JURNAL INFOTEL
VOL. 16, NO. 3, AUGUST 2024, PP. 660–677. DOI:10.20895/INFOTEL.V16I3.1168

RESEARCH ARTICLE

Design and Implementation of Home Industrial-Based Automatic Granulated Food Weighing Machine

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Received: April 16, 2024; Revised: August 8, 2024; Accepted: August 19, 2024.

Abstract: Automation activities are now essential in manufacturing processes. This can lead to significant improvements in efficiency and effectiveness, especially for industries requiring precise standards, such as the granulated food product industry. Fast, sanitary packaging processes and consistent weight are key priorities in this sector. While automated weighing systems are common in established industries, they remain a significant hurdle for traditional processes, particularly in small and medium-sized businesses. This study proposes the development of a prototype weighing mode that can maintain the weight accuracy of powder materials (sugar, rice, and coffee) before they are placed in product packaging. The research employed the experimental method, utilizing a load cell sensor and a screw conveyor to precisely measure the weight of powder raw materials based on the user-specified size and parameters. It is also equipped with a data deviation memory. Some testing was conducted to ensure the accuracy of the prototype. Based on the test results, this system can work with an accuracy rate of 99.693% at parameters 120 grams and 99.677% when testing the weight of powder raw materials of 120 grams, 125 grams, and 175 grams, respectively.

Keywords: automation, granulated filling machine, load cell sensor, weighing machine

1 Introduction

Automation activities in the production process have become indispensable, enabling companies to execute production tasks swiftly and precisely, thereby enhancing their market competitiveness [1,2]. The increasingly fierce business competition requires that every line of business carry out automation processes that can save production costs and speed up

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processes so that companies can compete [3–5]. However, increased productivity necessitates a corresponding increase in capacity or efficiency. In general, enhancing productivity involves balancing cost, quantity, and quality [6, 7]. Even though the automation process can reduce operational costs in the long term, it is undeniable that the initial investment cost is quite significant, which is still an obstacle, especially in medium- to lower-scale industries [8].

Companies that manufacture packaged products require a product packaging system capable of accurately weighing the product before its packing. Operators still perform the weighing process manually, which can lead to several issues such as uneven product weight (either too low or too high), prolonged processing times, and even waste of packaging material due to reprocessing rejected products. Automated machines can save time and reduce waste, resulting in better resource utilization and giving entrepreneurs a competitive advantage [3]. However, machines capable of supporting the production process, as well as checking weight automatically, are still expensive and not affordable for small and medium-scale businesses.

This issue has been discussed by several previous researchers. In 2017, the authors [9] made a flexible automatic bottle-filling machine using Arduino Uno. This machine uses a type of liquid as its input and is capable of producing an output of 600 bottles per hour. Some granulated filling machines introduced in the market, particularly for powders, are fairly sophisticated. For example, the design of granulated filling machines in the form of volumetric cup Fillers [10]. This kind is easily accessible on the market, however, due to its high cost it is not appropriate for home industrial usage.

This study aims to complement previous studies by proposing a prototype that measures product weight accurately and suitably before packaging, while also incorporating packaging functions. The authors built this work using 3D design concepts, weighing modes, and several components such as DC motors, infrared sensors, servo motors, ultrasonic sensors, and motor drivers, all under Arduino control.

2 Research Method

2.1 Proposed System Design

Figure 1 depicts a flowchart of the research framework. The research begins with a literature review, followed by hardware and software system design, system testing with trial and error, data gathering and analysis, and finally, a conclusion. As described in Figure 2, the system is made up of three sub-systems: input, processing, and output. The input subsystem employs several components, including an HX711 amplifier, a load cell sensor, an infrared sensor, a push button, and a DC motor driver L298N. The Arduino's function is to control each component to function correctly.

The command will be sent to the output subsystem, which includes an LCD 16x2, a DC motor 795, an LED, and a servo motor SG90. Arduino will execute the command based on the trigger input it processes. Information from the system is displayed on the 16x2 LCD. In this work, the DC Motor 795 acts as an actuator, controlling the speed of a screw conveyor as it moves through a row of powder-type materials and into the weighing hopper.

