ICT, Electronics, Programming, Geodesy

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ROBOTIC SORTING FOR THE MAIN TYPES OF SOLID HOUSEHOLD WASTE

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The analysis of existing and effective methods of robotic sorting of solid household waste is carried out. The main stages of sorting solid household waste according to these methods are described.

Introduction. Municipal solid waste (MSW) has become a global problem today. Since the 19th century, the amount of garbage has increased exponentially. That was supplemented by an ever-growing demand for new products. As a result, the humanity has huge landfills filled with thousands of tons with waste. This leads to the destruction of the ozone layer and to poisoning people and animals with toxic smoke due to burning of those landfills. Landfills also serve as a halo habitat for insects, birds, and rodents who become carriers of different infections.

One of the solutions to this environmental problem that exists now is the incineration of garbage in order to stop its accumulation in landfills and to prevent soil intoxication. However, this action is not environmentally friendly. A huge amount of carbon dioxide and toxins are released into the air. Also, the burning of garbage is not profitable in terms of economy. Therefore, people began to sort the garbage. Garbage sorting is mostly done manually using a moving conveyor. Therefore, the introduction and use of automated sorting with the help of robots is an urgent task to improve the environment [1].

The main advantages of robotic MSW sorting are: the reduction of costs for manual processing (wages for workers); people are not exposed to the danger of toxins while sorting MSW; the increase in efficiency of MSW sorting [2].

Let us look closer at the promising methods of automated sorting with the help of robots.

A method of robotic sorting using machine vision. It is the main method of sorting solid waste in the modern world. It uses machine vision and advanced intelligent control system. The information from cameras and sensors is transmitted to an intelligent control system which uses a spectrometer to improve the scanning accuracy and controls the gripper manipulators.

This method involves the sequential performance of stages for sorting solid waste.

The first stage: Separation of dust, sand, and fine slag. The conveyor uses the process of separating main garbage from small parts with a radius of less than 5 cm. by using an industrial sieve and air molasses. The size of the screen grid cell is regulated by an intelligent control system.

The second stage: Separation of very large pieces of garbage for crushing. The scanner detects the size of the objects and transmits the information to the control system. The camera recognizes the objects that are larger than 1 meter and sends a command to the manipulator. The manipulators put these objects to a crushing compartment. After the crushing process, formed fragments are carried to the conveyor.

The third stage: Separation of metal objects. Metal detectors plus electromagnetic separation are used. Metal parts are extracted by using an alternating magnetic field.

The fourth stage: Sorting of the main types of MSW using machine vision. Following the previous stages, the solid waste is analyzed while on a conveyor. The sensors recognize each piece of garbage and inform the intelligent control system about its geometric location on the conveyor belt as well as about its size and the type of material (plastic, wood, glass, etc.).

The intelligent system has multiple digital cameras to use machine vision functions to recognize objects in a specific area on the conveyor belt. The software of the intelligent system implements image recognition based on a convolutional neural network and generates a list of fragments with calculated parameters (size, type of material, orientation on the tape) for further sorting. The result of the software is shown on the Fig. 1 as a computer representation of the location of the debris fragments on the conveyor belt.

When the fragment reaches the area of operation of the manipulator, the latter, having received the calculated values of the size, position and the type of the material, captures and removes it from the conveyor. After, it places the fragment in a container with the appropriate type of material. The work of the manipulator is presented on the Fig. 2.

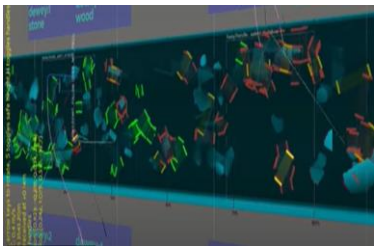


Fig. 1. – The computer vision how objects are represented on the belt

Fig. 2. – The manipulators for sorting the garbage

It is possible that some fragments of garbage will not be recognized with a high degree of probability. In this case, the manipulators will not sort them. Unrecognized fragments will be delivered by a conveyor for a specialized process, where they will be taken back to the beginning of the line for re-recognition. Due to the location on the conveyer belt and the relevance to each other, these fragments will be correctly re-recognized. The process will continue until the entire batch of garbage is decomposed according to the type of the material.

The accuracy of determining the materials depends on the degree of artificial intelligence (AI) training. The system remembers objects, color, and reflected spectrum. The speed of recognition and the number of recognized materials depends on the performance of the neural network. Machine vision can process data on various indicators simultaneously thanks to the use of high-performance neural networks. More than 90% of all existing companies use this method for sorting solid waste [5].

