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Weight System Calibration of Dynamic Load for Stingless Bee Application

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Abstract
This paper is presents the weight system for dynamic load with calibration for stingless bee. The calibration must be done first to get the minimum and maximum scale weight or resolution weight scale. In this study, weight sensor that have been chosen is load cell with maximum scale weight is 20 kilogram (kg). The calibration have been done by using formula y = mx + b where y is the raw value ADC from weight sensor, x is measured weight, b is the intersection but with no weight or value ADC after empty weight and m is multiplier or scale factor. From the calibration, the weight will be obtained. The equipment that have been used are Arduino UNO, load cell sensor, SD-Card Adapter.
Keyword: Weight Scale, Calibration, Load Cell, SD Card Adapter

Introduction

In present era, technology is the single most essential factor in determining how well humans can live their lives. It is possible to utilise technology to make the work easier for a person to accomplish and to read the value without being unsure whether or not the value is accurate. In addition to the previous research (Riyanti et al., 2022), the HX711 load cell, LCD, and Arduino UNO were used as instrument system components. The scale's weight sensor is only capable of measuring up to 25 kilogrammes at the highest possible weight reading (kg). After going through the process of calibration, the weight sensor was then validated with the help of a known reference. A two-load method was utilised by the researcher, with the first load being a static load and the second load being a dynamic load. By applying this method, the researcher was able to determine the amount of error as well as retrieve the weight from the sensor.

According to the findings of the researcher (Ud & Tani, n.d.), the load cell sensor was evaluated using four different capacities of the onion's weight, specifically 0.5 kilograms, 1 kilograms, 1.5 kilograms, and also 2 kilograms. Every capacity has an error, and the researcher calculates the average and average error. The measurements and calculations are as follows:

$$s = s1 + s2 + s3 + s4 \quad (1)$$

$$\text{Average} = \frac{s}{\text{number item in the set}} \quad (2$$

$$\text{Average error} = \frac{\text{Average}-X}{\text{Average}} \times 100\% \quad (3)$$

where s is the total of all the weights measured. The average is the sum of the totals weight divided by the number of items. X represents the weight capacities and all of the data has been recorded in the database.

The LPS400 scale was used as a weight sensor. The error or resolution of the weight sensor was calculated based on the tested weight in order to get an accurate reading. After that, the information was emailed to a specific address, where it was checked against error parameters and formatted to ensure that the system would not crash. After being monitored, the scale output was no more than two pounds (lbs) less than two pounds (lbs) (Lewis et al., 2014). Project have been carried out by (Rqh et al., 2017), and the apparatus for the weight sensor that has been utilised in their project is a flexi force A201 100lbs. The linear regression model was used to calculate the value weight, and the formula is

$$F = V\times 29.999-69.414 \text{ kilogram (kg)} \quad (4)$$

where V is the voltage measured by Arduino Yun and F is the weight collected by the sensor.

The accuracy of the load cell sensor was confirmed in the test lab by comparing the measured weight to the known weight applied to the load cell. Weight has been shown to vary in response to ambient temperature. As the temperature rises, the weight decreases. The temperature is varied by 1°C increments of up to 20 gram (g) (Kviesis et al., 2020). HX711 modules placed for weight measurement is integrated with four units of strain gauge load cells sensors (Anuar et al., 2019). Each sensor is an analog load cell with a flow of 50kg, connected to the other cells in Wheatstone Bridge configuration (Cecchi et al., 2019). The cell consists of four strain gauge and two precision resistors coupled in a Wheatstone Bridge configuration and driven by Vin = 5 V as formulated in (5)

$$Vout = \left[\frac{R3}{R3+R4} + \frac{R2}{R1+R2}\right] \times Vin \quad (5$$

where,

R_1 = the strain gauge resistance of the upper right load cell,
R_2 = the strain gauge resistance of the upper left load cell,
R_3 = the strain gauge resistance of the lower right load cell,
R_4 = the strain gauge resistance of the lower left load cell.

The latter for strain gauge is a 24-bit ADC designed for weight scale applications that also supplies the excitation voltage for the sensors. The signal obtained from the bridge is first amplified. A known weight is put on the scale and a vector X of 100 consecutive measurement is recorded (Cecchi et al., 2020; Terenzi et al., 2019). The uncertainty δx is estimated by formula (6)

$\delta x = max(X) - min(X)_2$ (6)

The PCE-PCS 30 is a weight sensor that can measure weights up to 30kg in 0.5kg increments. The margin of error is 0.5kg. The weight sensor has been properly calibrated, and it has a serial port connection that can be configured to send out the weight every second or as it changes (Michels, 2011). According to the findings of this research project, it is of utmost importance for the globe to have a weighing system that is capable of being calibrated. This is due to the fact that having such a system does not provide any values that are uncertain. The values are presented in a digital format and are referred to as easy to grasp and comprehend. Consequently, the primary purpose of this investigation is to assess the effectiveness of the system of weights for the stingless bee.

