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IoT-Enabled Automatic Sugar Filling Device with Weight-Based Control

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Abstract

In the era of Industry 4.0, efficiency and automation in production processes have become essential, particularly in the food sector. Manual sugar filling processes have several limitations, such as inaccurate measurements and reliance on human labor. Therefore, this study developed an automated sugar filling system based on the Internet of Things (IoT) with selectable doses of 500 grams, and 1 kilogram. The system is designed using an ESP32 microcontroller, a load cell sensor integrated with the HX711 module, servo and DC motors, as well as infrared and ultrasonic sensors. The device's data can be monitored in real time via the Blynk application on a mobile device. Testing results show that the system is capable of automatically dispensing sugar with high accuracy and can notify users when the sugar stock in the hopper is low. This system is expected to enhance the efficiency and effectiveness of sugar filling processes, particularly for small-scale industries or household applications.

Keywords: *Automation, IoT, ESP32, load cell, sugar filling, Blynk*

1. Introduction

In the era of industry 4.0, the application of automation technology and the Internet of Things (IoT) is growing rapidly in various fields, including in the food industry sector. One process that is often done manually and requires higher efficiency is the process of filling raw materials such as sugar. Manual sugar filling has several disadvantages, including inaccurate measurements, dependence on human labor, and potential delays in the production process. This is especially evident on a home industry scale that still uses traditional methods that take quite a long time[1].

The manual measuring process is usually done by putting the product into the packaging and then weighing it. If the weight is less than the net weight of the product, then it will be added. While if the weight exceeds the net weight, then the product will be reduced. This process certainly adds time to packaging and can reduce production efficiency [2]. The more an item is needed, such as staple foods, the faster production is required and able to keep up with needs.[3].

By utilizing automation technology, the sugar filling process can be done automatically and more precisely. The addition of the IoT system allows the device to be monitored and controlled remotely, making it easier for users to control the filling process and find out the status of the device in real time via mobile devices. The Internet of Things itself can be defined as the ability of various devices that can be connected and exchange information and data via the internet network. This technology is very useful because it can be used as a control, communication, or data exchange tool efficiently.

This IoT-based automatic sugar filling device is designed using several main components such as an ESP32 microcontroller, a weight sensor (load cell), a drive motor, and a connection to a mobile application. This system allows the filling process to be carried out automatically according to the specified weight, and provides a notification if the amount of sugar is less than the threshold. In addition, this device provides three weight options to users, namely 1 kilogram, ½ kilogram[4].

Sugar is a staple food that is very necessary for the people of Indonesia. Therefore, the development of an IoT-based automatic sugar filling device is expected to increase efficiency and accuracy in the sugar packaging process, especially in small-scale or household industries. The application of IoT technology also opens up opportunities for further innovation in automatic system monitoring and maintenance.

2. Research Methodology

This study uses an experimental method with a comparative approach to transmit the level of accuracy of an IoT-based automatic sugar filling system using a load cell sensor (with the HX711 module). The filling system is controlled by an ESP32 microcontroller and is designed to fill sugar into a container based on a specified weight. The load cell sensor is placed under the container to detect the weight of sugar entering during the filling process. The sugar flow is controlled by a servo motor that opens and closes the sugar delivery valve. The entire system is controlled by the ESP32 which will automatically stop the filling process when the sugar weight reaches the set target, for example 500 grams or 1000 grams.

During the process, weight data is displayed in real-time via the Blynk application and is also recorded via the Serial Monitor. This system is connected to the IoT platform using the Blynk application, so users can unify the filling status and get notifications directly via their smartphones. Testing was carried out five times for each target weight to obtain average data and produce consistency and accuracy of the load cell sensor in the filling process. The level of sensor accuracy is calculated using the absolute error formula as follows:

$$\%Eror = \frac{nilai\ Sensor - nilai\ Aktual}{Nilai\ Aktual} x100\%$$

2.1. Block Diagram

The image shows a block diagram of an automatic sugar filling system. The block diagram describes the system flow from input, process, to output.