The SG90 servo motor is a small and low-cost amateur servo with a lightweight motor capable of precise rotation. It operates by receiving a pulse width modulation (PWM) signal from a microcontroller, with a duty cycle of 600s to 2400s (measured) and a total period of

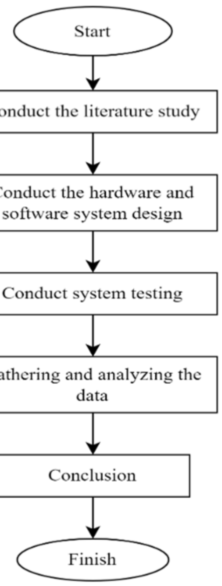

Figure 1: Research framework flowchart.

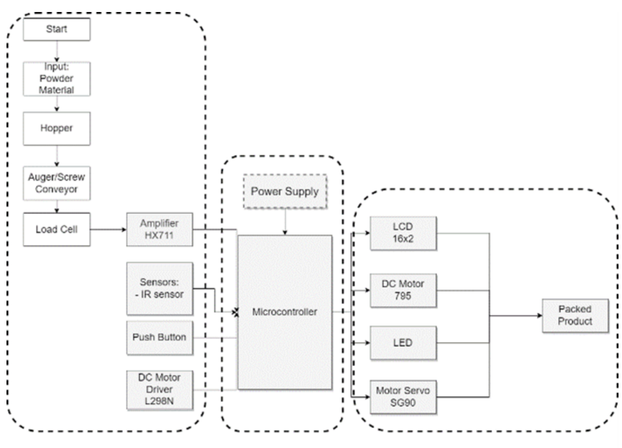

Figure 2: Block diagram of the system proposed.

20 ms (50Hz) [11]. The duty cycle of the PWM signal determines the position of the servo motor. A series of pulses with a fixed frequency and variable duty cycle make up PWM signals. The servo motor will rotate to its minimum angle when the PWM signal has a duty cycle of 5%. When the duty cycle is 10%, the motor will rotate at a slightly higher angle, and so on, until it reaches a maximum angle of around 180 degrees at a duty cycle of 10% [12].

In this work, the SG90 servo motor is an actuator that acts as a weighing hopper cover, preventing raw material transferred by the screw conveyor from falling directly into the packaging. This raw material holding process is required because the load cell sensor weighs raw material in the weighing hopper. The servo motor will receive a trigger from the input after determining the appropriate amount of weight to release or pour raw material into the packing. The proposed system's flowchart is depicted in Figure 3. It starts with system initialization and then configures both wiring and programming. The system prompts users to enter the parameters for use. The specific parameters will limit the system's desired data. The system will use these parameters to calculate the maximum weight it can process. Once the system is ready, it will prompt the user to run the product and instruct them to enter the raw material into the prototype.

The IR sensor will detect whether the packaged material, which will house the final material, is in the correct position. The system will begin to operate, and the Auger or Screw Conveyor will rotate to transfer raw material into the weighing hopper. Once the raw material is placed in the weighing hopper, the system will operate by using the load cell sensor to read the weight of the accommodated raw material. The system will perform a weighing operation by determining whether the weight of the raw material matches the stored parameters, followed by determining whether the packed material that will accommodate the finished material is in the proper position. If yes, the servo motor will open the line, allowing the raw material to fall into the pack; if no, the servo motor will close the hopper line, allowing the raw material to be accommodated by the hopper; and the flowchart stage will end.

2.2 Design of Automatic Granulated Foods Weighing Machine

The proposed prototype was designed using Autodesk Fusion 360 software to produce a three-dimensional model. This model was then physically constructed via 3D printing, with measurements of 20 cm $\times$ 20 cm $\times$ 47.7 cm. The design shos in Figure 4 and Figure 5.

2.3 Wiring Diagram of Automatic Granulated Foods Weighing Machine

The DC motor housing, weighing hopper, and auger or screw conveyor are the main components of this system. The wiring diagram describes the overall hardware implementation and how each element is connected, as in Figure 6.

2.4 Powder Filling Machine

A powder-filling machine is a vertical form-filling machine that fills powdered material into sachets with an even weight distribution [13]. The powdered material will first be accommodated in a large hopper before being transferred into the sachet via a screw conveyor equipped with a sensor that detects when the empty sachet is in the specified position. The

