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Design and Realization of a Refuse Sorting System for Educational Perspective

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ABSTRACT

Our project focused on developing a waste sorting machine for metal, plastic, and glass for educational purposes. We divided it into several parts, including waste types, sorting methods, and recycling processes. All processes were done highlighting the use of the Arduino Uno controller. Additionally, we outlined the tools required for an automated sorting system and go beyond simulations by creating a prototype. Our goal is to establish a waste sorting machine that promotes recycling and environmental protection, providing both financial returns and sustainability by diverting waste from burial or incineration, thus mitigating pollution.

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1. INTRODUCTION

The design of prototypes in research laboratories is a very common method to facilitate studies and experiments for supporting the teaching and learning process. This design method is in many fields such as solar energy, fluid mechanics, robotics, electronics, etc. The design and realization of a refuse sorting system involves various aspects such as the use of machine learning algorithms, real-time monitoring and control using IoT and computer vision, material flow analysis and life cycle assessment for system optimization, implementation of robotic arms and deep learning for mixed waste sorting, integration of sensor technologies for improved efficiency, and comparative analysis of sorting algorithms based on machine vision. The goal is to create an efficient and sustainable system for sorting and processing refuse waste (Khechekhouche *et al.,* 2021; Guerfi *et al.,* 2021; Khechekhouche *et al.,* 2019)

Furthermore, the references address the challenges and opportunities associated with planning and designing waste sorting systems. The rise in urbanization and improved living standards has led to a significant increase in both the diversity and quantity of waste generated. This surge places substantial pressure on resource utilization, environmental safety, and economic recycling. Urban residents, being the primary contributors to household waste, actively engage in waste sorting. Recycling serves as an efficient means to utilize waste resources, decrease waste volume, and contribute to sustainable development (Tang *et al.,* 2022; Yang *et al.,* 2018).

However, effective waste sorting necessitates extensive knowledge of different waste categories, and translating residents' willingness to sort waste into concrete actions can be challenging. Consequently, numerous countries have initiated research on smart waste sorting and recycling devices, which have been implemented in engineering applications (Cheah *et al*., 2022)

Achieving intelligent recognition of waste categories is a fundamental requirement for efficient sorting and recycling processes. Computer vision technology and deep learning algorithms play a vital role in automatically detecting and classifying waste categories, offering valuable technical support for waste sorting and recycling endeavors (Vo *et al*, 2019; Lin *et al.,* 2022).

Some studies have focused on the use of machine learning algorithms for sorting, while others have investigated real-time monitoring and control using IoT and computer vision. Material flow analysis and life cycle assessment have been employed for system optimization, and the implementation of robotic arms and deep learning techniques have been explored for mixed waste sorting. Additionally, the integration of sensor technologies has been investigated to improve system efficiency, and a comparative analysis of sorting algorithms based on machine vision has been conducted. These works collectively provide valuable insights into diverse approaches, technologies, and considerations for designing efficient and sustainable refuse-sorting systems (Tan *et al.,* 2022; Azadnia *et al.,* 2022; Kroell *et al.,* 2021; Jin *et al.,* 2023; Chen *et al.,* 2023).

Arduino boards can be utilized in refuse sorting systems to control and automate various functions, such as sorting mechanisms, conveyor belts, robotic arms, and sensor modules. The project aims to establish a waste sorting machine that promotes recycling and recovery of waste, as opposed to burying or burning it, which can cause environmental pollution. The implementation of this machine is expected to yield significant financial returns, as mentioned in the project proposal, while also contributing to environmental protection.

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2. METHOD

2.1. Refuse Statistics in Algeria

Algeria is experiencing an ecological crisis: degradation of the living environment, intensification of various pollutions, the proliferation of urban and industrial refuse, inadequate refuse management, etc. Thus, in the absence of a coherent and effective strategy, the management of household refuse was not mastered and did not in any way meet the universally accepted standards, despite the adoption in 1984 of the whole panoply of legal texts. On the ground, this has resulted in the appearance of thousands of wild dumps and dumps. For various reasons, local authorities were unable to take responsibility for the cleanliness of cities. **Table 1** shows the population number of Algeria in 2020 and it also shows the amount and type of refuse in Algeria.

