Plan and build a garbage can Automatic as a Motivator of Clean Civilization in the Campus Environment

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Abstract

Cleanliness problems and lack of awareness in sorting waste are still important issues in the campus environment. This research aims to design and build an Arduino Uno-based automatic trash can system that is able to automatically sort waste based on its type, namely metal, organic, and non-organic. The system is designed using a combination of inductive proximity sensors to detect metals, capacitive sensors to detect non-metallic materials, and ultrasonic sensors to detect the presence of objects. Additional components such as servo motors are used to drive the keg caps, and LCDs are used as information display media. The design method is carried out through the stages of needs analysis, hardware assembly, microcontroller programming, and functional testing. The test results showed that the system was able to recognize and direct waste to the right category with a 100% success rate in 30 tests, each for three types of waste. The system also displays information in real-time, providing educational value to users. With this success, the automatic trash can system is considered effective to be applied in the campus environment as an appropriate technological means that can encourage clean living behaviors, increase environmental awareness, and support more structured waste management.

Keywords: ***Automatic Trash Cans, Arduino Uno, Proximity Sensors, Waste Sorting, Campus Environment***

Introduction

Environmental cleanliness is one of the main factors in creating a healthy, comfortable, and productive atmosphere, especially in educational environments such as campuses. A clean campus environment not only reflects the discipline and awareness of the academic community, but also supports the creation of a conducive teaching and learning process (Sukandar et al., 2020). However, in practice, waste management on many campuses is still not optimal. There are still many piles of garbage, inadequate garbage cans, and students' lack of awareness of environmental cleanliness (Pratiwi & Rahmawati, 2021).

The problem of waste management can be overcome by taking advantage of technological developments that continue to make rapid progress. One potential innovation is automatic trash cans, which are trash cans equipped with sensors and an automation system that allows waste to open without touch, and even be able to classify waste types independently (Wahyudi et al., 2019). This technology can be part of a smart campus solution, where efficiency, convenience, and environmental awareness are combined in one smart system.

Automatic trash cans also have the potential to be a driver of a clean civilization, because their existence can encourage changes in the behavior of the campus community to be more concerned about cleanliness. With an interesting and interactive system, this tool can increase students' interest in disposing of waste in its place and understand the importance of separating organic and inorganic waste (Kusuma & Ningsih, 2022). The application of tools like this is in line with the concept of sustainable development goals (SDGs). Based on this background, this research aims to design and build a prototype of an automatic trash can based on a microcontroller with a waste type detection feature and an automatic opening and closing system. In addition to the technical aspect, this research also emphasizes the role of tools as environmental educators, so that they can form a clean culture among students and campus residents in general.

Literature Review

2.1 Clean Living Behavior and Campus Environment

Clean living behavior is part of the habits of individuals and groups in maintaining personal and environmental hygiene to prevent disease and create comfort (Notoatmodjo, 2012). In the context of the campus environment, clean living behavior includes the efforts of the academic community in disposing of waste in its place, keeping public facilities clean, and supporting an efficient waste management system (Sukandar et al., 2020). Campus cleanliness not only reflects the image of educational institutions, but also affects the quality of learning and student health (Pratiwi & Rahmawati, 2021). Therefore, technological innovations are needed that are able to facilitate and encourage the formation of clean living habits in the environment.

2.2 Design Concept

Design is a process that includes needs analysis, system design, hardware and software implementation, and testing to produce a new system or improve an existing system (Bambang, 2013). Presman (2010) added that the system development process must also pay attention to the aspects of user needs so that the system developed is effective and efficient.

Design and build in an automated bin project means designing physical systems (hardware) and software (software) to be able to detect, respond and process waste disposal actions automatically.

2.3 Automatic Trash Can

Automatic bins or *smart bins* are technology-based bins that can open and close their lids automatically using sensors and actuators. Some smart bins even have the ability to classify waste based on its type (organic and inorganic) (Sukarjadi et al., 2017). Smart bin aims to improve user comfort, minimize direct contact, and be an educational medium in shaping waste disposal behavior in its place. In the campus environment, this tool can be a trigger for changes in student behavior towards the importance of maintaining cleanliness.

2.4 Internet of Things (IoT) Technology

The Internet of Things (IoT) is a concept where physical devices can connect to the internet and exchange data. In the context of smart bin systems, IoT allows devices such as sensors, microcontrollers, and communication modules to work in an integrated manner to manage data and provide responses automatically (Behmann & Wu, 2015).

