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Design of an IoT-Based Automatic Weighing System for Catfish Farming to Support Smart Aquaculture

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ABSTRACT

Enhancing the accuracy and efficiency of the catfish weighing process is essential for farmers to optimize distribution to retailers and wholesalers while improving productivity and operational performance. This study focuses on developing an IoT-based automatic weighing system to provide a real-time and automated solution to these challenges. The proposed system incorporates a load cell sensor for weight measurement, an ESP32 microcontroller with a WiFi module for seamless data transmission, and an intuitive web-based interface for monitoring and control. Powered by solar energy, the system emphasizes the integration of renewable energy in aquaculture. The research involves designing the system's mechanical, electrical, and software components to create a practical and accessible tool for farmers. Field trials on catfish farms assess the system's performance in terms of accuracy and efficiency, comparing it to conventional manual weighing methods. This innovation aims to boost operational efficiency in aquaculture while contributing to the adoption of sustainable and intelligent farming technologies.

Keywords: Automatic Weighing System; Catfish Farms; ESP32; Internet of Things; Renewable Energy Systems

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1. INTRODUCTION

In the digitalization era, efficiency and automation in the livestock sector are crucial to enhancing productivity and reducing operational costs. In the context of catfish farming, manual fish weighing is often time-consuming, inaccurate, and stressful for the fish, which can negatively impact their health and growth. However, IoT-based automatic weighing systems are still rarely implemented in this industry, despite the technology's potential to improve accuracy, efficiency, and real-time monitoring [1]. Therefore, this research focuses on the design and evaluation of an IoT-based automatic weighing system that can be applied in catfish farming to support the concept of smart aquaculture. Through the development of this system, it is expected to provide a significant and practical solution to these challenges and support digital transformation in the aquaculture sector.

Several studies and developments serve as literature for this research. The first study was used the theory of weight measurement with load cell sensors and automation concepts using Arduino. The experimental method involved integrating a load cell sensor with a microcontroller, with data analysis using specialized software. The results showed a weighing accuracy with an average error of 0.66 grams, and the weighing process time was significantly reduced compared to the manual method. The researcher concluded that load cell sensors are effective in automatic weighing systems in aquaculture. Further development focused on IoT integration to improve efficiency and real-time monitoring [2].

The second study explored the theory of IoT in monitoring systems using wireless network concepts for data transmission. The methods, analysis, and approach involved hardware and software development, resulting in IoT implementation that enables real-time fish weight monitoring with high data accuracy[3]. The third study used a case study and experimental approach to examine the use of solar panels to increase energy efficiency through the aerator system in catfish ponds [4].

These studies underscore the need for comprehensive solutions that combine IoT and renewable energy to enhance operational efficiency and sustainability in catfish farming. However, no research to date has holistically addressed these elements. Specifically, there is a lack of studies focusing on the design, implementation, and evaluation of IoT-based automatic weighing systems powered by renewable energy. This research aims to bridge these gaps by developing and evaluating a solar-powered IoT-based weighing system tailored for catfish farming. By addressing inefficiencies in manual weighing and leveraging IoT for real-time monitoring, this study seeks to advance the concept of smart aquaculture.

This research involves the implementation and evaluation of an IoT-based automatic weighing system powered by solar energy, measuring its impact on the efficiency and accuracy of catfish weighing at farms. The goal is to provide a more efficient and accurate tool for catfish farmers to conduct weighing, ultimately enhancing productivity and profitability. Academically, this research adds to the literature and scientific knowledge in catfish farming, particularly in applying IoT and renewable energy technology in farm operations. By utilizing solar energy as the power source, this study also contributes to reducing fossil fuel usage, supporting renewable energy initiatives, and offering a more environmentally friendly solution.

2. RESEARCH METHOD

This research adopts a quantitative paradigm to systematically measure the performance of an IoT-based automatic catfish weighing device supported by renewable energy, specifically solar energy. The approach used is experimental with a case study conducted at several catfish farms in a specific region. This experimental approach allows for direct testing of the automatic weighing device's implementation in the field. A case study was chosen to gain an in-depth understanding of the device's use in the practical context of catfish farming. This study uses a case study and experimental approach to evaluate the effectiveness and efficiency of an IoT-based automatic weighing system powered by solar energy in catfish farming. The case study is conducted to understand the specific context and field conditions at catfish farms. This approach involves in-depth interviews with farmers and direct observation to gather qualitative data on their experiences and perceptions of the new system. The experiment tests and compares the efficiency and accuracy of the automatic weighing system with the manual weighing method. Quantitative data will be collected through direct weight measurements of the catfish using both methods.