Table 1. Type and refuse in Algeria.

Type	Number
population 2020	43,85 million
recycled household waste	1,3 million tons
quantities of waste produced	13,5 million tons
percentage of organic waste	53,61%
percentage of plastic waste	15,31%
percentage of paper and cardboard waste	6,76%
percentage of metal waste	15,32%
percentage of wood waste	1%
percentage of glass waste	8%
percentage of waste recovery	9,33 %
economic value of the waste recovery activity	78,4 billion dinars
economic value of the metal waste recovery activity	12,6 billion dinars
economic value of the plastic waste recovery activity	43,2 billion dinars
economic value of the glass waste recovery activity	0,3 billion dinars
economic value of the waste recovery activity other	22,3 billion dinars
percentage of wasted waste not generated	90,67 %
quantities of non-recycled landfill waste	6 million tons

2.2. Material used in This Project

Arduino Uno is a versatile platform for prototyping interactive objects, designed to unleash creativity in various applications. It consists of an electronic board and a programming environment that enable users to bring their projects to life through direct experimentation. With abundant online resources available, users can access a wealth of information to aid them in their endeavors.

Acting as a bridge between the physical and digital worlds, Arduino empowers users to enhance human-machine or environment-machine interactions. It serves as an open-source project, benefiting from a large and vibrant community of users and designers who actively contribute and support one another.

Arduino Uno, in particular, is a microcontroller board based on the ATmega 328P. It features 14 digital input/output pins, with 6 of them capable of functioning as PWM (Pulse Width Modulation) outputs. Additionally, it offers 6 analog inputs, a 16 MHz crystal, a USB connection, a power socket, and a reset button. The board includes all the necessary components to support the microcontroller.

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By examining the visible photo of Arduino Uno, depicted in **Figure 1**, you can observe its physical attributes and components.

Figure 1. The material used in this project.

A servo motor as shown in **Figure 2**, is a type of direct current motor that is position-controlled using a position sensor, typically a potentiometer, and an internal electronic circuit. It is operated through a control wire and powered by two additional wires—one connected to the positive supply of +5 or +6 V (depending on the specific servomotor), and the other connected to ground (GND). The control signal for a servo motor is typically a pulse width modulation (PWM) signal.

By modifying the duty cycle of the PWM signal, the motor is instructed about the desired position within a range of possible positions, usually spanning from 0 to 180 degrees. The frequency of the pulse width modulated signal is typically around 50 Hz (although some

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models operate at 30 Hz), and the pulse duration ranges from 1 to 2 milliseconds. To achieve larger ranges of motion, the gears of the servomotor can be changed. Additionally, the characteristics of a servo motor include its weight (9g in this case), stall torque (1.8 kgf.cm), operating voltage (4.8 V, with 5 V as an alternative), speed (0.1 s/60°), and the angle of rotation (180°). **Figure 3** represents shows the global system.

Figure 2. Servos motor.

Figure 3. Global system.

2.3. Simulation Part

The Proteus ISIS software is primarily known for editing electrical schematics. In addition, we can simulate these diagrams and thus allow the detection of certain design errors. Presentation of the simulation tools before proceeding to the realization, we simulated Proteus for circuit simulation and Arduino IDE for circuit programming. The process of creating a new project is very simple. We select a new project from the Project menu, as shown in **Figure 4**. A new window will appear as shown in **Figure 5**. Select the project name and location, and then click next to open a new empty window to write our circuit.

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Project circuit on Proteus as shown in **Figures 6 and 7**, the following figure represents the circuit of our project under Proteus which functions according to the same concept as the global circuit of the project. Because some components cannot be displayed in the Proteus library and will be used in the implementation. For the assembly of evacuation mats, we used in this circuit a 12 v battery with a potentiometer with a Mosfet IRFZ44N transistor to drive a 12 v DC motor the role of the potentiometer is the variation of the motor speed as shown in **Figures 6** and **7**.

