



Design and Production of an Automatic Solid Waste Sorting Machine with Smart Digital Counter

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Abstract

Sorting of objects is the first step of a waste management process. These objects should be sorted according to the type of material for effective waste recycling. Therefore, the focus of this work is to design and produce an automated sorting machine that can be used to sort metals and non-metals autonomously. The automatic sorting machine with a smart digital counter was designed to use a microcontroller (Arduino Mega) to control the conveyor systems which consist of the conveyor support, driving unit and the driven unit. The sorting mechanisms consist of the inductive sensor, infrared sensor and the actuating system using servo motor. The conveyor system helps in the conveyance of objects towards the sorting chute. The actuating system receives signal from the microcontroller and the device does the sorting of the objects based on their characteristics while the digital counter counts the number of metallic objects dropping into the designated cart. The time taken for the inductive sensor to sense an object, the waiting period for the servo motor to be actuated and the time taken for the counter to count after a metallic object is sensed are 1s, 2s and 1s respectively. After its development, it was tested and observed to meet the design requirements.

Keywords: Sorting, Microcontroller, Automation, Conveyor, Inductive sensor, Counter.

1.0 INTRODUCTION

Over the years, solid waste generation has uninterruptedly increased as a result of global changes associated with population, consumption and industrial growth [1]. The increasing solid waste should be effectively managed in order to prevent pollution of the environment and the associated harm to ecosystem and human health [2-3]. Waste sorting is an important step in waste management and recycling because it allows the recovery of a decent percentage of the resources contained in the disposed waste [4-5]. The success of the waste management policy is based on good sorting practice due to the fact that sorted waste can be treated further [6]. The statistics of waste management across the globe indicates that the cities which apply waste sorting system decrease the landfilling to a large extent and increase the recycling rate [7].

There are different ways to separate different fractions in a waste stream. For example, sorting can be implemented in material recovery facilities by sorting

machines or sorting several waste fractions at home by inhabitants [8-9]. Sorting of objects or products is a continuous industrial process. Centuries ago, manual sorting was the traditional approach used in the industries. In this approach, visual inspection is performed by human operators before the sorting process is carried out. Meanwhile, the traditional approach is tedious, time consuming, slow and inefficient [10]. The Industrial Revolution of about 1760 to sometime between 1820 and 1840 which was the transition to new manufacturing processes brought about automation that included going from hand production methods to machines processes [11]. Automation is the creation and application of technologies to produce and deliver goods and services with minimal human intervention.

The implementation of automation technologies, techniques and processes improve the efficiency, reliability and speed of many tasks that were previously performed by humans [12]. Other merits of automating the industrial processes are; productivity, greater consistency, flexibility, safety, cost reduction, elimination of human error and thus improvement in the quality and homogeneity of the products offered [13]. So, the aim of this work is to design and produce a machine that sorts automatically based on the classification of the types of object materials (metal and non-metals) and guide the

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objects into different carts in preparation for material recycling process. The design comprises proximity sensor that captures the images of the objects, the conveyor belt that transports the objects from one point to another, the infrared sensor that senses the presence of objects on the conveyor belt, the inductive sensor that distinguish metal from other objects, the servo motors that serve as the actuators, the 1.27cm seven segment display module that displays count outcomes and the Arduino based on the ATmega2560 which serves as the microcontroller of the system. Meanwhile, the incorporated counter enhances accurate measurement and statistics in the sorting process thereby increasing the efficiency of the system. This paper is organized as follows: after the introduction, a brief review of related works occupies section 2. Section 3 is centered on the design and production of the sorting machine. Section 4 presents the result and discussion, which is followed by the conclusion in section 5.

2.0 REVIEW OF RELATED WORK

Sustainable waste management systems are needed to handle the increasing amount of household waste in the world. Due to the fact that waste sorting is an important process in recycling and safe disposal of waste materials, it is critical to increasing the amount of waste that is recycled, as well as quality of recycled materials.

