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Fruit Sorting by Pizzo-electric Sensor and PLC Controlling

Aswant Kumar Sharma [a], Akshay Krishna Varak [a], Shubham Arun Gitaye [a], Nishant Vijay Gavali [a*] and Prathamesh Kishor Bate [a]

[a] Finolex Academy of Management and Technology, Ratnagiri, Maharashtra, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Abstract: The fruit sorting process traditionally relies on visual inspection, primarily considering size as a key quality parameter. However, industries engaged in large-scale fruit trading have turned to image processing technology for sorting, despite its high cost and impracticality for small traders. This paper proposes an alternative sorting system that offers an economical solution suitable for automated fruit sorting at various scales.
Aim: The aim of this study is to develop an economical automated fruit sorting system capable of classifying fruits based on their weight, thereby eliminating the need for manual labor and improving sorting accuracy and efficiency.
Place and Duration of Study: Department of Electrical Engineering Finolex Academy of Management and Technology, Ratnagiri, Maharashtra, between July 2023 to April 2024.
Study Design: This study employs a practical approach to design an automated fruit sorting system that utilizes Programmable Logic Controller (PLC) technology in conjunction with load cells. The system is designed to classify fruits based on their weight as they move along a conveyor belt, thereby automating the sorting process.

**Corresponding author: Email: ed220595@famt.ac.in;*

Methodology: The proposed sorting system integrates PLC technology and load cells to accurately measure and classify fruits based on their weight. By eliminating the need for manual intervention, the system enhances sorting efficiency and accuracy. The system is designed to be cost-effective and suitable for implementation by small traders and farmers.
Results: The developed sorting system demonstrates precise, reliable, and consistent sorting outcomes based on fruit weight. By automating the sorting process, the system achieves improved efficiency and productivity compared to traditional manual sorting methods. Moreover, the cost-effectiveness of the system makes it accessible to small traders and farmers seeking to enhance their sorting practices.
Conclusion: The proposed sorting system offers an economical and efficient solution for automated fruit sorting, particularly for small traders and farmers. By leveraging PLC technology and load cells, the system provides reliable alternative to costly image processing-based methods. The automation of the sorting process eliminates the risk of errors and inconsistencies associated with manual sorting, while ensuring accurate and quantitative classification based on fruit weight. This sorting system presents a practical approach to improving fruit trading operations, enhancing efficiency, and productivity.

Keywords: PLC (programmable logic control); fruit; load cell; conveyor belt.

1. INTRODUCTION

In the realm of modern agriculture and commercial farming, technological advancements have become imperative for maximizing efficiency, productivity, and quality. Among the myriad of innovations, the integration of piezoelectric sensors and programmable logic controllers (PLCs) stands out as a promising solution for fruit sorting [1]. This introduction will develop into the rationale behind employing such technology, elucidating its significance and the pressing need for its adoption in agricultural practices.

In the development phase of automation, the policy of country government will also effect. Various automation technologies are available for fruit sorting in agriculture industry, but this technology such as IoT, image processing is not economical [2-4]. The trend of technology development with internet is become a trend but everywhere in country like India and other developing country internet connectivity is not well available. The other technology such as computer-based fruit grading system [5-10] focuses on why technology important for sorting over manual sorting. The technology used to demonstrate the sorting of fruit disease detection and classification specifically of apple [11]. The computer vision technology used for tomato sorting using conveyer belt processing [12]. The technology such as raspberry-pi used in fruit sorting [13]. The major areas of quality evaluation of food grains, fruits and processed fruits had also found useful for determination insects infection in fruits and vegetables [3].

The computer vision or image processing analysis is based on size, shape and color analysis [14]. The sorting is based on the shape, color for quality. The mostly used technology for sorting is image processing. This technique is tested on various fruits such as apple, tomato, mango etc [15].

The other traditional techniques are manual sorting, size bases weight based which may include the hard labor, timing and cost for labor as well as low efficiency output.