2.5 Arduino

Arduino is an open-source microcontroller-based platform that is easy to program for a wide range of automation applications. Arduino supports a variety of sensors and actuators, and is suitable for use in the development of interactive tools such as smart bins (Jurnal Teknologika, 2023). Its C-like programming language has made Arduino popular with both beginner and professional automation system developers.

2.6 HC-SR04 Ultrasonic Sensor

The HC-SR04 sensor functions to detect objects based on the reflection of ultrasonic sound waves. These sensors are commonly used to measure the distance between the sensor and the object in front of it, with high accuracy and a range of 2 cm to 4 meters (UNITECH, 2023). This sensor is ideal for use as an automatic open-close system trigger on the bin.

2.7 Motor Servo

Servo motor is an actuator used to control the angle of position with high accuracy. This motor is controlled using PWM signals and is commonly used in automated systems that require precise movements, such as automatic openers or shutdowns on smart bins (Trianto, 2005).

Research Methods

Waste bin tool system design

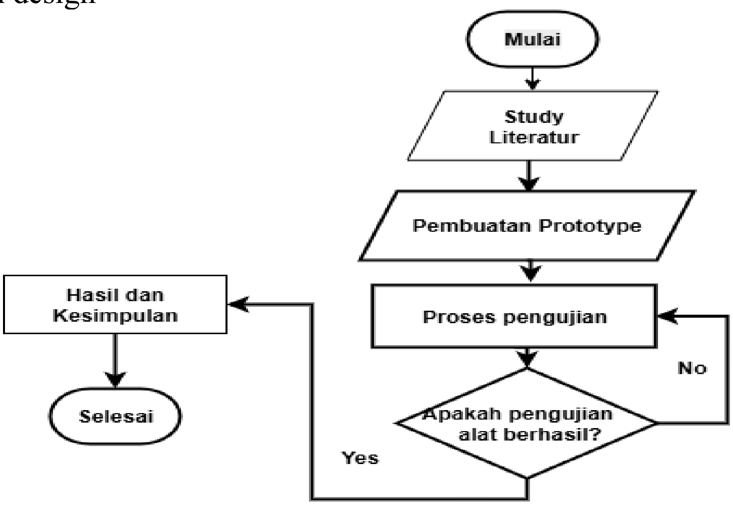

Figure 1. **Flowchart**

Information

1. Start

   The system activates automatically after getting the power supply. The Arduino and all supporting components (sensors, motors, sound modules) start working in standby condition.

2. System Initialization
   At this early stage, the system initializes the entire device such as the HC-SR04 ultrasonic sensor, servo motor, DFPlayer Mini module, and speaker. The goal is to ensure all components are ready and functioning properly before the main process is executed.
3. Object Detection by Ultrasonic Sensor
   The HC-SR04 sensor continuously monitors the area in front of the barrel cap. When an object is detected within less than 20 cm (such as a user's hand or garbage), the system will assume that the user will dispose of the garbage.
4. Servo Motor Activation to Open the Lid
   Once the object is detected, the Arduino sends a PWM signal to the servo motor. The servo motor then opens the lid of the barrel automatically, giving the user access to dispose of the garbage without touching the lid.
5. Educational Audio Playback (Optional)
   As a form of education and appreciation, DFPlayer Mini plays an educational sound through the speakers, such as saying: "Thank you for putting the garbage in its place." This aims to encourage clean living behavior in a sustainable manner.
6. Delay
   The system provides a time lag of a few seconds so that the user has enough time to dispose of the garbage in the bin.
7. Closing the lid automatically
   After the time lag is up, the servo motor will close the barrel lid back to its original position, maintaining the cleanliness and aesthetics of the surrounding environment.
8. Return to Monitoring Mode
   Once the process is complete, the system returns to its initial state to detect the next object, ensuring that operations are repeatable and automatic.
9. Stop (Shutdown - Optional)
   The system will continue to work until it is manually shut down by the user or when it is no longer needed. This feature is optional and can be customized as needed.

Results And Discussion

Testing is carried out on each system component to ensure that all components used function according to design and expectations. The components tested include Arduino Uno as a microcontroller, Infrared sensor, proximity sensor (consisting of capacitive and inductive proximity sensors), ultrasonic sensors, and LCD.

