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Smart Object Detector for a Small-Scale Recycling Automation System

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ABSTRACT

The increasing amount of waste generated each year necessitates immediate action to address and resolve this problem. This research establishes a small-scale recycling automatic system that allows us to detect objects based on different materials. The system is known as the Smart Object Detector for Small-Scale Recycling Automation System. Three types of objects, paper, metal, and plastic will be used to test the capability of the proposed system. The system will be equipped with the IR sensor, the capacitive proximity sensor, and the inductive proximity sensor. The conveyor belt is built, a servomotor is used to move the conveyor belt, and the containers are developed as part of a small-scale recycling automatic system conveyor system. The proposed smart object detector for a small-scale recycling automation system is found to be reliable for detecting, identifying, and segregating the object for different materials.

Keywords:
Smart object detector; Smart conveyer; Automated conveyor; IR sensor; Capacitive proximity sensor; Inductive proximity sensor

1. Introduction

Solid waste is one of the major problems in Malaysia [1]. Agricultural trash, demolition waste, industrial waste, mining leftovers, municipal garbage, and sewage sludge are examples of solid waste. According to the Business Dictionary, solid waste is solid or semisolid, non-soluble which include gases and liquids in containers. The amount of waste generated increases from year to year and immediate action is needed to address and resolve this problem. The most effective way to reduce a waste is recycling.

Waste disposal can be divided into recyclable and non-recyclable. Recycle waste disposal is products that can be processed, reused, and converted into new products or materials. A detailed classification of the type of waste can be found in [2-4]. Recycle waste will go through the standard

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recycling system process without being rejected or contaminating recycling streams. In contrast, non-recyclable waste disposal is products that cannot be processed in a standard recycling system that are rejected and contaminated. Certainly, the product cannot be processed, reused, and converted. Over time, many wastes are recyclable and non-recycled; thus, more items are listed under recycling and non-recycle waste categories. The provision of a waste management system is essential to solve the problem of abundant waste.

Managing non-recycled disposal wastes is more challenging due to their complexity and hazardous nature. The non-recyclable waste included food soiled paper, polystyrene, clothing, bulbs, and many others. According to Rinasti *et al.*, [5], it is essential to know which resources are non-recyclable [5]. Some items are non-recyclable because of their complexity and hazardous nature. It is extremely dangerous to dump contaminated non-recyclable items in containers. They can cause problems and can potentially contaminate recyclable items. This issue has been addressed by many researchers as in [6-8].

While recognizing the significance of addressing non-recycled disposal wastes within an enhanced waste management system [9], the current focus of this work remains specifically on recyclable products. The upcoming section outlines various pertinent studies contributing to the development of an intelligent management system for recyclable waste.

2. Related Work

The integration of the robotic arm with the vision sensor has been reported by Reddy *et al.*, [10]. The project offers a method for the seamless integration of a robotic arm for part separation based on a vision system. In this system, the geometric characteristics of objects are recognised. Then, a robotic arm is used to sort different objects into groups based on their size and shape.

Allen *et al.*, [11] proposed an object recognition using a vision and touch sensor. A system that is functional to object recognition with vision and tactile detection is described in a robotic environment. In order to match three-dimensional primitives to a database of complicated curved surface objects with holes and cavities, the active touch and passive stereo vision sensor is used. The ability to detect optically obstructed areas with touch is strengthened by the three-dimensional nature of the detected data. Since the model is hierarchical, it allows for matching at many levels to provide support for recognition.

Jeon *et al.*, [12] presented a problem for tracking object contours using integrated data from the force sensor and vision sensor. For a vision sensor, the relative area method measures the image features of interest straight from the threshold picture without any intermediate processes, allowing for the detection of the contour angle and distance from the image centre. A mobile manipulator robot follows the contour of an object in a straight line using the relative area approach. On the other hand, a mobile manipulator robot uses the canny approach to complete the object contour following a task based on a curved line segment of the object contour. The contact force between the tool and the object is then continuously controlled by a strain gauge force sensor.

