Must be editable and number aligned on the right side.

Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

Results

The results shall be by section of the article.

Annexes

Tables and adequate sources

Thanks

Indicate if they were financed by any institution, University or company.

ISSN 2444-4995

Conclusions

Explain clearly the results and possibilities of improvement.

References

Use APA system. Should not be numbered, nor with bullets, however if necessary numbering will be because reference or mention is made somewhere in the Article.

Use Roman Alphabet, all references you have used must be in the Roman Alphabet, even if you have quoted an Article, book in any of the official languages of the United Nations (English, French, German, Chinese, Russian, Portuguese, Italian, Spanish, Arabic), you must write the reference in Roman script and not in any of the official languages.

Technical Specifications

Each article must submit your dates into a Word document (.docx):

Journal Name
Article title
Abstract
Keywords
Article sections, for example:

1. Introduction
2. Description of the method
3. Analysis from the regression demand curve
4. Results
5. Thanks
6. Conclusions
7. References

Author Name (s)
Email Correspondence to Author
References

Intellectual Property Requirements for editing:

-Authentic Signature in Color of Originality Format Author and Coauthors

-Authentic Signature in Color of the Acceptance Format of Author and Coauthors

-Authentic Signature in Color of the Conflict of Interest Format of Author and Co-authors.

ISSN 2444-4995

Reservation to Editorial Policy

Journal of Technological Prototypes reserves the right to make editorial changes required to adapt the Articles to the Editorial Policy of the Journal. Once the Article is accepted in its final version, the Journal will send the author the proofs for review. ECORFAN® will only accept the correction of errata and errors or omissions arising from the editing process of the Journal, reserving in full the copyrights and content dissemination. No deletions, substitutions or additions that alter the formation of the Article will be accepted.

Code of Ethics - Good Practices and Declaration of Solution to Editorial Conflicts

Declaration of Originality and unpublished character of the Article, of Authors, on the obtaining of data and interpretation of results, Acknowledgments, Conflict of interests, Assignment of rights and Distribution

The ECORFAN-Mexico, S.C Management claims to Authors of Articles that its content must be original, unpublished and of Scientific, Technological and Innovation content to be submitted for evaluation.

The Authors signing the Article must be the same that have contributed to its conception, realization and development, as well as obtaining the data, interpreting the results, drafting and reviewing it. The Corresponding Author of the proposed Article will request the form that follows.

Article title:

– The sending of an Article to Journal of Technological Prototypes emanates the commitment of the author not to submit it simultaneously to the consideration of other series publications for it must complement the Format of Originality for its Article, unless it is rejected by the Arbitration Committee, it may be withdrawn.

– None of the data presented in this article has been plagiarized or invented. The original data are clearly distinguished from those already published. And it is known of the test in PLAGSCAN if a level of plagiarism is detected Positive will not proceed to arbitrate.

– References are cited on which the information contained in the Article is based, as well as theories and data from other previously published Articles.

– The authors sign the Format of Authorization for their Article to be disseminated by means that ECORFAN-Mexico, S.C. In its Holding Spain considers pertinent for disclosure and diffusion of its Article its Rights of Work.

– Consent has been obtained from those who have contributed unpublished data obtained through verbal or written communication, and such communication and Authorship are adequately identified.

– The Author and Co-Authors who sign this work have participated in its planning, design and execution, as well as in the interpretation of the results. They also critically reviewed the paper, approved its final version and agreed with its publication.

– No signature responsible for the work has been omitted and the criteria of Scientific Authorization are satisfied.

– The results of this Article have been interpreted objectively. Any results contrary to the point of view of those who sign are exposed and discussed in the Article.

Copyright and Access

The publication of this Article supposes the transfer of the copyright to ECORFAN-Mexico, SC in its Holding Spain for its Journal of Technological Prototypes, which reserves the right to distribute on the Web the published version of the Article and the making available of the Article in This format supposes for its Authors the fulfilment of what is established in the Law of Science and Technology of the United Mexican States, regarding the obligation to allow access to the results of Scientific Research.

Article Title:

Name and Surnames of the Contact Author and the Coauthors	Signature
1.	
2.	
3.	
4.	

Principles of Ethics and Declaration of Solution to Editorial Conflicts

Editor Responsibilities

The Publisher undertakes to guarantee the confidentiality of the evaluation process, it may not disclose to the Arbitrators the identity of the Authors, nor may it reveal the identity of the Arbitrators at any time.

The Editor assumes the responsibility to properly inform the Author of the stage of the editorial process in which the text is sent, as well as the resolutions of Double-Blind Review.

The Editor should evaluate manuscripts and their intellectual content without distinction of race, gender, sexual orientation, religious beliefs, ethnicity, nationality, or the political philosophy of the Authors.

The Editor and his editing team of ECORFAN® Holdings will not disclose any information about Articles submitted to anyone other than the corresponding Author.

The Editor should make fair and impartial decisions and ensure a fair Double-Blind Review.

Responsibilities of the Editorial Board

The description of the peer review processes is made known by the Editorial Board in order that the Authors know what the evaluation criteria are and will always be willing to justify any controversy in the evaluation process. In case of Plagiarism Detection to the Article the Committee notifies the Authors for Violation to the Right of Scientific, Technological and Innovation Authorization.

Responsibilities of the Arbitration Committee

The Arbitrators undertake to notify about any unethical conduct by the Authors and to indicate all the information that may be reason to reject the publication of the Articles. In addition, they must undertake to keep confidential information related to the Articles they evaluate.

Any manuscript received for your arbitration must be treated as confidential, should not be displayed or discussed with other experts, except with the permission of the Editor.

The Arbitrators must be conducted objectively, any personal criticism of the Author is inappropriate.

The Arbitrators must express their points of view with clarity and with valid arguments that contribute to the Scientific, Technological and Innovation of the Author.

The Arbitrators should not evaluate manuscripts in which they have conflicts of interest and have been notified to the Editor before submitting the Article for Double-Blind Review.

Responsibilities of the Authors

Authors must guarantee that their articles are the product of their original work and that the data has been obtained ethically.

Authors must ensure that they have not been previously published or that they are not considered in another serial publication.

Authors must strictly follow the rules for the publication of Defined Articles by the Editorial Board.

The authors have requested that the text in all its forms be an unethical editorial behavior and is unacceptable, consequently, any manuscript that incurs in plagiarism is eliminated and not considered for publication.

Authors should cite publications that have been influential in the nature of the Article submitted to arbitration.

Information services

Indexation - Bases and Repositories

LATINDEX (Scientific Journals of Latin America, Spain and Portugal)
EBSCO (Research Database - EBSCO Industries)
RESEARCH GATE (Germany)
GOOGLE SCHOLAR (Citation indices-Google)
REDIB (Ibero-American Network of Innovation and Scientific Knowledge- CSIC)
MENDELEY (Bibliographic References Manager)

Publishing Services

Citation and Index Identification H
Management of Originality Format and Authorization
Testing Article with PLAGSCAN
Article Evaluation
Certificate of Double-Blind Review
Article Edition
Web layout
Indexing and Repository
ArticleTranslation
Article Publication
Certificate of Article
Service Billing

Editorial Policy and Management

38 Matacerquillas, CP-28411. Moralzarzal –Madrid-España. Phones: +52 1 55 6159 2296, +52 1 55 1260 0355, +52 1 55 6034 9181; Email: contact@ecorfan.org www.ecorfan.org

Journal of Technological Prototypes

2444 4995
ISSN 2444 - 4995
www.ecorfan.org