e-ISSN: 2720-989X
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INTERNET OF THINGS (IoT) BASED SCALES FOR DYNAMIC LOADS WITH WEIGHT FORECASTING FEATURE

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Abstract

A scale is a measuring instrument used to measure the weight of an object. The current weighing system has not been able to identify the item being weighed and has not been able to save the weighting data automatically, in this study a weighing system was developed that can identify the load using RFID and can store the weighing data in a web browser so that there is no manipulation of the weighing data. and the system is able to predict the results of weighing the load with a linear regression method to determine the growth of the weight object. The microcontroller used is Arduino Uno and the weight sensor used is a half bridge type load cell. From the sensor accuracy test with a load weight of 0.90 Kg, 12.95 Kg, 55.42 Kg, 125.95 Kg, the highest error occurred when the load was 0.90 Kg while the lowest error was at 55.45 Kg. the object of a moving load is difficult to produce the same weight in the first measurement and so on. Testing the accuracy of predictions is evidenced by the MSE value of 0.0017 and MAPE of 0.0742%, which means that the prediction using the linear regression method is classified as very good.

Keywords: *Forecasting, Internet of Things, Load cell, Scale*

I. INTRODUCTION

Scales are measuring instruments used to measure the weight of an object. Currently, the scales have switched from analog to digital scales where the digital scales work, namely when measuring weight, the results of these measurements can directly display the nominal weight on the LCD. These digital scales are sufficient if used to simply determine the weight of an object, but for more complex uses the scales still have drawbacks.

Weaknesses in the current scale cannot identify the item being weighed and cannot store weighing results data automatically, so if you want to know the growth or shrinkage of the object being weighed you have to do a manual calculation. This is vulnerable to fraud or manipulation of data from measurement results. Therefore it is necessary to have a balance that can solve the problem. Scales can be designed to be able to identify objects, store measurement data. In addition, from the measurement results data can be computed for forecasting (predictions) to determine the level of growth and depreciation in the future automatically and can also be monitored remotely. This concept is in line with the Internet of Things (IoT). Implementation of IoT allows various devices to be connected to an internet connection that works regardless of distance[1][2][3].

II. METHOD

2.1 Research Flowchart

Fig 2. 1 is a stage in the research on Internet of Things (IoT) based scales for dynamic loads with a weight forecasting feature.

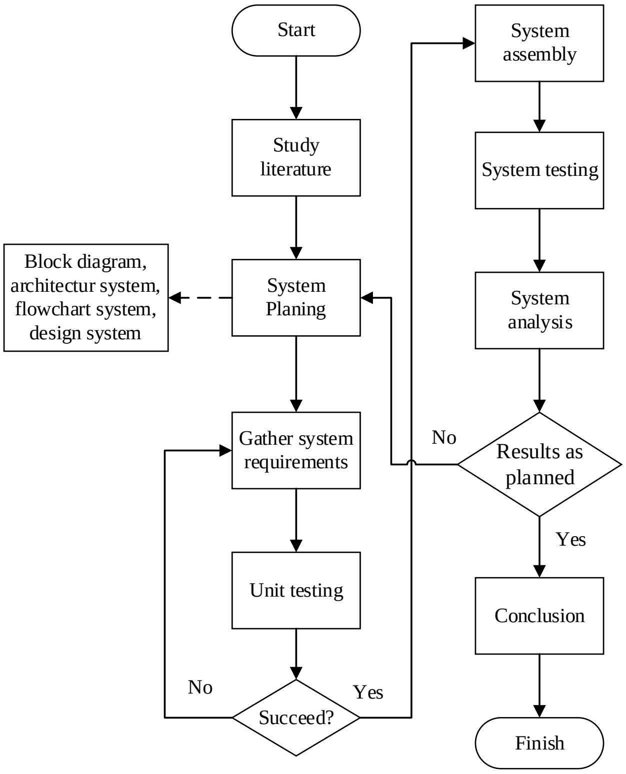

Fig 2. 1 Research Flowchart

2.2 System Design

Fig 2. *2* is a picture of the hardware design of the weighing system, the MCU used is Arduino Uno using a special chip as a USB to serial FTDI driver[4], while the sensor used is the load cell sensor. will convert the amount of pressure generated into a voltage value, the change in voltage that occurs is too small so it must be amplified by an instrumentation amplifier that will convert analog voltage to digital with a microcontroller controller, then digital data will be processed and displayed on the LCD contained on the scales [5].