Object shape recognition in images for machine vision applications presented by Zakaria *et al.*, [13] stated that images contribute an important role in human perception because vision is the most advanced of our senses. The group established a shape identification algorithm that can identify circle, square, and triangle objects in an image. Based on the Arduino capacitive proximity sensor in midi player [14], an extension of the capacitive proximity sensor is presented. The MPR121 proximity capacitive touch sensor controller allows the device to detect conductive objects or living people from a distance. Additionally, it can play an MP3 file using the IC audio codec VS1053b via an SD card and 3.5mm socket speaker once the object is detected. Inductive proximity sensors are used to detect metals which have been introduced by Naik *et al.,* [15]. For various metallic materials, a distance against current graph is demonstrated by this group.

Many researchers combine capacitive and inductive proximity sensors in their work. For example, George *et al.*, [16] suggested the hybrid capacitive inductive proximity sensor for seat occupancy. Combining the concepts of inductive and capacitive sensing results in a straightforward yet effective proximity sensor. This combination technique is very useful for a single sensor to detect the proximity of metallic objects and human beings as well as distinguish between them. Other related work based on the combination of capacitive and inductive proximity sensors can be found in [17-22].

One of the most fundamental and often used sensor modules in an electronics device is the infrared sensor circuit. An infrared sensor is a type of electronic device that detects and/or emits infrared radiation to sense specific aspects of its environment. In addition, infrared sensors can detect motion and measure or observe object heat. Many works based on this sensor can be found in [23-25]. For example, Vaswani *et al.,* [25] proposed a method to detect moving people or vehicles to communicate a few "best-view photographs" of each new object.

Motivated by the above-mentioned work, this research proposes a small-scale recycling automatic system called the Smart Object Detector for Small-Scale Recycling Automation System, which is capable of detecting, identifying, and segregating objects based on different materials. The system is equipped with IR sensors, capacitive proximity sensors, and inductive proximity sensors to detect different types of objects such as paper, metal, and plastic. The research highlights the use of capacitive sensing as a non-contact technique for detecting solids, liquids, metals, and non-metals, making it suitable for non-metallic targets. The appropriate sensors for level and feed monitoring in the system are capacitive proximity sensors, which can accurately gauge objects of different materials. The research also addresses the challenge of managing non-recyclable waste, emphasizing the importance of knowing which resources non-recyclable are to prevent contamination of recyclable items. The main components required for the project include Arduino UNO, inductive proximity sensors, and capacitive proximity sensors. Arduino UNO is a flexible and affordable single-board microcontroller platform used for electronics prototyping.

3. Methodology

3.1 Project Development Process

The project development process is divided into four stages that are the project plan, hardware, software, and integration of hardware and software. The following flow chart shows the four stages of the development process, as shown in Figure 1.

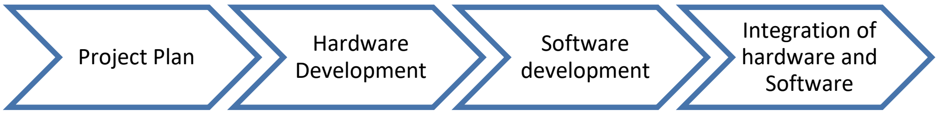


Fig. 1. Project Development Process

3.1 Project Components

There are a few main components that are required for this project, such as Arduino UNO, inductive proximity sensor, and capacitive proximity sensor. A single-board microcontroller called Arduino makes using electronics in cross-disciplinary applications more feasible. It is well-known open-source electronics prototyping platform constructed with user-friendly hardware and software. Arduino is made to be flexible to the requirements of the project. It is convenient to plug in or remove the components that we occasionally repair. This is mainly due to the cheap device and affordable and has a simple, cross-platform programming environment.

