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Enhancing Swine Husbandry: The IoT-Integrated Hog Feeding Assistant

Jezzer T. Tibreza[1], Fernandino S. Perilla[2]
[12]*University of Northern Philippines, Philippines*
[1]*jtimbreza.ccit@unp.edu.ph*
[2]*dino.perilla@unp.edu.ph*

ABSTRACT

IoT-Integrated Hog Feeding Assistant revolutionizes swine husbandry, offering hog raisers crucial insights into feed consumption and operational costs, thereby enhancing overall efficiency and comfort. This paper elucidates the system's development process, methodology, and usability assessment. Employing the Rapid Application Development model ensured a swift and flexible creation of the Hog Feeding Assistant, guaranteeing the timely deployment of a fully functional system. Essential data for system design and features were acquired through document analysis and surveys. The system's usability was systematically evaluated using the ISO 25010 software quality standard tool, assessing functional suitability, performance efficiency, compatibility, usability, reliability, security, and maintainability. This comprehensive evaluation provides a profound understanding of the system's capabilities and user-friendliness. The Hog Feeding Assistant with IoT Integration is strongly recommended for hog raisers due to its remarkable efficiency, convenience, and exceptional usability. Seamlessly integrating into daily operations, the system not only streamlines feeding processes but also furnishes valuable insights, empowering more informed decision-making in swine husbandry.

Keywords: *Swine husbandry, IoT integration, rapid application development, usability assessment, feed consumption optimization*

INTRODUCTION

The Internet serves as a platform for connecting people, and in contemporary times, it has evolved to enable things to sense their surroundings, interact, and collaborate. A prominent technology in this era is the Internet of Things (IoT), which holds significant potential across various industries. The IoT landscape encompasses a diverse range of interconnected devices, including sensors, robots, 2D and 3D cameras, microphones, Artificial Intelligence (AI), Radio-Frequency Identification (RFID), and more. This technological progression is particularly transformative for piggery automation, offering avenues for enhanced efficiency, health monitoring, and overall productivity.

The Internet of Things (IoT) can be defined as a paradigm where everyday objects are connected to the Internet, allowing them to send and receive data (Perilla et al., 2018). In the context of piggery automation, this connectivity enables seamless communication between various devices, such as sensors and robots, fostering a data-

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driven approach to enhance decision-making processes and streamline operational tasks. The transformative potential of Artificial Intelligence (AI) in pig production is highlighted by Houghton (2018). AI algorithms, in conjunction with hardware technology, facilitate individual pig tracking, monitor feed and water intake, and recommend optimal feeding programs. Facial recognition tools developed by Chinese technology companies offer potential improvements over traditional Radio-frequency Identification (RFID) tags. Robots have emerged as tireless contributors to pig welfare and production. Cleaning robots address environmental concerns, reduce odors, and enhance sanitation. AgriSales, Inc. (2019) emphasizes the benefits of robots in performing labor-intensive tasks and monitoring sow heat cycles. The integration of these technologies showcases their potential to elevate the well-being of pigs and streamline farm operations.

Sensors, as highlighted by Holt (2019), play a pivotal role in offering valuable real-time insights into pig movements, as well as feed and water consumption, alongside other behavioral patterns. This contribution aligns with the principles of Precision Livestock Farming, as defined by Wathes et al. (2008). In this framework, intelligent sensors and robots are employed to automate animal husbandry, ensuring the efficient monitoring of physical processes. Operating as a crucial component of the Internet of Things (IoT), sensors in pig farming perform a vital function in transmitting data and issuing real-time alerts. This multifaceted role includes detecting malfunctions, monitoring disease and heat cycles, and tracking food and water consumption, ultimately enhancing overall productivity. The inclusion of wearable devices and stationary sensors, measuring parameters like ammonia levels, dust, humidity, and temperature, further amplifies the capabilities of environmental monitoring within pig pens.

Cameras, both 2D and 3D, revolutionize pig farming by aiding in animal counting, weight estimation, and identifying behavioral anomalies. Infrared cameras enable monitoring in low-light conditions and provide temperature measurements without physical contact. Emerging technologies like 3D printing, as mentioned by Pig Progress (2021), further contribute to innovative solutions in pig farming.

