Embedded system for automatic real time weight based grading of fruits

Subir Kumar Chakraborty
Agro Produce Processing Division
ICAR-Central Institute of Agricultural Engineering
Bhopal
India
subir8275@gmail.com

Kumkum Dubey
National Initiative on Climate Resilient Agriculture
ICAR-Central Institute of Agricultural Engineering
Bhopal
India
dubey.kumkum@gmail.com

Abstract—**After harvest fruits are required to be prepared for sale. Arrangements on the part of the producer that lead to reduced handling will lower cost and preserve quality of the produce. Weight is a key factor based on which fruits are purchased by consumers. In the present research work a micro controller has been used to carry out weight based grading system for fruits. The machine is capable of weighing and separation of fruits into different weight categories without any human intervention. Developed machine comprises a load cell sensors, SSR relays, solenoid, anlaog to digital convertor and a Arduino Mega 2560 micro controller. Algorithm was developed to register weight recorded by load cells and accordingly actuate solenoids for accurate (±1 g) categorization of the spherical fruits under three weight categories, Small: < 70 g, Medium: 70 g to 120 g and Large: > 120 g. These weight categories can however be programmed as per the requirement of the user. The overall 'Accuracy' of the machine over all the weight categories was observed to be 88 percent.**

Keywords—load cell; micro controller; fruit grading

I. INTRODUCTION

In pack houses horticultural produce undergo a sequence of activities resulting in the final packaged product. Weight based grading of fruits and vegetables is a key operation for ensuring convineance of handling. Mechanical graders are quite common in packing – lines, but the segregation is limited by shape/size alone. As per Agriculture Processed Food Products Export Development Authority Act (APEDA) guidelines for packed fruits, the grades are identified and classified as large, medium and small on the basis of weight. Grading on the basis of weight is crucial as repeated small errors can lead to a huge revenue loss, this will negate the profitability associated with packaging quality and food quality [1]. There is therefore a constant quest to ascertain weight correctly [2]. Integration of automated weight based grading system has the potential of improving processing efficiency, reducing costs and minimizing waste from false grading [3].World over it is also becoming a legal binding to maintain high accuracy and efficiency in weighing. The machine reported in this research work shall be able to grade fruits on a real time basis vis-à-vis three weight categories, namely - small, medium and large. Since the fruits shall be in motion it will be crucial to have a faster reading rate under dynamic weighing condition [4]. The machine developed here shall have a load cell - micro controller based approach for weighing and grading the fruits automatically.

II. MECHANISM OF WEIGHT BASED FRUIT GRADING SYSTEM

The machine developed could grades fruits on the basis of their weight. The fruits are conveyed by a conveor and dropped on to the load cell for weighing. The weight was measured by cantilever strain sensor type load cell. The analog output signal from the load cell was converted to digital form by using an analog to digital convertor (HX711)module [5] for the micro controller. In this case the micro controller was Aurduino MEGA 2560. The input signal from the load cell through HX711 is registered by the microcontroller and classified in terms of three weight catergories. Simultaneously, the microcontroller also actuates the solenoid for opening the gate so that the fruit is dislodged from the weighing pan. Based on the weight of the fruit as signalled by HX711, the micro controller excites the SSR relay to actuate the solenoids for grading the fruits into three categories,- small, medium and large. The working principle of the machine can be understood from Fig.1.

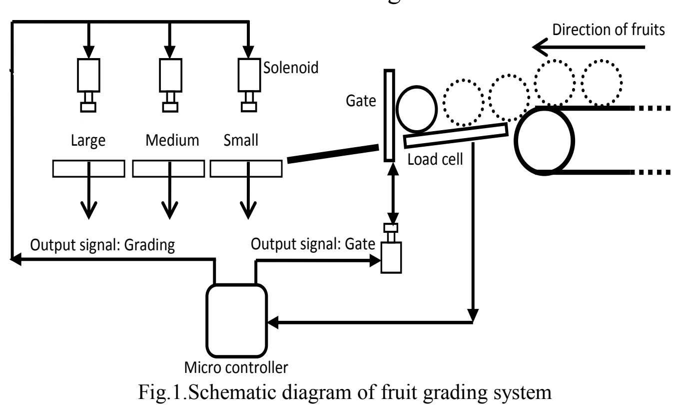

Fig.1.Schematic diagram of fruit grading system

The actual machine has three mutually independent channels. In other words there are three load cells followed by a set of three solenoids to segregate the fruits intothe weight categories. However, the gate is common to all the three channels (Fig. 2). When gate is "closed" the fruits in the three

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channels is weighed and when the gate is “open” the fruit roll down only to be separted in the designated weight category. Adequate delay is provided by the algorithm to the solenoid operating the gate to permit accurate weighing before actuation.