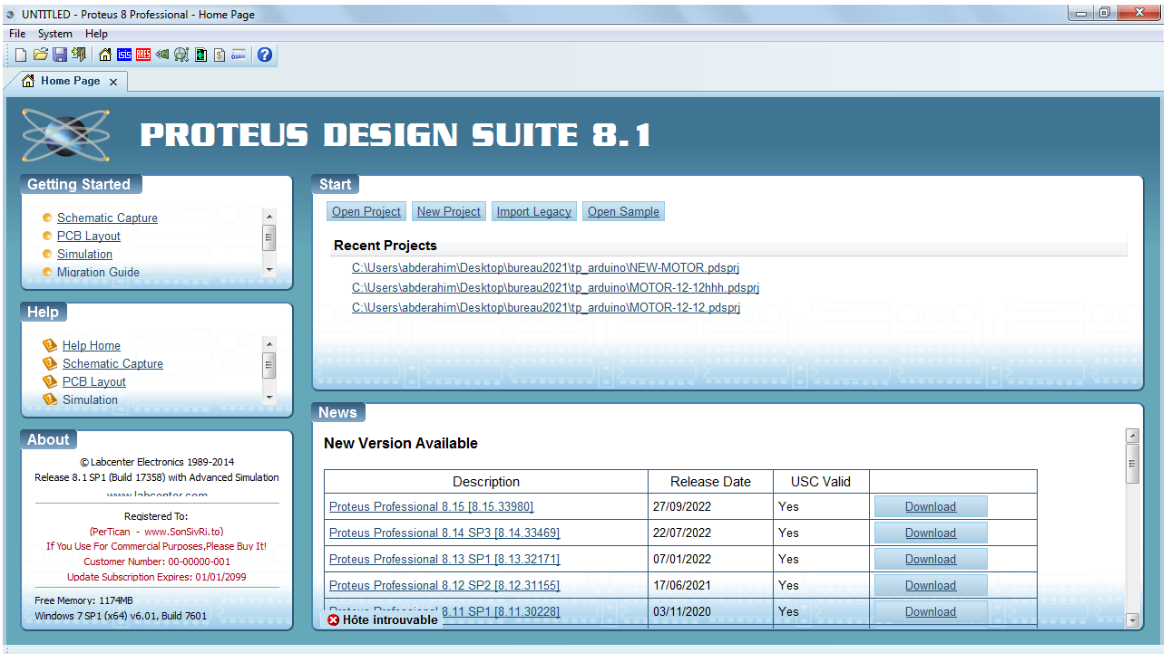

Figure 4. Project creation.

