Engineering

SENSOR SYSTEMS FOR AUTOMATED SEPARATE WASTE COLLECTION

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ABSTRACT:
INTELLIGENT WASTE COLLECTION SYSTEMS BECAME A PRIORITY ISSUE OF DEVELOPED COUNTRIES LEADING TO THE NECESSITY OF PROCESS AUTOMATION. IN THIS PAPER, WE AIM TO EXPLORE THIS TYPE OF SYSTEMS WHICH ARE ABLE TO DETECT, RECOGNIZE AND IDENTIFY THE WASTE. THE FIRST PART OF THIS PAPER INTRODUCES APPLICABLE TYPES OF SENSORS WHICH COULD BE USED WITHIN AN APPLICATION, WHILE THE SECOND PART CONTAINS A CASE STUDY PRESENTING SENSORS DISPOSAL METHODS WITH THE ADVANTAGES AND DISADVANTAGES WHICH MIGHT OCCUR. A VISION SYSTEM WILL BE USED FOR THE PROPOSED APPLICATION, WHICH WILL CONTAIN ONE OR MORE CAMERAS FOR THE CORRECT RECOGNITION OF WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT. FOUR POSSIBLE CONFIGURATIONS OF CAMERA POSITIONING WITHIN THE VISUAL RECOGNITION SYSTEM IN RELATION TO THE IDENTIFIED / RECOGNIZED PART ARE PRESENTED.

KEY WORDS: WASTE, SENSOR, VISION SYSTEM

INTRODUCTION

The purpose of this paper is to identify sensor system solutions for the detection, counting and recognition of waste electrical and electronic equipment within an automated separate waste collection system. Particular emphasis will be placed on the vision system for the shape recognition of the waste electrical and electronic equipment. This identification system complements the mechanical assembly used for the waste transport and transfer, thus forming an integrated system which is capable of making certain decisions by itself according to predetermined criteria.

The visual recognition sensor system is a digital system which takes over information from its range as images, processes them and transmits the result of the decisions to the command and control system. The sensor system is used to identify, count and target the

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parts to be inspected / identified. The major advantages of using such systems are the speed and the decisions accuracy in order to identify and select waste electrical and electronic equipment.

In the automatic waste collection centers, using sensor systems for the rapid identification of wastes is not really the issue, but the identification correctness and shape recognition of the waste electrical and electronic equipment.

The sensor system used will include, besides the visual recognition system of the waste shape, a weighing system and possibly a volume measurement system, allowing the central command system to make the correct decisions on the types of waste electrical and electronic equipment based on the shape / appearance and weight criteria according to the product selected from a predefined list.

WASTE ELECTRICAL AND ELECTRONIC EQUIPMENT

Waste electrical and electronic equipment (WEEE) is the fastest growing component in the solid waste streams, as people change their mobile phones, computers, TVs, audio equipment and printers much more frequently than ever before. In Europe, the quantities of WEEE generated show increases of 3-5% per year, 3 times faster than the total waste streams.

Waste electrical and electronic equipment (Figure 1) is a special category of waste, and the collection, treatment and recycling are important for several reasons:

- pollution with greenhouse gases or heavy metals harmful to health can be avoided - about 70% of the toxic substances which reach the cesspools (landfills) come from this equipment;
- significant quantities of secondary raw materials can be recovered as WEEE has a high recycling-reuse rate (between 85-90%);
- recycling reduces our dependence on natural (exhaustible) resources and is an important part of creating a sustainable society[5].

Fig.1. Waste electrical and electronic equipment

Waste electrical and electronic equipment has been identified as a priority waste stream by the European Commission due to the potentially hazardous characteristics, resource consumption in the manufacturing process and projected growth rates. In response, the European Commission has prepared legislative acts in the form of several directives, which require producers to take responsibility for taking over and recycling electrical and electronic equipment.

The directive provides for measures which are aimed at the following:

[5] Feng Wang et all, *A systematic and compatible classification of WEEE*, 2013; Kees Baldé et all, *The globale - waste monitor*, 2014;

- to create systems which should enable holders and end-distributors to hand over waste electrical and electronic equipment (WEEE) to collection points;
- to ensure the collection by the distributors of electrical and electronic equipment of the waste electrical and electronic equipment of the same type and in the same quantity as the equipment provided;
- to ensure the availability and accessibility, throughout the country, of the necessary collection points, taking into account, in particular, the density of the population;
- to reach 80% use of the average weight per equipment and 75% material use for: large household appliances and automatic dispensers;
- to reach 75% use of the average weight per equipment and 65% material use for: IT and telecommunication equipment as well as for consumer equipment;
- to reach of 70% use of the average weight per equipment and 50% material use for: small household appliances, lighting equipment, electric and electronic tools (except for large fixed industrial tools), toys, sports and leisure equipment, surveillance and control instruments[6].