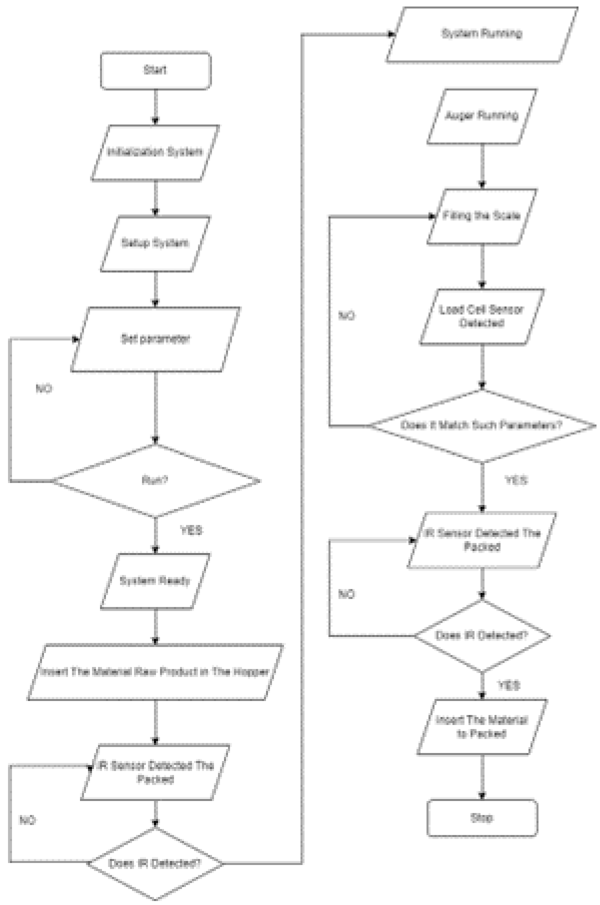

Figure 3: Flowchart of the system proposed.

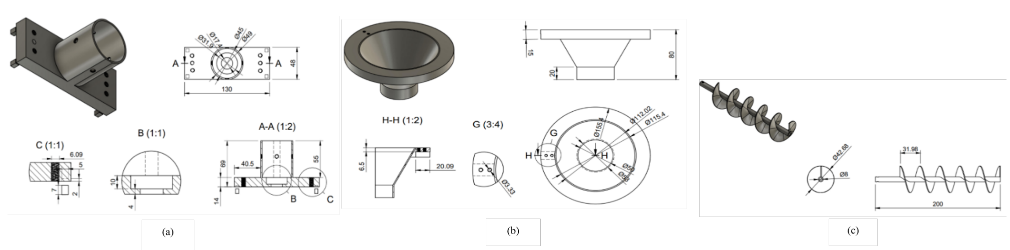

Figure 4: Main parts of automatic granulated food weighing machine: (a) dinamo house; (b) weighing hopper; (c) screw conveyor.

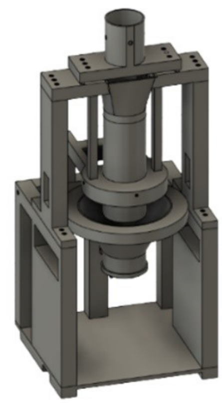

Figure 5: 3D Design of the proposed system.

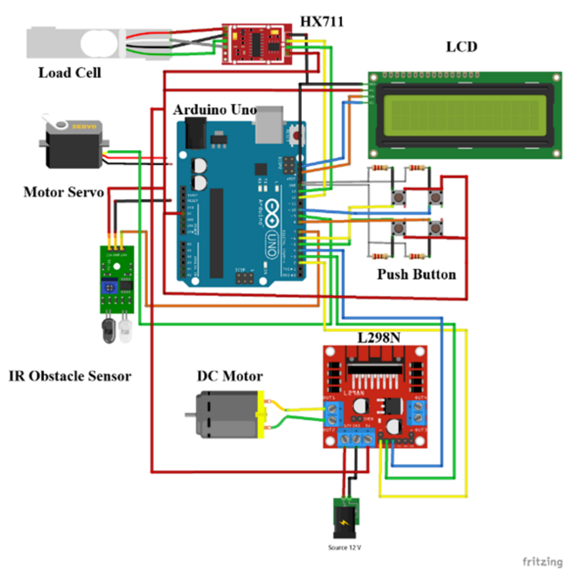

Figure 6: Schematic design of automatic granulated food weighing machine.

machine then fills the empty sachet with a timer system to determine the charging time. Figure 7 shows an example of a filling machine for powder material.

