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Sorting Machine of Ecopaving Materials Based on Digital Image Processing

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ABSTRACT

This final project focuses on the design and development of a prototype waste sorting machine with the goal of aiding the production of ecopaving by sorting plastic waste through digital image processing techniques. The main objective of this research is to address the environmental issues caused by household plastic waste, which has become a significant global challenge, especially in Indonesia. The proposed system uses a conveyor belt mechanism and integrates digital image processing programmed with Python, utilizing a Convolutional Neural Network (CNN) model for image classification. The prototype sorts waste into three categories: plastic, glass, and metal, using a webcam for detection and a servo motor to push the sorted materials. The automation of this system aims to improve efficiency and accuracy in the sorting process, reduce reliance on manual labor, and minimize processing time. This approach not only contributes to waste management but also promotes the recycling of plastic waste into valuable products such as ecopaving, in line with the 3R principle (Reduce, Reuse, Recycle). This final project is expected to provide an effective and efficient solution in reducing waste so that it can be more useful rather than just environmental waste.

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1. INTRODUCTION

Environmental problems are a significant issue that occurs in various countries, one of the main causes is household waste in the form of plastic waste. Overcoming the waste problem is one of the challenges that is difficult to overcome in various countries, especially in Indonesia, where cities are still filled with waste. In 2021, the total waste produced in Indonesia reached 21,872,092.95 tons per year, with a population of around 272,229,372 people [1]. Waste has a negative impact on the environment such as damaging aesthetic value, air pollution, soil pollution, and water pollution [2]. In addition, waste is a breeding ground for various diseases that have an impact on human health and dumping waste in the sea can damage the ecosystem in the sea. Overcoming the worsening environmental ecosystem requires waste management measures. Waste management is becoming increasingly important and urgent to be addressed effectively to reduce the amount of waste. One example of this action is to reuse the waste into goods that have utility value [3]. Thus, one of the effective efforts to reduce plastic waste is ecopaving. Ecopaving is a way of processing plastic waste by melting it at a certain temperature and then forming it into several objects according to the mold [4].

By using plastic waste as raw material for ecopaving, it not only reduces the amount of plastic waste in the environment, but also produces more economical products [5]. One of the products resulting from this ecopaving effort is environmentally friendly building materials in the form of paving blocks. However, this effort still requires many people who do not know the benefits of the ecopaving method in reducing plastic

waste [6] so that a system is needed to sort the waste. The current sorting system still uses conventional methods that require high labor, time and costs. Thus, an automatic plastic waste sorting machine is needed that utilizes digital images through computers to detect various types of waste so that the application of machine learning is more effective and efficient in the ecopaving production process [7]. In Machine Learning, algorithms are divided into several different types and each type has its own function and purpose. Some examples of the most popular Machine Learning algorithms include: Supervised Learning, Unsupervised Learning, Semi-supervised Learning, Reinforcement Learning [8]-[9].

The application of the method used in this study is the deep learning method whose algorithm is developed from artificial neural networks. This method concludes the function of labeled training data consisting of a set of training examples. There are many examples of algorithms owned by deep learning itself, including: Convolutional Neural Network (CNN), Long Short Term Memory Network (LTSM), Recurrent Neural Network (RNN), Self Organizing Maps (SOM) [10]. By using the CNN method which is very complex for object classification through image classification and is able to process two-dimensional image data [11]. However, before the image is entered, the image must go through an augmentation process and get results called variables that will be entered into the CNN. In addition to performing algorithms for two-dimensional data processing, CNN is also included in the type of Deep Neural Network due to the high network depth and large data input from images [12]. The use of this image classification can improve the waste classification process in the automatic waste sorting stage [13].