Automation, as explained by Saracco (2018), is evolving rapidly through sensor, actuator, and AI advancements. Digital technologies, spearheaded by the IoT, continue to shape the future of agriculture, with a focus on data-driven farming practices. The integration of smart farming technologies enhances pig well-being and management, catering to the evolving needs of global pig farming. In the study of Navarro et al. (2020), they mentioned that with the introduction of new agriculture advancements, corn growers are coping with the developments from manual to automated systems and equipment farming. Their study intended to design, develop, and evaluate a knowledge-based mobile system for upgrading corn yield productivity for the corn growers of Ilocos Sur, Philippines.

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Technological advancements extend beyond hardware to include automated systems, RFID technologies, and big data applications. Nedap (2021) emphasizes the role of automated systems in improving labor efficiency, attracting tech-savvy workers, and providing timely data for informed decision-making. Automated sorting equipment aids in reducing feed wastage and controlling costs by tracking animal weight regularly. Arruejo et al. (2021), also developed, designed, and tested a Strategic Forest Management Using a Decision Tree for the Department of Environment and Natural Resource -Abra Forest Land, which was found to be useful for the end users because of the data stored in the system and helped to manage in making important decisions like trees to be planted on different types of soil and providing important information about the different diseases that might affect the growth of the trees and how to avoid them.

The field of agriculture, as noted by Ravindra (2020), benefits from IoT through data-driven decision-making, remote monitoring of farm conditions, and the introduction of smart farming and precision farming applications. With the global population increasing, the demand for meat is expected to rise, making smart farming crucial for improving operational efficiencies, reducing costs, minimizing waste, and enhancing output quality. Hog raising, a prevalent business in the Philippines, involves daily tasks such as vaccination, medication, and providing suitable housing conditions. The importance of regular feeding and the dependence on the type of swine. As meat consumption is projected to increase globally, smart farming becomes essential for providing detailed information on health, well-being, and productivity.

Various automated feeders, like the Babyfeeder by Agromek, cater to pig farmers' needs by providing sensor-equipped automatic feeding for even the smallest pigs. DeRouchey et al. (2019) outline the common feeder designs used in different pig stages, emphasizing the importance of feeding space design for various pig sizes. Automatic feed control with IoT integration eliminates the need for manual calculations, providing convenience for pig farmers to monitor feed consumption and costs. The IoT's continuous evolution, driven by automation, AI, and sensor integration, holds tremendous promise for the pig farming industry. By adopting these innovations, the industry can witness enhanced productivity, improved animal welfare, and a shift towards more sustainable and efficient farming practices.

As the demand for meat is projected to surge by 73 percent by 2050, pig producers face the challenge of maximizing production per animal unit and increasing animal density. Smart farming, driven by the IoT, arises as a solution to provide farmers with detailed information on health, well-being, and productivity, especially as livestock production intensifies. Automated feeders equipped with sensors, such as the Babyfeeder by Agromek, exemplify the industry's responsiveness to the growing need for efficient and technology-driven solutions.

DeRouchey et al. (2019) emphasize the importance of feeder design in different pig stages, ensuring adequate feeding space for pigs of various sizes. The integration of

IoT technology in feed control eliminates manual calculations, providing pig farmers with a convenient and accurate way to monitor feed consumption. This automation not only streamlines operations but also ensures that each pig receives an appropriate and consistent amount of feed, contributing to their overall health and well-being.

The benefits of IoT extend beyond feed control and automation. The study recognizes the broader applications of IoT in agriculture, such as data-driven decision-making, remote monitoring of farm conditions, and the introduction of smart farming practices. The ongoing evolution of technology, particularly in IoT, AI, and automation, presents an opportunity for pig farmers to enhance their productivity and operational efficiency.

The challenges faced by hog raisers, including manual feed distribution, monitoring pig growth, and ensuring proper ventilation, are addressed through the proposed IoT Assisted Hog Feeding system. By leveraging the Rapid Application Development model, the study aims to develop a user-friendly and effective solution that integrates seamlessly into existing hog-raising practices. The development of the system also contributes to the waste management system. As mentioned by Atienza, (2018) the sustainability of solid waste management is important. This is because the waste generated by the populace is continuous. Since it is continuous, there is a need to sustain it to a certain level so that it is not only functional but effective at the same time.