This research is planned to take place over three months, covering the preparation stage, field survey, implementation, data analysis, and reporting of research results. The research will be conducted at an individual catfish farm located in Sukodadi Village, Paiton District, Probolinggo Regency. The location was chosen based on accessibility and cooperation in our region. It faces operational challenges commonly encountered by other catfish farmers, such as improving time efficiency and ensuring accuracy during the fish weighing process. The features of this location enable the research findings to have broader applicability, especially for small- to medium-scale catfish farming operations in regions with similar conditions.

The data sources include quantitative data on the weight of the catfish measured using both automatic and manual weighing systems, as well as the time required for each method. The primary data sources are the catfish farmers, as well as the devices and equipment used in the automatic weighing system. This research follows a series of systematic stages to ensure effective and accurate data collection, processing, and analysis. The following outlines the scenario and stages of this research. This study is anticipated to provide practical solutions that are not just relevant to the immediate research location but also contribute to the wider adoption and development of smart aquaculture systems.

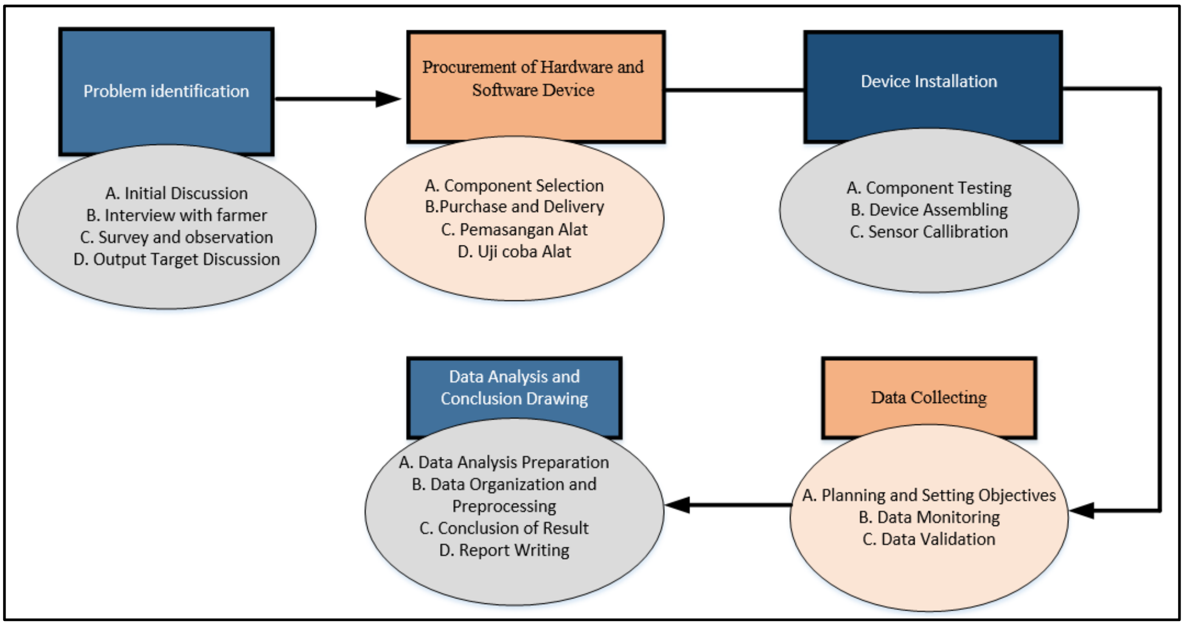

Figure 1. Stages of Research

The design of automatic weighing device includes mechanical, electrical, and software aspects, using an ESP32 as the microcontroller to compute data read by the load cell. The load cell needs to be calibrated to obtain an accurate reference value, ensuring precise weighing results. When an object is placed on the scale, data is sent to the ESP32 for processing. Through the WiFi module, the ESP32 sends the information to the Blynk application on a smartphone or PC connected with the appropriate network and token. The mechanism of the device's operation is illustrated in the following flowchart:

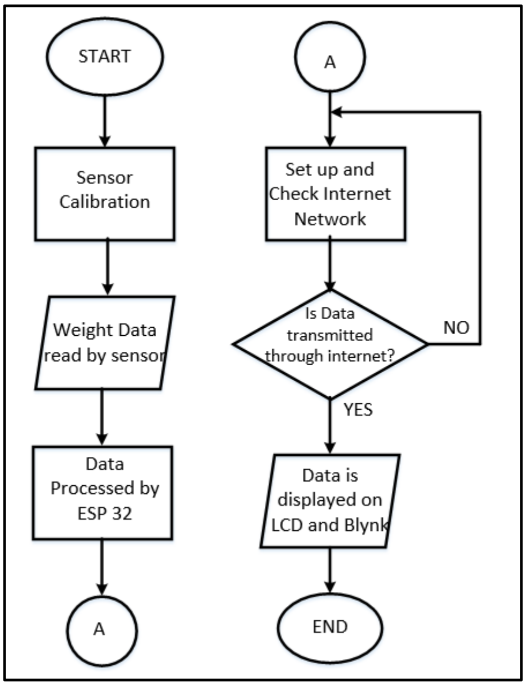

Figure 2. Automatic Weighing System Flowchart

The flowchart starts with the calibration of the load cell sensor to ensure accurate and reliable weight measurements. Once the calibration is complete, the system reads the weight data of the catfish using the load cell sensor. This data is then processed by the ESP32 microcontroller, which prepares it for transmission. After processing, the system proceeds to set up and verify the internet connection to ensure that the ESP32 can communicate with the cloud platform. If the internet connection is successfully established, the processed data is sent to the Blynk platform for monitoring and storage, and the process is completed. However, if the internet connection fails, the system loops back to the setup and connection verification step to attempt reconnection. This process continues until the data is successfully transmitted to Blynk.

3. RESULTS AND DISCUSSION

3.1. Design of System

After concluding the problem analysis, the researcher proceeded to the system design stage. This system design includes planning the hardware and software required to develop an IoT-based automatic catfish weighing tool powered by renewable energy. The components used in the design of this tool are listed in Table 1 below:

Table 1. Table Supporting Hardware

Component	Details	Purpose
Modul Load Cell	Max load = 10 kg Voltage source= 5-10 V	Weighing Detector
Modul ESP32	Voltage source= 5-10 V	Controller system
Solar Cell	25 WP 9 (400 x 350 x 25 mm) 17 -18 Volt 1.39 – 1.47 Ampere	Sunlight to electrical power converter
Modul SCC	MPPT Controller 5A 12V 100 x 70 x 30 mm	controller solar cell
Jumper Cable	Female to female	Wiring Device
Box Panel	15 x 10 x 5 cm	Where to store all electrical components
Battery	Lead-Acid 12 V	Energy Storage
Handphone	Connected to the same internet network as the ESP32	Monitoring Display

3.2 Electrical Design

At this stage, all electronic components, such as the weight sensor (load cell), solar cell, SCC, and ESP32 microcontroller, are assembled into one integrated system. This circuit is placed in a panel box to protect components from external weather conditions. Figure 3 shows the electrical circuit of the sensor and microcontroller. Meanwhile, Figure 4 shows the solar cell wiring process in the system. The IoT-based weighing system components, including the load cell, microcontroller, and data transmission module, were installed at the designated test site in a catfish farming environment The load cell was calibrated using standard weights to ensure accuracy and reliability. This step involved placing known weights on the platform and adjusting the calibration factor in the software.