The other technology in development process uses conveyor robots which uses electropneumatic conveyer belt robots with two separated lines. The control operation handled by PLC, sensor [16], gripper arm and electronics switches the procedure gives the unique accuracy and efficiency with medium cost. The conveyor robotics well given for the device sorting in [17].

The paper is well written and divided into sections and subsections. The section starts from introduction, followed by problem formulation, working principal part includes equipment used for the process, sematic diagram, ladder logic program, hardware implementation of conveyer belt, result, conclusion followed by references.

When we had studied about fruit sorting based on different criteria, we realized that the weight-based fruit sorting is best technique for small farmers over manual sorting. We got the result as weight-based sort, we categorized two weights above 120gm and below 120gm.

2. PROBLEM FORMULATION

In agriculture industry, especially considering the farmer sorting of fruit have various methods. Such as image processing, computer vision, weight sorting, ripe sorting these all method and machine equipped with these methods are not economically suitable for the farmers specially from under developed countries, developing countries. On the other hand manual procedure suffers from inefficiencies, inaccuracies and time consuming. The section identifies these challenges and the need of economically efficient sorting system on weight based as Indian marketing system is based on weight.

3. WORKING

In this project we have proposed a low-cost automation system for fruit sorting on the basis of their weight variation. The project mainly focused on sorting fruit using load cell. load cell dc gear motor, servomotor interface with programmable logic controller (PLC). A dc gear motor is used for the pushing fruit using conveyor belt. fThe system consists of conveyor belt which takes the fruit from the load cell and thus sorting decided by PLC. PLC is programmed with different logic each for sorting different fruit based on their weight. In this system the load cell is used for detect the weight of every fruit. Using conveyor belt segregate the fruit by their weight.

The Fig. 1 represents the process of fruit sorting using flow chart. The Fig. 2 represents the planned structure of the conveyer belt with operating motor, pushing motor, load cell. The two basket is placed which collect the fruit sorted less than 120 gm and greater than 120 gm.

If fruit is not above 120gram then motor will not start and that fruit is separated from conveyor. we use pushing motor to push fruit from load cell to conveyor. In our case the weight of fruit is above 120gram hence fruit goes straight on conveyor and separated. The Fig. 6 represents the projected structure for fruit sorting conveyer belt.