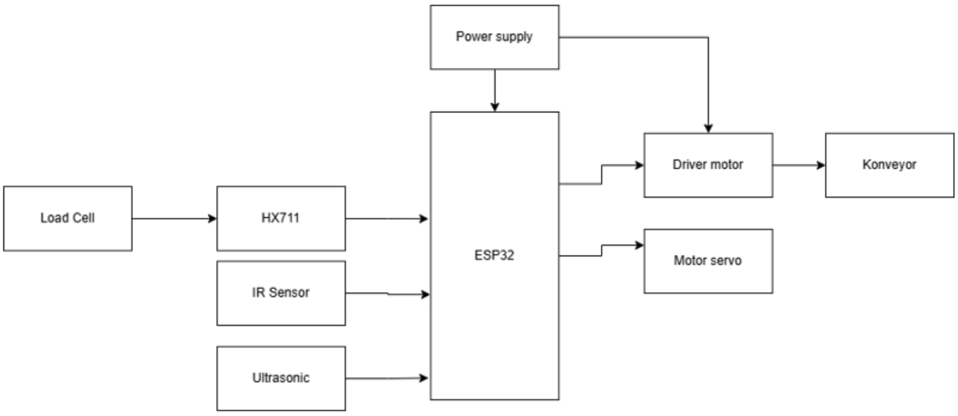

Fig. 1: The block diagram of an automatic sugar filling system

The block diagram shows an automatic sugar filling system controlled by ESP32. The power supply supplies power to all components such as motors, drivers, and sensors. The load cell with HX711 module measures the weight of sugar, the IR sensor detects the position of the container, and the ultrasonic sensor monitors the sugar stock. The ESP32 controls the servo motor to open and close the channel and control the conveyor. The system is connected to the Blynk application via IoT, allowing real-time remote monitoring and notification. The system will stop working automatically once the position of the container is detected by the IR sensor at the end of the conveyor.

2.1. Electronic design

Electrical design is an important stage in the development of an automatic sugar filling system, which involves arranging the connections between electronic components and sensors.

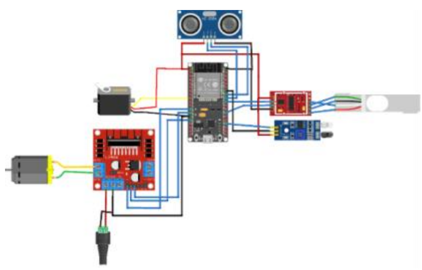

Fig. 2: The electronic circuit of the automatic sugar filling system

The figure above shows the electronic circuit of the automatic sugar filling system based on ESP32. This system uses a 12V power source that is reduced to 5V through a step-down module to supply power to the ESP32 and various sensors. The HC-SR04 ultrasonic sensor is used to connect the sugar level in the storage container, helping the ESP32 detect when the sugar stock is running low. An infrared (IR) sensor is used to ensure that there is a container on the conveyor before the filling process begins. Sugar weight measurement is carried out in real time using a 5 kg strain gauge type load cell connected to the HX711 module. This load cell has a maximum capacity of 5 kg with a sensitivity of around 1.0 ± 0.15 mV/V, an input impedance of around 1,000 Ω, and high accuracy class C3. This load cell is usually made of aluminum alloy and is able to detect weight changes with precision up to ±0.01 kg, making it suitable for filling applications such as sugar. A servo motor is used to control the opening and closing of the filling line, while a DC motor controlled through the L298N driver drives the conveyor so that the container moves automatically.

