Techniques for Sorting Components from Dismembered Medical PCBs

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Abstract— **A printed circuit board, or PCB, is a piece of hardware that acts as a base and provide electrical connections to the mounted components. PCBs are present in almost all types of electronic waste including cellphones, computers, printers, and medical devices. Waste of electrical and electronic equipment (WEEE) is one the fastest growing waste streams in the EU and is expected to grow to more than 12 million tons by 2020 [1]. The waste PCBs contain metals and major hazardous components and this make them the most difficult parts of WEEE to be recycled. Waste PCBs recycling is a preoccupation not only to their rich content, but also due to their potential risk for environment and human health. E-waste causes damage the nervous system, circulatory system, kidneys, lungs or skin [2]. The paper aims to develop a smart sorting system for components resulted from dismembered medical PCBs. The proposed application is based on image processing and it was tested at a laboratory scale. The application can be included in a complex e-waste sorting system.**

Keywords— **printed circuit board (PCB), e-waste, recycling, intelligent sorting system,**

I. Introduction

Printed circuit boards (PCBs) have become extremely important in the medical field. In recent years, technology has experienced an explosive development in the medical field ranging from medical diagnosis, treatment to medical research. This involves computerization and consequently the use of reliable, high-performance and high quality medical PCBs. These requirements have led to a continuous process of renewal of medical equipment and to the early renunciation of so-called “old” equipment. The consequence of this process is the accumulation of a large amount of electronic waste or “Waste Electrical and Electronic Equipment” (WEEE).

Regarding the WEEE management, two main aims of it can be specified. [3]. The first one is referring to the rational and conservative usage of natural resources by recovery of the materials and energy included in waste and the second one concerns the protection of natural environment by reducing the quantity of unsorted waste.

The medical PCBs, and so the resulting e-waste can be found in a large variety of devices and applications like: pacemakers, defibrillators, heart monitors, electrocardiogram (ECG) equipment, magnetic resonance imaging (MRI) or computer tomography (CT) scanners, ultrasonic equipment, body temperature monitors, blood glucose monitors, electrical muscle stimulation equipment but also computers and their peripherals, computer monitors, telephones, wireless devices, televisions, printers so on [2]. As a remark, medical devices often do not have typical standards of PCBs shape and size. The reason is that medical printed circuit boards must fit into as small of an area as possible while still remaining resistant to damage.

Recycling e-waste is now a priority for humanity. The state of the art in PCB recycling depends on the quality of the board, which is defined by the consistency of noble metals and the number of recyclable components. For instance, researchers indicate that the PCB from active implantable medical devices, like pacemakers or implantable cardioverter defibrillators, present quantities of gold, superiors of PCB of other electronic devices [4]. It has been demonstrated that these implantable medical devices have the conditions to be valorised, since they were disinfected after their explantation.

In the e-waste recycling perspective [5], the separation or sorting process is of great importance. There are many sorting methods but those of based on dissembling have the advantage of hazardous components (polychlorinated byphenyls, mercury) isolation. In PCBs recycling systems there are used selective disassembly based on “look and pick” principle and simultaneous disassembly based on “evacuate and sort” principle like in Figure 1, [6][7].

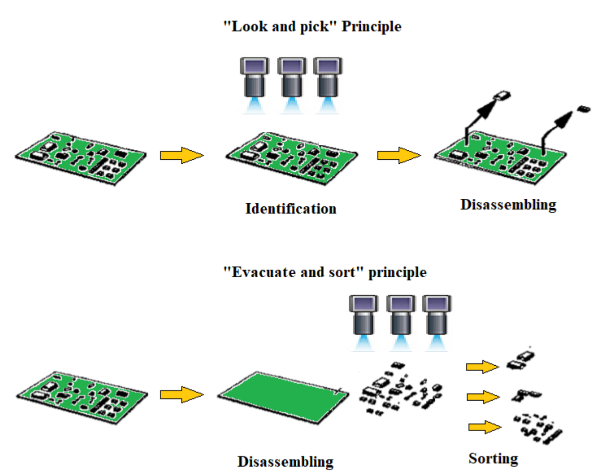


Fig 1. Disassembly principles

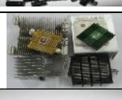
Regarding the second method, the PCB components can be sort using intelligent systems based on specific sensors and computerized visual inspection. Thus, systems use real-time "machine vision" principles combined with artificial intelligence. The purpose of smart sorting is to preserve the shape and structure of the PCBs components, without crushing them, for the easy and economical separation and recycling of secondary waste [8].