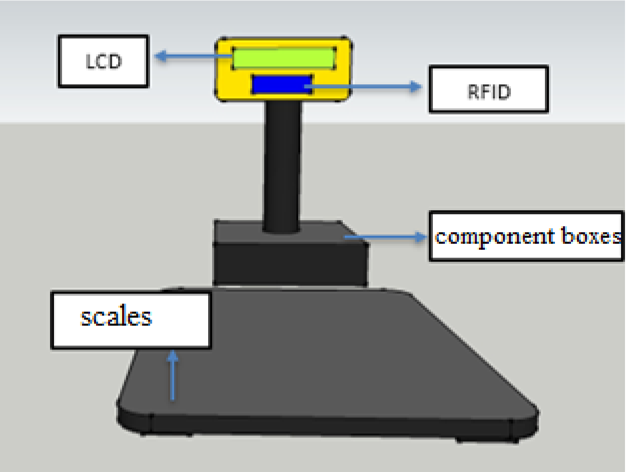

Fig 2. 2 Weighing System Design

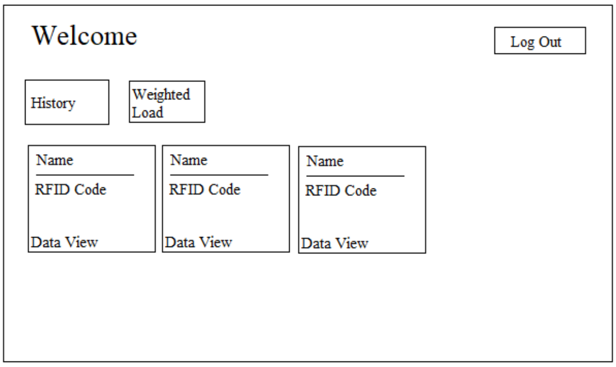

Fig 2. 3 Web Browser Display

Fig 2. *3* is a Web Browser Display where a web browser is a software that can be run on a user's computer that can display information or documents from the web that have been processed and retrieved from a web server[6]. The web server is responsible for HTTP request-response and detailed information logging and follows the standard HTTP protocol[7].

In the web browser there is a weighing history column that can display all weighing data, while the weighted load column will display the name of the object being weighed and the RFID code.

III. RESULTS AND DISCUSSION

3.1 System Planning

1) Block Diagram

Block Diagram serves as a reference in the flow of hardware work systems. The block diagram is divided into four parts. The following is an explanation of the block diagram in Fig 3. 1

1. Input

   In the input section, the sensor will send sensor data, namely weighing data and code from RFID to the Arduino UNO microcontroller.
2. Process

   In the process section, there are Arduino UNO, and Application Server. Arduino UNO functions to process data from sensors and RFID after the data is processed the data will be sent to ESP8266-01, then ESP8266-01 receives data from Arduino UNO via serial communication.
3. Network

   In the Network section there are ESP8266-01 and MQTT Broker. ESP8266-01 that has been connected to WiFi will send data to the MQTT Broker, then from the MQTT it will be processed on the application server to perform the linear regression computation process..
4. Output

   In the output section, there is an LCD display which functions to display data from sensors and the code from RFID, the Web Browser functions as a viewer for all weighing results data as well as the results of online linear predictions..