2.3. Mechanical Design

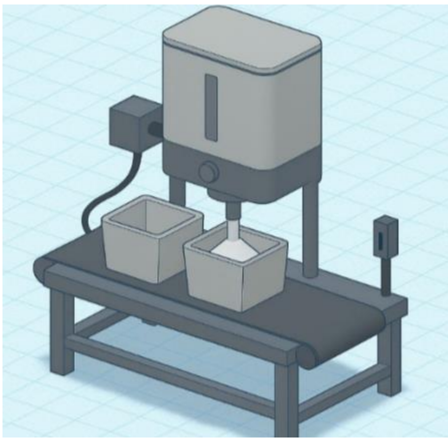

Fig. 3: The main mechanical design

The main structure of the tool consists of a lightweight acrylic or aluminum frame that functions as a support for all components. At the top there is a box-shaped sugar storage container (hopper) equipped with a discharge valve controlled by a servo motor. This valve opens automatically when the filling process begins and closes when the dose is reached. Under the hopper, there is a storage container placed on a 5 kg load cell, which is stably mounted on a stand to ensure accurate weight readings. On the side of the hopper, an HC-SR04 ultrasonic sensor is installed that points into the storage container to combine high sugar and provide stock information to the ESP32 microcontroller. At the bottom of the system, there is a mini conveyor driven by a DC motor and controlled using the L298N motor driver. At the end of the conveyor, an infrared (IR) sensor is installed to detect the presence of the container before the filling process begins. All sensor and motor cables are neatly arranged using cable ducts and connected to the ESP32 main control board.

3. Results and Discussion

Testing was conducted to evaluate the performance of load cell sensor readings in an ESP32-based automatic sugar filling system. Two filling targets were used, namely 500 grams and 1000 grams. Each test was carried out five times, and the sensor reading results were compared with the actual weight measured using a digital scale as a comparison. Data from the load cell is recorded via the Serial Monitor during the filling process. The load cell sensor measures the weight of sugar in real-time as the sugar flows into the container. When the weight reaches the target, the ESP32 automatically stops filling by controlling the servo motor that opens and closes the sugar path. This test aims to see the level of accuracy and consistency of the load cell sensor readings compared to the actual weight, so that the system can be assessed for its performance in filling sugar accurately and automatically.

Table 1: Sensor Test Results on 500 g Target

Percobaan	Nilai aktual	Loadcell	Error (g)	Eror (%)
1	498	473	25	5.02
2	502	497	5	1.00
3	495	484	11	2.22
4	500	498	2	0.40
5	497	496	1	0.20
	Rata rata error		8.8	1.77

Table 1: Sensor Test Results on 1000 g Target

Percobaan	Nilai aktual	Loadcell	Error (g)	Eror (%)
1	998	973	25	2.51
2	1003	1028	25	2.49
3	997	1037	40	4.01
4	1005	1025	20	1.99
5	1002	1027	25	2.50
	Rata rata Error		17.0	2.40

Based on the test results of the load cell sensor on the ESP32-based automatic sugar filling system, the error value obtained is still within the tolerance limit for both filling targets, namely 500 grams and 1000 grams. For the 500 gram target, the average sensor reading error is 8.8 grams or equivalent to 1.77%. Meanwhile, at the 1000 gram target, the average error increases to 17.0 grams or 2.40%.

Although there is a slight increase in error at a larger filling weight, the system still shows fairly good and stable accuracy. This shows that the load cell sensor is suitable for use in an automatic filling system because it is able to provide consistent readings and can be controlled in real-time. Thus, this automatic sugar filling system is considered efficient, accurate, and suitable for use in the IoT-based automatic sugar filling process.

4. Conclusion

This study successfully developed an IoT-based automatic sugar filling device utilizing an ESP32 microcontroller and a load cell sensor with HX711 module. The system was designed to dispense sugar in predefined weights of 500 g, and 1000 g, with real-time monitoring and control capabilities via the Blynk mobile application.

Experimental results demonstrated that the system operates with a high level of accuracy. For the 500 g filling target, the average error was 1.77%, while for the 1000 g target, the average error slightly increased to 2.40%, which remains within an acceptable tolerance range for small-scale applications. These findings confirm the reliability and consistency of the load cell sensor in automated filling tasks. Overall, the implementation of this device significantly enhances the efficiency and accuracy of the sugar filling process, making it particularly suitable for household or small-scale industry use. Furthermore, the integration of IoT technology enables real-time system monitoring and opens avenues for future improvements in automated process control and maintenance.

Errors in weighing using load cells can occur due to several factors, both technical and environmental. One of the main causes is mechanical interference, such as a load that is not placed exactly in the center of the sensor surface, which causes uneven force distribution and results in inaccurate weight readings. In addition, electrical interference such as noise in analog signals, voltage fluctuations, or unstable cable connections can also affect the reading results of the HX711 module connected to the load cell.

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