The proposed system aligns with the broader trends in agriculture, where the adoption of smart technologies is becoming increasingly prevalent. Nedap (2021) emphasizes the role of automated systems in improving labor efficiency and providing timely data for decision-making. The study contributes to this trend by introducing an IoT-based solution tailored specifically for hog feeding, catering to the unique needs and challenges faced by pig producers.

The continuous evolution of technology, particularly within the realm of IoT, AI, and automation, holds tremendous promise for the pig farming industry. The integration of these technologies into daily practices, as proposed by the study, has the potential to revolutionize traditional farming methods, enhance productivity, and promote the overall well-being of pigs.

Objectives of the Study

The primary objective of this study is to develop an IoT Assisted Hog Feeding system using the Rapid Application Development model. The study has the following objectives: identify available technologies for piggery automation, create a comprehensive system architecture design, and conduct a thorough assessment of the system's usability.

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METHODOLOGY

Research Design

This study employed a content analysis approach within a development research design.

Data Gathering

Available Technologies for Piggery Automation. To identify technologies for automating piggery, a comprehensive review was conducted, incorporating past studies on the Internet of Things (IoT) and automation. Data sources included technology reviews by various authors. The results were analyzed using a tabular form, and the findings were discussed.

*System Architecture Design for an Automatic Piggery Feeder***.** A review of available technologies and an assessment of similar systems guided the integration of components into the design architecture of an automatic piggery feeder. Data sources included studies on relevant technologies. The system architecture design was presented using a tabular method for ease of interpretation.

Development of Hog Feeding Assistant with IoT Integration Using Rapid Application Development (RAD) Model. The Rapid Application Development (RAD) model, a prototyping and iterative approach, was adopted for designing the IoT Automatic Piggery Feeder. This model, featuring five phases (Business Modeling, Data Modeling, Process Modeling, Application Generation, and Testing and Turnover), allowed for quick iterations without starting development from scratch. Business Modeling: Information flows related to pig feeding times and feed variety were identified, informing system requirements.

Data Modeling: Information gathered during business modeling was analyzed to conceptualize system outputs. Process Modeling: Data objects were transformed to establish business information flow, facilitating processes for modifying and tracking feed data. Application Generation: The system was coded based on the conceptual design, resulting in the creation of a prototype. Testing and Turnover: The prototype underwent testing in cycles, identifying and addressing issues. Separate tests for the IoT component were conducted before integration.

Data Analysis

A Likert scale serves as a psychometric tool employed to gauge participants' attitudes and perceptions regarding specific elements of the IoT Assisted Hog Feeding system. This scale finds application in the study's surveys or questionnaires, where respondents encounter a series of statements or queries relating to their opinions and experiences with the system. Participants express their agreement or disagreement with each statement on a scale, typically ranging from "Strongly Disagree" to "Strongly

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Agree." The Likert scale offers a structured means of gathering and quantifying subjective data, enabling researchers to analyze and interpret participants' sentiments toward the developed system.

Table 1
The norm for the level of usability results interpretation

Point	Statistical Range	Descriptive Equivalent Rating	Descriptive Interpretation
1	1.00-1.49	Poor	Not Usability
2	1.50-2.49	Fair	Fairly Usability
3	2.50-3.49	Good	Acceptable
4	3.50-4.49	Very Good	Highly Usability
5	4.50-5.00	Excellent	Very Highly Usability

The developed IoT Assisted Hog Feeding system, underwent evaluation by end-users (hog raisers) and IT experts, involving a sample size of 10 participants. The ISO 25010 tool assessed Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, and Maintainability. Evaluation results were interpreted using a norm-based approach (Table 1), with ratings spanning from 1 to 5. The interpretation follows a scale where 5 indicates "Excellent" usability, and 1 reflects "Poor" usability. To enhance clarity and ease of comprehension, the results were succinctly summarized and presented in tabular form.