The more effectively waste is sorted, the more efficient the recycling process, enabling the production of secondary raw materials of an equivalent or higher quality than virgin material. Bankole et al, [14], modeled design of an automatic sorting machine using proximity sensor. The developed automated sorting machine incorporated flexibility and separate species of non-ferrous metal objects and at the same time move objects automatically to the basket as defined by the regulation of the Programmable Logic Controllers (PLC) with a capacitive proximity sensor to detect a value range of objects.

The result obtained shows that plastic, wood, and steel were sorted into their respective and correct positions with an average sorting time of 9.903 s, 14.072 s and 18.648 s respectively. Santhanakrishnan et al, [15], designed and produced a programmable Logic Controller (PLC) based sorting device using conveyor system where objects are sorted based on differences in heights. Low speed (24 rpm) DC geared motor was used to drive the conveyor belt which carries the different sizes of objects. The PLC was programmed to allow free movement of medium sized objects directly into the bin at the other end of the conveyor belt while large sized objects are identified by the infrared sensor and pushed into another bin by the action of the double acting cylinder.

This design is effective but lacks the counting module that displays the number of objects in the bins. Nilima et al, [16], developed a programmable Logic Controller (PLC) based object sorting automation system for sorting light weight objects on the basis of height variation. The design mainly focuses on sorting three objects of different heights using photo-electric sensors and DC geared motors interfaced with Programmable Logic Controller (PLC). The system consists of conveyor belt which conveys objects like bottles, small boxes or packages in front of sensors and thus sorting logic is decided by PLC. The PLC is programmed with three different logics, each for sorting different height product.

The system consists of total 4 proximity optical sensors or photo-electric sensors used to detect the presence of object and height of boxes. The design can be further improved by incorporating counter module that displays the number of objects in the bins. Object Sorting by Image Processing using Raspberry Pi 3 and a computer as the controlling unit was carried out by Rahul [17].

The design uses a low cost hardware and open source software for achieving the set goal. The stepper motors are initialized to run the conveyor belt. Objects were fed on the feed-side of the belt and landed on the rotating conveyor belt for onward movement to the discharge end. USB camera was used to continuously monitor the objects and identify them. Once the objects are recognized or classified into a particular group, the actuators are activated thereby sorting the objects. Automatic sorting machine that sorts metals and non-metals colored objects using programmable Logic Controller (PLC) was designed by Moe et al, [18]. The operation of the system is as follows; the conveyor belt is initiated by a DC motor, it is then loaded with sizable blocks of metals and colored wooden blocks ejected by the cylinders from machining operation. The conveyor unit takes the pieces towards the sorting chute where type A pieces are detected by the metal sensor which triggers the nearby piston, pushing the block into slit 1 and type B pieces are detected by the color sensor which triggers the nearby piston, pushing the pieces down to slit 2. Kannaki et al, [19], developed an advanced automatic sorting machine using weighing mechanism. The system comprises two conveyors that are perpendicular to each other, proximity capacitive sensor, DC motor and a controller. A conveyor moves the manufactured product to the other conveyor where the weight of the product is measured. After the measurement, the controller receives an active signal and compares the measured weight of the product with the stored pre-set weight. If the product's weight equals the pre-set weight, an actuator pushes the product into slit A for packaging.

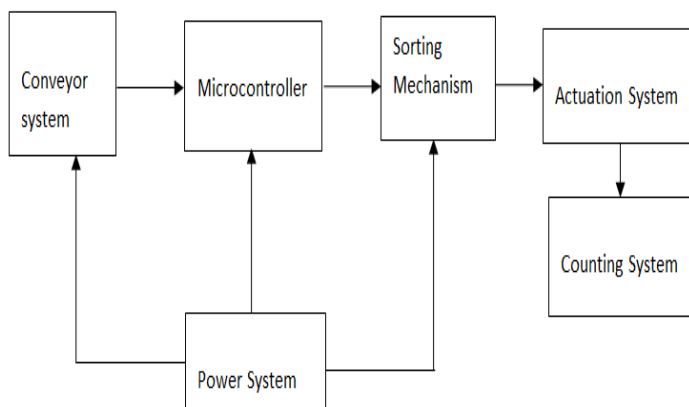
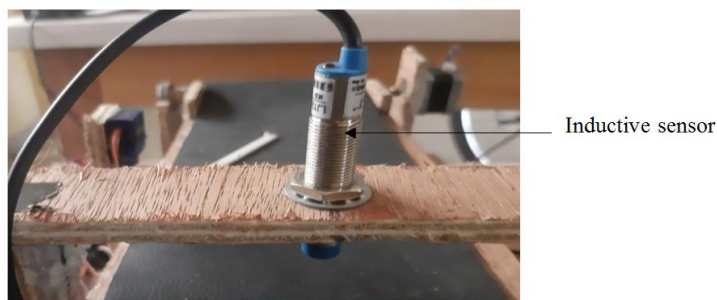
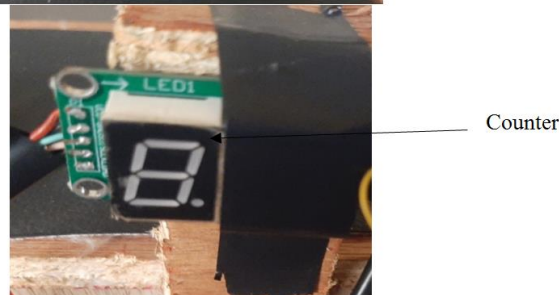


