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Automated Conveyor-Belt Product Sorting: An Industry 4.0 Initiative

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Abstract: In this paper, an automated conveyor belt-based product counter and faulty product detector along with the sorting mechanism using IR sensor array with microcontroller interfacing have been fabricated and analysed. Product transport line of a factory is utilized to convey this item starting with one station to another. This conventional methodology is tedious, less intense and non-predictable. The proposed system has turned out to be progressively easy and less time-consuming product transport system for an automated industry 4.0 utilization. In this manner, the authors proposed the structure and execution of programs utilizing core microcontroller. In the implemented system, the product rolling over a conveyer belt detection has been sensed by infrared technology. Using IR sensors, the dimensions (height and width) of a product which may be smaller or larger has been determined. Once the size of a product is determined, the proposed system will automatically count and sort the objects as per its size and dimension and the product is placed by using a stepper motor.

Keywords: *automated industry 4.0; microcontroller; conveyor belt; IR sensor; stepper motor*.

1. Introduction

The present world is particularly based on industrial automation. Industries today are playing a vital role in the economic development of a country. Automated industries pave the way to the road map of development in the industrial sector. Modern industries are focusing on product quality and control management including information security [1, 2]. In the present condition, automation is required to take the challenge of the modern industrial revolution. Market challenge, effectiveness is typically respected as the key of progress for an automated industry. Automation plays a role in distinguishing influence in a worldwide diversity of industries as well as manufacturing technologies. Automated industry deals with the optimization technique of less time requirement as well as energy-efficient driven systems by developing detailed and precise control strategies and measurement technologies [3]. Nowadays, power and energy-efficient drive systems in automated industrial techniques are progressively relevant. The conveyor belt is the most advantageous stratagem in the industry for various resolutions which is computerized.

Conveyor belts are reliable and durable accessories used in the automated industry. In integration with computer-operated pallet handling things, this permits for well-organized marketing, and industrial application. A conveyor belt consists of two or more pulleys driven belt system, with a constant loop of material that interchanges about them. One of the pulleys is powered by a drive system which affects the belt and move the material on the belt onward. The powered hoist is baptized as the drive pulley while the unpowered pulley is called the idler. There are two main industrial classes of belt conveyors; those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transference industrial and agricultural materials, for example, grain, coal, ores, etc. largely in alfresco sites. Commonly, companies providing general material handling type belt conveyors do not provide conveyors for bulk material handling [4, 5]. A conveyor can move an object or materials from one station to another with a constant or variable speed according to the manufacturing operation. Fig. 1 shows a conventional conveyor belt sorter. A conveyor belt consists of a perpetual belt of resilient material connected between two flat pulleys. Typically, conveyor belt is utilized in numerous applications for transportation of materials or different products from one spot to other in industry. In this undertaking our goal is to build up a model of conveyor belt using dc motor, which are precisely associated with one another. On the opposite end we will have a programmed sorting system based on the height and width of the product. This sorting techniques are utilized by a logical expression into the microcontroller. Toward the finish of the belt we will have an IR sensor, when the product set on the belt breaks the IR array an advanced counter will begin checking. The authors have proposed low cost and low power consumption segment arranging which can sort the product depending on size and dimension [7-9]. Where it is set on transport line which is passing persistently with the help of D.C motor. The target of the task is to sort the segment as indicated by dimension. Our proposed works goes for the testing of the products by a conveyor belt driven system which opposed to utilizing manual way. It reduces the human function and simultaneously increment the profitability and exactness levels that can't be accomplished with manual tasks.

Fig. 1. Conveyor belt type sorter (Conventional) [6]

2. METHODOLOGY

In this system the product is driven through the conveyor belt. When passing through the conveyor an array of IR sensor detects the size and the width of the product. A proximity sensor senses the product speed. When two consecutive products have made a smaller distance between the proximity sensor sensed the distance between them and speed up the conveyor by increasing the speed of the motor. A stepper motor is used to place the product sorting to the box according to their size and weight. Product sorting is performed by the defined parameter of height and weight. Outranged value from controller is considered as faulty product and placed into the faulty box by operational technique of motor stepper.