A list of existing companies which use machine vision in a robotic system for sorting solid household waste are the following:

a) SamurAI Robot from Canada's Machinex Technologies: recognizes plastic, cardboard, boxes, and packaging with the help of machine vision. The robot's accuracy is already equal to that of a human.

b) Russian robot for sorting waste from the GC "Environmental and Energy Technologies": recognizes 20 types of plastic among other garbage that moves along the conveyor, using not only cameras, but the spectrometer which scans chemical composition and color.

c) Finnish company ZenRobotics has developed an industrial robot and software for recycling garbage. The sensors of the system constantly monitor the flow of solid waste, and the program analyzes the data in real time. As a result, the garbage is sorted quickly and accurately.

The method of using pressure sensors. With the help of this method, the robotic system is able to determine the type of material by using tactile sensors. Such a system is able to determine whether an object is wood, metal, or plastic. The system includes a soft teflon hand that uses tactile sensors at the fingertips to determine the size and the stiffness of objects. The appearance of the manipulator equipped with a tactile system is shown on the Fig. 3.

This method was found to be 85 percent accurate when detecting materials in statics and 63 percent accurate on a real simulated conveyor belt. The most common mistake was the recognition of metal cans covered with paper. They were identified as paper.

A further development of such systems is the use of a touch-sensitive skin for the robot's grip, which provides tactile feedback that allows to distinguish between a wide range of objects, from hard to soft. On the Fig.4 a robot manipulator with teflon fingers is shown.

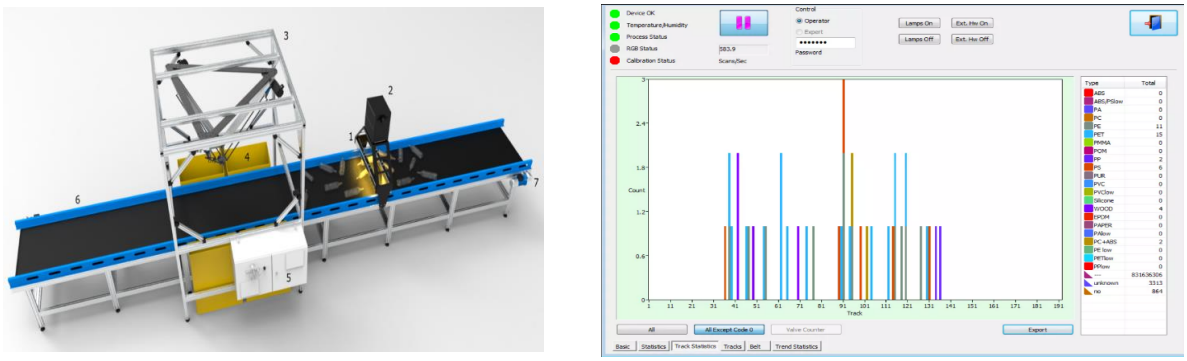
Fig 3. – Solid waste sorting process with the help of the robotic system that uses pressure sensors

Fig. 4. – Tactile system

When the system captures an object, it evaluates the size of the object and uses its two pressure sensors to measure the force which is required to capture the object. These indicators along with the calibration data about the size and the stiffness of the objects (which are made of various types of materials) are what gives the idea of what material the object is made of. Since the tactile sensors are also conductive, they can detect metal by the measured change in the electrical signal. The robot evaluates the size and measures the pressure difference between the current closed hand and the pressure while the hand is opened. The control system uses this pressure difference and the size to classify objects based on the available information about the objects that the machine has already measured.

The next step in the development of such systems is to compare tactile data with actual video data from the robot's digital cameras. This will improve the accuracy and will provide more subtle differentiation between different types of materials [3].

Chemical analysis method. This method, like the previous ones, uses a moving conveyor. The sorted garbage arrives at the beginning of the conveyor belt and moves to the robot manipulator. As it moves, it crosses a light beam which analyzes the chemical composition: a spectrometer is used to analyze the chemical composition. The spectrometer is assisted by machine vision cameras. Plastic is selected according to several criteria – the geometry of the container (all plastic cans, bottles, plates, packaging, etc. have a similar geometry, glass containers have a constant chemical composition).



a) b)

a) A robotic complex: 1 is a light beam, 2 is a scanning device placed above the tape, 3 is a robot manipulator with a control system, 4 is garbage containers, 5 is a block containing software, 6 is a conveyor;
b) Chemical analysis software

Fig. 5. – Robotic complex for sorting solid waste with chemical analysis

Therefore, it is possible to "teach" the industrial vision system to select products with the geometry needed, by using the information which is stored in its database. Solid waste color (plastic packaging is varied in color, but most often has several main colors: white, transparent, blue, red, yellow, green, and brown).