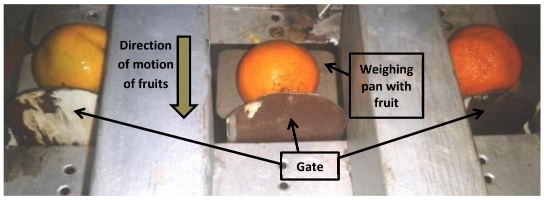

Fig.2. Fruits on load cell pan being weighed with gate closed

III. SYSTEM COMPONENTS

The development of automatic micro controller based fruit grading system was envisaged with the following theoretical weight measurement approach (Fig.3).

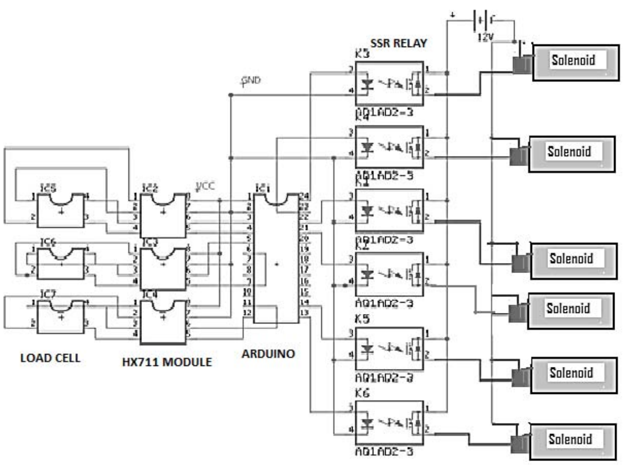

Fig.3. Circuit lay out for the system

A. Hardware Structure

The hardware comprised,- load cell, analog to digital convertor (ADC), micro controller, SSR relay and solenoids.

1) Load cell : These are transducers which performs the functionality of converting force into a measureable electrical output. The strain gauge is bonded onto a beam or structural member that deforms when weight is applied. This strain changes electrical resistance of the gauges in proportion to the load [6]. The specification of the load cell used in this research work is depicted in Table I.

TABLE I. LOAD CELL SPECIFICATIONS

Capacity	10 kg
Output	0.5 mV/V ±10%
Excitation	5 Vdc (8 Vdc max)
Non-Linearity	0.5% FS
Hysteresis	0.3% FS
Zero Balance	±1 mV/V
Bridge Resistance	350 Ω

2) Analog to digital convertor (ADC): It is a device that convert input analog signal coming from sensor into binary digital output for micro controller. In the present system development HX 711 module was used as an ADC. This module amplifies the original sensor analog signal and enables the conversion to a suitable bit resolution allowing superior measurement accuracy. The digital output value of HX711 is then transmitted to the micro-controller by 2-wire serial interface. HX711 is a precision 24-bit ADC designed for weigh scales and industrial control applications to interface directly with a bridge sensor. It contains crystal oscillator which provides clock signal for module, so that it does not require any external clock signal. There is no programming needed for the internal registers. All controls to the HX711 are through the pins. The power signal to this module can be routed through micro controller.

TABLE II. HX 711 SPECIFICATIONS

Power supply	2.6 ~ 5.5V
Gain	32, 64 and 128
Output data rate	10SPS or 80SPS
Frequency	50 and 60Hz
Temperature range	-40 ~ +85℃.

3) Microcontroller:

The microcontroller used in this system is Arduino Mega 2560. The Arduino Mega 2560 controls the whole system on the basis of load signals generated from the load cells. The Arduino Board is programmed using the Arduino IDE (Integrated Development Environment) software. Programming for this micro controller can be done in C language. It has 54 digital input / output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. This micro controller provides digital output to the relay for solenoid actuation, both for opening the gate after weighing as well as for weight based grading.

TABLE III. MICROCONTROLLER SPECIFICATIONS

Microcontroller	AT Mega2560
Operating Voltage	5V
Input Voltage	7-12V
Input Voltage	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB
Clock Speed	16 MHz

4) Solid state relay (SSR): SSR is an electronic switch which can turn a circuit ‘on’ and ‘off’. The SSR is triggered by an external voltage applied across its control terminal. It has no moving parts and thus can operate much more quickly and last longer than a traditional switch. It uses LED light as a contact; the two sides of the relay are photo-coupled. Thus it can save input side from loading effect. Here in this circuit DC to DC SSR relays are used. Input terminals have voltage 3-32V DC and output terminals are operated at 12-32V DC up to 10 ampere. Internal circuit of SSR relay is shown in Fig. 4. The purpose of including an SSR is for using low voltage (5V DC from micro controller) signal for actuating high voltage (12V DC solenoid) drive.