3. System Design

Circuit Design is very important for electronic fabrication, in the proposed system the circuitry has been developed with lower complexity for better current flow and ease of use. Fig. 2 depicts the schematic circuit diagram for the proposed system.

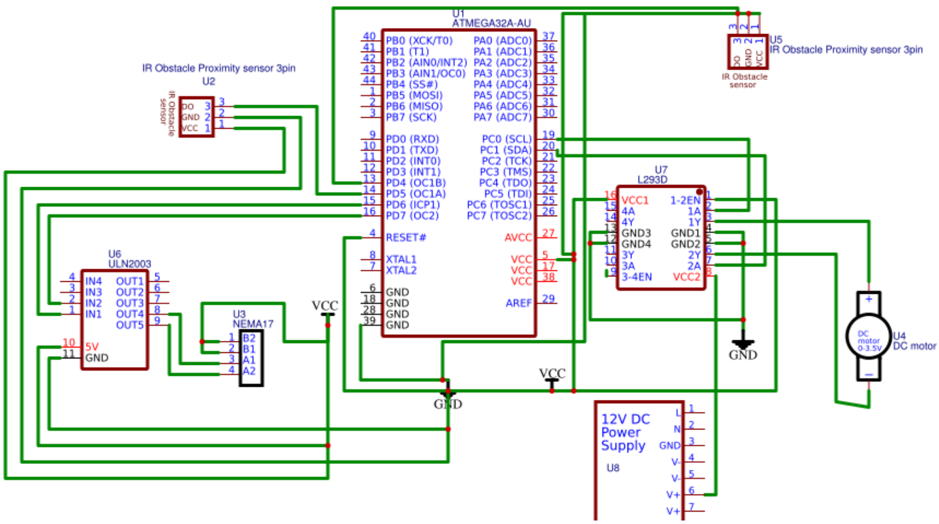


Fig. 2: Circuit Diagram of proposed conveyor sorting mechanism.

Now, as the sorter sorts specified selections of samples so it must have a swift control mechanism. Feedback is a very well-known method for this kind of controls where a reference value is predefined. Fig. 3 shows the control diagram of the proposed system.

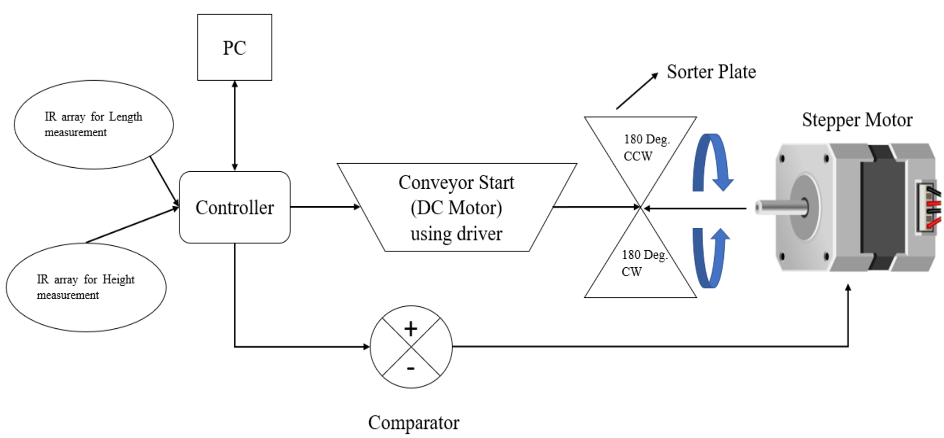


Fig. 3. Control Mechanism of proposed system.

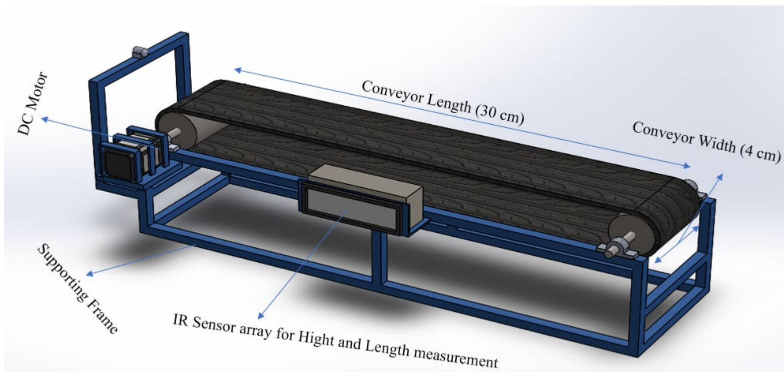
Let define ‘R’ as a reference value or parameter which is the threshold for the system. If ‘U’ is the input parameter from the sensory calibration, then for feedback action two cases must be considered:

- Case-1; if $R - U < 0$ then negative feedback takes place and it must be compensated by actuation. So, for this case, $Feedback\_State \ ==$

1 and $Stepper\_State == CCW$ (Counterclockwise) and the product goes to defective product collector.

- Case-1; if $R - U \geq 0$ then positive feedback takes place and no compensation of state is needed. So, for this case, $Feedback\_State == 0$ and $Stepper\_State == CW$ (Clockwise) and the product goes to good product collector.

Fig. 4 shows both schematics of the CAD model and experimental setup.

a)


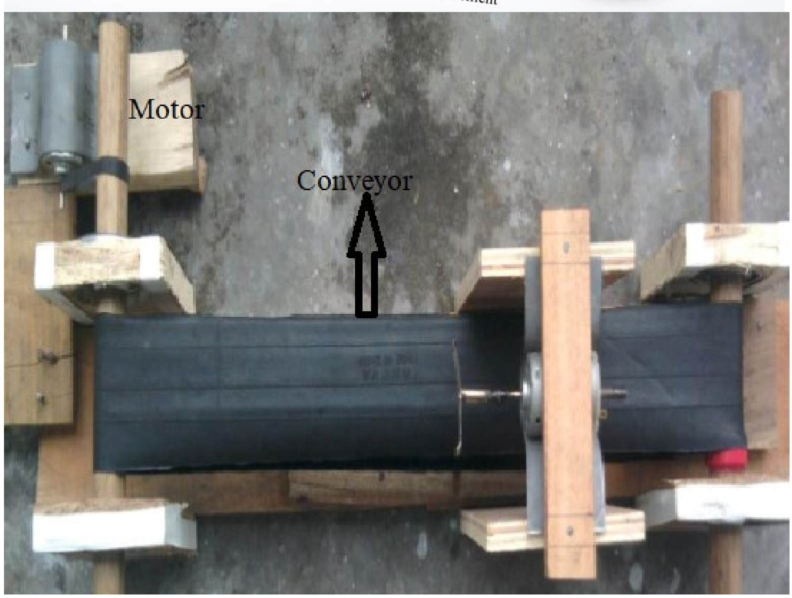
b)


Fig. 4. Proposed Conveyor belt sorter (a) CAD model (b) Fabricated model.

For the CAD model only, physical properties are taken into consideration. For the experimental setup the supporting frame is taken wood for its easy availability and high load bearing capacity. The BOM (Bill of Materials) are shown in Table 1, which is approximately 1500 BDT (< 20 USD). For same dimensional conventional setup, it will cost almost 1.5-3 times.

Table 1. Approximated Cost Estimation of the proposed system.

Components	**Price (BDT)**
DC motor (2 PC)	260
Microcontroller (ATmega32)	175
Belt	50
IR sensor	290
LCD Display	150
Steeper motor	400
Proximity Sensor HC-SR04	120
Total	**1445**

4. Mathematical Modelling

For mathematical modelling of the geometry first the conveyor shape has been transformed into its vector form (Fig. 5).

