



AUTOMATIC BATTERY SORTING USING AN EMBEDDED SYSTEM AND CONVEYOR BELT FOR SMART BATTERY RECYCLING

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Abstract:

The use of batteries in electronic devices, cars, electric vehicles, and energy storage systems is growing, which means there is more used battery waste being created. When batteries are not handled or disposed of properly, it can pollute the environment and waste valuable materials that could be reused through recycling [1], [5], [31]. Different types of batteries, like lithium-ion and lead-acid, have different features and recycling needs, so it's important to sort them correctly before recycling [2], [6], [17]. This research introduces an automatic battery sorting system that uses an embedded system and a conveyor belt to help with smart battery recycling. The system includes a conveyor belt, a sensing unit, an embedded controller, a motor, and an automatic sorting mechanism. Automated conveyor systems and smart sorting methods are being studied as ways to improve how materials are identified and separated [92], [100], [101]. Used batteries are moved along the conveyor belt and are scanned at a sensing station. The sensors check certain battery features, and the embedded controller uses that information to decide which sorting category the battery should go into. An actuator then moves the battery into the correct collection bin. The system is meant to reduce the need for manual handling, make sorting more consistent, and offer a



useful way to sort battery waste before recycling. Developing automated and intelligent battery management systems is seen as an important step in improving battery recycling and helping with sustainable material use [18], [22], [28], [29]. The system can also be improved using technologies like IoT, artificial intelligence, machine vision, and data monitoring [28], [29], [79]. Overall, this approach helps with safer battery handling, more efficient recycling, recovering materials, and better waste management [12], [31], [91].

Keywords: Battery recycling; automatic battery sorting; embedded system; conveyor belt; lithium-ion battery; lead-acid battery; sensors; automatic sorting; smart recycling; sustainable waste management..

1. INTRODUCTION

The fast growth of electronic gadgets, electric cars, energy storage systems, and other battery-powered items has led to more spent batteries being created. Batteries are important for storing electricity, but once they are no longer useful, they need to be properly collected, handled, sorted, and recycled. If batteries are not disposed of correctly, it can harm the environment and also waste valuable materials that could be reused. Lithium-ion and lead-acid batteries are commonly used but are very different in how they are built, the materials they use, their physical features, and how they are recycled. Because of these differences, it is important to properly identify and sort different types of batteries before recycling. Mixing different battery types during recycling can make the process harder and reduce the safety and effectiveness of the recycling process. Traditionally, batteries are sorted by hand, using things like what they look like, their labels, size, and shape. While this method is easy to use, it can take a lot of time, require many workers, and can make mistakes. As more battery waste is created, there is a need for a system that can automatically detect and sort batteries with less human help. This research suggests an automatic battery sorting system that uses an embedded system and a conveyor belt for smart battery recycling. The system uses a conveyor belt to move used batteries through a detection area. Special sensors are used to check specific features of the batteries, and an embedded controller uses the sensor data to decide which sorting group the battery should go into. An automatic actuator then separates the batteries into their correct collection bins. This system offers a practical way to automate the first step in battery recycling. It aims to reduce the need for manual work, improve the consistency of sorting, and make battery recycling more efficient. The system can also be improved by adding IoT, artificial intelligence, machine vision, and data monitoring for better classification, real-time tracking, and more efficient recycling. Overall, this approach supports sustainable battery waste management, helps recover valuable resources, and promotes circular economy practices.