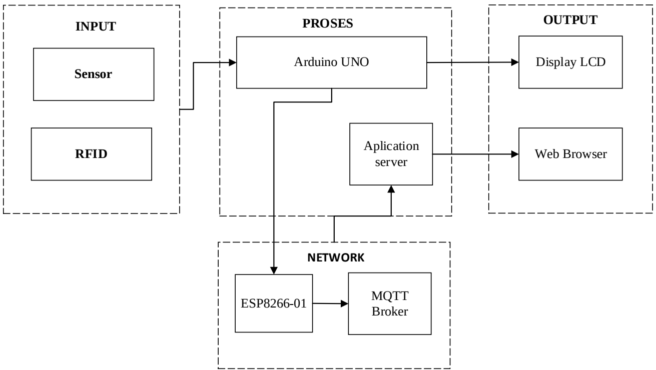

Fig 3. 1 Block Diagram

2) Architectur System

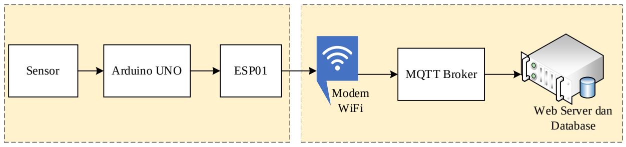

Fig 3. 2 System Architectur

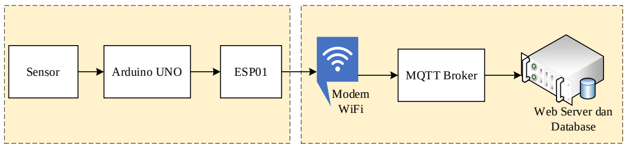

Fig 3. *2* in the System Architecture section, is a system design section that describes the physical components that have been arranged into a unified system so that it can run the system. In Fige 3.2 there are parts of the system where each system is connected to one another.

3.2 Testing

1) RFID RC522 Testing

RFID is the development of wireless communication technology that is capable of automatically identifying certain objects that communicate via radio waves[8].

Testing on the RC-522 RFID is carried out by bringing the RFID Tag card closer to the RFID Reader, the RFID Reader reads the ID contained in the Tag. This RFID test uses three different types of tags, namely card types, key chain types and e-ID cards.

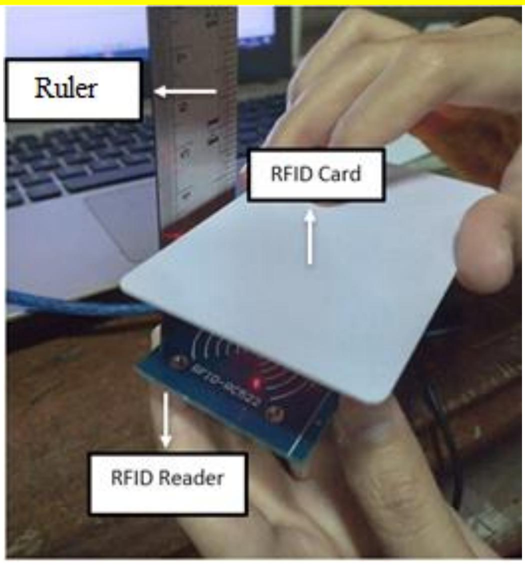

Fig 3. 3 Testing the distance of RFID Tag type Card

Tbl 3. 1 The results of testing the distance of the RFID Tag type card

Number of Testing	**Distance (cm)**	**Description**
1	0	Read
2	0,5	Read
3	1	Read
4	1,5	Read
5	2	Read
6	2,5	Read
7	3	Read
8	3,5	Can't be read
9	4	Can't be read
10	4,5	Can't be read

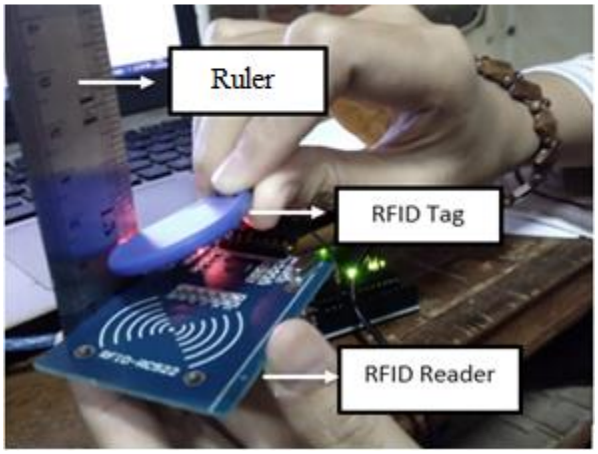

Fig 3. 4 Testing the distance of RFID Tag type key chain

Tbl 3. 2 The results of testing the distance of the RFID Tag type key chain

Number of **Testing**	**Distance (cm)**	**Description**
1	0	Read
2	0,5	Read
3	1	Read
4	1,5	Read
5	2	Read
6	2,5	Can't be read
7	3	Can't be read
8	3,5	Can't be read
9	4	Can't be read
10	4,5	Can't be read