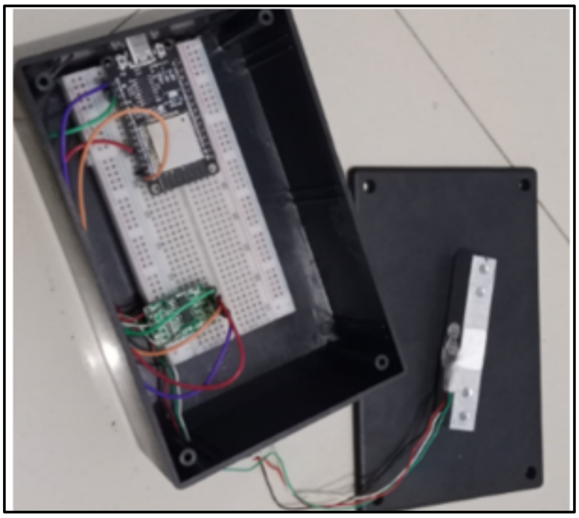

Figure 3. Electrical Component Assembly

Figure 4. System Assembly with Solar Cell

3.3. Software Design

The software design aims to program the automation of the catfish weighing process and make it easier to send data in real-time to a cloud-based platform. This system is integrated with the Blynk application to monitor data from sensors which is processed by the ESP32 and sent to the farmer's cellphone. By utilizing renewable energy, this system can operate independently in the field, supporting environmental sustainability by using environmentally friendly energy. Software implementation is carried out via the Arduino editor which is uploaded to the ESP32. The results of the software design are shown in Figure 5.

```
const char* password = "123456789";
const char* serverName = "http://example.com/datareceiver"; // Ganti dengan URL end
// Definisikan pin CLK dan DOUT untuk HX711
const int DOUT_PIN = 21;  // Pin DOUT dari HX711 dihubungkan ke pin GPIO 21
const int CLK_PIN = 22;   // Pin CLK dari HX711 dihubungkan ke pin GPIO 22

HX711 scale;

void setup() {
  Serial.begin(115200);
  scale.begin(DOUT_PIN, CLK_PIN);
   Serial.begin(115200);

  // Koneksi ke jaringan WiFi
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");

  sendDataToServer();
}


void loop() {
  // Baca nilai timbangan dari sensor
  float weight = scale.get_units(10); // 10 adalah jumlah pembacaan rata-rata yang

  if (isnan(weight)) {
```

Figure 5. System programming using Arduino IDE

3.4. System Implementation and Testing

After all components are assembled and software is installed, the system is tested in the laboratory and then implemented in the field to measure the accuracy of the tool. The measurement results using an automatic weighing tool are compared with conventional tools, as shown in the following table:

Table 1. Components of Automatic Catfish Weighing Equipment and Their Functions

The weight of the scale is read on the cellphone dashboard (gram)	Manual Scale Weight (gram)	Percentage error (%)
510	500	2%
1011	1000	1.1%
1513	1500	0.86%
2016	2000	0.8%
2516	2500	0.64%
3019	3000	0.63%
3020	3500	0.57%

Based on the table above, the highest error percentage is found in the first trial, which is 2%, and the lowest error percentage is found in the seventh trial, with a value of 0.57%. Based on the error percentages above, the average error percentage of the weighing experiment results can be determined using the following equation:

$$\bar{\bar{x}} = \frac{A}{B} \tag{1}$$

Where X represents the average error, A is the total sum of all error values, and B is the number of trials. Based on the equation above, it can be seen that the average error result after 7 trials is 0.82%.

3.5. Implementation and Evaluation Results

The implementation results show that this IoT-based automatic catfish weighing tool has succeeded in meeting farmers' needs to obtain accurate and real-time data. Data sent directly to mobile phones via the Blynk application makes it easier for farmers to monitor catfish weight developments and sales management. Based on the evaluation results, this tool is very helpful in the catfish cultivation process, with a low error percentage and uses environmentally friendly energy. The implementation of the entire system can be seen in Figure 6.

Figure 6. Overall System Implementation

4. CONCLUSION

This research has demonstrated the successful development of an IoT-based smart catfish weighing system powered by renewable energy, offering highly accurate and real-time measurements. The system effectively addresses critical challenges faced by catfish farmers, particularly improving the efficiency of the weighing process and enhancing data management for cultivation. Its implementation significantly benefits farmers by boosting productivity, optimizing operational efficiency, and promoting the adoption of eco-friendly technologies in the aquaculture sector.

The primary contribution of this system lies in its ability to integrate automation, real-time data processing, and sustainability, setting a foundation for smart aquaculture practices. However, this study also identified limitations, such as the need for regular maintenance and the potential challenges faced by users with limited technical expertise. This research also revealed several limitations, such as the need for regular maintenance and potential technical obstacles for users with limited technological knowledge. For this reason, it is recommended that further research focus on improving operational and maintenance guidelines that are easier for farmers to understand and apply. By continuing to refine and expand this technology, it has the potential to make a significant impact on improving the efficiency, sustainability, and overall success of catfish farming, paving the way for advancements in smart aquaculture.

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