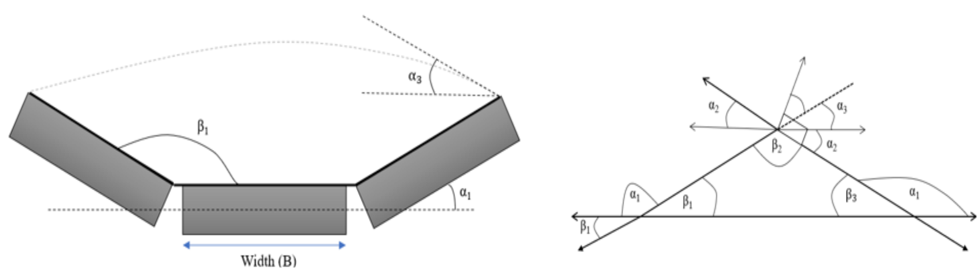
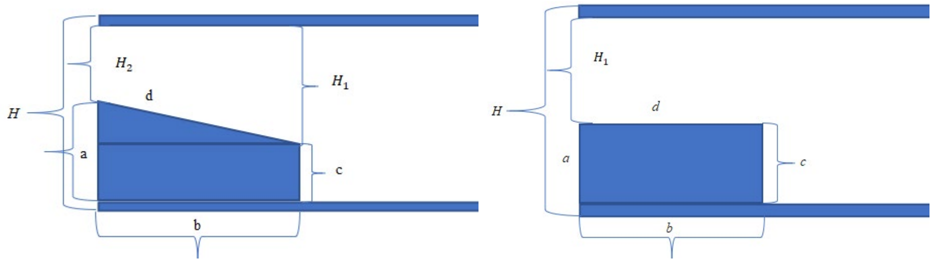


Fig. 5. Vector model of geometry.

The most common design consideration of 3 rolls of equal length has been the choice for the mathematical modelling. Here, Trough angle (α_1) = 55^0, Inside angle (β_1) = 180^0 - α_1 = 125^0. So, $\beta_2 = \beta_3 = 27.5^0$ and β_3 alternate $\alpha_2 = 27.5^0$. Thus, Surcharge angle (α_3) = $90^0 - (\beta_2 + \alpha_2)$ = 35^0, Belt dimension ($x_1.y_1.h_1$) = 30×4×1 cm^3. Now, for sensory calibration of height and length measurement, some considerations are also mandatory as (Fig. 6); $H_1 - H_2 = \delta, \frac{sin90^0}{d} = \frac{sin\beta_4}{sin\beta_5} = \frac{b}{\delta}$. Thus, $\frac{H_1}{H_2} > 1$ or $\frac{H_1}{H_2} < 1$. For, $H_1 - H_2 = 0$, the object will be of diagonal shape having right angled at both sides.



(a) (b)

Fig. 6. Dimensional two-dimensional schematic:
(a) trapezoidal shaped right angled object, (b) diagonal shaped object.

Now for the IR sensor, from the datasheet the formula of distance measurement can be obtained (Fig. 7):

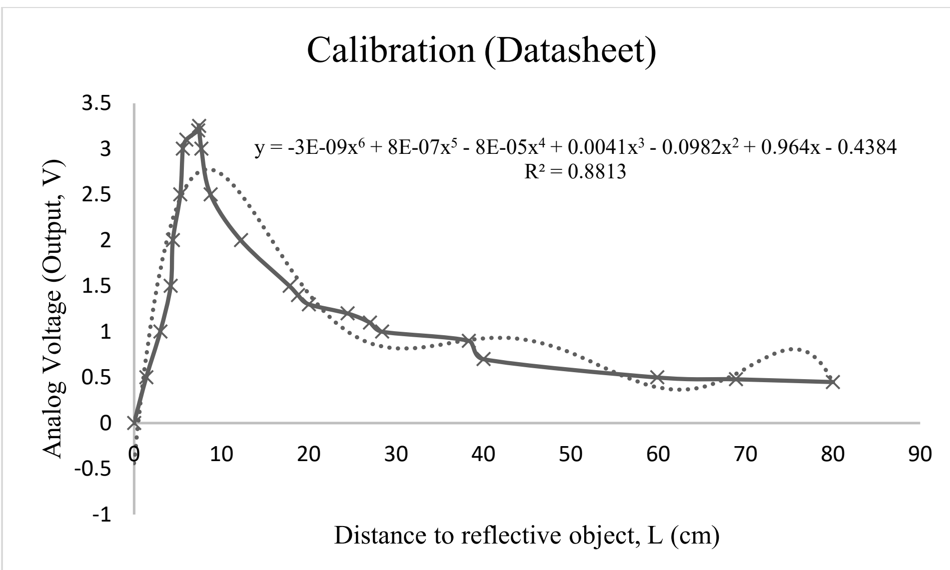


Fig. 7. Calibration formula using datasheet and 6th order polynomial.