Many studies have been conducted on waste sorting tools from various researchers, including, such as the Design of Organic and Inorganic Household Waste Sorting Machines using capacitive proximity sensors as waste sorters [14]. Utilization of Plastic Waste for Making Paving Blocks [15]. Different from previous studies on waste sorting tools, the author intends to design and build an automatic waste sorting tool by classifying waste through model images managed by digital images by utilizing the Convolutional Neural Network (CNN) artificial intelligence method. In addition to utilizing image classification from CNN, the tool in this final project will also use an ATMega 328 microcontroller for the microcontroller used in the object sorting machine [16]. The object sorting machine to be made can sort waste into 3 classes from several types of inorganic waste, namely plastic class, glass class, and metal class. The conveyor material used uses Aluminum profile material.

2. METHOD

The research method used to collect data from the tool experiment uses the experimental method. The tool design is intended to determine the components of a tool to be made, so that the final results will be obtained as expected. The design also makes it easier in the process of making the tool later.

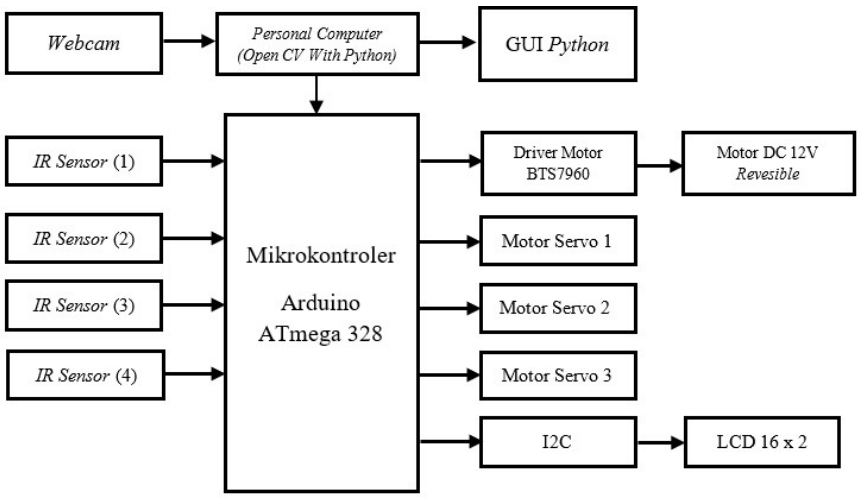


Figure 1. Diagram block of sorting machine

Based on Figure 1, there are several blocks that have various functions, here is an explanation of each block diagram: 1) Personal Computer (PC) functions as a control center for digital image processing and Graphical User Interface display, 2) ATmega 328 microcontroller is used as a control center that is more focused on processing or controlling the hardware on the sorting machine, 3) Webcam functions as a sensor to capture images of waste objects to be tested, 4) Infrared sensor is used as validation of object detectors

sorted on the belt conveyor, 5) Motor Driver functions as a tool that translates digital data from the microcontroller to the DC motor, 6) DC motor functions as an actuator for driving the belt conveyor, 7) Servo motor as an actuator for separating sorted waste objects, 8) I2C functions as an LCD controller, 9) 16x2 LCD functions as a display of data from reading the classification of waste objects, and 10) Python GUI as an interface display that functions to make it easier for users to operate the sorting machine. All components are assembled according to the shape and size that have been designed. Figure 2 below shows the design dimensions of the sorting machine that will be made.