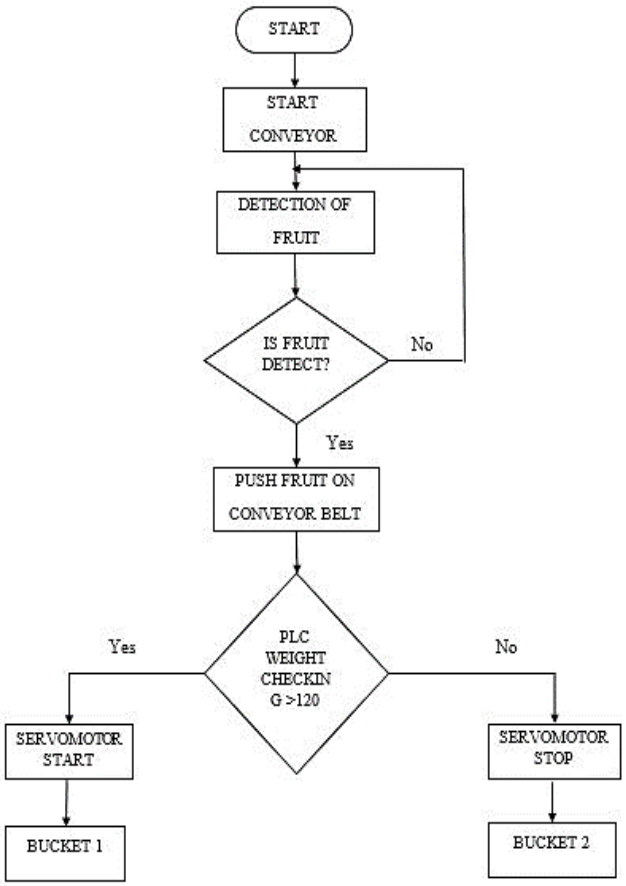

Fig. 1. Flow chart of system for fruit sorting process

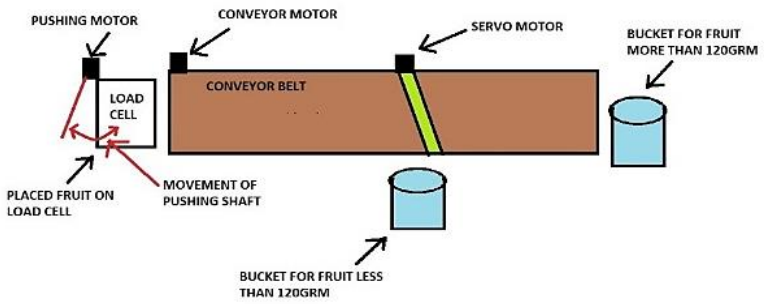

Fig. 2. Planned hardware system with load cell placement and operating motors

3.1 Components

3.1.1 Load cell (1kg)

Capacity - 1Kg
Rated output (MV/V) - 2.0 ± 0.15
Input resistance – 402 ± 6
Output resistance – 350 ± 3
Operating temperature range - -35 ~ +80C°
Method of connecting wire - Input = Red (+), Black (-)
Output = Green (+), White (-)

Output signal of load cell is a millivolt level voltage signal proportional to weight/load. Load cells usually have an excitation voltage of between 3 and 15 volts DC.

3.1.2 Load cell transmitter/weight transmitter

The analog input module of ordinary PLC cannot directly process. So, additional analog load cell Transmitter is required to convert weak sensor signal into the standard industrial process signal of (0-5) V/ (0-10) V or 4-20 mA (0-20mA).

Input signal = 0-20mV.
Output signal (DC) = 0 - ±5V, 0 - ±10V, 4-20mA.
Excitation voltage (selected) = DC (5-15V).
Power supply = DC (18-30V).

The general formulas for weight measurement, signal processing, threshold sorting, control logic and efficiency are as follows.

1. The weight measurement using Piezoelectric sensors

$$W = m \times g$$

2. Signal Processing for weight detection

$$V_{out} = S \times F$$

3. Threshold Determination for Sorting

$$F_{Threshold} = k \times W_{average}$$

We assuming the value of K is (+ - 0.5).

4. Control Logic using Programmable Logic controller

$$F_{measured} \geq F_{Threshold}$$

It is the logical sorting mechanism,

5. Efficiency Calculation

$$\eta = \frac{\text{Number of fruits sorted correctly}}{Total\ number\ of\ \ fruits\ sorted} \times 100$$

We take total 100 fruits for performing our sorting process. In this process 65 fruits are greater than 120 gm and 35 fruits are less than 120 gm. We sorted our fruits accurately on their weight basis and it gives 100% efficiency.

In above W is the weight of the fruit, m is the mass of the fruit, g is the acceleration due to gravity. V_{out} is the output voltage of the piezoelectric sensors. S is the sensitivity of the sensor, F force exerted on the sensor by fruit. $F_{threshold}$ threshold force for sorting, k constant factor determining the threshold level. $W_{average}$ is the average weight of the fruits being sorted.

The weight signal transmitter plays a role in the fruit sorting system employing piezoelectric sensors and PLC controlling. The component used to convert physical weight of the fruit into an electrical signal that can be processed by control system.

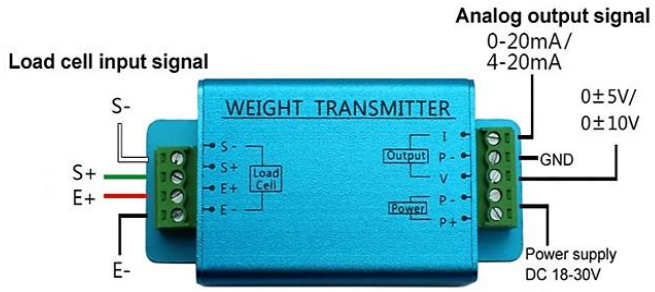

Fig. 3. Weight signal transmitter

3.1.3. Servomotor MG996R (360° rotation)

Weight = 55g
Operating voltage = 4.8 ~ 6.6 V
Operating speed = 0.19sec/60degree
Stall torque = 9.4kg/cm (4.8V), 11kg/cm (6.0V)
Gear Type = Metal gear
Dead bandwidth = 1us
Wire Length = 32cm