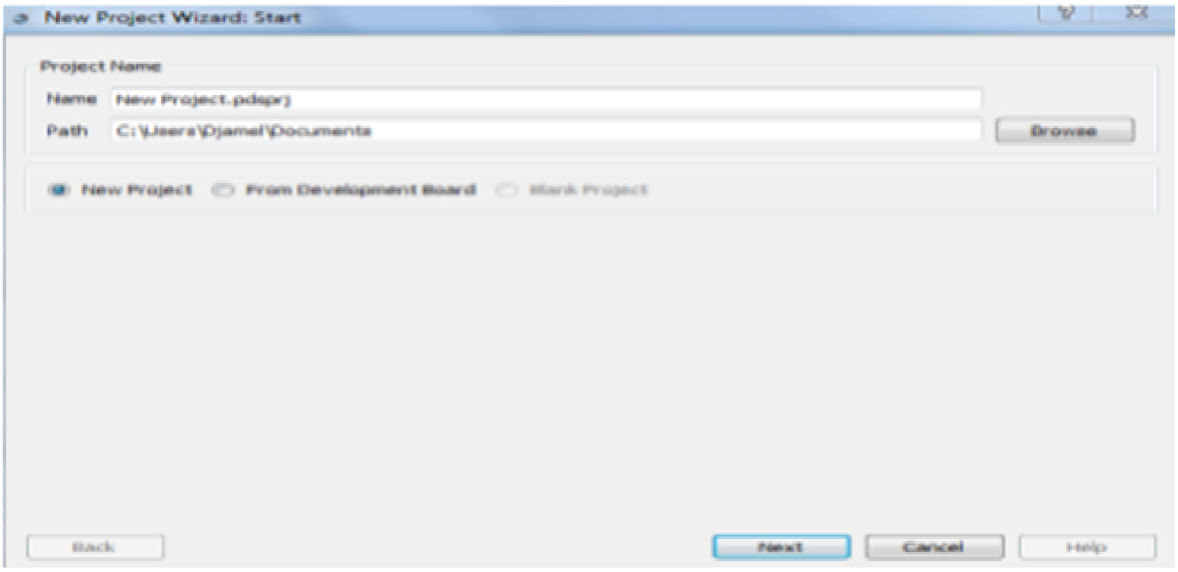

Figure 5. Project configuration.

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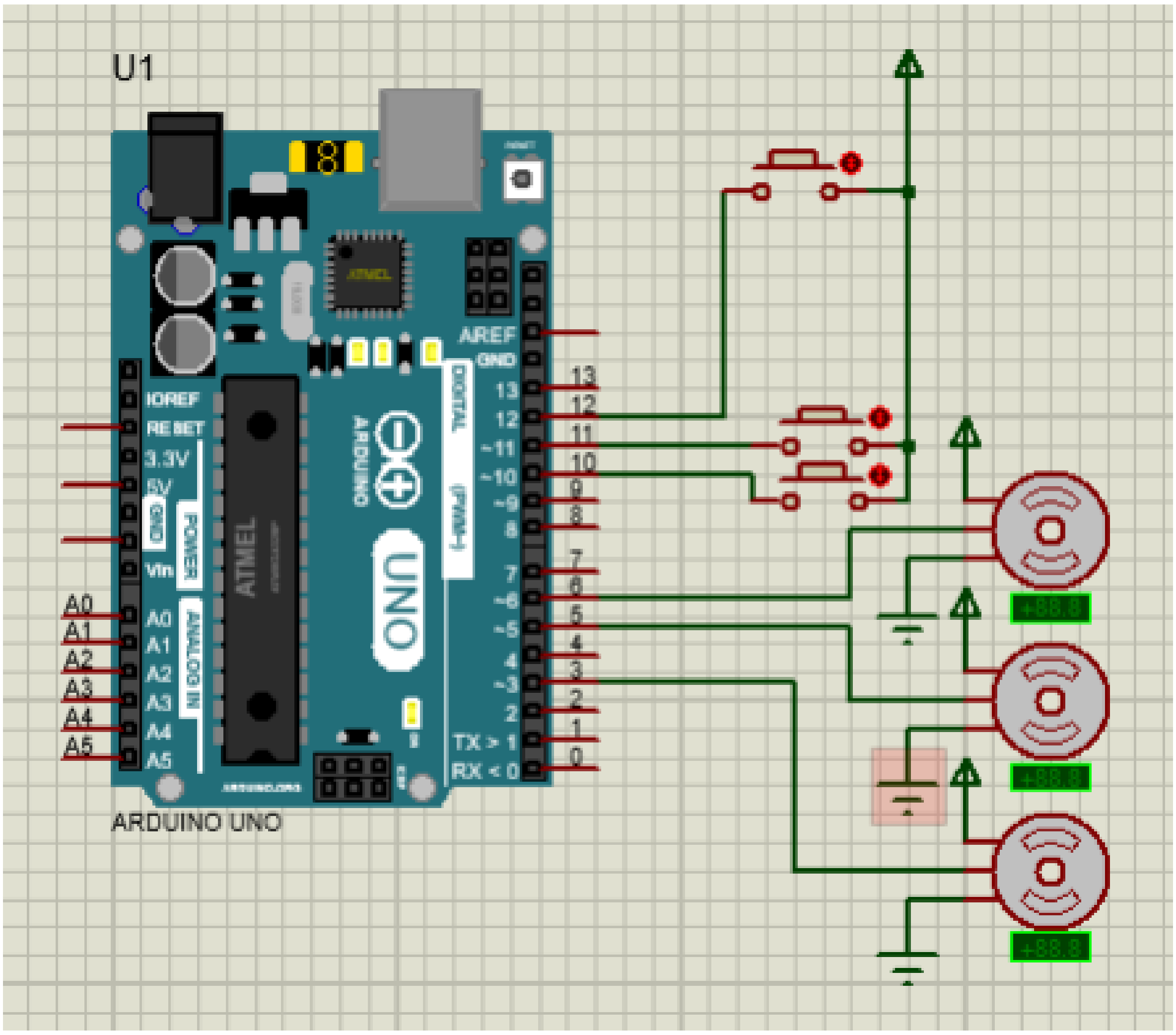