Applying the proposed technologies would result in a high rate of recovery of the various materials (gold, silver, copper, aluminium, tin, platinum, palladium, gallium, tantalum, tellurium, germanium, selenium, iron, glass, plastic) contained in electronic waste.

II. Sorting Criteria and System Principle

The printed circuit boards in general, and the medical types in particular, consist of three basic parts: the non-conducting substrate or laminate, the conductive circuits printed on or inside the substrate and mounted components. The components mounted on PCBs generally include transistors, chips, connectors, capacitors, etc. each of them having different material composition [9], [10]. The waste resulted from dismembering of printed circuit boards can be classified as in Table 1.

Table 1: Waste resulting from dismantling printed circuit boards

Components types	Components aspect	Components types	Components aspect
Capacitors	 9	Plastic components	
Radiators		Screws	
Chips and SMD microchips		Batteries	
Magnetic components		Undissolved components	 124.29
Dismantled PCBs		Transistors	

Presuming a PCB recycling process, where the disassembly stage has already been completed, the next stage that of separation is very important. There are various sorting methods for the PCB scraps like those based on size, material properties (density, magnetic characteristics, conductivity) color, shape etc. The separating process can be made in steps according to the flowchart illustrated in Figure 2.

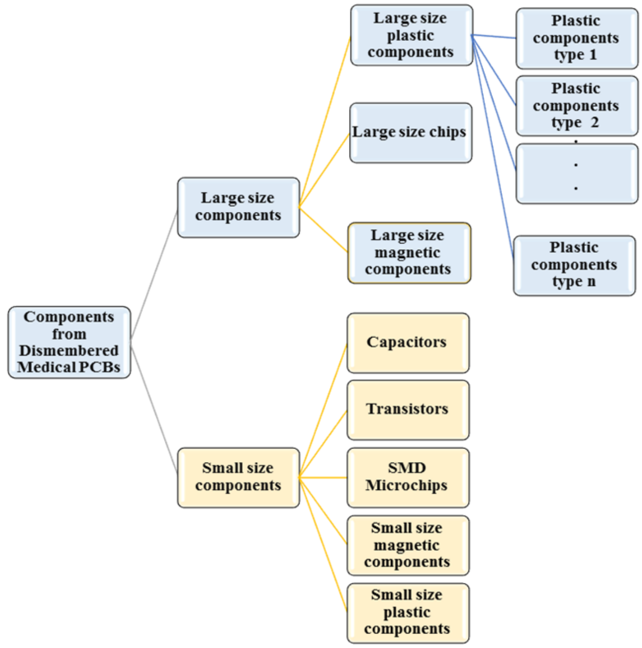


Fig. 2. Sorting criteria for PCBs components

Regarding the large size components, a smart separation that is based on their image recognition can be made by using a machine vision system (Figure 3). The most of sorting machine vision systems are made on belt conveyors and they include a lighting system, an image acquisition system, a PC platform, an inspection software and a process controller [11], [12]. The software in such systems is often a multifunctional one, so that it fulfills functions such as image processing, calibration, conveyor belt control, robotic arm guiding, object presence checking, object counting, and more.

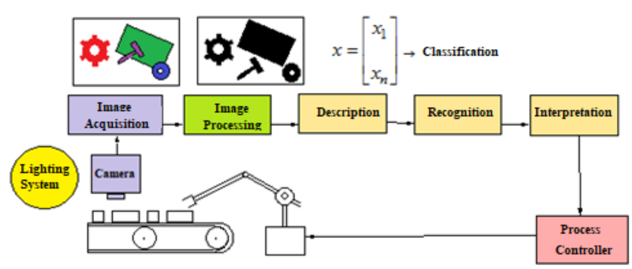


Fig. 3 Sorting Machine Vision System

In the classification process, a characteristic vector will comprise the extracted features of the input image. Extracting features reduces the amount of information in the image by measuring certain properties that fit these images into different classes. For sorting applications, it is necessary to select as efficiently as possible the characteristics that preserve class separation. A form descriptor is a characteristic vector based on the analysis of particle measurements. Each type of descriptor contains one or more form measurements from a sample.