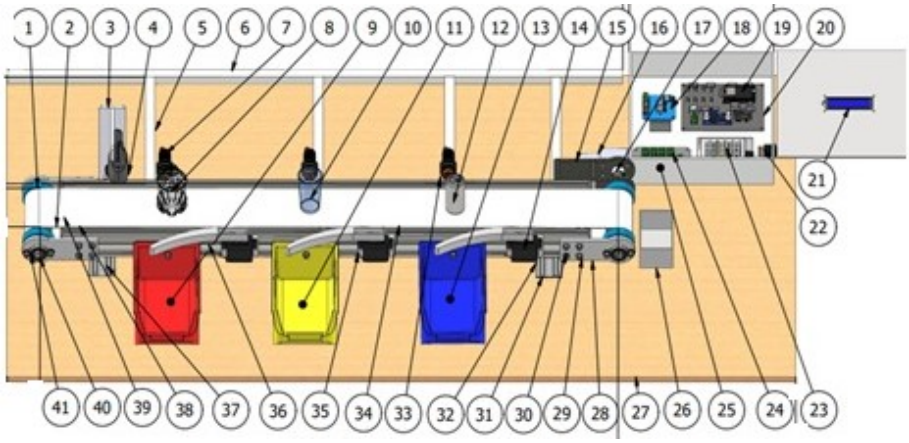


Figure 2. Design of sorting machine

After the soring machine design frame is complete, the next step is assembling the circuit using a PCB circuit board. The circuit plays an important role in a moving object such as the tool in this study. In the process of assembling an electrical circuit, a schematic diagram of the circuit is required, as shown in Figure 3 below.

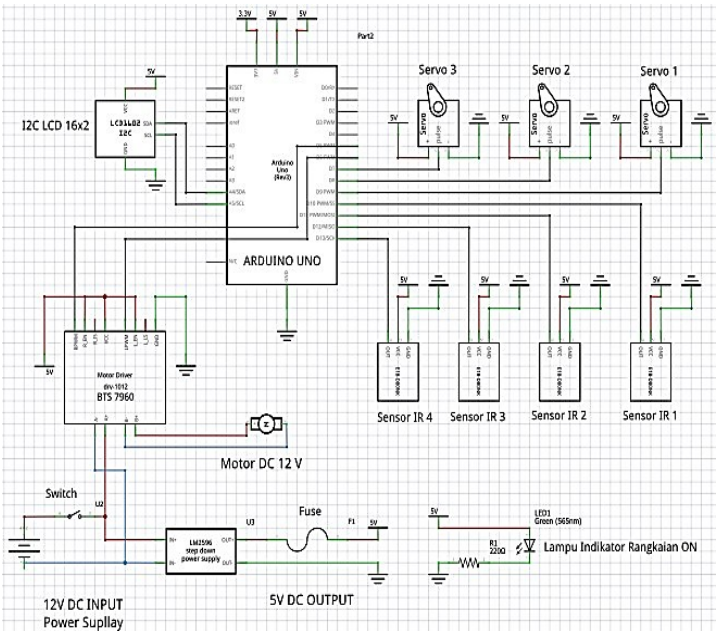


Figure 3. Circuit scheme of sorting machine

The assembled and equipped sorting machine will be programmed using Visual Studio Code and Arduino IDE software. The programming language used in Visual Studio Code is Python. While the programming language used in Arduino IDE is C programming language. This final project uses two software because of the GUI (Graphical User Interface) design which functions as a monitoring display by the user in image processing or image processing shown in Figure 4. The second software is used for the

Arduino ATMega 328 microcontroller in controlling the separator actuator and sensors on the sorting machine