Figure 6. Circuit de projet sur proteus.

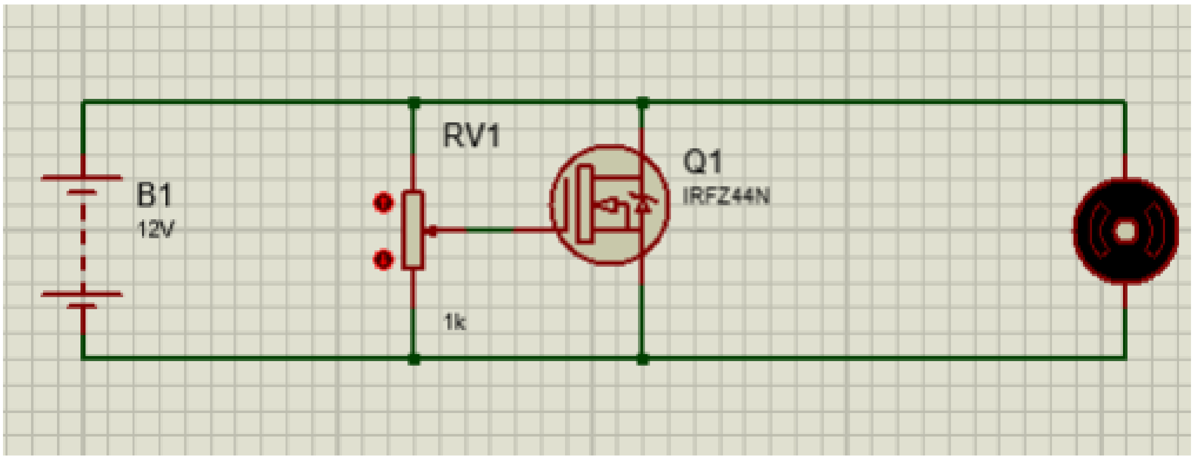

Figure 7. Design of electricity.

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The sensors used in this study. If there is no in this program, we replace them with buttons to replace:

(i) If we press the button which is connected with pin 12 the motor which connects with pin 3.
(ii) If we press the button which is connected with pin 11 the motor which is connected with pin 5.
(iii) If we press the button which is connected to pin 10 the motor which is connected to pin 6 Button 12 simulates the detection of plastic material; Button 11 simulates the detection of glass material; Button 10 simulates metal material detection.

3. RESULTS AND DISCUSSION

3.1. Creation of a Project Program

Figure 8 represents the window corresponding to the sending of the program to the Arduino card.

3.2. Introducing Factory I/O

Factory I/O is simulation software that offers seven versions or editions to cater to different needs. These editions are:

i) Starter Edition: This is the basic version of Factory I/O, providing essential features for creating industrial simulations.
ii) Allen Bradley Edition: Designed specifically for Allen Bradley PLCs, this edition allows seamless integration with Allen Bradley programmable logic controllers.
iii) Siemens Edition: Tailored for Siemens PLCs, this edition enables users to connect and interact with Siemens programmable logic controllers.
iv) Modbus and OPC Edition: This edition supports communication via Modbus and OPC protocols, allowing integration with devices and systems that utilize these standards.
v) MHJ Edition: Developed for use with the WinSPS-S7 virtual PLC and the Siemens WinPLCEngine PLC simulator, this edition facilitates simulation using these platforms.
vi) Automgen Edition: This edition provides connectivity with the Automgen software, allowing users to establish connections and interact with it.
vii) Ultimate Edition: The Ultimate Edition is the most comprehensive version of Factory I/O, offering a complete range of features and functionalities. It includes an SDK (Software Development Kit) for driver development communication, allowing users to extend and customize the software.