4.1 Arduino Uno Testing

The Arduino Uno test was carried out to find out if the microcontroller was functioning properly and could execute the given commands. This testing process is carried out by turning on and off the LEDs connected to pin 13 and GND. The LEDs are programmed to turn on for 2 seconds and turn off for 2 seconds repeatedly. The test results showed that the Arduino Uno was able to respond to these commands precisely and consistently. This is an indication that the microcontroller is ready to control the other components in the system.

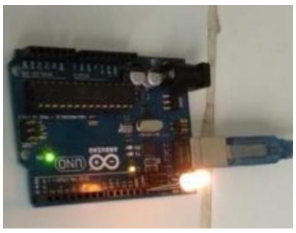

Figure 2. Arduino One

4.2 Ultrasonic Sensor Testing

Ultrasonic sensor testing aims to test the sensor's ability to detect the presence of objects based on a certain distance. The ultrasonic sensor used has a distance detection threshold of 3 cm. When the object is at a distance of less than 3 cm, the sensor will send a signal to open the bin lid automatically via the servo motor. On the other hand, if the object is at a distance of more than 3 cm, the lid of the bin will remain closed. This test proves that the ultrasonic sensor is capable of working accurately as per the system's requirements.

4.3 Infrared and Proximity Sensor Testing

Infrared sensors and proximity sensors, both capacitive and inductive, are tested to ensure they can detect objects or materials well according to their respective functions. Capacitive proximity sensors are used to detect the presence of non-metallic waste, while inductive proximity sensors function to detect metal waste. The test results showed that both sensors were able to detect objects precisely and send signals to the microcontroller to direct the debris to the appropriate place.

4.4 LCD Testing

LCD functions as a display medium to provide information about the status of the tool and the results of waste sorting to the user. The test was conducted by displaying the system name and sorting status in real-time on the LCD screen. The test results showed that the communication between the Arduino and the LCD module was smooth so that the information could be displayed clearly and accurately. This function is very helpful in increasing user interaction and education on the waste sorting process.

Figure 3. LCD Testing

4.5 Testing the Whole System

Once all components have been individually tested and ensured to be in good working order, the next step is the overall assembly process of the tool. Assembly is carried out by combining all components into one integrated system, accompanied by microcontroller programming using Arduino Uno. This programming aims to allow each component to interact automatically and work according to the logic that has been designed. After the assembly process is completed, final testing is carried out on the finished smart bin tool. This test aims to ensure that the tool can automatically sort the type of waste according to the desired category. If the waste being put in is metal, then the inductive proximity sensor will detect it and direct the waste to the metal bin. If the waste is plastic or other non-metallic materials, then the system will continue sorting to the second stage using capacitive sensors. For types of waste such as leaves or plant residues, the system will recognize it as organic waste and direct it to organic bins.

4.5.1 Non-Organic Waste Testing

The first test was carried out using non-organic waste, with an example in the form of plastic bottles. The waste is put into a smart bin, then the first sorting system works to detect whether the material is metal. Because plastic bottles are not metal, waste is directed to the second sorting stage. At this stage, the sensor detects that the material is not organic, so the system directs the plastic bottle to the non-organic bin.

Figure 4. Non-Organic Waste Testing

4.5.2 Organic Waste Testing

The next test was carried out using organic waste, in this case in the form of dry leaves. The leaves are put into the smart bin, and as before, the first sorting system will ensure that the waste is not metal. After that, the second sorter will detect the type of material. Since the material is recognized as a natural (organic) material, the system directs the waste to the organic bin. This process shows that the sensor works accurately in distinguishing the type of waste based on its material characteristics.

Figure 5. Organic Waste Testing

4.6 Automated Waste Sorting System Testing

After all components have been individually tested, the system assembly and overall testing are carried out. The system is designed to recognize and sort three main types of waste: metallic, organic, and non-organic. The test results showed that the system was able to sort with 100% accuracy from 30 tests (10 tests for each category of waste).

Important Notes from the Test:

1. Metal waste is recognized directly by a metal sensor (*proximity inductive*) and directed to a metal barrel without going through an advanced sorting stage.
2. Non-metallic waste will be processed through the second stage to differentiate between organic and non-organic using additional sensors.
3. The sensors used in the second sorting stage are able to distinguish the characteristics of the material accurately and consistently.