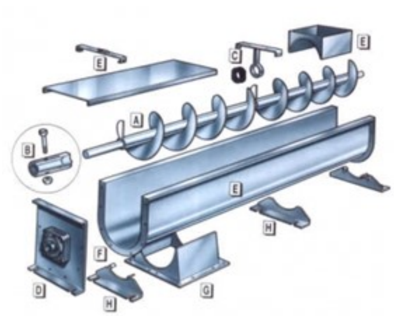

Figure 7: Filling machine [14].

2.5 Screw Conveyor

A screw conveyor, or auger conveyor, is a mechanism that moves liquid or granular materials by rotating helical screw blades, usually within a tube [15], as described in Figure 8. Screw conveyors deliver semi-solid materials such as food waste, wood chips, aggregates, cereal grains, animal feed, boiler ash, meat and bone meal, municipal solid waste, and much more. The most common type of screw conveyor is the horizontal screw conveyor. The horizontal screw conveyor transports bulk items from one section of a process to another [16]. Industries such as minerals, medicines, agriculture, chemicals, cement, sand, and food processing primarily use it for moving and mixing granular materials [17, 18].

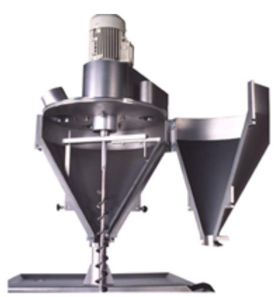

Figure 8: Screw Conveyor [**?**].

2.6 The Load cell Sensor

A load cell is a sensor that converts an applied load, force, or weight into an electronic signal [19, 20]. This electronic signal can be a current change, voltage change, or frequency change, depending on the type of load cell and circuit used. Load sensors employ the piezo-resistivity principle. When a load, force, or stress is given to the sensor. Three types of load sensors exist resistive strain gauges, capacitive load cells, and piezoelectric load cells. The most common type of load sensor is a resistive strain gauge, which attaches a thin metal foil to a flexible backing material [21]. Strain gauge load cells work on the premise that when the load cell's material deforms properly, the strain gauge (a planar resistor) deforms as well. The electrical resistance of a strain gauge varies proportionally to its deformation. The resistance change of the strain gauge produces an electrical value change that is enumerated as the weight applied to the load cell.

2.7 HX711 Amplifier

The HX711 is a precision 24-bit analog-digital (ADC) converter intended to interface directly with bridge sensors in weighing scales and industrial control applications [22]. A micro controller can read the digital values that this component amplifies and converts from load cell or strain gauge output signals. It has two differential analog inputs, A+ and A-, for connecting to load cells or strain gauges, and it uses a 24-bit analog-to-digital converter (ADC) to convert the amplified analog signal into a digital signal with high precision and resolution. When a weight is applied to the load cell, it produces a small electrical signal that is proportional to the weight. The HX711 amplifier communicates with the micro controller through a two-wire serial interface. Before reading the digital output, the micro controller instructs the HX711 amplifier to set the gain and output data rate.

2.8 The IR Sensor

Electronic devices known as IR (infrared) sensors detect and measure the intensity of infrared radiation that objects emit. Typically, it consists of an infrared emitter, which emits infrared radiation, and an infrared detector, which detects the radiation and converts it into an electrical signal. The sensor absorbs or reflects some of the emitted infrared radiation when an object passes in front of it, enabling the infrared detector to detect it. The working principle of an IR sensor can vary depending on its specific design and application. In general, IR sensors work by interacting with infrared radiation and the material properties of the sensor components [23].

2.9 Servo Motor

DC servo motors are widely used to achieve precise power and position control. Furthermore, because of the low cost, exceptional control performance, and simple structure, Due to their low noise, energy efficiency, low manufacturing cost, quick reaction, torque-to-inertia ratio, small volume, and high accuracy, DC servo motors have proven useful for industrial motion control systems.

2.10 Arduino UNO

In this work, the Arduino UNO serves as the controller for the prototype filling machine. The authors use an Arduino Uno microprocessor to manage the sensor input and DC motor actuator, as well as generate output as needed. The first step in sending data is to assign a value to the load cell, which will then be transferred to the HX711 and read by Arduino. To operate the automation idea on the load cell, a tare system must be introduced to the software, and this system aims to preserve stability in the outcomes of the prototype. A tare function in the tare system reverses the received value to zero.