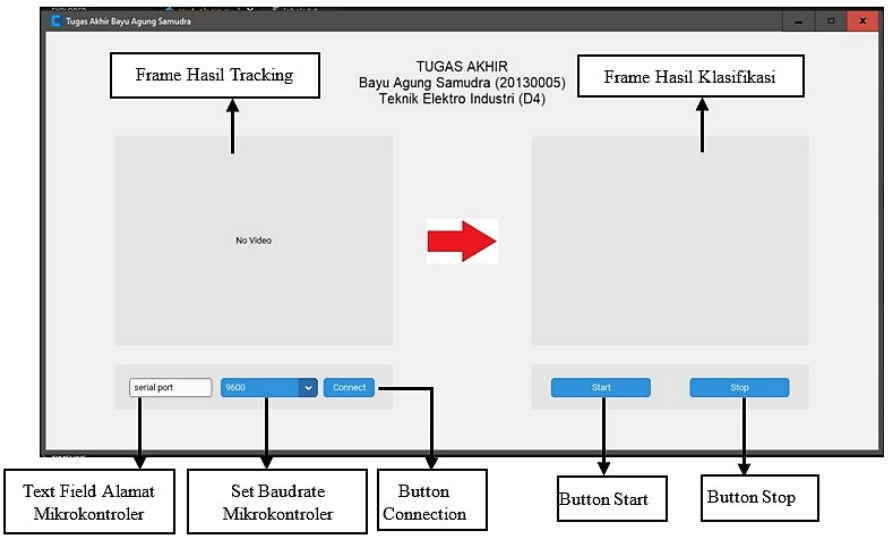


Figure 4. GUI screen display

3. RESULTS AND DISCUSSION

The results of this test will be used as a benchmark for the success of the tool system performance, and the tool performance will be analyzed based on the test results to draw conclusions about the effectiveness and efficiency achieved. The purpose of hardware testing is to determine the working principle and results of the performance of each circuit block that has been designed according to the expected goals. Hardware testing also aims to compare the test results on the manufacture of the tool with the design of the tool. The physical form of the tool that has been made is shown in Figure 7..

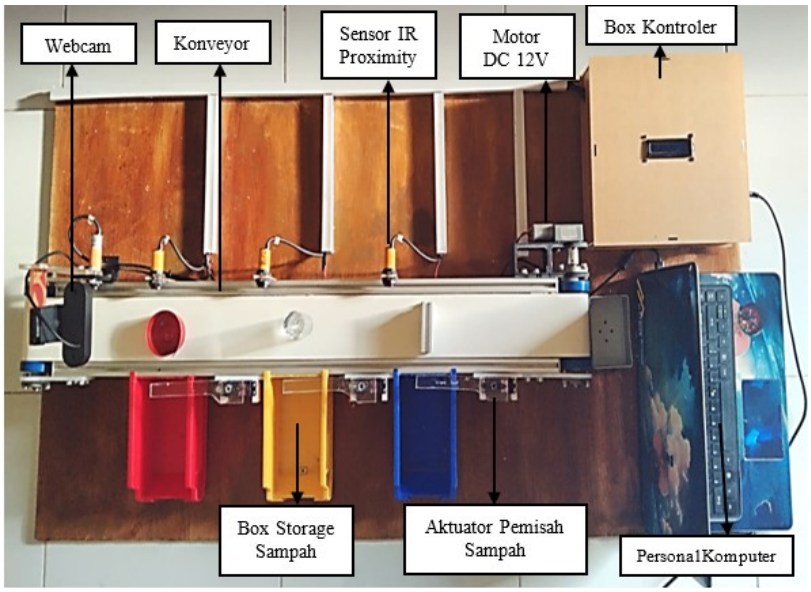


Figure 5. The results of making a waste sorting machine

Figure 5 shows the physical form of the controller box where there are electrical components for the device being made. The components contained in the controller box are: 12v 3.2 A power supply, motor driver, power divider terminal block, relay, PCA servo driver and Arduino ATmega 328 microcontroller. Furthermore, testing is carried out to identify whether the previously designed software can match or not with the results made. This testing includes PC communication with the microcontroller, the GUI display that has

been made and detection of object classification. Figure 6 shows the results of the tests that have been carried out.



Figure 6. The experimental results

The test results show that the waste sorting machine proposed in this study has successfully detected various types of waste, such as plastic, metal or glass.

4. CONCLUSION

This study proposes an ecopaving material sorting machine based on digital image processing using Arduino. The performance of the tool was tested with various types of materials, such as plastic, glass and metal. From the results of testing and comprehensive analysis, it can be concluded that the mechanism and system on the sorting machine have functioned well according to the design that has been done and for the detection of plastic waste objects, glass waste, and canned waste to be sorted, good results have been obtained. This can be proven by the function of the servo motor that works as an actuator to separate plastic waste objects so that they enter the storage box according to the object classification has been running well. In addition, communication between the personal computer (Python GUI) and the ATMega 328 microcontroller runs smoothly and without obstacles.

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