RESULTS AND DISCUSSIONS

Emerging Technologies for Piggery Automation

The Internet of Things (IoT) plays a pivotal role in advancing information technology, encompassing a spectrum of interconnected devices embedded with sensors, robots, 2D and 3D cameras, microphones, AI, RFID, and various technologies. These innovations contribute to modernization by facilitating the seamless exchange of information across different devices and frameworks on the Internet.

To explore the technologies relevant to piggery automation, researchers conducted a thorough review of related literature. The gathered data, as depicted in Figure 1 alongside the respective authors, underscores the multifaceted landscape of available technologies for advancing pig farming practices.

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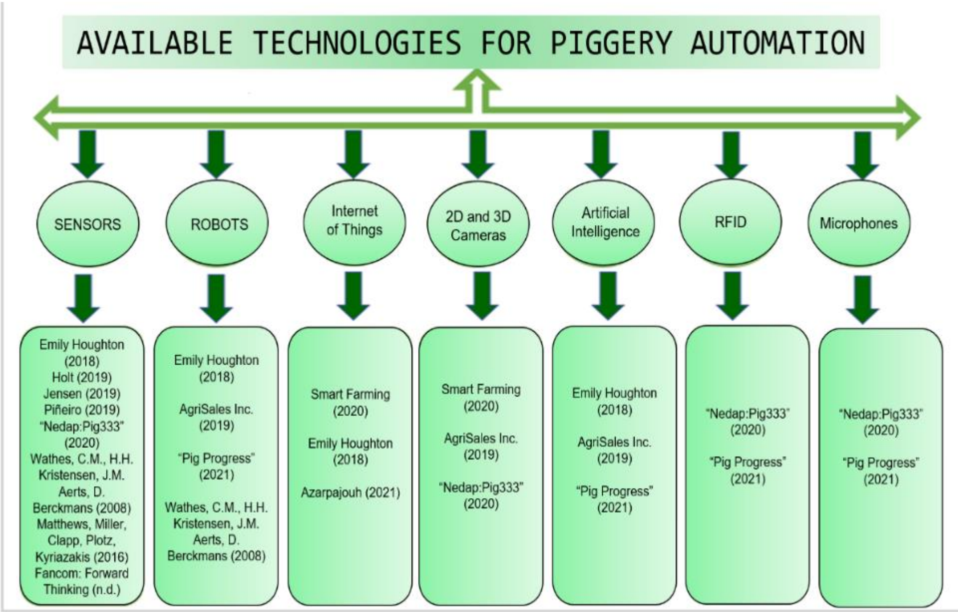
Figure 1
Available technologies for piggery automation



The findings reveal a unanimous consensus among nine authors who advocate for the integration of sensors as a fundamental technology in piggery automation. Additionally, four authors concur on the inclusion of robots, the Internet of Things (IoT), and 2D and 3D cameras. Artificial Intelligence (AI) emerged as a significant technology, as highlighted by three authors. Furthermore, the collective insights of two additional authors emphasize the importance of incorporating Radio Frequency Identification (RFID) and Microphones as integral components in the automation toolkit.

This comprehensive exploration underscores the diversity and consensus within the academic community regarding the technological arsenal available for enhancing efficiency and automation in the domain of pig farming.

System Architecture Design for IoT-Integrated Hog Feeding Assistant

The system design introduces a prototype for an IoT-integrated hog feeding assistant, offering a feeding plan that specifies the optimal time for meals and the precise amount of food required daily for each pig. This architecture encompasses key modules, namely Liquid Crystal Display (LCD), Load Cell, Radio Frequency Identifier (RFID), Buttons, Servo Motor, and IoT device. Additionally, the prototype incorporates essential components such as User Authentication, Pens Configuration Table, Feeds Configuration Table, Server, and Database. These elements are seamlessly integrated