The suggested system has various advantages, including the use of several sensors to collect full information on material weight and presence, as well as its adaptability. The Arduino serves as the system's brain, providing precise control over each component, making it simple to design and adapt. Furthermore, the use of DC Motor 795 to drive the screw conveyor and an SG90 servo motor to cover the hopper demonstrates a thorough knowledge of the actuation requirements in the weighing process. The DC motor provides good speed control for material flow, while the servo motor allows for precision hopper opening and shutting. Finally, the existence of a 16x2 LCD gives the operator with valuable visual input, such as the material's weight. This improves usability and makes it easier to track the weighing process.

However, the use of load cells has limitations. The system's accuracy is heavily dependent on the quality and calibration of the load cell. Therefore, it is crucial to select a load cell with a capacity suitable for the weight range of the materials to be weighed. Furthermore, while the SG90 servo motor is affordable, it has limited torque. Overall, the proposed design, which employs appropriate components and precise control, is a major step toward an efficient and economical solution; nevertheless, for larger and widespread usage, the quality and specifications of some components must be improved.

3 Results

The prototype of the filling machine depicted in Figure 9 was created as part of this study. The dimensioning prototype is 20 cm x 20 cm x 47.7 cm and includes a DC motor actuator for moving raw material to the weighing hopper. The system is controlled by a control board made up of several integrated Printed Circuit Boards (PCB), with the main components being an Arduino Uno microcontroller, HX711 signal amplifier, LCD display with I2C module, infrared sensor, push button, servo motor, L298N motor driver, DC motor, load cell sensor, and a 12 Volt power supply.

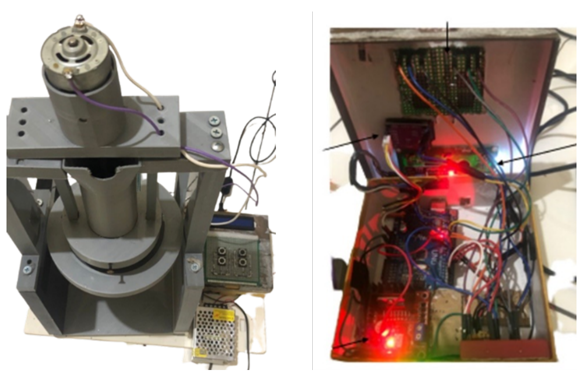

Figure 9: Automatic granulated food weighing machine and circuit board of the system.

Function testing must be done on each element of the proposed system to ensure system functionality. The tests include load cell sensor calibration tests, parameter set function tests, system performance tests, and general system testing. We provide the specifics of each test result in the following sub-chapters.

3.1 Load Cell Calibration

A load cell sensor's calibration factor (cal factor) is the number that adjusts or calibrates the sensor's output readings to the actual load it is measuring. The mechanical characteristics and geometry of the sensor determine the distinct cal factor of each load cell. To calibrate a load cell, one must identify and utilize the cal factor to determine the real load value based on the measured sensor output. This is critical for ensuring measurement precision and avoiding data interpretation errors. We accomplish the calibration of the load sensor through trial and error by varying the calibration factor and a known weight on the load sensor. The authors collected data five times while conducting calibration experiments. The material used in this testing is rice with different weights of 41 grams, 39 grams, 28 grams, 60 grams, and 45 grams, as shown in Table 1. The calibration factor is determined based on the data in Table 1 using the following formula:

$$\text{Average cal factor} = \frac{\sum \text{Average cal factor}}{\sum \text{Testing}} = 352.248$$

Table 1: Cal factor value from load cell calibration test result

Objects	Weight	Cal Factor
Granulated food (rice)	41 g	335.42
Granulated food (rice)	39 g	350.23
Granulated food (rice)	28 g	362.36
Granulated food (rice)	45 g	356.33
Granulated food (rice)	60 g	356.90
Average Value		352.248

From the calculation, it can be seen that the average calibration factor of this system is 352.248. Once the calibration factor has been found, it is used as the load cell sensor initialization value in the main Arduino code, as shown in Figure 10.

```
float calibration_factor = -352.248;
float grams;
```

Figure 10: Calibration initialization of load sensor.

3.2 Parameter Set Function Testing

The purpose of testing the function of the load cell sensor's set parameters is to ensure that the sensor works correctly and gives accurate load measurements. We use the calibration factor value from the previous test as a reference for the zero parameters. The zero parameter influences the sensor output reading when the sensor is not under any load. Inaccurate or unstable sensor output may result from improper adjustment of the zero parameters.

Therefore, the null test ensures that the sensor output remains zero in the absence of any load. The results given in Figure 11.

Figure 11: Set parameter testing.