THE COMPONENTS OF A VISUAL RECOGNITION SENSOR SYSTEM

Modern visual recognition systems contain fast and powerful PC platforms and integrated software applications, making these systems easy to use and much more inexpensive than other complex identification systems.

Visual inspection / recognition systems can be used in a wide variety of operations across different types of processes, for repetitive inspection or recognition tasks where accuracy and reliability are required. For this purpose, a vision system will be used for the proposed application, which will contain one or more cameras for the correct recognition of waste electrical and electronic equipment.

Because visual sensor systems are very diverse, the specific components vary from system to system. However, most systems include a vision camera, a light source, image capture triggering sensors, an acquisition board, a PC platform, the connection network and visual recognition software (Figure 2).

[6] Kees Baldé et all, *The globale - waste monitor*, 2014; Felicia Boar et all, *Gestionarea deşeurilor, strategia viitorului pentru conservarea resurselor naturale*, Cluj-Napoca, 2011; Keshav Parajuly, Henrik Wenzel, Potential for circular economy in household WEEE management, 2017

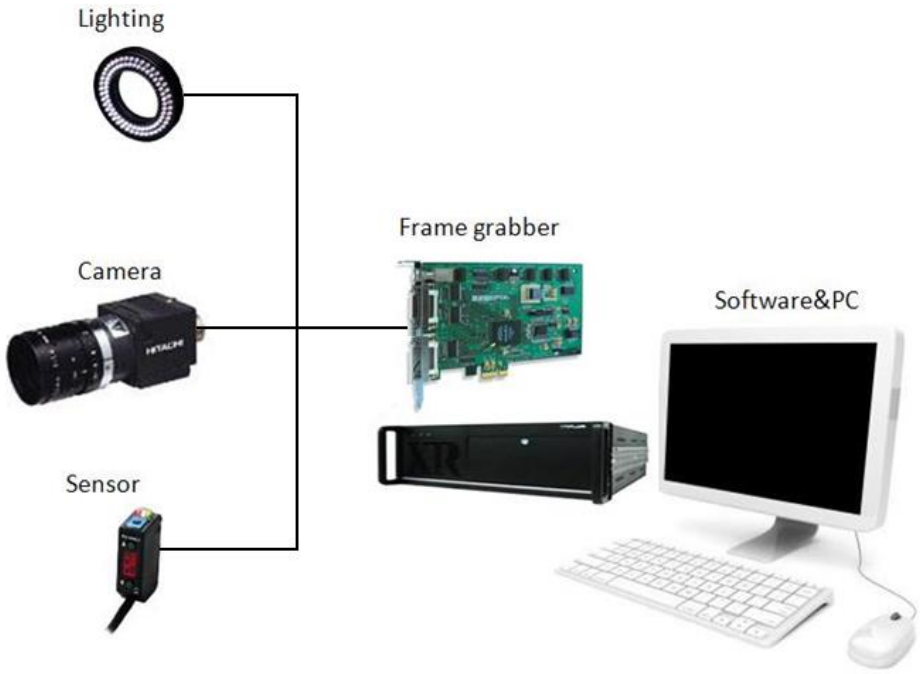

Fig. 2. Components of the visual recognition system

The vision camera (Figure 3) performs the graphical capture and transmits it to the data acquisition board. Modern inspection systems feature compact vision cameras provided with both their own light source and the graphical capture processing hardware interface (the data acquisition board).

Fig. 3. Camera models for visual recognition[7]

The equipment lighting for the optimal data acquisition implies the existence of an external light source. The lighting systems are of different shapes and sizes and varying intensity (Figure 4).

Fig. 4. Outdoor lighting models for vision systems[8]

The acquisition or graphical capture board (Figure 5) performs the interfacing between the image units (vision cameras) and the computer. The acquisition board takes over the

[7] Industrial camera vision, available at: http://www.xenics.com, *Accessed*: 2017-04-04; Industrial camera vision, available at: http://rodtechuk.com, *Accessed*: 2017-04-05

[8] Industrial light source, available at: www.yagoptics.com, *Accessed*: 2017-04-05; Industrial light source, available at: http://www.tpl-vision.fr, *Accessed*: 2017-04-05

image data provided by the camera in a digital or analog format and converts them into information which can be used by the PC[9].

Fig. 5. Models of data acquisition boards for vision cameras[10]

The vision system software can have one function (designed for one operation only) or it can be multifunctional (designed with a number of features/functionalities: bar code reading, calibration, visual guidance of robots, verification and recognition of shape, area, color, etc.). Since the recognition of waste electrical and electronic equipment involves the use of several differentiation criteria, a multifunctional software application will be used.

CASE STUDY

Further on, four possible configurations of camera positioning within the visual recognition system in relation to the identified / recognized part are presented.