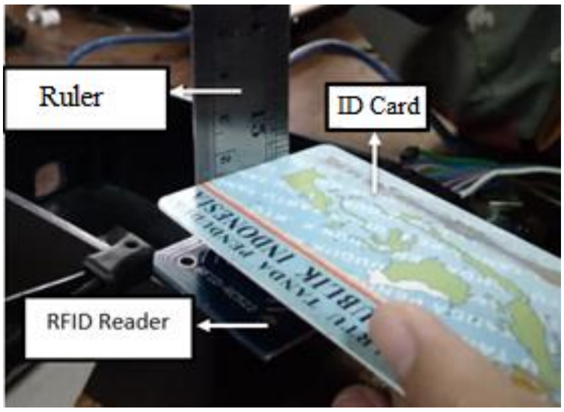

Fig 3. 5 Testing the distance of RFID Tag type ID Card

Tbl 3. 3 The results of testing the distance of the RFID Tag type ID card

Number of Testing	**Distance (cm)**	**Description**
1	0	Read
2	0,5	Read
3	1	Read
4	1,5	Read
5	2	Read
6	2,5	Can't be read
7	3	Can't be read
8	3,5	Can't be read
9	4	Can't be read
10	4,5	Can't be read

2) Loadcell Sensor Accuracy Testing

Testing the accuracy of the load cell sensor is carried out by storing the load on the cross section of the scales and then comparing the value of the load reading without using a filter and reading the load using a moving average filter. The Moving Average Filter will reduce noise that occurs by averaging the samples, so the value to be processed will be the result of the average number of samples. Moving Average Filter Equation[9]:

$$SMA = \frac{data1 + data2 + \ldots data\,n}{n} \qquad (3.1)$$

The results of the next test are compared with the validated loads. The weight used in this test uses reference data with various weights, namely 0.90 Kg, 12.95 Kg, 55.45 Kg, 125.96 Kg. Fig 3. 6 is a graph of the results of the load test, while

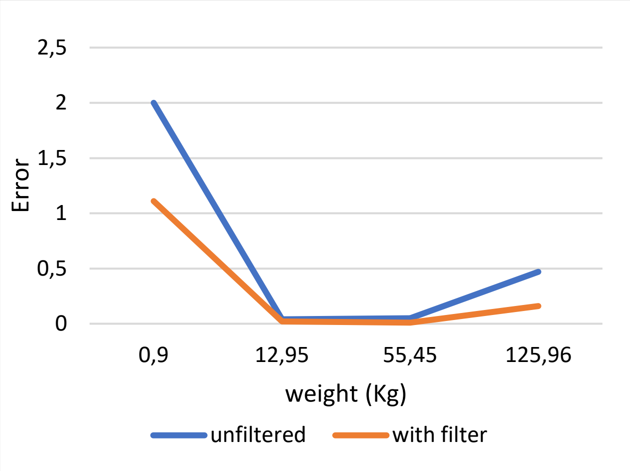

Fig 3. 7 is the average value of the load cell measurement error.