Methodology

First and foremost, work will be done on developing a weight sensor circuit. The weight sensor is made up of three components: a microcontroller, an SD card adapter, and a HX711 load cell sensor that serves as the weight sensor. The schematic diagram of the circuit is shown in Figure 1.

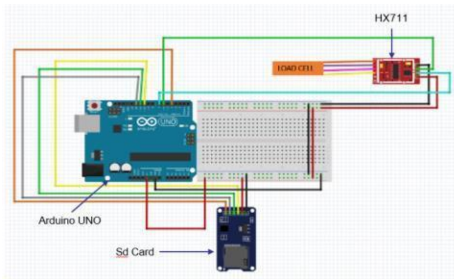

Figure 1: Circuit diagram

To obtain the scale factor, the weight sensor must first be calibrated. There are many different types of weight sensors, each with its own characteristic scale factor. Every load cell sensor has a minimum scale weight as well. After that, the accuracy of the weight sensor, as well as its performance, will be evaluated using some different tests.

Hardware Development

This section discusses the hardware involved in this study. The main component for weight system is HX711 load cell sensor, Arduino UNO as microcontroller, SD Card adapter and USB type B or power supply (9V) as shown in Figure 2.

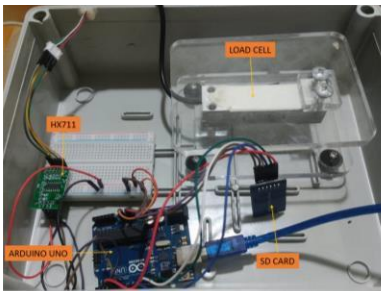

Figure 2: Component for weight system

The SD card adapter shown in Figure 3 can operate in a voltage (V) range of 4.5V to 5.5V direct current (DC), with a current requirement ranging from 0.2 milliampere (mA) to 200 mA. The SD card adapter supports FAT files and micro SD cards with capacities of up to 2 GigaBytes (GB).

Figure 3: SD card adapter

Figure 4 show the flow chart of the development of weight system. The placement of the weight sensor must be set up first, and only then will the calibration process get started. After the weight has been tested, the scale factor will be received via the Arduino Serial Monitor. Before beginning the calibration process, the weight that is obtained through testing will be compared with the real weight that was previously weighted. The calibration is considered to have been successful if the expected weight and the actual weight were equal.

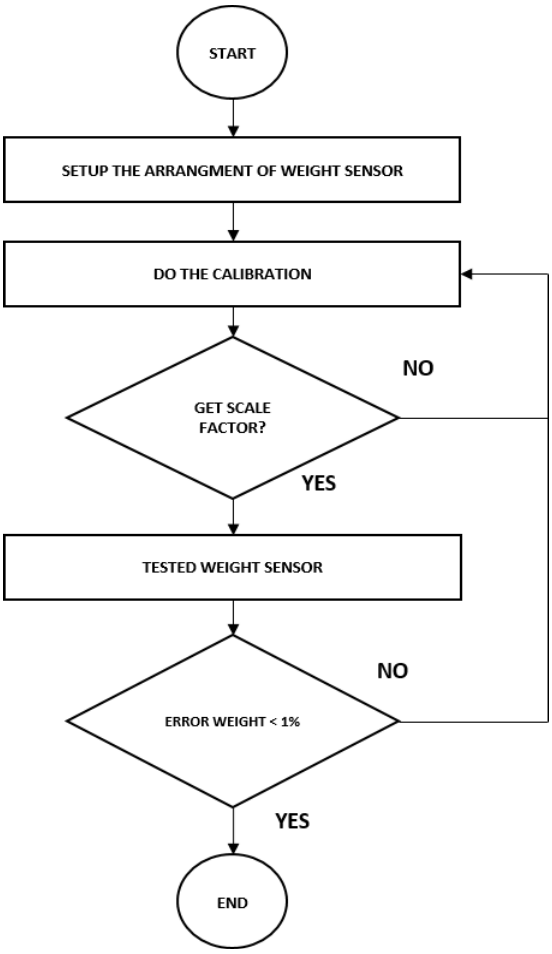

Figure 4: Flow chart of development weight system

From Figure 5, the instrument that have been used in this project are HX711 load cell as input, Arduino UNO as microcontroller, SD-card and serial monitor from Arduino IDE as output. The function of SD-card is to store the value of weight in memory card and function of serial monitor is to display the time and also the data of weight. Arduino UNO is being used as a brain to control the input and output of the device.