The calibration formula can be estimated using polynomial expression:

$$y = -3E-09x^6 + 8E-07x^5 - 8E-05x^4 + 4E-03x^3 - 0.0982x^2 + .965x - 0.4384 \quad (1)$$

The equation (1) is a 6th order formula which in terms of calculation creates much complexities. Thus, on simplification of this equation by trial and error method it can be reduced to,

$$x = 27.726^{y-1.2045} \quad (2)$$

From equation (2), the output voltage can be converted into length or height of the object to be determined by the infrared sensor array.

5. Test Results and Discussion

For parametric calculation, encoding conversion between controller pulse and conveyor displacement is a prime factor (relationship is shown in Fig. 8).

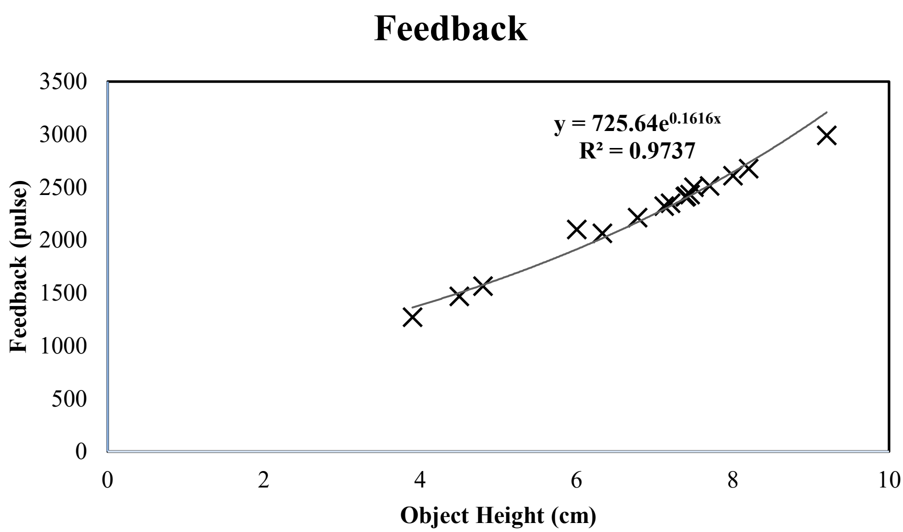


Fig. 8. Feedback pulse with respect to input.

From Fig. 5, the relationship between feedback and sensory calibrated data are exponentially proportional. So, for this system the feedback pulse (ψ) can be formulated as:

$$\psi = 725.64e^{0.1616x} \tag{3}$$

Where, x is the object height/length measured by sensory calibrated formula which can be found in datasheet. Here, for this research the sorting conveyor was taken about 30 cm (about 60.5 cm conveyor belt was used) in length and rate was defined 4 sec/unit.

Table 2 shows the experimental chart for test samples where about 79% accuracy was observed.

The separation of the conveying path must be perused misleadingly, which will cause error while data-logging. Human errors can be decreased by using precise instruments or by clipping stickers with callipers on the edge of the conveying line.

The feedback of steady encoder changes with respect to incremental encoding values time to time. Even though the speed of the conveying line stays constant, the input pulse to the PLC still changes. Arbitrary error some values must be corrected by calibrating test outputs.

Table 2. Sorting Statistics.

No. of Samples	Type 1	Type 2	Defective
1st sorting	9	17	7
2nd sorting	6	8	21
3rd sorting	11	13	8
4th sorting	8	12	20
5th sorting	5	7	22
Correct Rate		79%	

6. Conclusion

In Recent decades, industries need to be well equipped for taking part in highly competitive world economy. Flexible manufacturing system and lean production technique should be undergone through the automation. So, the management should focus on to the highly integrity of production system as well as production quality and inspection from raw materials entry to final product supply chain. To maintain the quality of the products and to accelerate the process, automation is required. Automatic production system related process needs to be introduced for the next industrial revolution. It is very necessary to follow up variety in products considering size, colour and shape etc. By implementing the proposed model an industry can easily get rid of those criteria and convey them to the way of industrial automation.

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