2. PROBLEM STATEMENT

More and more batteries are being used in things like phones, cars, electric vehicles, and for storing energy. This has led to a lot of old batteries being thrown away. If these used batteries aren't collected, handled, and disposed of properly, they can pollute the environment and waste valuable



materials that could be reused if recycled. One big problem in recycling batteries is sorting them into the right categories before they are processed further. Different types of batteries, like lithium-ion and lead-acid, have different designs, materials, physical features, and recycling needs. Traditional ways of sorting often involve people looking at each battery one by one, which takes a lot of time and effort and can lead to mistakes. It's even harder when there are a lot of mixed batteries to sort. Because of this, there is a need for an automatic, fast, and cost-effective way to sort batteries with very little need for human help. This research introduces a system that uses a conveyor belt, an embedded controller, and sensors to automatically sort batteries. In this system, batteries move along a conveyor belt, are detected by sensors, and are then classified by the controller based on certain measurable traits. An automatic sorting mechanism then puts each type of battery into the correct collection bin. The system is designed to make sorting more consistent, reduce the need for manual work, and offer a better starting point for the recycling process.

3. EXISTING AND PROPOSED METHOD

Existing Method

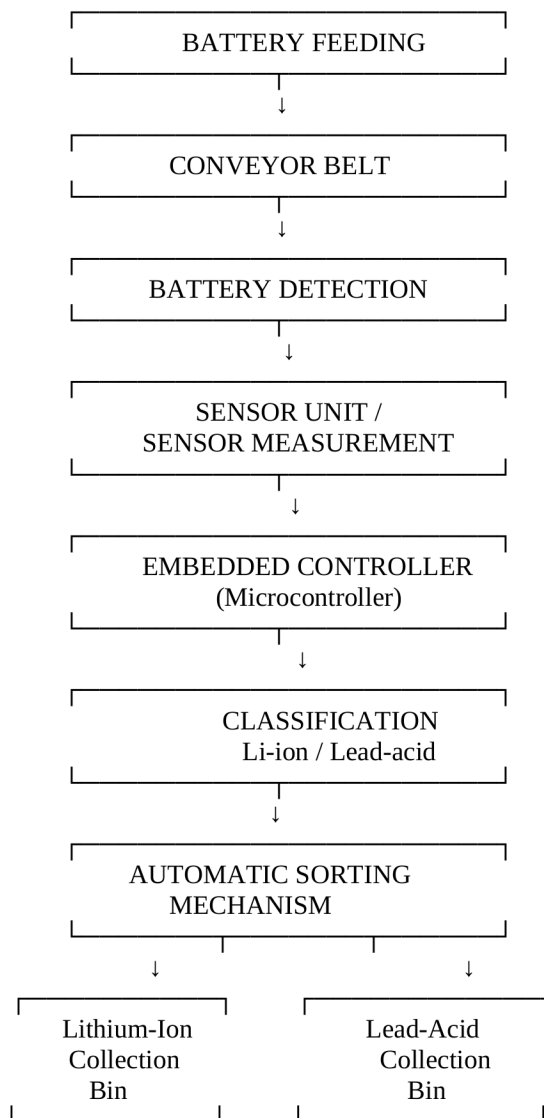
In the traditional way of recycling batteries, used batteries are first gathered and separated before they are recycled.

To identify the type of battery, people usually look at it by eye, check the labels, and examine its size and shape. The person then puts the battery into the correct group based on what they see. This method that relies on people has some problems. It needs a lot of human work and can take a long time when there are many mixed batteries. Mistakes can happen, leading to wrong groupings. Also, handling old batteries by hand can be dangerous, especially if the batteries are broken or still hold some electricity. Some machines can help by using features like size, shape, and weight to sort batteries. But these machines might not work well if different battery types are similar in size or shape. So, the usual ways of sorting batteries don't always do a good job at classifying them automatically and consistently.

Proposed Method

The new method uses an automatic system that includes a conveyor belt, sensors, and a computer-controlled system. This setup is meant to cut down on the need for human help and allows for continuous movement, detection, sorting, and separating of used batteries.

The proposed process includes the following steps:



When a battery is put on the conveyor belt, it moves toward the sensing area. Special sensors check the battery and measure the specific features needed to classify it. The controller inside the system gets the sensor data, processes it, and decides which sorting group the battery belongs to. Once the decision is made, the controller turns on the sorting device at the right moment. The device then moves the battery into the correct bin, like the one for lithium-ion batteries or lead-acid batteries.