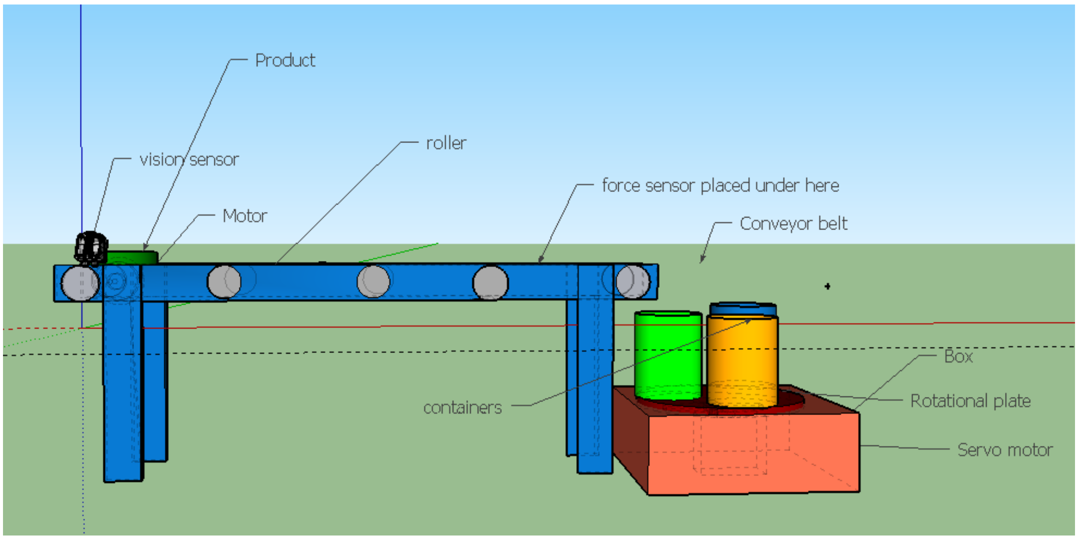
This project considers an infrared sensor, which emits light to detect certain features of its environment. An IR sensor can gauge the temperature and spot movement. Instead of generating light, this kind of sensor simply measures infrared radiation. All items typically emit some type of thermal radiation in the infrared range. An infrared sensor can detect this kind of radiation that is invisible to human eyes. A simple IR LED serves as the emitter, while an IR photodiode, which is sensitive to IR light with the same wavelength as the IR LED's, serves as the detector. The output voltage and resistances change proportionately to the amount of IR light received as it strikes the photodiode. An IR sensor is employed in this project to identify the presence of the object. The conveyor motor will start to run as soon as it receives the signal.

Capacitive sensing is a non-contact technique that can be used to detect solids, liquids, metals, and non-metals. However, because of its unique properties and lower cost than inductive proximity sensors, it is best suited for non-metallic targets. The appropriate sensors for level and feed monitoring are capacitive proximity sensors. In addition, the sensor can accurately gauge the object of different materials, such as paper or wood, granules, or liquids in the production process and during the final inspection.

