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Digital Automatic Livestock Weighing System Using Single Beam Load Cell

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Abstract. The livestock market in Indonesia is still categorized as a traditional market due to the absence of the standard price and/or open sale. One recommendation that can be applied to livestock market is the application of weighing and management of livestock data, i.e. digital weighing system and cage structure with automatic door that can be opened and closed automatically. The proposed system is a cage that consists of digital scale based on single bending beam load cell with dimension 160cm x 80cm x 120cm. It has a sliding door driven automatically by DC motor. The livestock to be weighed is detected by the LDR-laser system which would notify the Mega 2560 arduino microcontroller to command the DC motor at the entrance and the exit spaces to open/close the door. The weighing results are displayed in LCD screen. The digital livestock scale could weigh linearly in the range of 0-440 kilograms with an average error of 0.265% and could measure a maximum weight of 620 kilograms.

INTRODUCTION

In an integrated livestock market and feedlot, a weighing system is a must in which the sale and purchase of livestock should be fairly and mutually beneficial for both parties, i.e. sellers and buyers [1][2]. Meanwhile, information about the need for animal products is not provided in real-time, making the fulfillment for such product is usually delayed and even deficit [3][4][5]. Therefore, there is urgent requirement for a technology that combines the needs of weighing system and information system, both in livestock market and feedlot.

The digital cattle weighing systems can be integrated with the market system of livestock market operators. Livestock market trading systems have very profitable prospect, because the database can trace the needs and availability of animal products for the community[6]. As for feedlot, the use of weighing system that can be directly connected with the database system is also very profitable because it can track the growth of livestock system with the existing treatment, so it can be a reference for the next treatment process [6][7].

Nowadays, there are several forms of digital scales for cattle that have been developed and widely used. Similar scale has been patented, namely the U.S. Patent No. 7129423B2, in which it uses livestock detection methods by using electric sensors as information thus the weighing process can be carried out [8]. The difference in the scale developed in the present study from previous invention is the existence of automatic door system with a DC motor. The use of this DC motor is also different from the general automatic doors used previously on other types of scale, which use pneumatic or hydraulic principles.

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The scope of the present invention relates to the design of a livestock weighing system device used in the field and the trading of livestock, namely digital cattle instrument with automatic doors. The developed instrument is designed to complement and enhance the benefits of the existing livestock scales, so that the use of digital scales can be more extensive and effective. The scale is built for four legged animals weighing up to several tons with a cage model. The scale is designed to be placed in the path of the animal crossing to ascertain the cattle move into the cage one by one, to be weighed. The opening and closing of the door should be done carefully where each animal must be ensured to be precisely inside the cage. Because once the door is closed and it hits the animal body, it will make the cattle become traumatized.

Livestock scale that meets the market needs, including livestock, slaughterhouses, and livestock markets, must have a good quality and standard or reasonable price [9][10]. In the present study, the developed digital cattle ration uses only one beam load cell that is placed at the center point of the mass [9][11], with a cage size adjusted to the size of the animal to be weighed. The size of the cage is adjusted to the size of the animal with the aim that the position is directly above the load cell, so that the weight of the animal can be measured with a high degree of accuracy. In addition, to ensure the animals enter the scale one by one, the scale is placed in the middle of the path of the livestock with a width of the scale adjusted to the width of the walking lane. This line system establishes a livestock queuing system, allowing only one animal to pass through and to be weighed. To avoid any potential trauma, the door that opens and closes automatically is equipped with an electronic control mechanism (hardware and software) by using laser and LDR transmitter system with a certain position to ensure that the animal has been on the scale and safe. The door system is driven by a DC motor, which requires less power than the power used on a pneumatic system. The result of the animal weighing is displayed on the LCD screen and sent to the RFID-based database identification system.

RESEARCH METHOD

This section explains how the system design is functionally and structurally built, how the flowchart of software is designed to run the whole system, and how the selection of components is carried out.

The Structural Design

The structural approach shows the design of the system in its physical form. Fig. 1 shows the approximate shape of the system and the flow of livestock within the integrated livestock market.