Table 1 C. Comparison of Existing and Proposed Methods

Parameter	Existing Method	Proposed Method
Sorting process	Mainly manual	Automatic
Battery transportation	Manual handling	Conveyor belt
Detection	Visual/manual inspection	Sensor-based detection



Parameter	Existing Method	Proposed Method
Decision making	Human operator	Embedded controller
Sorting mechanism	Manual separation	Automatic actuator
Human involvement	High	Low
Sorting consistency	Depends on operator	More consistent
Processing capacity	Relatively low	Higher potential
Data monitoring	Limited	Can be added
IoT/AI integration	Difficult	Possible in future
Safety	More manual handling	Reduced manual handling
Main purpose	Basic battery separation	Smart automated battery sorting

4. DESIGN AND DEVELOPMENT

A. Design Concept

The design and development of this system focus on creating an automatic battery sorting machine using an embedded system and a conveyor belt. The system is made to move used batteries, check their features, sort them, and automatically put them into separate bins. The design uses a modular approach, so each part like sensing, control, conveyor, and sorting can be made and tested on its own.

B. System Design

The system is made up of these main parts:

1. Battery Input Unit – Used batteries are put on the conveyor system.
2. Conveyor Unit – Moves batteries from the input point to the sensing and sorting areas.
3. Sensing Unit – Checks if a battery is there and measures some of its features.
4. Embedded Control Unit – Takes the sensor data and decides how to sort the battery.
5. Motor Drive Unit – Controls the conveyor motor.
6. Sorting Unit – Uses an actuator to send the battery to the correct bin.
7. Collection Unit – Gathers the different types of sorted batteries.
8. Display/Monitoring Unit – Shows system details and can be used for internet-based monitoring in the future.

C. Mechanical Design

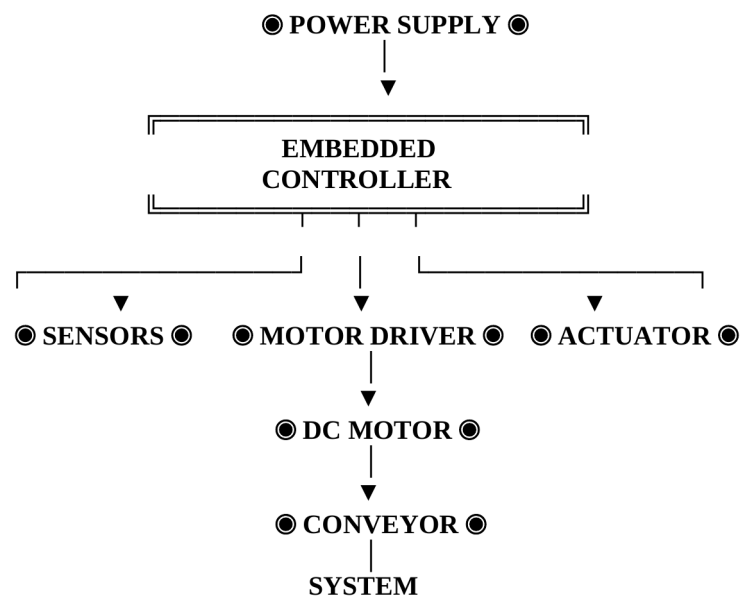
The mechanical structure has a conveyor belt, a frame, rollers, a DC motor, a motor driver, a sensing station, and a sorting mechanism. The frame supports the conveyor and other parts. The

conveyor belt is set up so batteries can move smoothly from the feeding area to the sensing part. The rollers help guide the belt, and the DC motor provides the needed movement. The sorting mechanism comes after the sensing area. Once the embedded controller knows the battery type, the actuator moves at the right time to send the battery into the proper bin.