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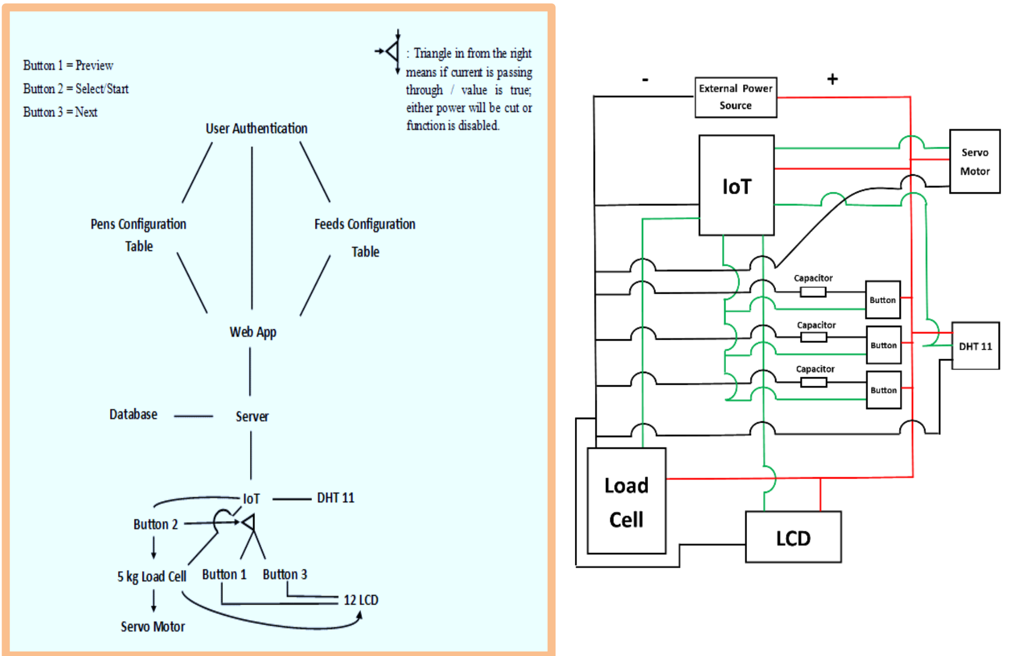
and programmed through an Arduino microcontroller, culminating in the creation of a functional and efficient automatic piggery feeder.

Figure 2 further illustrates the schematic diagram of the developed system. This comprehensive diagram outlines various components, including the external power source, IoT, servo motor, load cell, LCD, buttons, DHT11, and capacitors, collectively contributing to the system's functionality.

Figure 2

System architecture, and schematic diagram



As illustrated in Figure 2 the Web App provides a user-friendly interface for configuring and saving settings to the database. Two configuration tables, one for feeds and one for pens, enable meticulous customization. Another table delineates the distribution of feed pellets calculated during storage in the pigpen. Additionally, a feeding guide displays the recommended feed amount for individual pigs. Access to these features is restricted to authorized individuals via authentication measures.

The system employs a 12C LCD to exhibit the real-time status of the IoT, encompassing network connectivity, setup details, pen selection, and feed portions. Buttons 1 and 3 facilitate control over the prototype's movements, with IoT transmitting either "previous" or "next" events to the database, enabling pen configuration selection. The server responds with the corresponding pen name and associated feed portion, subsequently displayed on the LCD. Button 2 serves as the trigger for initiating or canceling feed dispensing. Upon activation, the servo motor rotates to a 180-degree position, facilitating feed flow, and temporarily disabling buttons 1 and 2 while enabling the load cell to measure and display the dispensed feeds on the LCD. Once the selected pen portion in kilograms is reached, the servo rotates to a 0-degree position to cease feed flow.

The integration of the Internet of Things and the multifunctional features within the system architecture sets it apart from conventional automation systems. The IoT functionality enables data collection and recording, contributing valuable insights for decision-making and continual refinement in the design of piggery feeders and other automation processes, ultimately enhancing the overall system design.

System Development using Rapid Application Development Model

The SDLC leveraged the Rapid Application Development (RAD) model, encompassing key phases such as Business Modeling, Data Modeling, Process Modeling, Application Generation, and Testing and Turnover.