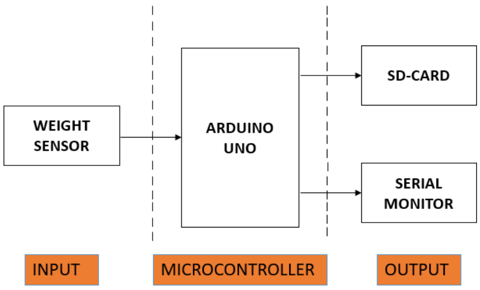

Figure 5: Block diagram of weight system

Result and Discussion

This section will discuss results obtained from this study. The rice is chosen to be the reference weight for calibration. The rice has been weighted by manually using weight scale and the weight is 500 grams (g) as shown in Figure 6.

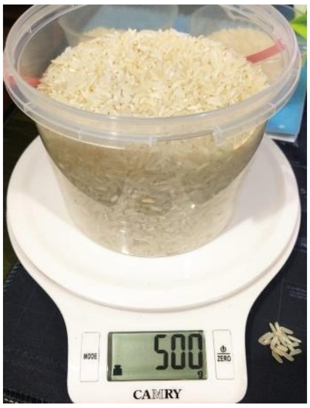

Figure 6: The weight of rice by manually weighted

Figure 7 show the value of ADC weight without weighted rice, b.

```
21:50:51.582 -> After setting up the scale, the value b without weight is: 114519
21:50:53.311 -> Readings:
21:50:53.311 -> The value of y is: 114551
21:50:54.991 -> The value of m is 224.27 after do the calibration
```

Figure 7: Value of ADC weight without weighted rice, b

Figure 8 shows the scale factor, m where the value is 224.27 after empty weight. This method is by using serial monitor and also coding library from Arduino IDE but in Figure 10, the value of scale factor, m can be obtained by using the formula in equation (7)

$$y = mx + b \quad (7)$$

```
21:31:41.115 -> Startup is complete
21:31:41.210 -> ***
21:31:41.210 -> Start calibration:
21:31:41.210 -> Place the load cell an a level stable surface.
21:31:41.304 -> Remove any load applied to the load cell.
21:31:41.304 -> Send 't' from serial monitor to set the tare offset.
21:31:52.350 -> Tare complete
21:31:52.350 -> Now, place your known mass on the loadcell.
21:31:52.395 -> Then send the weight of this mass (i.e. 100.0) from serial monitor.
21:32:02.372 -> Known mass is: 500.00
21:32:04.555 -> New calibration value has been set to: 224.27, use this as calibration value
21:32:04.695 -> Save this value to EEPROM adress 0? y/n
21:32:13.968 -> Value 224.27 saved to EEPROM address: 0
21:32:14.014 -> End calibration
21:32:14.014 -> ***
```

Figure 8: Calibration the weight system

In order to calculate the scale factor, m from the weight and the value ADC of the weight, the formula as in equation (8)

$$m = \frac{y_2 - y_1}{x_2 - x_1} \quad (8)$$

where y is the value ADC of the weight that have been weighted and x is the value of reference weight. The value of x_1 is 50g, x_2 is 600g, y_1 is 125831 and y_2 is 249574 as shown in Figure 9. By manually calculate, the value of scale factor, m is 224.99 using the formula (8).

Figure 9: Calibration manually using formula

Figure 10 shows the data regarding the weight of 50g of rice. Figure 11 shows the values of the data weight for 100g of rice, and Figure 12 shows the distribution of the data weight for 150g of rice. The total weight of the rice is being measured with a HX711 load cell sensor, and each value is being recorded five times. To get the value of measured weight, the formula in equation (9) is applied after the calibration done

$$x = \frac{(y-b)}{m} \quad (9)$$

where x is measured weight, y is the value ADC after put weight above the weight sensor and b is the value of ADC before put the weight and m is the scale factor.

```
21:53:30.696 -> The value of y is: 125831
21:53:32.287 -> The value of m is 224.27 after do the calibration
21:53:32.380 -> So, by using formula y = mx + b, the value of x is: 50.35
21:53:33.174 ->
21:54:02.171 -> The value of y is: 125824
21:54:03.757 -> The value of m is 224.27 after do the calibration
21:54:03.849 -> So, by using formula y = mx + b, the value of x is: 50.26
21:54:04.595 ->
21:54:33.623 -> The value of y is: 125842
21:54:35.252 -> The value of m is 224.27 after do the calibration
21:54:35.299 -> So, by using formula y = mx + b, the value of x is: 50.39
21:54:36.091 ->
21:55:05.082 -> The value of y is: 125801
21:55:06.714 -> The value of m is 224.27 after do the calibration
21:55:06.759 -> So, by using formula y = mx + b, the value of x is: 50.16
21:55:07.550 ->
21:55:36.547 -> The value of y is: 125778
21:55:38.174 -> The value of m is 224.27 after do the calibration
21:55:38.221 -> So, by using formula y = mx + b, the value of x is: 50.04
```