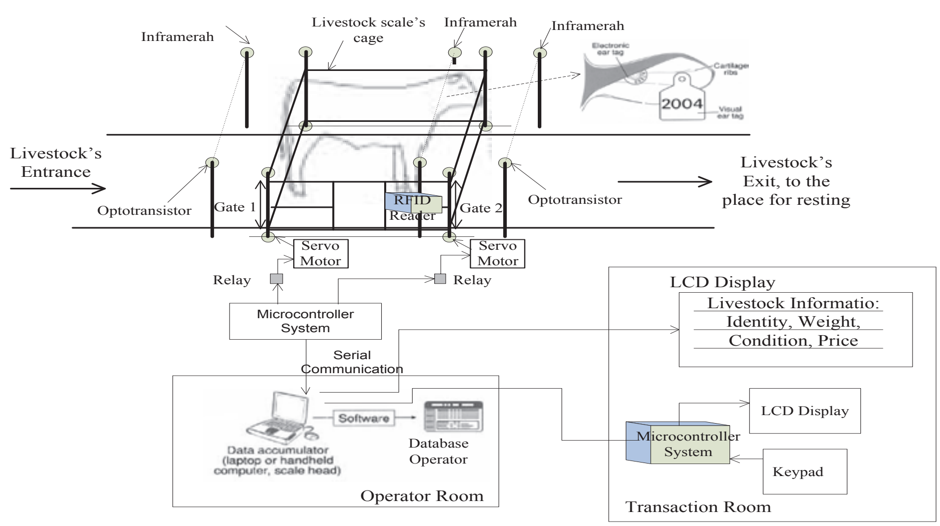

FIGURE 1. The structural design of an integrated livestock market system

The integrated livestock market system consists of three parts, namely: automatic livestock weighing system, transaction system and database system of livestock market operators. The present study was focused on the automatic livestock weighing system as presented in Fig. 2.

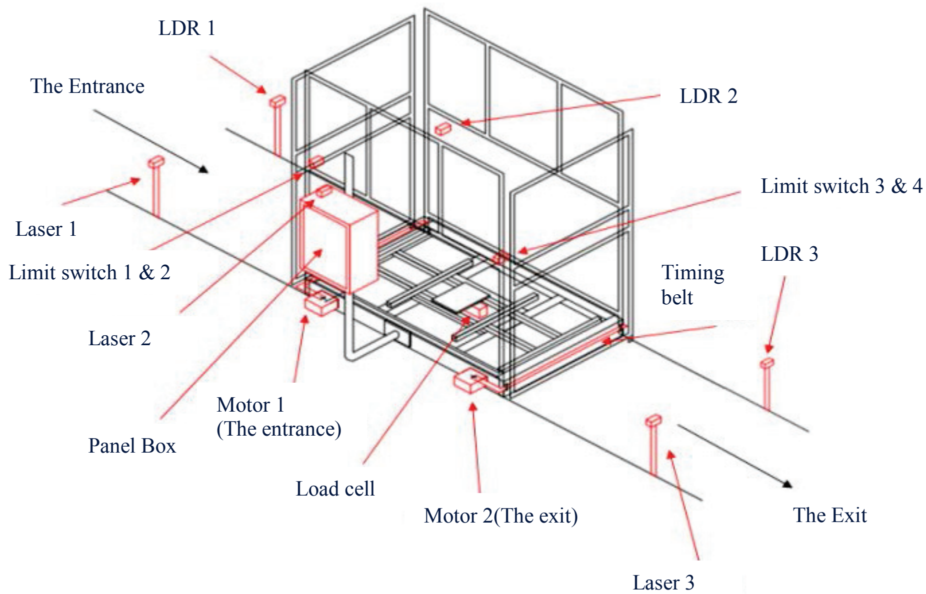

FIGURE 2. The structural design of automatic livestock weighing system

The automatic weighing system uses single beam load cell as a heavy sensor, combined with HX711 module as a signal output amplifier from load cell, H-bridge motor driver for rotation direction of motor, Arduino Mega Microcontroller, LCD as display viewer, DC motor as automatic driver for opening and closing cage's door, Limit Switch and pairs of Laser sensors and LDRs.