3.3 System Performance Testing

The prototype filling machine's performance was tested to evaluate the functionality of the data storage system as well as the infrared sensor's object detection capability. In addition, the performance of the DC motor in operating the screw conveyor to move raw materials to the weighing hopper was evaluated. The infrared sensor's test findings demonstrate that it can detect raw material objects after passing through the weighing process. Meanwhile, the DC motor completed its work of moving raw materials to the weighing hopper shows in Figure 12.

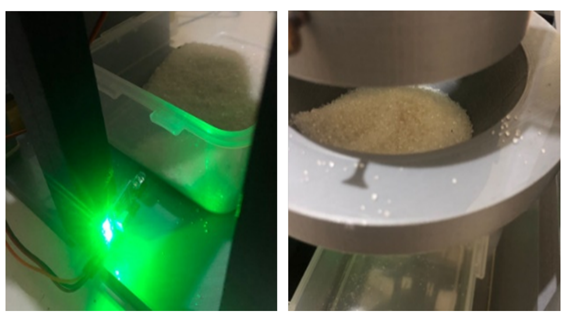

Figure 12: Set parameter testing: (a) IR-sensor testing; (b) DC motor testing.

The load cell test is performed to determine the overall weight of raw materials moved by the screw conveyor using a DC motor. The load cell test results will be adjusted based on the number of parameters set that have been previously specified. When the parameter group is active, data storage occurs. The load cell test findings can be displayed on the LCD, as shown in Figure 13.

Lastly, the next step is to check if the servo motor can open the weighing hopper lid and deposit the raw material into the container. According to the test findings, the servo motor can pour raw materials into the container, representing the desired conditions, as shown in Figure 14.

Figure 13: Load cell testing.

3.4 Overall System Testing

After each subsystem has been tested separately, a comprehensive evaluation of the system is performed. The purpose of this evaluation is to measure the performance of the system as a whole. Tests were conducted with granulated food raw materials at three different weight variations respectively 120 grams, 125 grams, and 175 grams, with ten repetitions for each weight variation.

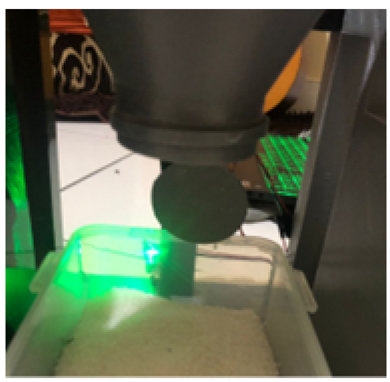

Figure 14: Servo motor testing.

The test data was then analyzed to calculate the percentage of system error. This calculation is based on the comparison between the weight measurement results obtained by the proposed system and the measurement results obtained using a digital scale as a reference:

$$\text{Error Value} = \left| \frac{\text{Sensor Value} - \text{Parameter Value}}{\text{Parameter Value}} \right| \times 100\%$$

The average error from the system's load cell sensor is calculated as follows:

$$\text{Average Error} = \frac{\sum \text{Error Value}}{\sum \text{Testing}}$$

Table 2: Testing with a parameter set =120 grams

Test	Set Parameter	Result Sensor	Status	Error (grams)
1	120.00 g	120.00 g	Success Filling	0.000
2	120.00 g	121.00 g	Success Filling	0.833
3	120.00 g	120.86 g	Success Filling	0.717
4	120.00 g	119.75 g	Success Filling	0.208
5	120.00 g	119.87 g	Success Filling	0.108
6	120.00 g	120.51 g	Success Filling	0.425
7	120.00 g	120.67 g	Success Filling	0.560
8	120.00 g	120.00 g	Success Filling	0.000
9	120.00 g	120.00 g	Success Filling	0.000
10	120.00 g	121.00 g	Success Filling	0.833
		Average		0.368

Table 2 demonstrates the result of the load cell data test table with a parameter set of 120 grams. According to Table 2, the obtained sensor values still have error values that do not match the previously set parameter set. As a result, here is an example of calculating the obtained error value.

$$\text{Average Error} = \left|\frac{\text{Sensor Value} - \text{Param Value}}{\text{Param Value}}\right| \times 100\% = \left|\frac{121-120}{120}\right| \times 100\% = 0.833 \text{ gr}$$

The average error calculation is carried out as follows:

$$\text{Average Error} = \frac{\sum \text{Error Value(set\_parameter)}}{\sum \text{Testing}} = 0.368$$

The calculation is done by changing parameter values to percent to get a value for the sensor accuracy level as follows:

$$\text{Average Error}(\%) = \frac{\text{Average Error(set\_parameter)}}{\text{Parameter Value}} \times 100\% = 0.307\%$$

$$\text{Accuracy rate}(\%) = 100\% - 0.307\% = 99.693\%$$

The calculations above demonstrate that the system can accurately measure the raw material with a 99.693% accuracy rate. Furthermore, the test was also performed with two different weights, 125 grams, and 175 grams, as shown in Table 3 and Table 4. The purpose of this test is to determine the prototype filling machine's capability to work continuously with various sample weights.