Figure 10: 50 gram of rice

```
21:56:08.014 -> The value of y is: 136920
21:56:09.647 -> The value of m is 224.27 after do the calibration
21:56:09.692 -> So, by using formula y = mx + b, the value of x is: 99.79
21:56:10.487 ->
21:56:39.484 -> The value of y is: 136978
21:56:41.109 -> The value of m is 224.27 after do the calibration
21:56:41.155 -> So, by using formula y = mx + b, the value of x is: 99.97
21:56:41.944 ->
21:57:10.984 -> The value of y is: 136970
21:57:12.569 -> The value of m is 224.27 after do the calibration
21:57:12.615 -> So, by using formula y = mx + b, the value of x is: 100.00
21:57:13.407 ->
21:57:42.431 -> The value of y is: 137018
21:57:44.062 -> The value of m is 224.27 after do the calibration
21:57:44.108 -> So, by using formula y = mx + b, the value of x is: 100.14
21:57:44.898 ->
21:58:13.896 -> The value of y is: 136958
21:58:15.528 -> The value of m is 224.27 after do the calibration
21:58:15.574 -> So, by using formula y = mx + b, the value of x is: 99.79
```

Figure 11: 100 gram of rice

```
21:58:45.388 -> The value of y is: 148222
21:58:46.970 -> The value of m is 224.27 after do the calibration
21:58:47.016 -> So, by using formula y = mx + b, the value of x is: 150.09
21:58:47.805 ->
21:59:16.852 -> The value of y is: 148227
21:59:18.434 -> The value of m is 224.27 after do the calibration
21:59:18.480 -> So, by using formula y = mx + b, the value of x is: 150.23
21:59:19.274 ->
21:59:48.299 -> The value of y is: 148184
21:59:49.929 -> The value of m is 224.27 after do the calibration
21:59:49.977 -> So, by using formula y = mx + b, the value of x is: 150.04
21:59:50.768 ->
22:00:19.772 -> The value of y is: 148257
22:00:21.356 -> The value of m is 224.27 after do the calibration
22:00:21.449 -> So, by using formula y = mx + b, the value of x is: 150.25
22:00:22.198 ->
22:00:51.215 -> The value of y is: 148227
22:00:52.848 -> The value of m is 224.27 after do the calibration
22:00:52.895 -> So, by using formula y = mx + b, the value of x is: 150.18
```

Figure 12: 150 gram of rice

Figure 13 show the weight of the rice that have been weighted manually. And then have been tested on weight sensor.

Figure 13: Tested weight manually

The error for this weight system can be derive as:

$$\%Error = \frac{\text{measure weight} - \text{actual weight}}{\text{actual weight}} \times 100\% \quad (10)$$

where the measure weight can be obtained from serial monitor and the actual weight is the reference weight.
Table 1 shows the error for minimum, maximum and average error. The average weight is calculated using equation (2). As a result, the error will be positive or negative depending on whether the measured weight is greater or less than the reference weight.

Table 1
Error for minimum, maximum and average

Actual weight (g)	Minimum weight (g)	Maximum weight (g)	Average weight (g)	Minimum error(%)	Maximum error(%)	Average error(%)
50	50.16	50.39	50.24	0.32	0.78	0.48
100	99.79	100.14	99.94	-0.21	0.14	-0.06
150	150.04	150.25	150.16	0.027	0.17	0.11

Conclusion

In this study, a weight system was successfully developed to evaluate the performance of a load cell as a weight sensor. The experimental results analysis reveals a 1% error in detecting the different weights of rice. Furthermore, the newly developed Arduino load cell sensor is more effective in determining dynamic load. Last but not least, this weight system is accurate enough to be used on weighted honey stingless bees, with an error of no more than 1 gram.

The weight sensor HX711 load cell can measure dynamic load weight because the error is less than 1% when tested on weighted rice.

Recommendation

At the end of this study, a few recommendations are identified that can be used for the purpose of making improvements in the future. This project can be improved by adding an external voltage to obtain a constant value of ADC or a higher voltage to supply to the weight sensor. Furthermore, the size of the weight sensor can be small in order to be sizeable for prototype or commercialization. The weight being measured must also be less than or equal to the standard weight being used as a reference. Finally, for long term, the device should be on Printed Circuit Board (PCB) to prevent from the equipment got damaged.

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