The Use Case diagram, depicted in Figure 3, serves as a visual representation of the primary system functionalities. Two user roles are identified: the authenticated user and the general user. The authenticated user initiates the creation of a new user account by clicking on their username, navigating to 'Accounts,' and filling out the Registration form with name, username, and password, then clicking 'Register.' After successful registration, the Authenticated User activates the account by clicking their username, selecting 'Accounts,' and clicking the 'Active' button next to the user's name. The User logs in by entering their username and password following a successful account activation. In the event of a forgotten password, the Authenticated User triggers account recovery by changing the website link, inputting a new password in the Recovery form, clicking 'Update,' and proceeding with the login. To change the account password, the Authenticated User navigates to 'My Account,' inputs the old password for validation, enters a new password, and clicks 'Update' to save changes.

The Authenticated User configures feed parameters, including days for consumption, total feed amount, and current usage, with an option to reset if needed. Adding a new pen entry, the Authenticated User sets pen details, calculates total serving, and selects a pigpen using either Button 1 (previous) or Button 3 (next). The User initiates feed dispensing by pressing Button 2 (start), prompting the servo motor to rotate for feed dispensing and stop when the set amount is reached. After dispensing, the Authenticated User resets usage by clicking the 'Reset' button. The User triggers a Factory Reset by pressing the Previous and Next buttons on the Arduino for 10 seconds, followed by logging in using the default to create a new account for web app access.

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Figure 3
Use-Case diagram for iot-integrated hog feeding assistant

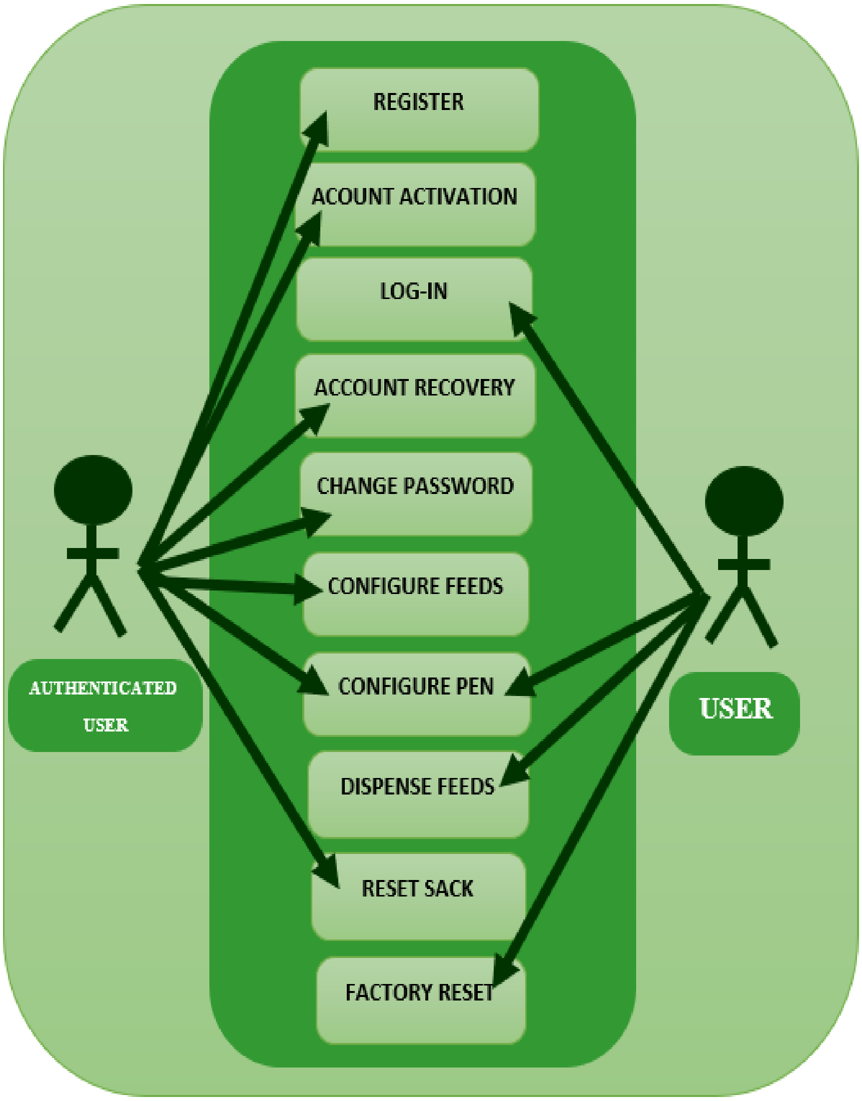

Figure 4 displays the developed web application for overseeing the IoT-Integrated Hog Feeding Assistant, while Figure 5 showcases the Feeding Assistant Dashboard Configuration Form. This form serves as a tool for adjusting system settings following parameters tailored to the distinct needs of the particular piggery.