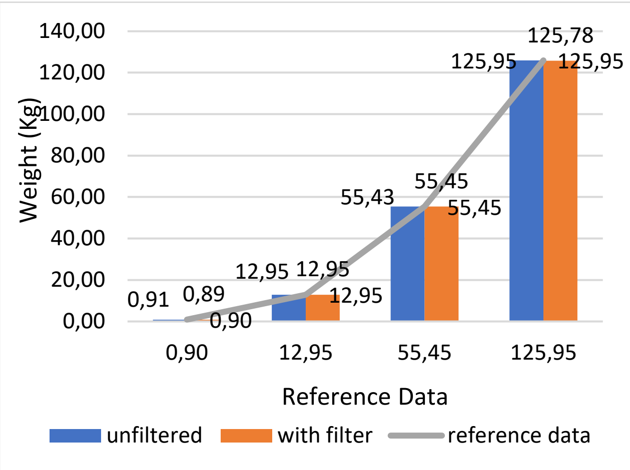

Fig 3. 6 Graph of the average value of load testing

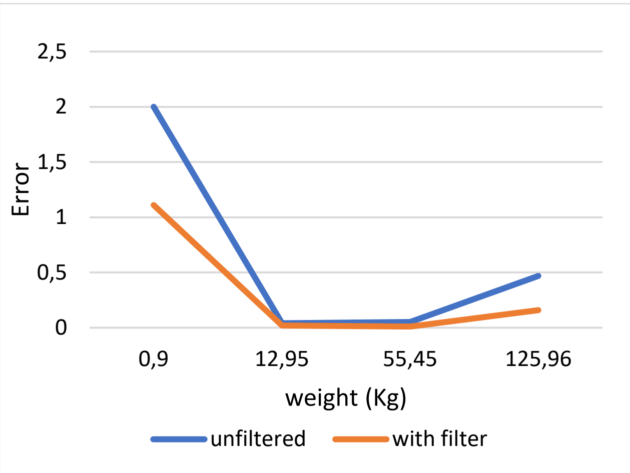

Fig 3. 7 Graph of Average Load cell Testing Error

3) Comparison Test of Loadcell Sensors in Static and Dynamic Conditions

Comparison test of the loadcell sensor in a static and dynamic state with a frequency of 0 Hz, a slow moving load with a frequency of 1 Hz, and a load in a fast moving state with a frequency of 3 Hz, its frequency means the number of beats in one second with a comparison between loads measured using a moving average filter in accordance with equation 3.1 and the load is measured without using a moving average filter, then the value of the test results is compared with the measurement results from conventional scales of 47.00 Kg the test results can be seen in Tbl 3. 4.

Tbl 3. 4 Hasil Pengujian Perbandingan Sensor Loadcell Dalam Keadaan Statis dan Dinamik

Numb of Test	Dynamic load freq (hz)	Unfiltered weight	Error (%)	Weights with filters (kg)	Error (%)
10 Seconds Idle Load Characteristics					
1	0	46,98	0,05	47,01	0,02
2		46,99	0,02	47,01	0,03
3		46,97	0,07	46,97	0,06
4		47,01	0,02	47,00	0,00
5		47,02	0,04	47,00	0,00
6		47,00	0,01	47,01	0,02
7		46,94	0,13	46,99	0,03
8		47,04	0,08	47,01	0,02
9		46,98	0,04	46,99	0,03
10		47,07	0,15	47,06	0,13
Average		47,00	0,06	47,00	0,03
10 Second Slow Moving Load Characteristics					
1	1	46,84	0,34	46,88	0,26
2		46,84	0,34	46,87	0,27
3		46,77	0,49	46,88	0,25
4		46,74	0,55	46,83	0,35
5		46,78	0,47	46,86	0,29
6		46,86	0,29	46,88	0,26
7		46,77	0,50	46,84	0,33
8		46,85	0,33	46,92	0,17
9		46,76	0,51	46,80	0,42
10		46,77	0,48	46,84	0,34
Average		46,80	0,43	46,86	0,29
10 Second Fast Moving Load Characteristics					
1	3	46,93	0,15	46,97	0,05
2		46,89	0,23	46,92	0,17
3		46,90	0,22	46,91	0,19
4		46,82	0,37	46,88	0,26
5		46,82	0,38	46,85	0,32
6		46,86	0,30	46,87	0,28
7		46,72	0,59	46,75	0,53
8		47,11	0,24	47,09	0,19
9		47,08	0,18	47,08	0,17
10		47,11	0,24	47,08	0,17
Average		46,93	0,29	46,94	0,23