There are 5 (five) sensor positions on the automatic digital cattle weighing system. They are:

1. A pair of Laser and LDR sensor at the entrance (Sensor 1)
2. A pair of Laser sensor and LDR on the inside of the cage (Sensor 2)
3. A pair of Laser sensor pair and LDR at the exit (Sensor 3)
4. A pair of Limit Switch sensor at the entrance (Sensor 4)
5. A pair of Limit Switch sensor at the exit (Sensor 5)

Sensor 1 is a pair of Laser and LDR sensor placed with a distance of 1 meter from the front entrance of livestock scale. This sensor will be active when the light from the laser is blocked by an object when the animal passes by, and then send a signal to the microcontroller which then gives a signal to activate the motor and the entrance of the cage scale will open and stop when it touches limit switch 1.

Sensor 2 is placed inside the cage with a distance of 10 cm of the entrance. When the cage's door is already in opened, the door will not immediately close once an animal has enters the cage and then passes through sensor 2. It will close when the light blocked by the animal is not blocked any longer, which means that the animal is already safe inside the cage. Subsequently, the sensor will send a signal to the microcontroller which then sends a signal to activate the motor so that the entrance of the cage will automatically close and stop when the door touches the limit switch 2.

Once the entrance is closed, the scale will start weighing. The animal in the center of the cage is weighed using a load cell transducer located just below the cattle. The weight data of the animal is then displayed on the LCD screen. Time needed for weighing process uses time delay program, which starts when the entrance is closed and it touches the limit switch 2. After the weighing process is completed, the exit door will automatically open and stop when the door touches the limit switch 3.

The animal will come out and pass through sensor 3 (a pair of the laser and LDR). When the animal has passed through sensor 3, the sensor sends signal to the microcontroller which then gives the command to activate the motor so that the outlet cage will automatically close and stop when it touches the limit switch 4.

While the weighing is in process, the system will detect the identity stored in the earstag and then it sends the scale record to the operator database. The system will then display the data of the animal, including the identity, weight and price on the LCD display in the transaction room.

Flowchart of System

The flowchart of livestock integration systems is shown in Fig. 3. It entails the transaction system and database system of livestock market operators.

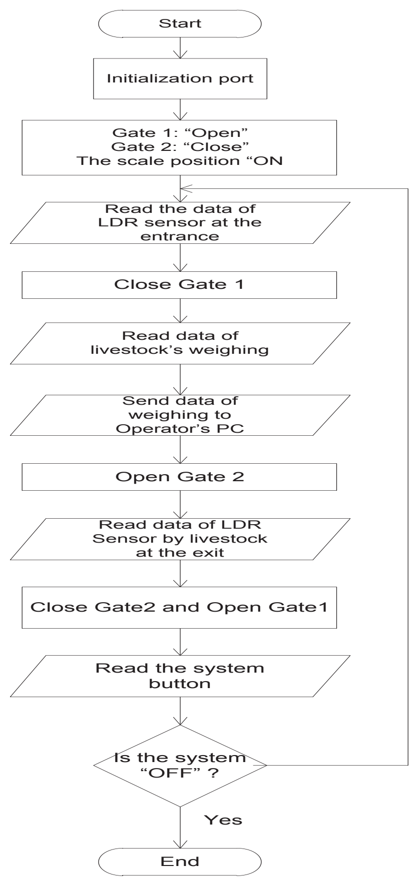

FIGURE 3. The flowchart of the whole microcontroller system

The hardware system in the automatic livestock weighing system consists of three types of hardware, namely: the cage structure system—which involves the automatic entrance and exit setting during the weighing process; the digital cattle weighing system; and the RFID-based animal identity reading system [12][13][14]. Each of this hardware system has certain support components and software which ensures the system is operated based in the flowchart above.

RESULTS AND DISCUSSION

With the acquisition of all the structural components and the integrated livestock market system, the research process is followed by the implementation and testing of the system. This section will present the implementation process, the testing accomplishment and the results.

Implementation of Structural Design of the Weighing System

The implementation of the cage structure design has been done and the supporting components of the cage structure have been established. Fig. 3 shows the final result of the cage structure for the weighing system in the integrated livestock market system.