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Figure 4

IoT-Integrated hog feeding assistant dashboard

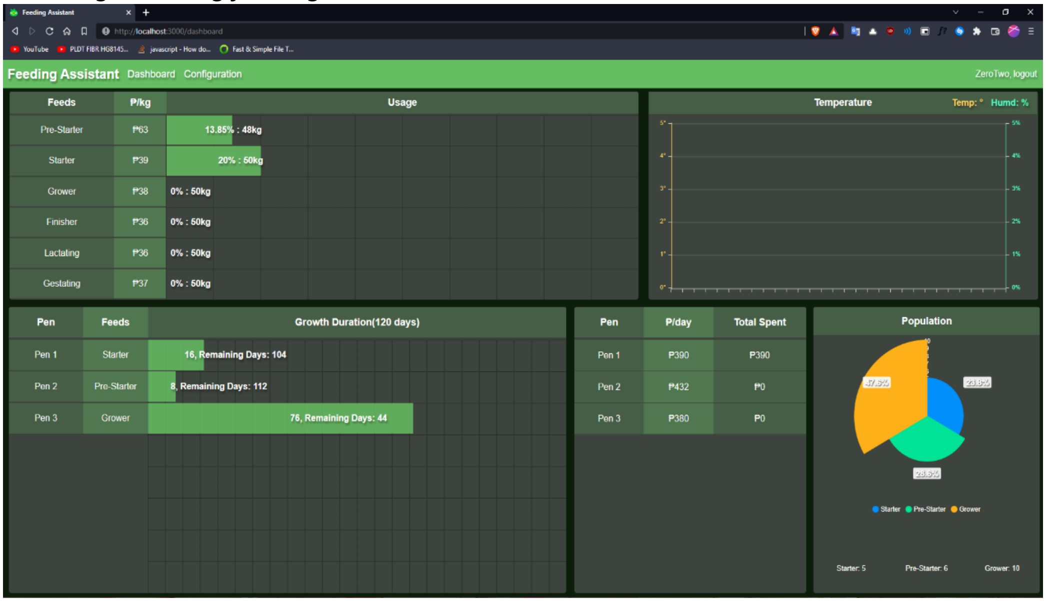
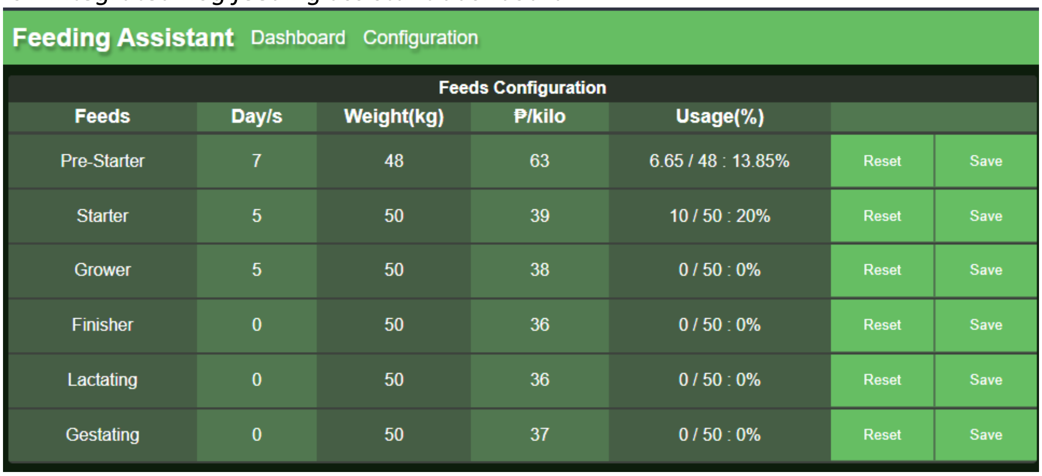