Next, the system which consists of a robot, a control system, and an industrial computer with its own software analyzes and signals to the robot where the fragment is located on the conveyor belt. It also signals about its size and the type of material. This is necessary for the correct positioning of the vacuum gripper. At present, the complex determines and sorts the types of materials according to their chemical composition: glass, plastic, and paper [4].

The development of a sorting robot based on the LEGO educational platform. At the moment, Polotsk State University has grounds for creating prototypes of robotic sorting machines based on LEGO Mindstorms EV3 educational set. To design a robot that is able to sort garbage, the experiment was carried out which includes the following steps:

The first stage. The study of the requirements for sortable objects. Here, we selected three types of objects: metal, glass, and plastic. The main task of the robot l was to distinguish those three objects.

The second stage. The selection of the system as well as the model for building the robot. The LEGO Mindstorms EV3 educational system was chosen for the robot development [6]. This system allows to create complex robotic structures. It also allows to create a program which helps a robot work independently without human intervention. A mobile robot with a gripping claw was chosen as the model.

The third stage. The model was assembled. Some changes were made to the design of the robot: an additional magnetic sensor was installed which made it possible to distinguish metal objects. The principle of selecting metal objects is as follows: the robot uses its claw to grab the object; if a magnetic sensor is triggered, the object is considered metallic. The robot with a magnetic sensor is shown on the Fig 6.

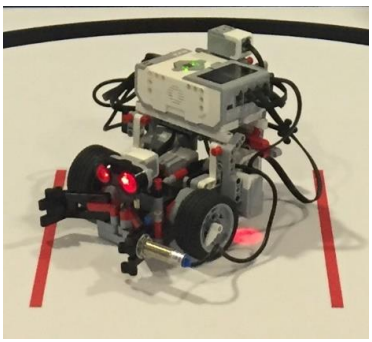


Fig. 6. – Solid Waste Sorting Robot

The fourth stage. The program is compiled in the LEGO Mindstorms environment. The program was as follows: the robot begins to rotate around its axis. When an object appears in the area of the ultrasonic sensor, the robot captures this object. The robot begins to analyze the material of the captured object. If a magnetic sensor is triggered, the robot decides that it has captured a metal object. If the magnetic sensor does not trig, the robot tries to squeeze the object. If the robot manages to squeeze the object, it decides that it is a plastic object. It can also decide and detect when a glass object is captured.

The fifth stage. To organize the experiment for distinguishing objects made of glass, metal and plastic, the following items were selected: a metal can, an empty plastic bottle, and a glass bottle.

The experiment was conducted on a flat plastic surface. The robot was placed in the center of a circle with a diameter of 1 meter. The robot began to rotate around its axis clockwise. One item was put for the detection by the robot. Once the item was detected, the drove up to it, captured it, and reported the type of the captured object with sound signals. Next, the robot took the object out of the circle and returned to its original position. See, the Table 1 below.

Table 1. – The results of the object recognition experiment

Item name	Number of times displayed	Number of correct recognitions	Number of incorrect recognitions
Metal jar	30	30	0
Plastic bottle	30	23	7
Glass bottle	30	27	3

The results indicate that the developed robot has managed the tasks. To reduce the number of incorrect recognitions, it is necessary to improve the design of the robot and to add new sensors.

Conclusion. People cannot put everything on the landfill for burial. Solid household waste must be presorted. This will allow sorted municipal solid waste to be used as a renewable resource for some new materials. Replacing manual labor for sorting solid waste at waste sorting enterprises will reduce personnel costs and the number of people who are endangered due to toxins of solid waste. It will increase the efficiency of sorting solid waste, thereby improving the environmental condition of the Planet.

The experiment has showed that the developed design of the sorter robot has a high percentage of object recognition. Therefore, the use of robots for sorting solid household waste is effective for saving the environment. Further research is the expansion of the line of sorted waste objects that can be used for recycling and for the production of new items.

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