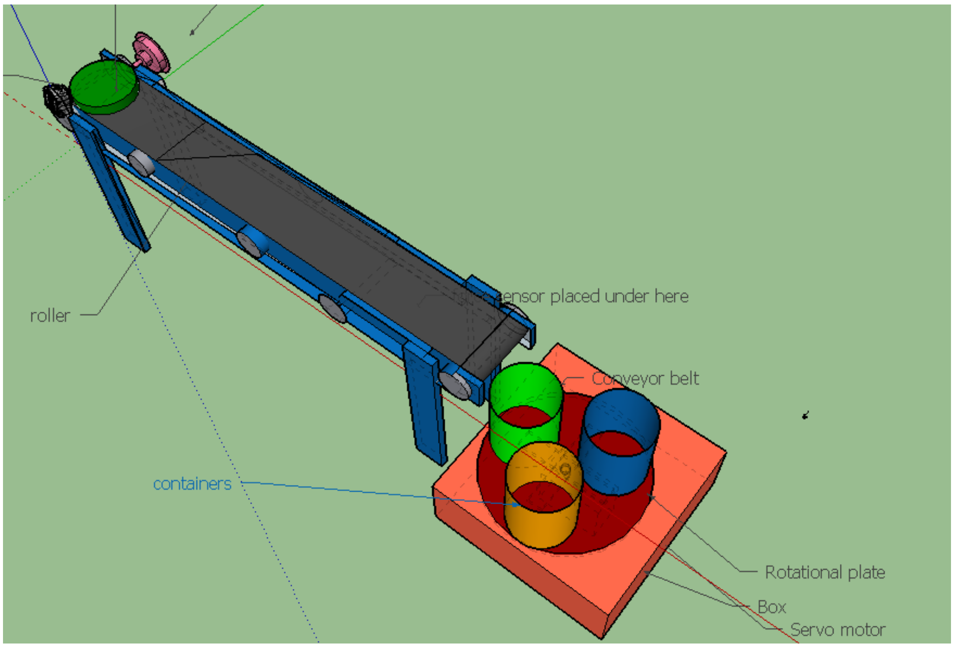
Lastly, another non-contact technique is the inductive proximity sensor. In contrast to the capacitive sensor, the inductive proximity sensor is best suited for a metallic target. The range of detection is generally less than 50 mm. In principle, Inductive proximity sensors emit an alternating electro-magnetic sensing field. Eddy currents are created in a metal target when it enters the sensing field, which reduces the signal's amplitude and causes a change in state at the sensor's output. An inductive proximity sensor is employed in this project to identify the presence of metal.

3.2 Conveyer Design

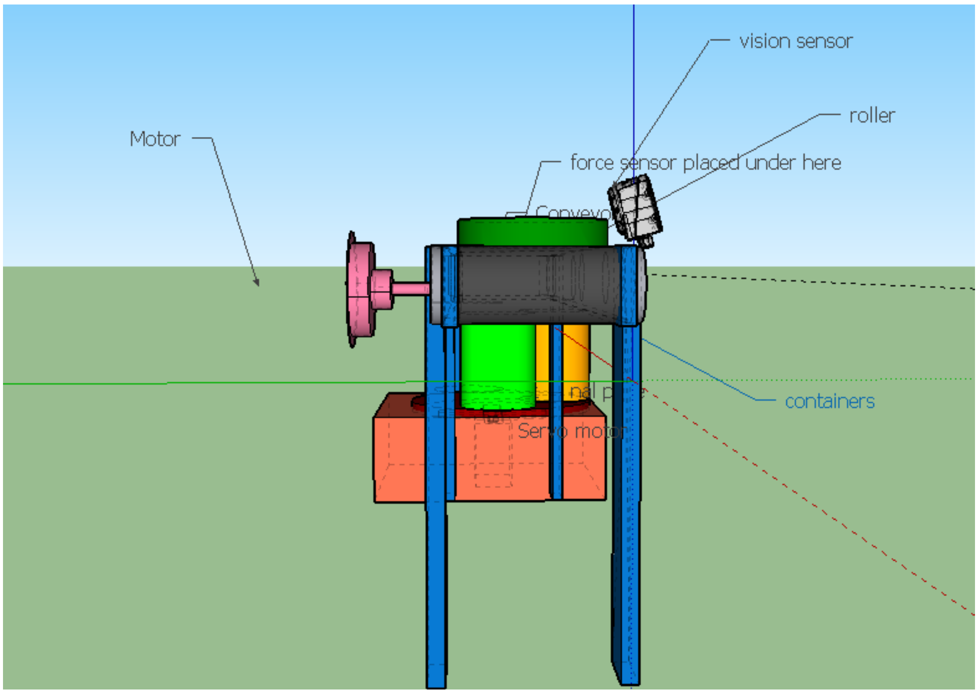
The conveyer design is sketched using Google Sketchup. Google Sketchup is a user-friendly approach that allows us to design the 3D modelling. More specifically, it allows us to develop impeccable designs, detailed and very constructive layouts, generate documentation and create 3D designs. The software design for the automatic conveyer for this project is illustrated in Figure 2. In particular, Figure 2(a), Figure 2(b), Figure 2(c) show side, top and front view of the conveyer design respectively.