D. Electrical and Electronic Design

The electronic system includes an embedded controller that is connected to the sensors, motor driver, conveyor motor, and sorting actuator

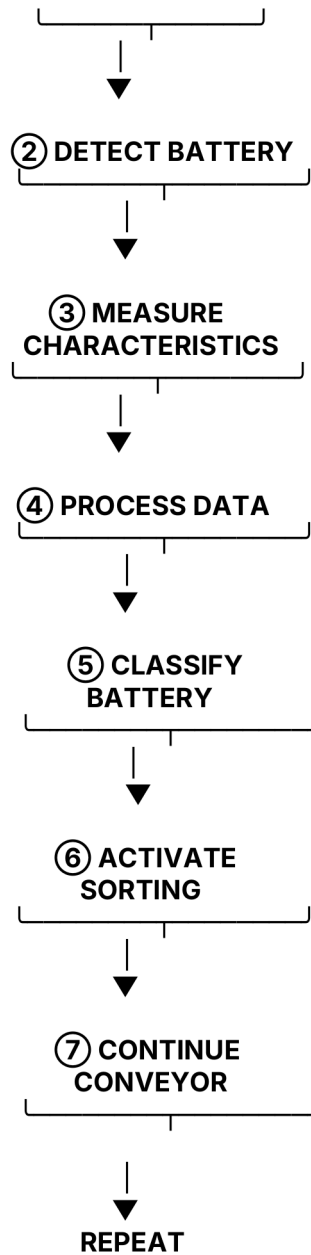
.The basic electrical flow is:



The sensors send signals to the controller. The controller uses the programmed rules to process these signals. The motor driver gets instructions from the controller and turns on the conveyor motor. The actuator is directed to carry out the needed sorting action.

E. Embedded System Development

The embedded controller is programmed to coordinate the complete sorting process. The program follows the sequence:



The controller keeps watching the sensing unit all the time. When a battery goes into the detection area, the controller gets the sensor readings and checks them against the set rules for classification.

E. Conveyor Belt Development

The conveyor system is built to move batteries in a controlled way.

The speed of the conveyor is chosen based on how fast the sensors and actuator can respond.

The development steps include:

- * Making the conveyor frame.



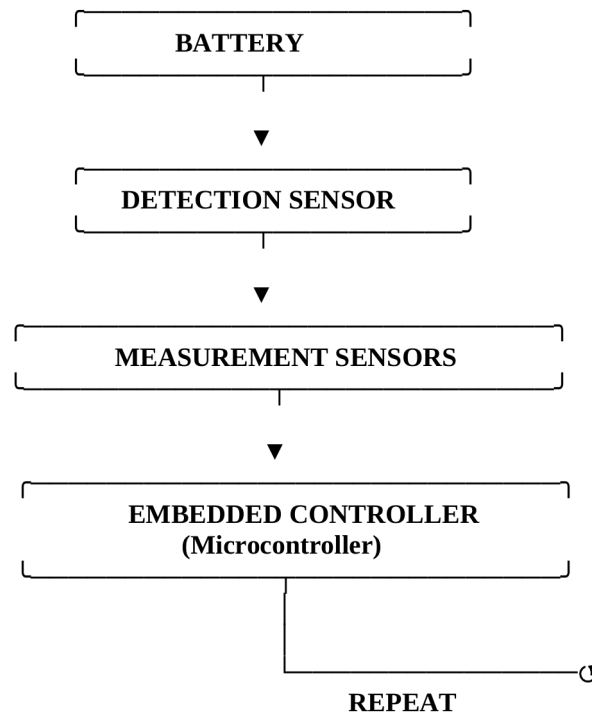
- * Putting in the rollers.
- * Adding the belt.
- * Attaching the DC motor.
- * Connecting the motor driver.
- * Testing how the belt moves.
- * Adjusting the conveyor speed.
- * Aligning the sensing and sorting parts.

F. Sensor Unit Development

The sensing unit is placed on the conveyor at a fixed spot where it can detect batteries.