20 Seconds Idle Load Characteristics					
1	0	47,05	0,11	47,05	0,12
2		47,05	0,12	47,04	0,08
3		47,03	0,06	47,01	0,02
4		47,06	0,13	47,05	0,10
5		47,06	0,12	47,05	0,10
6		47,01	0,03	47,00	0,01
7		46,89	0,24	46,88	0,25
8		46,95	0,10	46,96	0,09
9		47,04	0,09	47,05	0,10
10		47,04	0,09	47,04	0,09
Average		47,02	0,11	47,01	0,09
20 Second Slow Moving Load Characteristics					
1	1	46,83	0,35	46,88	0,25
2		46,86	0,30	46,91	0,18
3		46,79	0,44	46,84	0,34
4		46,82	0,38	46,82	0,37
5		46,79	0,44	46,85	0,32
6		46,78	0,46	46,81	0,40
7		46,81	0,41	46,83	0,37
8		46,78	0,47	46,87	0,28
9		46,78	0,48	46,81	0,41
10		46,77	0,48	46,81	0,41
Average		46,80	0,42	46,84	0,33
20 Second Fast Moving Load Characteristics					
1	3	47,16	0,34	47,15	0,31
2		47,12	0,26	47,13	0,27
3		47,14	0,30	47,13	0,28
4		47,11	0,23	47,12	0,25
5		47,10	0,22	47,12	0,25
6		46,92	0,17	46,95	0,11
7		47,02	0,05	47,00	0,00
8		46,94	0,14	46,96	0,08
9		46,97	0,06	46,97	0,06
10		46,98	0,04	47,00	0,00
Average		47,05	0,18	47,05	0,16

4) Load stability testing of load identification and data sent

This test is carried out when the load is unstable and after it is stable. The measurement results can be seen in Tbl 3. 5

Tbl 3. 5 Load stability test results

No	Load Status	RFID Status	Data Status
1	Stable	Detected	Sent
2	unstable	Not detected	Not sent
3	Stable	Detected	Sent
4	unstable	Not detected	Not sent
5	Stable	Detected	Sent
6	unstable	Not detected	Not sent
7	Stable	Detected	Sent
8	unstable	Not detected	Not sent
9	Stable	Detected	Sent
10	unstable	Not detected	Not sent

5) Testing sending sensor data to the Web

Testing of sending sensor data to the Web is carried out using an Arduino uno microcontroller connected to the ESP8266. This test is carried out by sending sensor data from ESP8266 to MQTT Broker and forwarded to the Web. Furthermore, the data that has been sent will be displayed on the Web in Tbl 3. 6

Tbl 3. 6 Test results of sending sensor data to the Web

Number of Testing	Load Weight (Kg)		RFID Code	Status
	Sent	Accept		
1	45.7	45.7	93CAA34	Sent
2	46.13	46.13		Sent
3	46.62	46.62		Sent
4	47.13	47.13		Sent
5	47.7	47.7		Sent
6	48.03	48.03		Sent
7	48.66	48.66		Sent
8	49	49		Sent
9	49.77	49.77		Sent
10	50.1	50.1		Sent
11	81.88	81.88	63F844	Sent
12	82.29	82.29		Sent
13	82.91	82.91		Sent
14	83.34	83.34		Sent
15	83.7	83.7		Sent
16	84.65	84.65		Sent
17	85.14	85.14		Sent
18	85.63	85.63		Sent
19	86.32	86.32		Sent
20	86.54	86.54		Sent

6) Testing the influence of the WiFi signal on data transmission.

The results of testing the effect of WiFi signal strength on data transmission. From the test it can be seen that signal strength has no effect on sending data to ESP8266, MQTT broker, and to the Web. For data transmission time from ESP8266, the difference in data is not that significant, but for sending data to the Web, it takes 3 seconds. when WiFi is disabled no data is sent to the MQTT broker and to the Web.

7) Forecast testing of data scales

Forecast testing of data scales using linear regression method. Linear regression can be used to predict changes in the value of the dependent variable when the value of the independent variable fluctuates or fluctuates. equality linear regression can be written [10]:

$$Y = a + bX \tag{3.4}$$

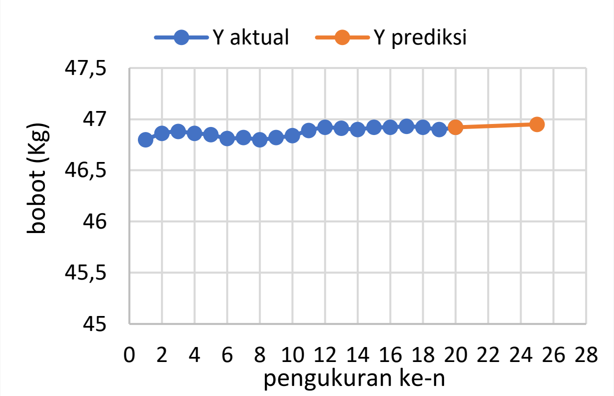

Fig 3. 8 Forecasting Chart

8) Forecasting accuracy Testing

Forecasting accuracy is determined by how much the error value deviation occurs between the actual data and the predicted data. The magnitude of the error can be caused by large unexpected factors (outliers), basically there is no prediction method that is capable of producing accurate predictions. The way to calculate inaccuracies in predictions is to calculate errors, by calculating MSE (mean square error) and MAPE (absolute percentage error)[10].

Formula MSE :

$$\text{MSE} = (\frac{1}{n}\sum Y_t - Y'_t)^2 \tag{3.2}$$

Formula MAPE :

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n} \frac{|Y_t - Y'_t|}{Y_t} \tag{3.3}$$

Tbl 3. 7 Forecasting accuracy Testing

X	Actual Value	Forecasting Value	MSE	MAPE
1	46,80	-	-	-
2	46,86	-	-	-
3	46,88	46,92	0,0016	0,0854
4	46,86	46,92667	0,0044	0,1423
5	46,85	46,9	0,0025	0,1067
6	46,81	46,88	0,0049	0,1494
7	46,82	46,84333	0,0005	0,0498
8	46,80	46,83	0,0009	0,0640
9	46,82	46,8125	0,0001	0,0160
10	46,84	46,81083	0,0009	0,0622
11	46,89	46,818	0,0052	0,1536
12	46,92	46,84127	0,0062	0,1679
13	46,91	46,86788	0,0018	0,0898
14	46,90	46,88423	0,0002	0,0336
15	46,92	46,89352	0,0007	0,0565
16	46,92	46,90581	0,0002	0,0303
17	46,93	46,91525	0,0002	0,0314
18	46,92	46,92493	0,0000	0,0105
19	46,90	46,93033	0,0009	0,0646
20	46,92	46,93035	0,0001	0,0221
	Jumlah Kesalahan		0,0017	0,0742

IV. CONCLUSION

1. The load identification process is carried out using RFID, when the load is above the cross section of the scales and has obtained a stable load weight value, when an RFID is detected, the system can read the RFID code to be able to identify the load being weighed. Each weighing object has a unique code from a different RFID card so that it is easy to distinguish one weighing object from another.
2. Dynamic load measurements from the load cell sensor display data that fluctuates according to the movement of the measured load. To reduce noise from fluctuating data, a moving average filter is used. Using this filter, it takes an average of 3 seconds to get a stable value. From the results of load testing within 10 seconds and 20 seconds, it shows that the moving method is difficult to get a value. actually because between the first test and so on it shows a different load reading value in each measurement. So the motion method is not recommended for motion that cannot be regulated.
3. The process of sending weighing data is done online using a WiFi network. When the system weighs the load, the system can send the weight of the load that has been validated to be stable to the Web, so that the results of the weighing can be monitored remotely via the Web. The time needed to process weighing data from the system so that it can be sent and displayed on the web is 3 seconds, while the WiFi signal strength does not affect sending data to the Web, and when the system is not connected to WiFi, weighing data from the system cannot be sent to the Web so that weighing data can only be displayed on the LCD.
4. The results of weighing the load with the same load object that has been weighed repeatedly, the growth of the load object can be predicted using a simple linear regression method as evidenced by the test results of the MSE value of 0.0017 and MAPE of 0.0742% less than 10% according to The MAPE forecasting Tbl with the simple linear regression method is classified as very good.

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BIOGRAPHY

Veni Silviani, I was born in Bogor on December 6, 1998, I studied at the Department of Electrical Engineering, Faculty of Engineering, Siliwangi University, with a concentration in control systems. With the research title Internet of Things (IoT) Based Scales for Dynamic Loads with a Weight Forecasting Feature.