4.6.1 Non-Organic Waste Testing

The test was carried out by incorporating various types of non-organic waste such as plastic, glass, and used electronics. The system successfully recognizes and directs the waste to the appropriate place.

Table 1. Non-Organic Waste Test Results

No	Types of Garbage	Output	Status
1	Plastic Bottles	Non-Organic Waste Bins	Succeed
2	Snack Packaging	Non-Organic Waste Bins	Succeed
3	Crackle	Non-Organic Waste Bins	Succeed

No	Types of Garbage	Output	Status
4	Socket	Non-Organic Waste Bins	Succeed
5	Glass	Non-Organic Waste Bins	Succeed
6	Battery	Non-Organic Waste Bins	Succeed
7	Used Tires	Non-Organic Waste Bins	Succeed

Success Rate: 100% of 10 tests.

4.6.2 Organic Waste Testing

Organic waste such as food scraps and natural materials is tested to ensure the system is able to recognize them.

Table 2. Organic Waste Test Results

No	Types of Garbage	Output	Status
1	Rotten Fruit	Organic Waste Bins	Succeed
2	Dried Leaves	Organic Waste Bins	Succeed
3	Tea Grounds	Organic Waste Bins	Succeed
4	Eggshell	Organic Waste Bins	Succeed
5	Vegetable Skin	Organic Waste Bins	Succeed
6	Bread	Organic Waste Bins	Succeed
7	Tissue	Organic Waste Bins	Succeed

Success Rate: 100% of 10 tests.

4.6.3 Metal Waste Testing

Types of metal waste, such as beverage cans, used kitchen utensils, and household metal components, are tested to ensure the ability of inductive proximity sensors to detect metal materials directly and accurately. This test aims to verify that the system can automatically identify metal waste without the need to go through the second sorting stage, as well as direct the waste directly to the metal category bin. The test results show that the detection is going well, in the absence of any misclassification.

Table 3. Metal Waste Test Results

NO	Types of Garbage	Output	Status
1	Paint Cans	Metal Trash Can	Succeed
2	Beverage Cans	Metal Trash Can	Succeed
3	Copper Cable	Metal Trash Can	Succeed
4	Zinc	Metal Trash Can	Succeed

Success Rate: 100% of 10 tests.

Discussion

Based on the results of testing the Arduino microcontroller-based automatic bin system, it can be concluded that the system has functioned well and is able to respond to environmental conditions according to design. The system successfully executes the waste detection and sorting process based on metal, organic, and non-organic categories with a high level of accuracy. The inductive proximity sensor can precisely detect metal waste and direct it to the metal barrel without going through an advanced sorting process. Meanwhile, non-metallic waste will go through the second stage of sorting, where other sensors such as capacitive sensors and ultrasonic sensors determine whether the waste is organic or non-organic.

In addition, the LCD module works well in displaying real-time information about the status of waste sorting, such as the categories of detected waste and the destination of its disposal. This visual display provides feedback to users and becomes an educational element that reinforces awareness of the importance of waste sorting. The integration between sensors, microcontrollers, motors, and display modules shows that the system has been working synchronously, responsively, and accurately. With this success, it can be concluded that the designed automatic trash can system is not only able to carry out sorting functionally, but also provides added value in terms of education and increasing environmental awareness among students and the academic community. This system is feasible to be implemented in the campus environment as a technological innovation that supports clean and environmentally friendly living behaviors.

Conclusion

Based on the results of the design, assembly, and testing of the system, it can be concluded that the Arduino-based automatic trash cans that have been developed are able to work effectively and accurately in detecting and sorting waste based on its type, namely metal, organic, and non-organic. This system successfully integrates various components such as inductive and capacitive proximity sensors, ultrasonic sensors, servo motors, and LCD modules synchronously through Arduino Uno microcontroller programming. The sensor is able to recognize the characteristics of the waste material with 100% accuracy from the tests performed, while the LCD display provides sorting status information in real-time as visual feedback to the user.

Overall, this tool not only functions as an automatic waste sorting system, but also acts as a medium for education and environmentally friendly technological innovation in the campus environment. The implementation of this system has the potential to encourage clean living behavior and increase the awareness of the academic community on the importance of waste sorting from an early age.

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