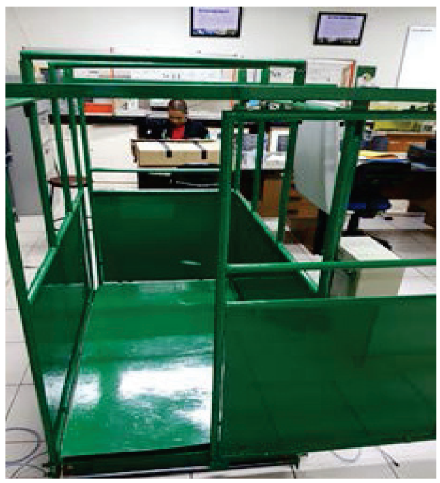

FIGURE 4. The cage structure of the automatic livestock weighing system

Implementation of Electronic Circuit Design of the Weighing System

The implementation of the electronic circuit design for the scales system is illustrated in the form of schematic diagram as presented in Fig. 4 Below.

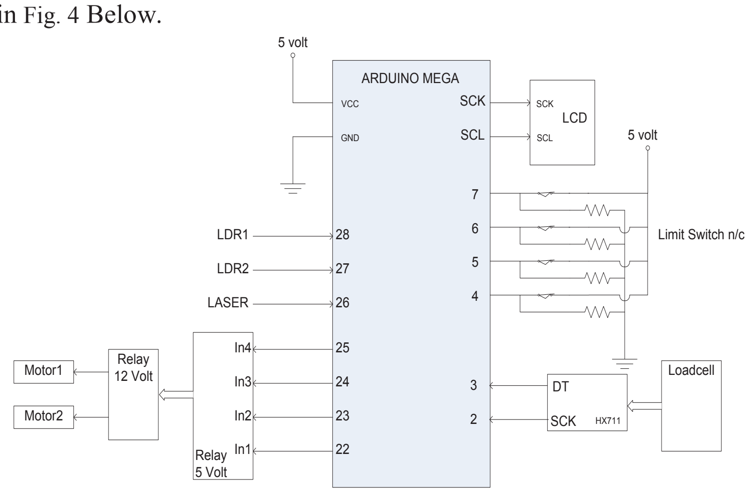

FIGURE 5. The overall series of digital cattle weighing system

Testing of Automatic Livestock Weighing System

After the implementation process has been completed, it is necessary to validate the results of the implementation of the design by testing the functions specified in the design and system characterization for evaluating whether the system is in accordance with the initial specification. The following explanation is the elaboration of the tests performed to validate the system.

Testing of Weighing Accuracy

The weighing accuracy test was carried out to determine the difference in load that can be measured by the commercial weighing system and the developed scale. The test consisted of 2 (two) tests, namely the minimum and maximum accuracy loads. Minimum load is given a burden in the form of sand that has been weighed with various weights. Testing was also carried out by placing a load on 9 (nine) variations of the load position with a minimum load to find out the possible maximum accuracy of the weighing system at a certain position. The test results are shown in Table 1 for the minimum accuracy load and Table 2 for the maximum accuracy load.

TABLE 1. Testing of Weighing Accuracy on Minimum Load

Weight [kg]	Weight based on its weighing position on the scale floor (kg)									Average	Differences
	1	2	3	4	5	6	7	8	9		
0.05	0.04	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.00
0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.00
0.15	0.13	0.14	0.14	0.14	0.14	0.14	0.13	0.14	0.14	0.14	0.01
0.20	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.02
0.25	0.23	0.23	0.23	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.02
0.30	0.27	0.28	0.28	0.28	0.28	0.28	0.27	0.28	0.27	0.28	0.02
0.35	0.34	0.34	0.34	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.02
0.40	0.38	0.38	0.38	0.38	0.38	0.38	0.37	0.37	0.38	0.38	0.02
0.45	0.43	0.43	0.43	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.03
0.50	0.48	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.03
0.55	0.52	0.52	0.52	0.52	0.52	0.52	0.51	0.51	0.51	0.52	0.03
0.60	0.58	0.58	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.57	0.03
0.65	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.60	0.60	0.61	0.04
0.70	0.66	0.66	0.66	0.65	0.65	0.65	0.65	0.64	0.65	0.65	0.05
0.75	0.71	0.71	0.71	0.70	0.70	0.70	0.71	0.70	0.70	0.70	0.05
0.80	0.75	0.75	0.75	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.06
Average of Difference											0.03

Table 1 is the result of testing the accuracy of the scales for minimum loads by using sand that had been previously weighed with commercial scale and packaged with various weights—which were then weighed in 9 (nine) weighing positions. The weight of the measured load on the tested scales almost showed the same results even though it was placed in various positions with a difference of only about 10 grams at each weighing position, with a total average difference of 30 gr.