Factory I/O empowers users to create simulated systems by utilizing a library of industrial parts commonly found in real-world industrial installations. This integrated library adds a new level of realism to industrial simulations that were previously unavailable in traditional training environments.

The software offers a simple and intuitive interface, enabling users to quickly build systems by dragging and dropping desired parts into the scene. The simulation can be run at any point in the process, allowing users to test sensors and actuators in real time. It is important to note that Factory I/O does not include proximity sensors such as capacitive and inductive sensors. However, users can still create simulations of various industrial processes, such as a glue sorting system where each type of glue corresponds to a specific material.

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garbage_sorting §

```
#include <Servo.h>
Servo myservo1;
Servo myservo2;
Servo myservo3;
int sensorPinplas = 12;
int sensorPinglas = 11;
int sensorPinmetal = 10;
int sensorValue1 = 0;
int sensorValue2 = 0;
int sensorValue3 = 0;
void setup() {
    myservo1.attach(3);
    myservo2.attach(5);
    myservo3.attach(6);
    myservo1.write(0);
    myservo2.write(0);
    myservo3.write(0);
    Serial.begin(9600);
}
  void loop()
  {
sensorValue1 = digitalRead(sensorPinplas);
sensorValue2 = digitalRead(sensorPinglas);
sensorValue3 = digitalRead(sensorPinglas);
    if(sensorValue3==0){
        Serial.println(sensorValue1);
        myservo3.write(90);
       delay(1000);
        myservo3.write(0);
    }
    if(sensorValue2==0){
         myservo2.write(90);
       delay(1000);
        myservo2.write(0);
  }
    if(sensorValue1==1){
        myservo1.write(90);
       delay(1000);
        myservo1.write(0);
    }
}
```

Figure 8. Sending program.

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3.3. Creating a Program that Controls the Glue Sorting System

Control I/O is a simple yet powerful Soft PLC designed exclusively to be used with Factory I/O. The main goal of Control I/O is to provide a brand-independent tool that is easy to grasp for those new to the field of automation. With Control I/O, you can develop programs using functional block diagrams, incorporating the most commonly used functions found in a real programmable logic controller (PLC).

Used a conveyor belt and 3 three sensors each sensor controlling a cylinder as shown in **Figures 9, 10** and **11**. **Figure 10** was taken in the middle of the simulation so that the evacuation belt moves the parts to reveal the first station which reveals the gray color, so the cylinder responsible for the exit pushes it into the box and the principle of operation does not differ not with the two green and blue pieces; just the gluer sensor will change.