III. SYSTEM IPLEMENTATION

An experimental smart sorting system, for large size PCBs disassembled components from a typical PCB computer motherboard, was implemented (Figure 4). The system is a low cost one and its principles can be used in a complex material recycling process that uses components resulted from dismembered PCBs.

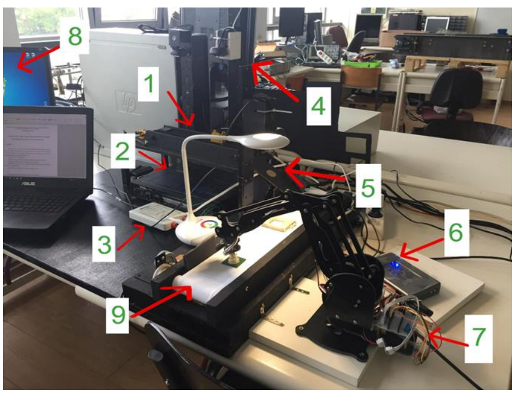


Fig. 4. The smart sorting system

The PCB components come one by one on the conveyor belts, first on the black conveyor belt (1) and then on white conveyor belt (9). The two servomotors that controls the conveyors are controlled by MID 7604 controller (2) from National Instruments. Images are acquired by three Microsoft LifeCam HD-3000 web cameras (4). The components are classified and sorted. For the class of large size chips the sorting process is made by using a robotic arm (7). These objects will be placed in a separate container.

The software system components use the LabVIEW programming environment from National Instruments, along with NI Vision Development Module, LabVIEW Motion Control Tools and LabVIEW for MyRIO board [13].

The application runs on two computers (8), the first one is used for the conveyors control and for objects classification, and the second one for controlling the robotic arm through the MyRIO device (6). For sensing the presence of metallic composition or metallic inclusions in the plastic components, a proximity sensor (5) and a MyDAQ board (3) were used. A The block diagram in Figure 5 shows the interaction mode between the hardware components.

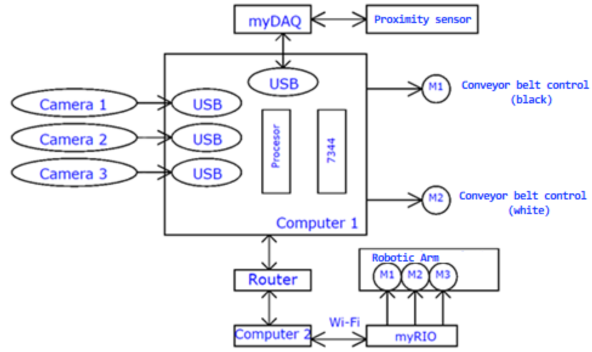


Fig. 5 Sorting system hardware configuration

A. *Conveyor Belt System*

The mechanical part of the proposed system consists of two conveyor belts that are designed to carry the sorted components from one strip to another (Figure 6). The conveyor belts are driven by two stepper motors and they are disposed at a level difference from one another to facilitate the passage of the components. The passage of the objects between the two conveyers is made on a smooth surface on which a proximity sensor has been placed to notify the presence of the metal elements in the sorted objects. The significant difference between these two conveyor belts is their size and material color (black and white). This is justified by the color of the PCBs components. Because the image acquisition is made with a CCD camera, the lighter (colored) objects have images with high contrast on black surfaces and the dark ones have high contrast on a white surfaces.

Fig.6 The Conveyor belt 1(black surface)

B. Sorting algorithm

The front panel of the LabVIEW application contains information about the steps taken in the classification process (Figure 7).