A presence sensor finds out when a battery enters the sensing area. More sensors are used to measure the features needed for the chosen classification method.

The data from the sensors is sent to the embedded controller for processing.



The right mix of sensors should be chosen based on what your real prototype can measure accurately.

G. Sorting Mechanism Development

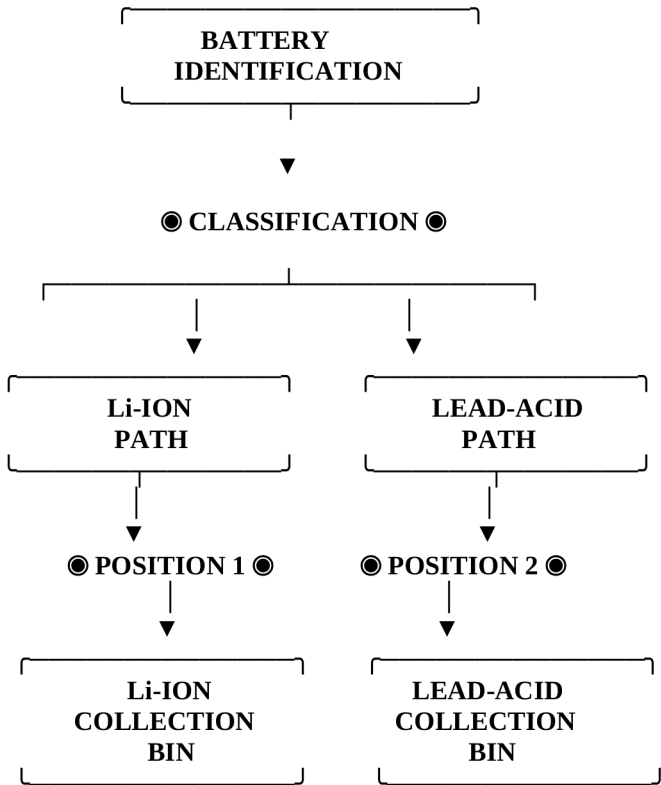
Once the items are sorted, the controller sends a signal to the actuator.



The actuator moves and physically moves the battery to the correct place.

Table 2

Component	Suggested specification	Function
Presence sensor	IR/photoelectric sensor	Detect battery
Height sensor	Ultrasonic sensor	Measure battery height
Voltage sensor	Voltage measurement module	Measure voltage
Controller	Arduino Uno	Process sensor data
Actuator	Servo motor	Operate sorting mechanism
Motor driver	L298N/equivalent	Control conveyor motor
Conveyor motor	DC geared motor	Drive conveyor
Power supply	Regulated DC supply	Power electronic components
Collection	Two bins	Li-ion and lead-acid separation



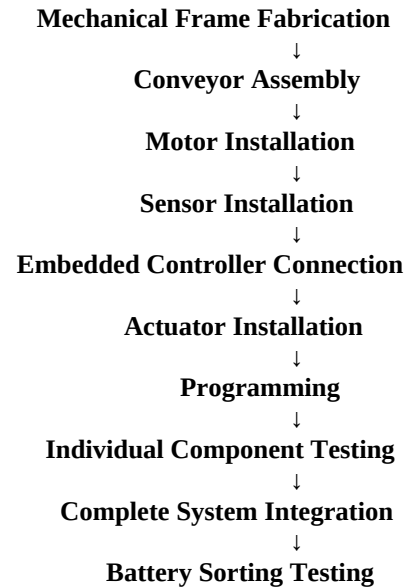
The actuator timing needs to match the conveyor's movement. If the timing is wrong, the battery might go into the wrong collection bin.



H. Prototype Development

The full prototype is built by combining the mechanical and electronic parts.