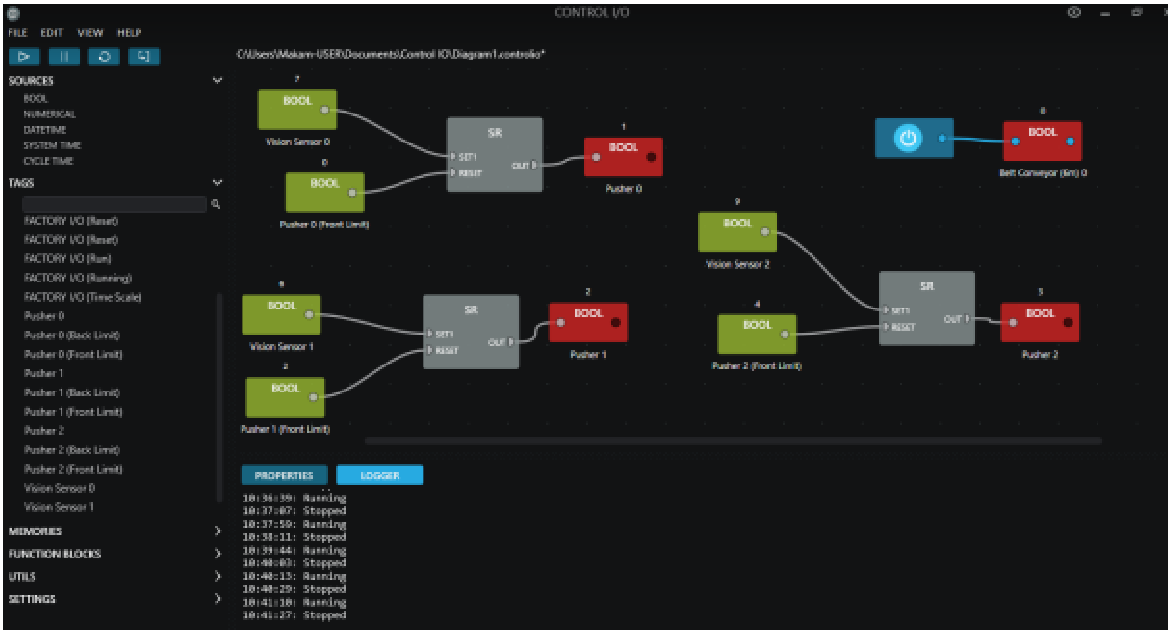

Figure 9. Assembly code on factory I/O.

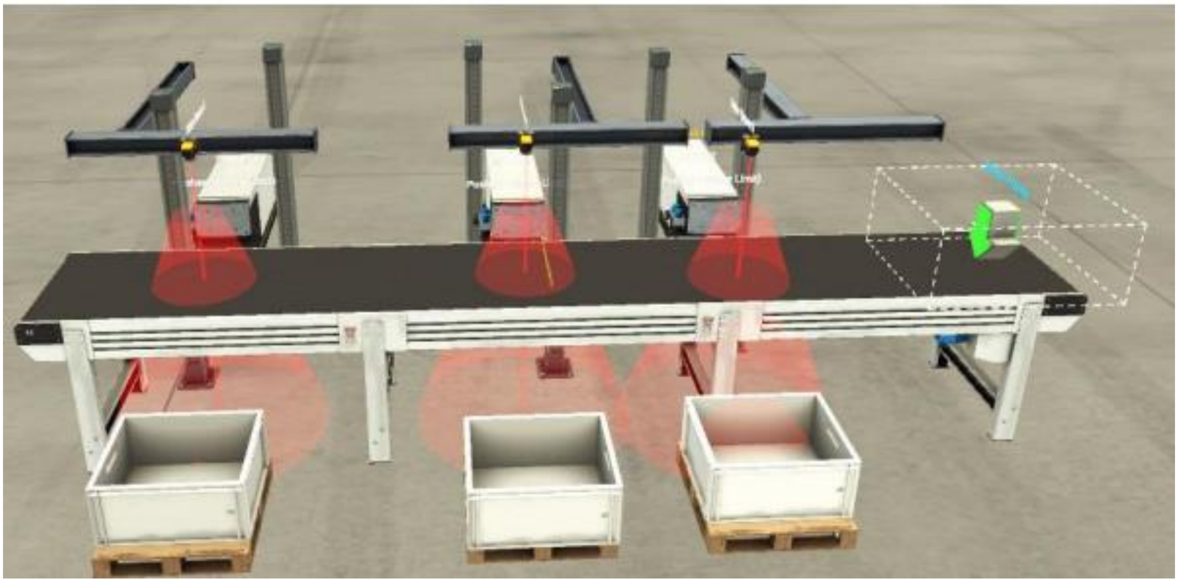

Figure 10. Assembly on factory I/O.

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Figure 11. Operation on factory I/O.

4. CONCLUSION

Incorporating microcontrollers and sensors to automate the sorting process can greatly increase efficiency and reduce errors. It is also important to consider scalability when implementing such a system in larger installations, as different components may need to be used. Integrating Raspberry Pi and additional sensors to further refine the sorting process and obtain more information on recyclable materials is an excellent idea. The addition of a Schrader arm to transfer sorted materials to a sorting belt can also increase efficiency. The project has great potential to improve waste management systems, and it is important to continue developing and refining it to make it even more effective.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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