We perform calculations using the same formula for various raw material weights, using the same calculation technique as described in Table 3 and Table 4. Table 3 shows that the average error value (%) is 0.323% and the accuracy level is 99.677%, whereas Table 4 shows that the average error value (%) is 0.205% and the accuracy level is 99.795%. The weighing results obtained from the three calculations above, using raw materials with various weights, have an average error value of 0.307%, 0.323%, and 0.205%, respectively, indicating that the level of accuracy obtained from the results of each test is 99.693%, 99.677%, and 99.795%. The results of testing the function of each sub-system, as well as testing the system as a whole, show that the proposed system could function correctly, with an acceptable average error that ranges up to 0.323% and a level of measurement accuracy of

Table 3: Testing with a parameter set=125 grams

Test	Set Parameter	Result Sensor	Status	Error (grams)
1	125.00 g	125.00 g	Success Filling	0.000
2	125.00 g	125.00 g	Success Filling	0.000
3	125.00 g	126.00 g	Success Filling	0.800
4	125.00 g	125.55 g	Success Filling	0.440
5	125.00 g	125.88 g	Success Filling	0.704
6	125.00 g	124.97 g	Success Filling	0.024
7	125.00 g	124.00 g	Success Filling	0.800
8	125.00 g	125.98 g	Success Filling	0.784
9	125.00 g	124.60 g	Success Filling	0.320
10	125.00 g	125.00 g	Success Filling	0.000
Average				0.3872

Table 4: Testing with a parameter set=175 grams

Test	Set Parameter	Result Sensor	Status	Error (grams)
1	175.00 g	175.00 g	Success Filling	0.00
2	175.00 g	175.95 g	Success Filling	0.543
3	175.00 g	175.30 g	Success Filling	0.171
4	175.00 g	174.50 g	Success Filling	0.286
5	175.00 g	176.00 g	Success Filling	0.571
6	175.00 g	174.00 g	Success Filling	0.571
7	175.00 g	175.88 g	Success Filling	0.503
8	175.00 g	175.00 g	Success Filling	0.00
9	175.00 g	175.00 g	Success Filling	0.00
10	175.00 g	175.00 g	Success Filling	0.00
Average				0.265

99.722%. With such precision, the error rate remains within the tolerance limit, showing that the tool is functional.

4 Discussion

This study successfully designed and implemented a prototype automated weighing system for powdered raw materials (such as sugar, rice, and coffee) specifically targeting small and medium-sized firms (SMEs). The system uses a load cell sensor and a screw conveyor to accurately measure material weight based on user-defined parameters with a high degree of precision. This development is valuable for small and medium-sized enterprises operating in the food and beverage processing industry. By adopting precise and cost-effective automated weighing systems, SMEs can improve their production efficiency, ensure consistent product quality, and comply with increasingly stringent sanitation standards. These strategies can help SMEs enhance their market competitiveness.

The test findings, as mentioned in the results section above, show that there are two critical components in our design. First, regarding the hardware function, it is clear that the suggested automatic food-weighing machine can carry out the functions outlined in the initial design. Some of the functional tests performed include load cell sensor calibration testing, parameter set function testing, system performance testing, and general system testing.

The primary task is to estimate the load cell sensor calibration factor (cal factor), which will be used to calibrate or modify the sensor output readings to the actual load being measured. This is critical for ensuring measurement precision and avoiding data misinterpretation. The average calibration value of this system is 352.248 based on the load cell sensor calibration test results. Meanwhile, testing the load cell sensor parameter setting function ensures that the sensor works correctly and provides accurate load measurements. The test results reveal that the sensor's display indication, using the calibration factor value, displays zero parameters when no load applies. This null test result confirms that the sensor's output remains zero in the absence of a load. The goal of system performance testing is to demonstrate that the system can identify the whole weight of raw materials transmitted by direct current screw conveyors with the established parameters displayed in the data storage function.