(a) Side View



(b) Top View



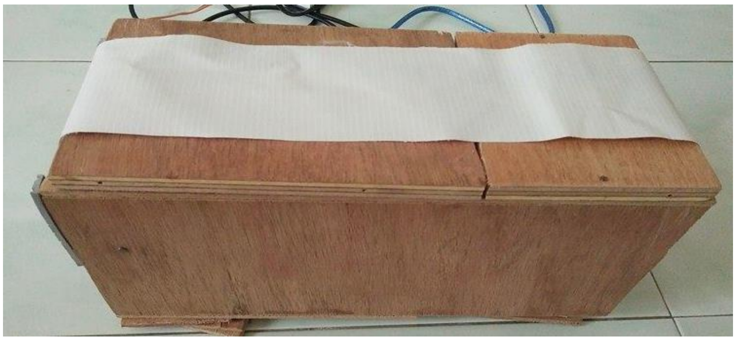
(c) Front view

Fig. 2. Development of Conveyer System using Google Sketchup

4. Results and Discussion

4.1 Prototype of Conveyer

The board is used to develop the conveyor. The board is shaped as a rectangular box, as shown in Figure 3(a), Figure 3(b), and Figure 3(c) for the side, front, and top view, respectively. The conveyor size is 31 cm x 13 cm x 16 cm. This conveyor uses a TowerPro MG995 360° servo motor to rotate it. This servomotor is mounted together with the conveyor belt inside the board.



(a) Side View

(b) Front View

(c) Top View

Fig. 3. Development of the conveyer system

4.2 Sensor

In this project, a capacitive proximity sensor, an inductive proximity sensor, and an IR sensor are used. Three of the sensors are placed in parallel, as shown in Figure 4. Both the capacitive proximity sensor and the inductive proximity sensor are placed underneath the conveyor belt. Due to the low sensing range of the capacitive sensor, the object must touch its surface; only it can detect the object. Therefore, to ensure precision, the capacitive sensor is attached under the conveyor belt to allow the object to touch its surface.

Fig. 4. The capacitive proximity sensor, the inductive proximity sensor, and the IR sensor are in parallel

An infrared sensor is used to detect the presence of the object. Once the object is detected, the conveyor servo motor will move. As a result, the conveyor belt will move and send the object to the bin. When the inductive proximity sensor detects the object, it implies that the metal object is detected. On the other hand, when the capacitive proximity sensor senses the object, it implies that the paper is detected. In addition to these conditions, other materials are detected (in this case, a plastic object).

4.3 Prototype of Container

Figure 5 shows the containers of the conveyor system. The MCD recycled paper cup was used as the bins in this project. Three paper cups are labelled with metal, paper, and plastic. Three of them are placed on a round plate to support them on the servo motor. More specifically, initial position of the containers is on the left for metal material, on the right for paper material and in the centre for other materials (i.e. plastic). In principle, when there is a plastic, the container will stay in the origin position (i.e. container not moving) to allow the plastic to fall into the plastic container. On the other hand, when a paper is detected, the servo motor will rotate anticlockwise, and now the paper container is located in the centre. As a result, the paper will fall into the paper-labelled bin. If a metal is detected, the servo motor will rotate clockwise and the metal bin will be located in the central position, so the object will fall into the metal bin. Note that the container will be back to the initial position every time the object is detected and collected.

Fig. 5. The Containers of the Conveyor System

4.4 Complete Small-Scale Automation System

The final product of the smart object detector for a small-scale automation system is slightly different compared to the earlier stage of design as depicted in Figure 6 for different views. At first, it was planned to use force, shape, and vision sensors to build this automated system. Force, shape, and vision sensors are tedious and require more study of how to operate them. For example, it is difficult to determine the material by its weight or shape. For the same weight and shape object, it might be made up of different materials such as plastic bottles and tins. Their weight is nearly the same, and their shape is also cylindrical. However, they are made of different materials.