3.1.4. DC gear motor

Speed = 100 rpm
Voltage = 12 volts
Material = Iron

3.1.5. Arduino uno

The Arduino Uno is a microcontroller board based on the ATmega328P chip. It is a popular development board used for various electronics projects and prototyping. The board comes with a range of features that make it ideal for beginners and professionals alike.

The main features of the Arduino Uno board include:

Microcontroller: The Arduino Uno is built around the ATmega328P microcontroller, which is a 8-bit AVR microcontroller with 32KB of flash memory, 2KB of SRAM, and 1KB of EEPROM.

I/O Pins: The board comes with 14 digital input/output pins, 6 analog inputs, and 6 PWM (Pulse Width Modulation) outputs. These pins can be used to connect various sensors, actuators, and other devices to the board.

USB connection: The board has a USB port that can be used to connect it to a computer, allowing it to be programmed and powered through the USB cable.

Power: The board can be powered by either USB or an external power supply (7-12V DC).

Compatibility: The Arduino Uno is compatible with a range of shields (boards that plug into the Arduino board to extend its functionality) that can be used to add additional capabilities to the board.

The Arduino Uno board is programmed using the Arduino Integrated Development Environment (IDE), which is an open-source software application that allows users to write, compile, and upload code to the board. The IDE comes with a range of libraries and examples that can be used to get started with the board.

In summary, the Arduino Uno is a versatile microcontroller board that is popular for various electronics projects and prototyping. Its wide range of features, ease of use, and compatibility with shields make it an ideal choice for beginners and professionals alike.

In system, to place the fruit on load cell mechanism. when push the start button the conveyor have start. once the conveyor starts after 5sec pushing motor is also start (give 5 sec time delay between conveyor motor and pushing motor for sensor to sense the weight of fruit) between that 5sec if sensor sense the weight of fruit is above120gram then the servomotor will start and on for 10sec and fruit goes straight on conveyor.

The following table gives the technical analysis details of technology on factors such as technology used, cost and other aspects. The table shows that the technology offered have high accuracy, speed with moderate complexity, Cost scalability maintenance requirement and flexible. The ability to handle the various fruits type is good.