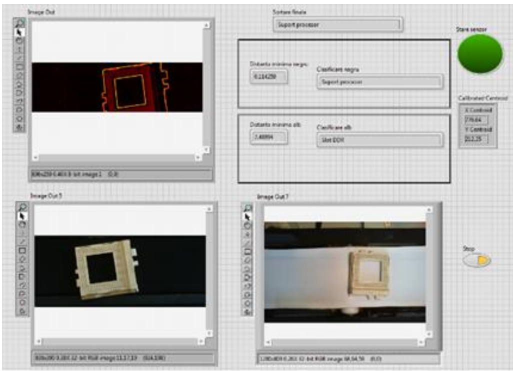


Fig. 7 Sorting LabVIEW application-Front panel

The application is made in a "State Machine" architecture and it contains the following states:

Image acquisition from camera 1 (camera 1, Default).

The first web camera senses the presence of an object on the strip and resets the state of the proximity sensor (False). If the object is present, the sorting process starts.

Image acquisition from camera 2 (camera 2,).

The first conveyor belt (black) is moving until the object is right under camera 2. This moment is detected using the next image processing by extracting the color plan (green), applying a mask and drawing interest area (ROI), filtering with a Gaussian smoothing filter, applying a Sobel filter (Edge Detection) and respectively by applying a Edge Detector edge detector. These steps were established using the NI Vision Assistant

Image acquisition from camera 2 and object classification on the black conveyor belt.

The image of the object is acquired with a minimal level of brightness (30) and then processed by application of a mask, a value plane extraction and finally a “Particle Classification” algorithm.

A "Particle Classifier" file has been created for the object having light colors. Each time in the classification process a training based on the images of objects taken in different positions was made. The final information refers to the object class and the minimum distance to this class. After classification, the conveyor will start again by passing the over the proximity sensor.

Image acquisition from camera 2 and object classification on the white conveyor belt.

In this step by applying a centroid operator on the preprocessed image, the coordinates x, y of the object center is obtained. Then a new object classification on the white conveyor belt is made. The algorithms are similar to the object classification on the black conveyor belt, but with a different “Particle Classifier” file.

Sorting objects on the conveyor belt.

The stepper motor will move the object in the sorting area. Here, based on the classification results and on minimum distances, the class of the objects are decided. According to that the components will get out of the conveyor belt in the proper container. For the large size chips the robotic arm will place the component in a separate container (Figure 8).

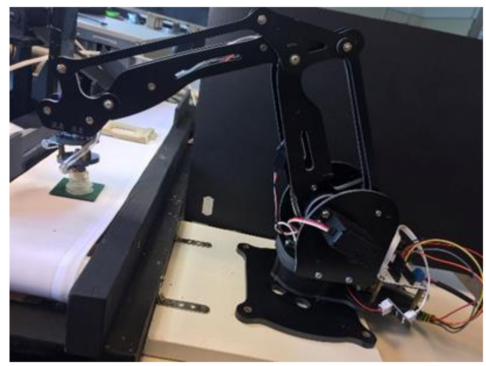


Fig. 8 Sorting robotic arm

Resuming sorting steps.

The sorting system can work continuously with the restriction that the feeding of the objects on the strip is at the rate required by all the above steps.

The system was tested for different dismantled components resulted from the PCB. They were sorted into the following classes: power supply connectors, IDE cable connectors, analog audio connectors, processor sockets, VGA connectors, PCI connectors, LPT/RS232 connectors, LPT socket supports, integrated chipsets, integrated circuits, DIN power connectors/battery supports, DDR slots, ISA slots and IC sockets.

IV. Conclusions

Regarding waste electrical and electronic equipment (WEEE), large quantities of waste printed circuit boards (PCBs) are released into environment [5]. E-waste recycling consists of three main steps: collection, preprocessing and end-processing [14]. Each step is critical for the recovery of metals and recycling economy. In the preprocessing stage, the component sorting of dismembered PCBs can be made in an intelligent way in order to reduce at minimum the mechanical processing (crashing) of the e-waste scrap.

In the proposed intelligent sorting application, large size components, commonly met on a PCB motherboard, are transported on two strips, one black for the classification of the light objects and the other for the classification of the dark ones. The system ensures the visualization and classification of the components and the presence of the metal in their composition. Objects are classified according to their shape and dimension in several categories.

The proposed algorithms have the advantage of being efficient and relatively easy to implement which makes it possible to use them on a waste medical PCBs sorting specific system. In this case, a careful knowledge about components regarding their dimensions, shapes or materials is needed. Thus the classifier will be adapted to the specific application.

V. Acknowledgement

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