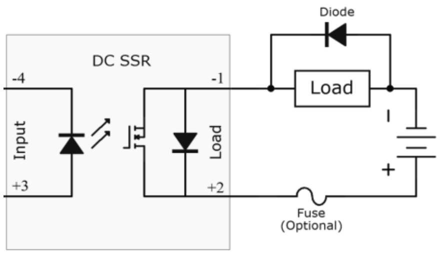

Fig.4. Basic structure of a solid state relay

*5) Solenoid:*A solenoid is a coil of insulated wire wound on a rod-shaped form made of solid iron, solid steel, or powdered iron. When DC voltage applies then it performs mechanical action. Operating voltage of solenoid is 12V DCand current is 8 ampere. The power to the solenoid is provided through 12V, 10 ampere SMPS. The opening and closing of the ‘pull’ type solenoid is explained in Fig.5. Depending upon the weight category, the micro controller turns ‘ON’ a solenoid to drop a fruit of designated weight category by pulling the movable plunger inside, while in ‘OFF’ position the fruit rolls over to be dropped down as per its weight category upon turning ‘ON’ of some other subsequent solenoid. The actual placement of solenoids in the developed system can be seen in Fig.6.

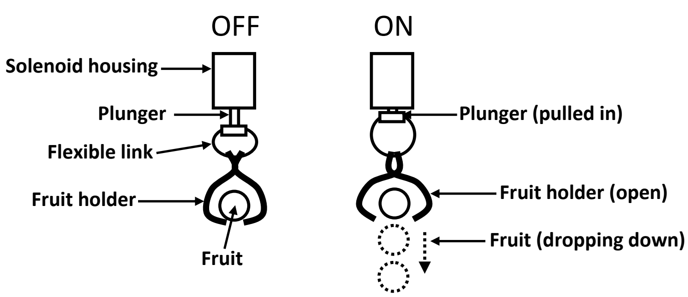

Fig.5. Weight based fruit dropping mechanism by solenoid actuation

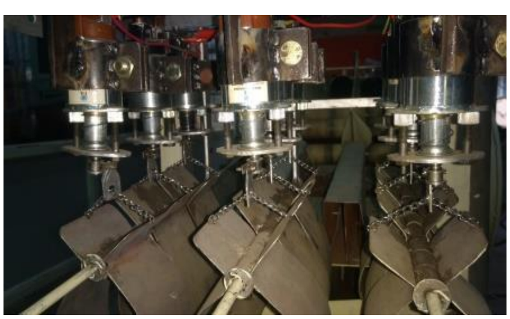

Fig.6. Battery of nine solenoids for three channels classifying fruit into three (small, medium and large) categories in each channel.

All the components described above have been interfaced with the micro controller for serial port communication as shown in Fig.7.

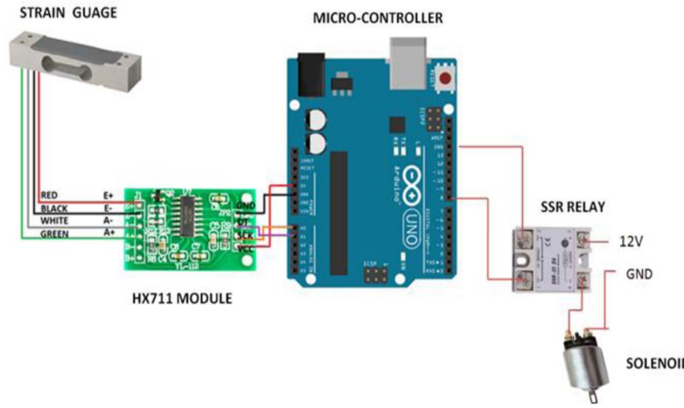

Fig.7. Interfacing of various hardware components with microcontroller

B. *Software Structure*

Arduino IDE software was used to write and upload the computer code to the physical board. Basic structure of Arduino programming language is “void setup and void loop”. Setup() is the first function of program which follow declaration of variables, set pin mode and initialize serial communication. Void setup run only once in program, whereas loop consecutively allowing the program to change, respond and control Arduino board.