Figure 1: System block diagram

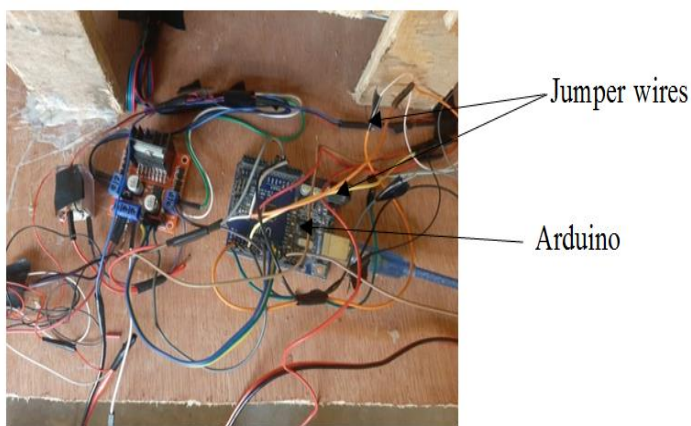


Inductive sensor



Counter

Figure 3: Positions of the inductive sensor and counter on the device



Jumper wires

Arduino

Figure 2: System circuitry

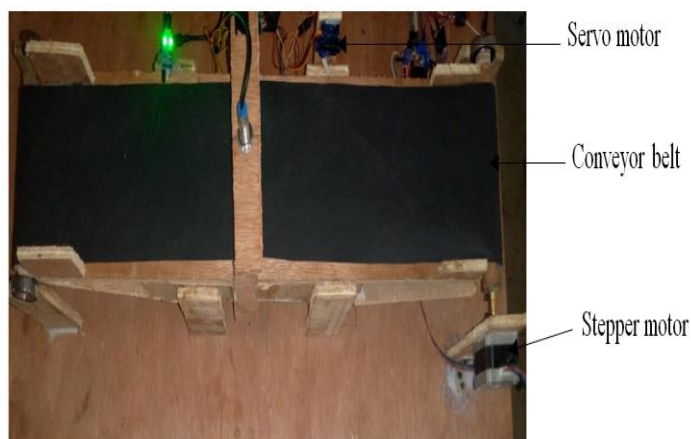
On the other hand, If the product’s weight is less or greater than the pre-set weight, the actuator pushes the product into slit B for further processing.

The counting module incorporated into the design circuitry of our work improves the statistics of the sorting operation.

3.0 SYSTEM DESIGN AND PRODUCTION

Various components were connected together as shown in Figure 2. The design and production of an automatic sorting machine carried out in this work uses a conveyor belt system controlled by the stepper motor, an inductive sensor that senses metallic objects that are conveyed on the conveyor belt, a servo motor, 1.27cm seven segment display module, L298n motor driver module, relay, infrared sensor switch, 5V USB power supply cable interfaced with the Arduino mega with functionality interference to achieve the main purpose of sorting. The block diagram of the system is shown in Figure 1.