(a) Top View (b) Front View

(c) Side View

Fig. 6. The Complete Small-Scale Automation System

4.5 Test Object

Three types of material, namely paper, metal, and plastic, are tested for the reliability of the proposed system. More specifically, various types of objects are tested, such as A4 paper, a hand phone, a plastic bag, a plastic bottle, a key, and others. Figure 7 shows examples of different types of materials tested.



(a) Paper (b) Key (c) Plastic

Fig. 7. Examples of Test Objects

For paper, there must be a stack of paper to be tested; then it can only detect it as paper. Certainly, one piece of paper is not sufficient to reach the threshold value of the capacitive proximity sensor. For the metal, the inductive proximity sensor can detect it easily. In this experiment, any metal-made object used can be detected successfully compared to other materials. The fact that the small-scale conveyor belt is utilized in this project; the appropriate size of the object must be considered.

4.6 Coding

The coding of the proposed system is shown in Figure 8. In principle, when an object such as a metal is placed on the conveyor belt, the process starts. The IR sensor will detect the presence of the object and start to move the conveyor belt. At the same time, the capacitive proximity sensor and the inductive proximity sensor will start to operate and detect the material of the object. Lastly, the object will drop the appropriate container. Meanwhile, the detail of the coding is provided in Table 1.

Table 1
Coding for a Small-Scale Automation System

```
#include<Servo.h>
Servo myservo;
float angle=0;
Servo myservo2;
int sensorPin = 6;
int capsensorPin = 7;
int indsensorPin = 8;
int reading;
void setup ()
{
myservo.attach(9);
myservo2.attach(10);
pinMode(sensorPin, INPUT); pinMode(indsensorPin, INPUT); pinMode(capsensorPin,
INPUT); Serial.begin(9600);
 }
void loop ()
{
reading = digitalRead (indsensorPin);
reading = digitalRead (sensorPin);
delay (1000);
if (reading == LOW)
{
reading = digitalRead(capsensorPin);
if (reading == LOW)
{
reading = digitalRead(indsensorPin);
if (reading == LOW)
{
Serial.println("Metal Detected");
myservo.write(90);
delay (5000);
myservo.write(120);
delay (5000);
myservo2.write(0);
delay (4000);
myservo2.write(85);
delay (1);
}
else
{
Serial.println("Paper
Detected");
myservo.write(120);
delay (5000);
myservo2.write(180);
delay (4000);
myservo2.write(85);
delay (1);
}
}
else
{
Serial.println("Plastic
Detected");
myservo.write(120);
delay (5000);
myservo2.write(85);
delay (4000);
myservo2.write(85);
delay (1);
}
}
else
{ Serial.println("No Item");
myservo.write(90); delay(1);
}
}
```