The servo motor can open the weighing hopper cover and load the raw materials into the container; the IR testing barrier sensor can recognize the object in front of it; and the DC motor can travel in a circle and pass the raw materials into the storage vehicle, according to the test findings. After going through the weighing process, IR sensors were able to detect raw material objects. On the other hand, DC motors have been proven in Figure 13 to be capable of moving raw materials into the storage hopper. In the final test, we tested the material using 120 grams, 125 grams, and 175 grams. According to the test findings as described in Figure 15, the system could function successfully with an accuracy rate of 99.693%, 99.677%, and 99.795%. As a result, the proposed system has an average accuracy level of 99.722%.

From the analysis it can be seen that the novelty of the proposed system lies in several aspects, including (1) compact size to support household industries with smaller sizes; (2) ease of use and maintenance by non-technical users; and (3) this solution aims to develop a system with lower production costs than similar systems already developed by other researchers. the results show in Figure 15.

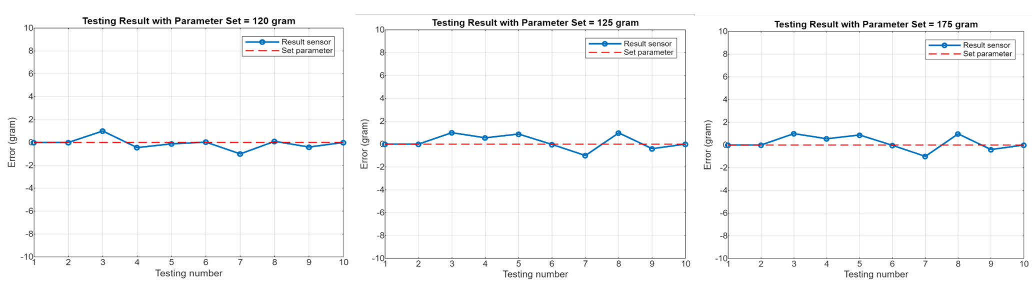

Figure 15: Error finding for testing results.

This study diverges from previous research in terms of its objective and methodology. Unlike past studies that utilized powdered materials enhanced the efficiency of the filling process, and aimed to reduce the time required for filling, weighing, and sealing by 60% to 80%. Similarly, in the study involving the filling of liquid containers, a time-based control system is utilized, capable of filling at a rate of 67 ml per second. This study primarily examined the precision of the measurement outcomes, resulting in an accuracy with an average level of 99.722%. However, this prototype has a limited scope because it only tests three types of powdered raw materials (sugar, rice, and coffee) and their weight changes. Certain constraints that require further improvement in the future, including its limited adaptability, which is less able to adapt to changes in operating conditions, such as variations in raw material characteristics (e.g., differences in size, density, or humidity) or external disturbances (e.g., vibration or temperature changes). This skill is critical in practical systems. As a result, fuzzy or SMO approaches can be used to address this issue.

The current suggested system may be greatly enhanced by including a more advanced control system. Control systems such as PID, Fuzzy, and SMO can increase the flexibility, stability, optimization, and accuracy of automated grain weighing systems, resulting in better and more consistent performance under a variety of operating situations. Furthermore, fuzzy adaptive control systems can eliminate the requirement for human calibration by learning from operational data and automatically adjusting the control parameters.

5 Conclusion

A prototype of a home industrial automatic granulated food weighing machine has been completed based on the results of design and testing. Each sensor was used according to its intended function. Load cell sensor testing provided parameter data for three parameters (120, 125, and 175 grams), all of which worked accurately. The load cell sensor has an accuracy of 99.693% at parameter 120 grams, 99.677% at parameter 125 grams, and 99.795% at parameter 175 grams. On average, the level of measurement accuracy was 99.722%. Furthermore, the prototype filling machine can operate continuously with precision suitable for real-world applications. For future advancement, further trials in a genuine small and medium-sized company (SME) production environment are required to confirm its efficacy and dependability in real-world settings. Moreover significantly improved by including a more advanced control system like PID, Fuzzy, and SMO can be considered to improve the flexibility, stability, optimization, and accuracy of automated grain weighing systems, resulting in better and more consistent performance in a range of operating conditions. Fuzzy adaptive control systems are also suggested for future research to eliminate the need for manual calibration and enable automatic adjustment of control settings.

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