Positioning a single camera above the object to be recognized

For this case, the camera is positioned above the object (Figure 6) and the scanning is performed on a single face of the objects to be recognized. From the viewpoint of the implementation cost, this configuration is the best, but depending on the type of waste, it may not be recognized by the vision system.

Positioning 3 cameras to scan the 5 sides of the object

This configuration can be used on any type of transport system, and the five sides scanning of the part can be done with three cameras due to the scanning at a 45 ° angle (Figure 7). The objects must be aligned with an accuracy of ± 15 ° on the transport system. The disadvantage of using this configuration of the vision system is the waste positioning with the required precision, which makes it necessary to check the correct positioning.

[9] Graphics acquisition board, available at: http://sine.ni.com/, *Accessed*: 2017-04-11
[10] Graphics acquisition board, available at: http://sine.ni.com/, *Accessed*: 2017-04-11

Fig. 6. Positioning the camera above the object to be identified[11]

Fig. 7. 5-way scanning with 3 cameras[12]

Positioning 5 cameras to scan the 5 sides of the object

This configuration can be used on any type of transport system, and the 5 sides scanning of the part is done with 5 cameras (Figure 7). In this case, the visual recognition system is the most complex of the above presented ones, but the implementation costs are higher.

Scanning which combines volume measurement, weighing and recognition

In addition, other types of measuring equipment can be added to check other characteristic parameters specific to the waste electrical and electronic equipment presented in Figure 8. Thus, the resulting recognition and identification system combines the image capture for five sides of the part, volume and weight measurement, and all data are analyzed by a central computing system (Figure 9). The system also includes an internal memory for storing information and has a display for the interaction with the operator interaction. This configuration meets the requirements for waste recognition and identification.

Fig. 8. 5-way scanning with 5 cameras[13]

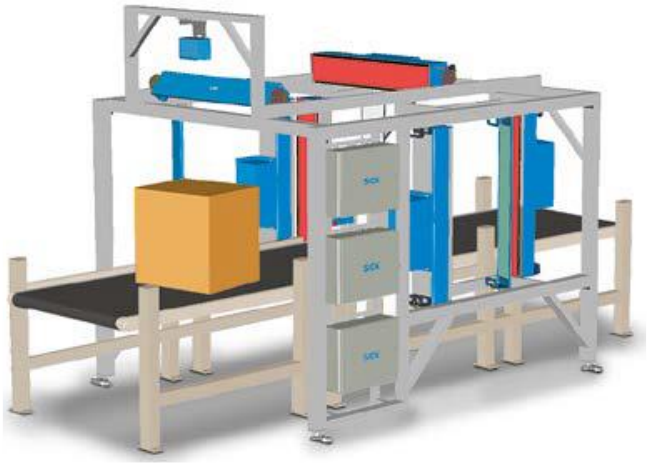

Fig. 9. Scanning which combines volume measurement, weighing and recognition[14]

[11] Industrial applications, available at: http://www.sick.com, *Accessed*: 2017-05-10
[12] Industrial applications, available at: http://www.sick.com, *Accessed*: 2017-05-10
[13] Industrial applications, available at: http://www.sick.com, *Accessed*: 2017-05-10

The information flow regarding the criteria based on which the types of waste electrical and electronic equipment will be correctly identified is the following:

- Selecting the type of waste from a predefined list which will contain most types of electrical and electronic household appliances (refrigerators, washing machines, microwave ovens, electric ovens, kitchen mixers, TVs, audio systems, desktop computers, laptops, tablets, phones etc.);
- visual recognition of waste by the vision system by comparing the real-time captured images with images of the parts found in the command and control system specific database;
- weighing the waste and comparing its weight with the predefined weights in the command and control system specific database;
- in the case of using a waste volume measurement system, measuring its volume and comparing it with predefined volumes in the command and control system specific database.

The final validation, the recognition of the equipment as the one initially selected from the predefined list and its acceptance for storage, is made after the result of interrogating/querying the database for each of the 3 or 4 criteria presented above is affirmative (the equipment selected from the predefined list corresponds to the real weight and the shape / volume of the product to be identified).

CONCLUSION

In order to have a proper waste management, its collection has to be done continuously. This can be done through automated waste collection and storage systems.

The construction of such a center implies the use of a complex sensor system, which allows to check all the characteristic parameters specific to the waste electrical and electronic equipment for its correct identification and recognition. From this view point, it is necessary to check the parameters specific to the weight, shape and eventually the volume of the waste to be collected.

Even if in a first phase, the investment to equip a waste collection systems with modern recognition and identification systems is high, this will pay off over time and the collection centers will be able to work without human operators continuously, which ensures a strict record of the amount and types of waste electrical and electronic equipment.

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[14] Industrial applications, available at: http://www.sick.com, *Accessed*: 2017-05-10

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