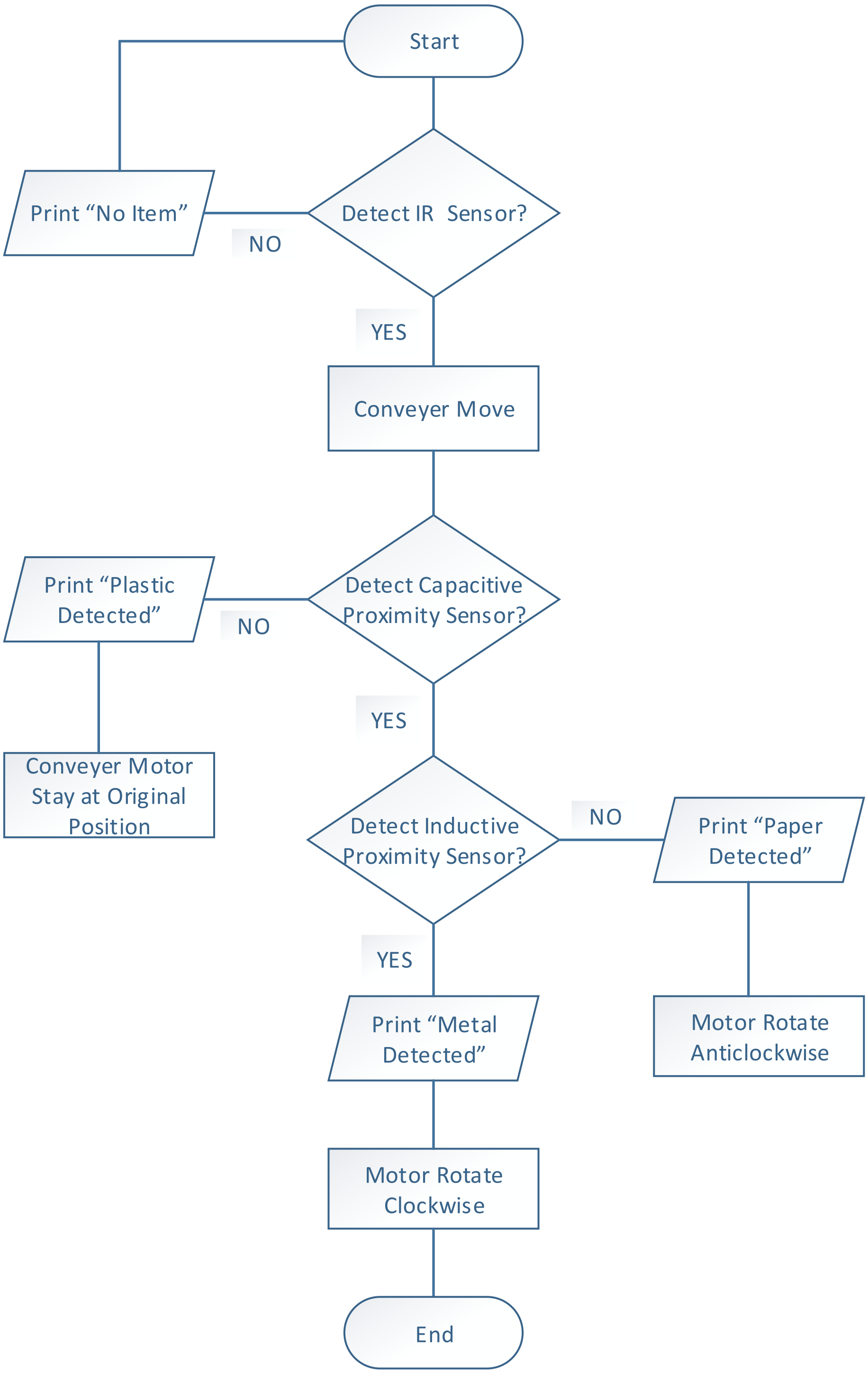


Fig. 8. Flow chart of system operation

4.7 Operating System

The overall operating system is illustrated in Figure 9. This conveyor uses a servo motor to operate the system. The servomotor is powered to move the conveyor belt. In particular, a TowerPro MG995 360o servo motor is used to rotate the container. When there is a plastic, the container will stay in the origin position. Hence the object will fall into the plastic container. On the other hands, when there is a paper sensed, the servo motor will rotate anti-clockwise and now the paper container is located at the centre to collect the object. Conversely, if there is a metal detected, the servo motor will rotate clockwise and the metal container moved to the central position, then, object will fall into it. As mentioned above, the container will move back to the initial position every time the object is detected and collected. Otherwise, clockwise and anticlockwise movements will not work as desired. Based on this test, it found that this small-scale detector for a small-scale recycling automation system is functioning and operating successfully as required.

Fig. 9. Operating System

5. Conclusions

The smart object detector for a small-scale automation system has been successfully built. This intelligent object detector automation system is equipped with an IR sensor, a capacitive proximity sensor, an inductive proximity sensor, conveyor belts, and other components. The presence of the inductive proximity sensor and the capacitive proximity sensor allows this automation system to detect and recognize different objects. This system not only is helpful for the waste management system, but it can also be used in the factory for segregating different products based on paper and metal. For future recommendation, a higher speed servo motor is used to increase the speed of the conveyor belt for faster work process. Furthermore, one more capacitive proximity and inductive proximity are recommended in this research for better accuracy.

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