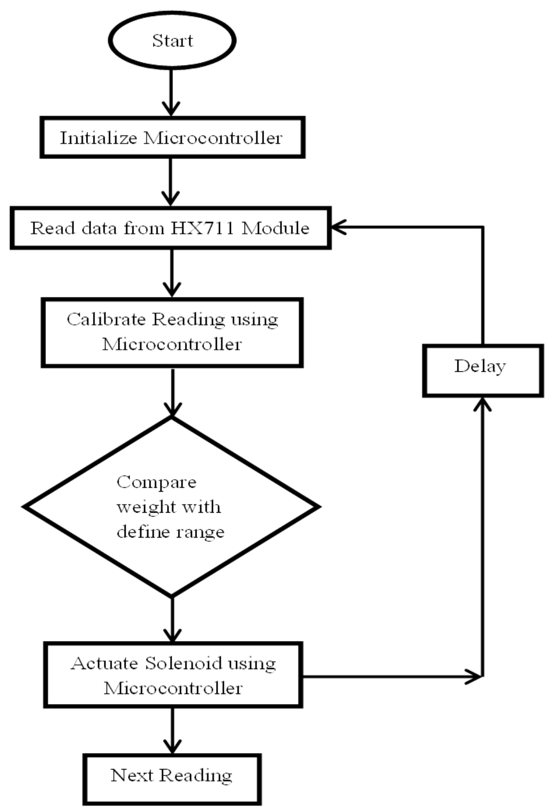

Fig.8. Decision flow chart for the micro controller

The programme starts with initialization of micro controller, followed by registering and interpreting the data coming from load cell through ADC module HX 711. Calibration of HX711 is carried out by taking readings of known sample weight. This is followed by converting voltage values in terms of weight and then compare the different weight ranges. Suitable delays have been introduced at places in the codes so as to make the machine real time. The logical flow for running the micro controller to successfully carry out the real time weight based sorting of fruits is describe in the flow chart (Fig.8).

IV. RESULTS

A. Performance of Load Cell Sensor

The success of this dveloped microcontroller based automatic fruit grading system was entirely dependent on the performance of the load cell. The correctness of the load cells was verified in actual environmental conditions to study the relationship between load and voltage output. Tests were conducted for different weights (0 to 120g) and the output voltage (mV) was registered as an average of five readings. The graph (Fig.9) shows that results were almost linear (R^2=0.996) and established the suitability of these load cells for use in the developed system.

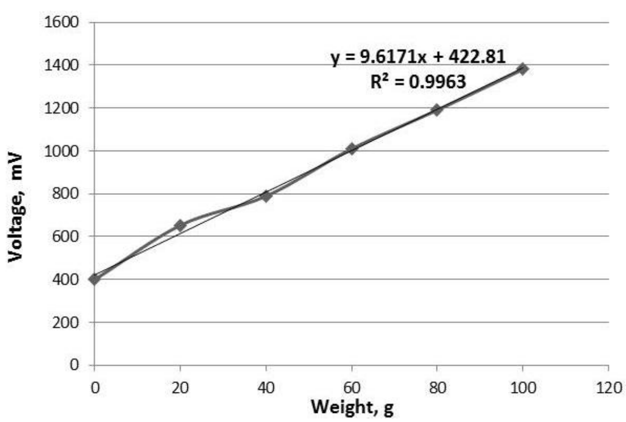

Fig.9. Graphical depiction of load cell linearity

The load cells were fitted in all the three channel with a weighing pan connected on top of it.

B. Efficiency of Classification

Rigorous tests were conducted on the machine to evaluate the efficiency of the separation of fruits into the three categories. Orange fruits were purchased from the market and batches of 120 fruits at a time was made to pass through this machine. The range of the three weight categories,- Small: < 70 g, Medium: 70 g < M < 120 g and Large: L > 120 g; was used for testing the developed weight based classification system.

Confusion matrix is a potent tool to express the efficiency of a classification system. The reliability of a classification system with respect to various categories can be expressed by this method. The results of the tests is reported in Table IV. The values in the square brackets indicate 'Reliability' of classification by the machine in a particular weight category, e.g. the machine could classify 37 oranges as 'small' out of the 40 'small' oranges, or in other words the reliability of classifying a 'small' orange correctly was 95 per cent. The overall 'Accuracy' of the machine over all weight categories was observed to be 88 per cent. Accuracy here means that how often the classification is correct.

TABLE IV. CONFUSION MATRIX FOR FRUIT GRADING

		Actual		
	Accuracy = 0. 88	**Small (40)**	**Medium (40)**	**Large (40)**
Predicted	Small	37 [0.95]	2	0
	Medium	3	34[0.80]	6
	Large	0	4	34[0.90]

V. CONCLUSION

Seamless integration of Arduino Mega 2560 could be successfully carried out with load cell in conjuction with ADC module HX711 to actuate solenoids for mechincally effecting weight based sorting of fruits into thre categories Small: < 70g, Medium: 70g to 120g and Large: > 120g. The software developed can be easily modified by the user for different commodities. The signals from the load cells could be suitably conditioned and data acquisition hardware was successfully developed so that the system can obtain various load measurements for a wide span of time. The performance of the machine was also found to be demonstrating an accuracy of more than 88 per cent. Thus this machine can provide automation solution to fruit handling, packaging and transportation.

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