The framework of the prototype of the automatic sorting machine was constructed using ply wood and leather. Servo motor was attached to the conveyor frame



Servo motor

Conveyor belt

Stepper motor

Figure 4: Implemented prototype

few millimeters from the inductive sensor while the counter was stationed at the side of the conveyor frame as shown in Figure 3.

The length, width and height of the conveyor system are 65cm, 15.5cm and 7cm respectively while the height of the fixed overhead mechanism is 5.5cm as shown in the implemented prototype of Figure 4.

Arduino IDE, version 1.8.9 was used to write the Arduino codes and Fritzing version 0.9.9 was used for the circuit simulation.

4.0 RESULT AND DISCUSSION

The operation of the system is as follows; when the system is initialized, the microcontroller loads the program and activate the conveyor belt through the stepper motor. The conveyor is then loaded with object to be

sorted. The conveyor unit takes the object towards the sorting chute. When the object cut across the line of sight of the infrared sensor, the sensor establishes the presence of object and send a signal to the microcontroller. The microcontroller then activates the inductive sensor for action. The inductive sensor senses the object to establish the presence of metal or otherwise and send a feedback to the microcontroller indicating the type of object. The decoded data is compared with the pre-set values and the micro-controller sends a signal to the servo motor and the digital counter. The servo motor is actuated to push the metallic object to its designated cart after which the servo motor goes back to its original position till the next signal is received. The digital counter will make an increment of number on its display based on the received signal. If the object is not a metal, it is conveyed into another designated cart at the end of the conveyor line. The system completes the entire operation of sorting and counting in a number of steps shown in the flow chart below in Figure 5

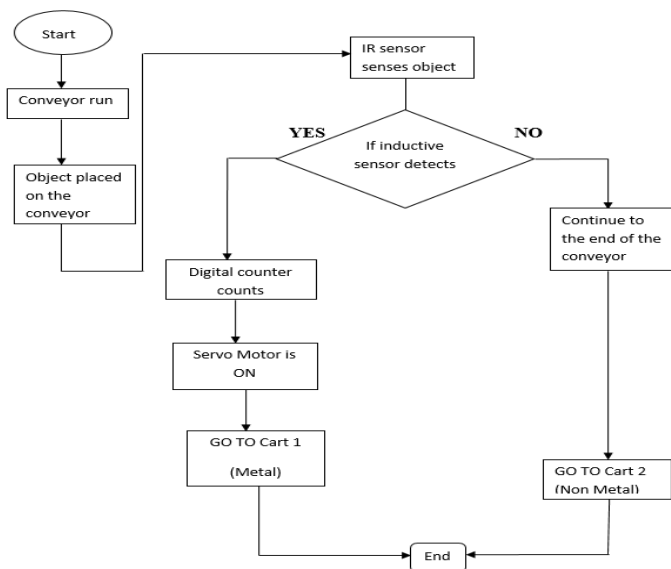


Figure 5: System operation flow chart

Table 1: Design Test Result

S/N	Operation	Metallic	Non-Metallic
1.	Time taken for the inductive sensor to sense an object.	1sec	No sensing
2.	The waiting period for the servo motor to be	2secs	No actuation
3.	Time taken for the counter to count after a metallic object is	1sec	No increment

The outcome of the test carried out on the machine is shown in Table 1.

5.0 CONCLUSION

This work describes the design and production of an automatic solid waste sorting machine with a smart digital counter. The machine was designed using a microcontroller (Arduino Mega) to control the conveyor system which consist of the conveyor support, driving unit and the driven unit. The sorting mechanism consist of the inductive sensor, infrared Sensor and the actuating system using servo motor. The conveyor system helps in the conveyance of objects towards the sorting chute. The actuating system receives signal from the microcontroller and the device does the sorting of the objects based on their characteristics while the digital counter counts the number of metallic objects dropping into the designated cart. The time taken for the inductive sensor to sense an object, the waiting period for the servo motor to be actuated and the time taken for the counter to count after a metallic object is sensed are 1s, 2s and 1s respectively. After its development, it was tested and observed to meet the design requirements. Due to the prevalence of plastic wastes, future research may be geared towards the incorporation of a sensor that senses plastic materials to the solid waste sorting machine for fast and effectual waste recycling.

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