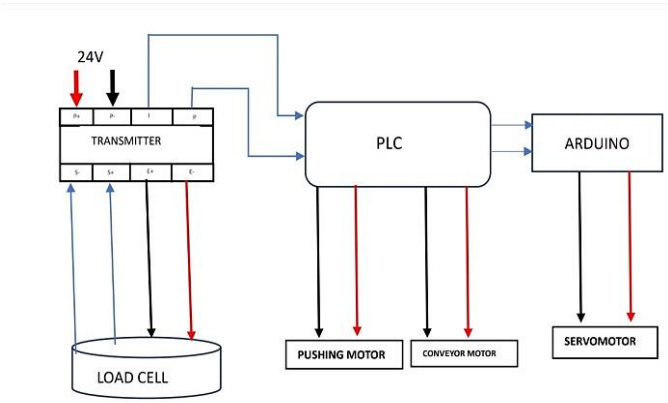

Fig. 4. Block diagram of model connections

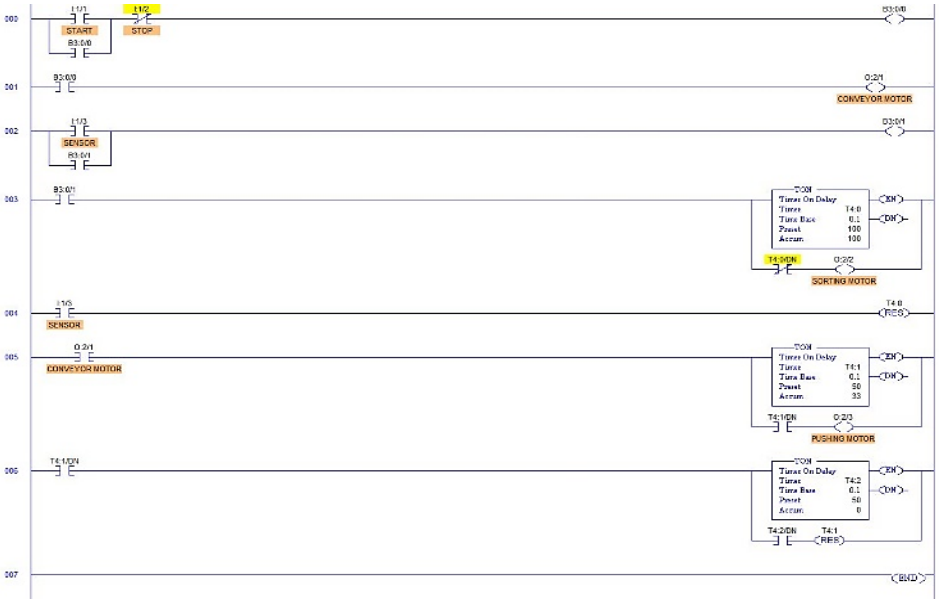

Fig. 5. Ladder logic program for fruit separation and operation the motor

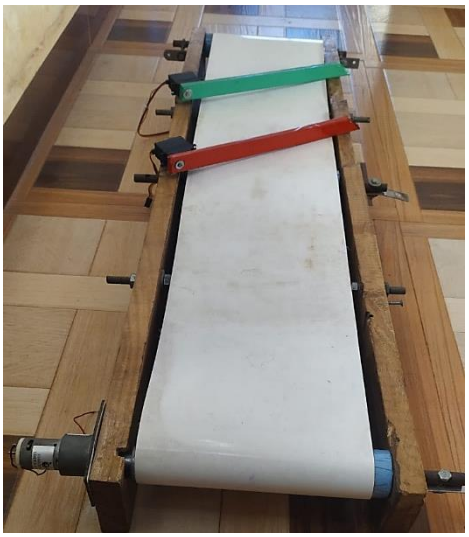

Fig. 6. Hardware system for fruit sorting

Table 1. Comparasion of sorting technologies using various ascepts

Aspect	Pizoelectric sensors and plc controlling	Image processing based sorting	Weight-based sorting	Size-based sorting	Manual sorting
Technology Used	Piezoelectric sensors, PLC	Cameras, image processing	Load cells	Mechanical sizing	Human labor
Accuracy	High	High	High	Moderate	Variable, depends on human operator
Speed	High	Moderate	Moderate	Moderate	Variable, depends on human operator
Cost	Moderate	High	High	Moderate	Low
Complexity	Moderate	High	Moderate	Low	Low
Flexibility	Moderate	High	Moderate	Low	High
Scalability	Moderate	High	Moderate	Low	High
Maintenance Requirements	Moderate	High	Moderate	Low	Low
Ability to Handle Various Fruit Types	Good	Good	Good	Limited	Limited
Automation Level	High	High	Moderate	Low	None
Integration with Existing Systems	Moderate	Moderate	Moderate	Low	Low

4. CONCLUSION

In conclusion, employing PLCs for fruit sorting based on weight improves efficiency and accuracy within fruit processing industries. By streamlining operations and maintaining consistent quality control, this system utilizes load cells or weight sensors to precisely gauge the weight of individual fruits against predetermined thresholds. This approach reduces reliance on manual labor, diminishes errors, and boosts throughput, ultimately driving cost-effectiveness and profitability. Moreover, the adaptable nature of PLC programming enables customization to accommodate different fruit varieties and sorting criteria, making it a versatile solution tailored to the evolving demands of the industry.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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