The steps to develop it are:

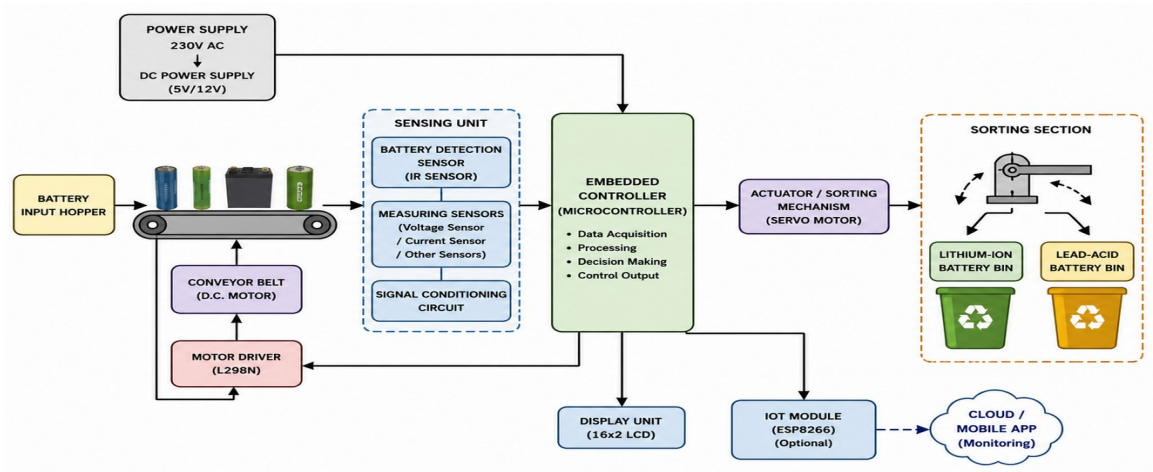


I. Testing and Development Validation

Once assembled, the system undergoes testing with various battery samples. The primary performance metrics are:

- 1) Battery detection accuracy
- 2) Battery classification accuracy
- 3) Sorting accuracy
- 4) Sorting time
- 5) Conveyor speed
- 6) Number of correctly sorted batteries
- 7) Number of incorrectly sorted batteries
- 8) Overall system efficiency

The sorting accuracy can be calculated as:



This design and development approach establishes a practical foundation for an automated battery pre-sorting system, with the potential for future expansion to include IoT monitoring, machine vision, AI-driven classification, support for multiple battery categories, and high-speed industrial sorting capabilities.

Figure 4 1. Design and development Automatic Battery Sorting Using an Embedded System and Conveyor Belt for Smart Battery Recycling

5. CONCLUSION

This proposed research introduces an automatic battery sorting system that utilizes an embedded system and a conveyor belt to facilitate smart battery recycling. The primary goal of the system is to enhance the pre-sorting of spent batteries and minimize reliance on manual sorting. Properly separating different battery types, especially lithium-ion and lead-acid batteries, is a crucial step before proceeding with further recycling and material recovery. The developed concept integrates a conveyor belt, sensors, an embedded controller, a motor driver, and an automatic sorting mechanism. As the batteries move along the conveyor, they are detected in the sensing section. The embedded controller processes the battery characteristics measured by the sensors. Following the programmed classification criteria, the controller triggers the sorting mechanism and guides the battery into the correct collection bin. The proposed system can minimize manual handling, enhance sorting consistency, and offer a systematic approach for managing mixed battery waste. It also provides a practical and cost-effective platform for demonstrating automated battery sorting. System performance can be assessed through metrics such as detection accuracy, sorting accuracy, sorting time, and overall system efficiency. Although the proposed system is currently a prototype, it lays the groundwork for future enhancements. Combining IoT, artificial intelligence, machine vision, advanced sensors, real-time monitoring, and various battery types can further enhance the system's accuracy, capacity, and intelligence.

In summary, the proposed battery sorting system advances sustainable waste management, enhances safety, streamlines recycling, facilitates the recovery of valuable materials, and supports



circular economy initiatives. It illustrates how embedded systems and automation can be leveraged to create a smarter and more efficient approach to battery recycling.

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