Figure 5

IoT-Integrated hog feeding assistant dashboard


Feeding Assistant Dashboard Configuration

Feeds Configuration

Feeds	Day/s	Weight(kg)	₱/kilo	Usage(%)		
Pre-Starter	7	48	63	6.65 / 48 : 13.85%	Reset	Save
Starter	5	50	39	10 / 50 : 20%	Reset	Save
Grower	5	50	38	0 / 50 : 0%	Reset	Save
Finisher	0	50	36	0 / 50 : 0%	Reset	Save
Lactating	0	50	36	0 / 50 : 0%	Reset	Save
Gestating	0	50	37	0 / 50 : 0%	Reset	Save

Evaluation of the Developed System

The software quality of the product encompasses seven criteria, further subdivided into sub-characteristics that pertain to the product and the outcome of the system within a specific framework. These distinct characteristics and sub-characteristics are defined to ensure the relevance and application of the system, facilitating the measurement and evaluation of software product quality, thereby offering completeness and usefulness.

Table 2 summarizes the Software Product Quality evaluation of the IoT Integrated Feeding Assistant.

Table 2
Software product quality summary

Indicator	Mean	Descriptive	Interpretation
1. Functional Suitability	4.71	Excellent	Very Highly Usable
2. Performance Efficiency	4.71	Excellent	Very Highly Usable
3. Compatibility	4.64	Excellent	Very Highly Usable
4. Usability	4.67	Excellent	Very Highly Usable
5. Reliability	4.75	Excellent	Very Highly Usable
6. Security	4.80	Excellent	Very Highly Usable
7. Maintainability	4.71	Excellent	Very Highly Usable
Overall Mean	**4.71**	**Excellent**	**Very Highly Usable**

All respondents unanimously agreed that the system is very highly usable, as evidenced by the ISO 25010 instrument, achieving a grand mean of 4.71. The system demonstrated high usability across all evaluated criteria, including functional suitability, performance efficiency, compatibility, usability, reliability, security, and maintainability. Notably, "Security" received the highest mean of 4.80, while "Compatibility" had the lowest mean of 4.64. However, all seven Software Product Criteria were rated as "Excellent" and interpreted as "Very Highly Usable." In conclusion, the level of usability of the IoT-Integrated Hog Feeding Assistant was consistently evaluated as "Very Highly Usable," as indicated by respondents' ratings. They concurred that the system is apt in function, efficient in performance, compatible, usable, reliable, secure, and maintainable.

CONCLUSIONS

There exists a multitude of available technologies capable of automating piggeries, providing pig farmers with the means to minimize their workload and maximize profitability. The integration of the Internet of Things into the system architecture design renders it unique and unparalleled. The Hog Feeding Assistant with IoT Integration is poised to significantly simplify the daily tasks of hog raisers, ensuring that each pig in the pen accurately consumes the prescribed amount and type of feed based on its age. The developed Hog Feeding Assistant with IoT Integration proves to be highly valuable, as evidenced by positive evaluations from the respondents.

RECOMMENDATIONS

Pig farmers are strongly advised to promptly integrate and deploy the Hog Feeding Assistant with IoT Integration into their operations to harness its benefits in optimizing feeding processes. The Hog Feeding Assistant with IoT Integration is recommended for an immediate market launch, ensuring that its innovative features and advantages are made readily available to a broader audience of pig farmers. Future research endeavors should focus on refining the system's design and introducing additional features and sensors to further elevate its overall performance. Researchers are encouraged to formulate customized algorithms for planning feed consumption tailored to diverse feed types. The study supports the implementation of the Hog Feeding Assistant with IoT Integration in large-scale piggeries, affirming its pronounced usefulness and potential for streamlining operations in expansive pig farming setups.

ETHICAL STATEMENT

This study upholds ethical standards by securing participant consent, ensuring confidentiality, and respecting the voluntary nature of participation. Participants' personal information is treated with utmost privacy. The research follows ethical guidelines in data collection, analysis, and reporting, prioritizing transparency and accuracy. The study aims to contribute valuable insights while prioritizing the well-being and rights of all involved stakeholders.

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