TABLE 2. Testing of Weighing Accuracy on Maximum Load

No. of Load (Sacks)	The real weight [kg] (No. of load x 40kg)	The reading weight [kg]	Differences [kg]	% of Error
1	40	40.09	0.09	0.23
2	80	80.47	0.47	0.59
3	120	119.64	0.36	0.30
4	160	160. 3	0.33	0.21
5	200	200.9	0.94	0.47
6	240	240.37	0.37	0.15
7	280	280.44	0.44	0.16
8	320	320.27	0.27	0.08
9	360	360.15	0.15	0.04
10	400	399.06	0.94	0.24
11	440	438.04	1.96	0.45
12	480	473.76	6.24	1.30
13	520	513.81	6.19	1.19
14	560	553.35	6.65	1.19
15	600	592.11	7.89	1.32

Table 2 is the result of testing the accuracy of the scales for the maximum load. It was given in the form of whole cement in the packaging of 1-sack with a fixed load equal to 40 kg. The test was carried out by increasing the load gradually with a total of 15 sacks of cement or a total weight of 600 kg. Per increase in load was measured and it was examined whether the weight measured by the scales showed the same results as the real cement load given. In the test results, it was found that the reading of the tested scales showed the best scales accuracy in the range of 0 kilogram– 440kilograms, with an average error percentage of 0.265%; and the difference in load was quite high in the load range of 440 kilograms– 600 kilograms, with an average error percentage of 1.25%.

Automatic Scales System Testing

To validate automatic weighing system testing, the measuring of interval weighing system was used to see how far the measuring range can be done by the developed scale, by looking at the maximum load that can be measured by the scales. Measuring process range was done by turning hammer wrench on manual press. In order to know how many laps hammer wrench that had been done since it could reflect the number of rounds of a given torque, thereby representing the measured mass, then the stud bolt and nut were marked with a white marker. The result of the test is presented in Table 3.

TABLE 3. The experimental results of test range with manual press

No	No. of spinning (times)	Measuring weight (kg)
1	1	290
2	2	620

From the results of the experiment, it can be identified that the load cell range exceeds the offered specification, which was 620 kilograms of standard 500 kilograms. From the results of the weighing process, it is also seen that when the object is in the center position, the weighing result is similar to the result of the commercial scale. Meanwhile, if the position is on the edge, either near the entrance or near the exit, then the scale has a difference of +/- 0.5 kg. It is caused by the scale only uses one load cell mounted in the center. However, since the dimensions of the scale were made so that the weighted animal would be in a straight and centered position, the weighing results are expected to be the same with that of a commercial scale.

The subsequent testing is the scale accuracy. This test was performed to determine the minimum load that could be measured by the scale system. In this test, various kinds of weights were given with various weights. Table 4 shows the results of the accuracy test.

TABLE 4. Testing of Score Accuracy

The sample	Weight [kg]
Tipp Ex	-
Stapler	-
Combination Pliers	0.14
Wiper Motor	1
Two sets of pliers	0.4
Hammer wrench 46mm	0.6
Pliers	0.16
Solder's tin	0.11
Vivo V5 Smartphone	0.05
Samsung S7 Edge Smartphone	0.07

Based on the testing that has been carried out, it can be claimed that the scale has the capacity to accurately measure the weight of 0.05 kg.

CONCLUSION

From the results of the present study, it can be concluded that:

- The cage system can function appropriately based on the initial specification, e.g., the LDR-laser system works in accordance with the design so that the cage door can be opened and closed automatically.
- Digital cattle weighing system functions based on the design, in which it can measure with measuring range up to 620 kg with the accuracy of the scale of 0.05 kg.
- Linear weighing is in the range of 0 - 440 kg with an average error percentage of 0.265%.

Furthermore, in relation with the present study, some works can be done in the future, including:

- The establishment of operators database of livestock market.
- The establishment of real time on-site online transaction system.
- The integration of transaction system and the system references of livestock market operator database.

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