PET waste clasification method and Plastic Waste DataBase WaDaBa

Janusz Bobulski[1] and Jacek Piatkowski[1]

Czestochowa University of Technology
73 Dabrowskiego Str., 42-201 Czestochowa, Poland
januszb@icis.pcz.pl and jacek.piatkowski@icis.pcz.pl

Summary. The main purpose of this work was creation of a plastic waste database of images of objects constituting the typical contents of municipal waste. This group of waste, by using methods of Computer Vision can be automatically selected on the sorting lines businesses for waste disposal. Digital images of items that will be received for processing should reflect the specific conditions of places where real objects have to be found. Thus, each thing is placed in this database should be presented in the course of several collections of images, taking into account different lighting conditions and different arrangement relative to the image recorder, and the different degree of deformation of these objects as a result of previous processes. Images created in the collection will be divided into groups based on the type of material from which individual objects were made. An second main aim of the article is to present the method of plastic waste selection based on histogram analysis. The method has to be fast so that it can be used in a waste sorting plant.

1 Introduction

Recycling is one of the most important methods of environmental protection, the purpose of which is to reduce the amount of waste stored in landfills and conservation of natural resources. The term recycling means the recovery of raw materials, which consists in the transformation of substances or materials contained in waste in the production process to obtain the substance or material on the fate of primary or other purposes, including organic recycling, excluding energy recovery. Method of processing steel to use in the 70-ies of the last century, when significantly increased the amount of waste produced. At the same time appeared the possibility of their reuse and noted that the waste put to landfill are not environmentally neutral. Some of them are extremely durable. For example, the decomposition of cotton material is 5 months, paper tissue - 3 month, aluminium cans - 100 years, plastic bag - 300 years. Taking into consideration the fact that the average man is producing the about 350 kg of waste annually, and the fact that the pace of producing rubbish much is

exceeding the pace of their disintegration, creating new garbage dumps is necessary. Here a problem of high building costs and a problem of environmental, social and economic influences appear [1]. Effectively pursued politics of the waste management and re-using them allows us to prolong the operation of the landfill by up to 60% and reduce the need for new landfills. The recycling should be more widely applied and promoted. However in order to apply the recycling a sorting of waste is necessary on the ones being recyclable and on remaining. Mixed waste in sorting plants is segregated manual and mechanical. The need for manual sorting selectively collected fractions of municipal waste due to the lack of the corresponding transmission of information related to the rules of the system of selective collection of recyclable materials with low environmental consciousness of society. In addition, manual sorting is time consuming and expensive, so it is advisable to establish and develop methods for automatic sorting of plastic waste. The establishment of a database of images of objects constituting the typical content of the municipal waste, produced by households, i.e. packages of different kind and everyday articles are a main goal of the work. Created in the framework of the project public database of waste images, becomes the starting point for research to develop methods for automatic sorting of waste with the use of modern techniques of image processing and recognition [2].

The main motive for the creation of the work was the fact that not developed methods for automatic sorting of waste, using methods of pattern recognition. In search of reasons for this situation, it was noted that, despite the existence of several databases of images of various objects, among them no a database with waste images. Hence emerged the idea of creating a database of waste images. This database will be the basis for testing methods for automatic sorting of waste, and also will allow to compare the effectiveness of various methods. In the development of new methods of pattern recognition free access to the database of images are required. It allows you to test the method and compare the obtained results with other methods. The effectiveness of the different image recognition systems can be compared only if you use the same set of input data, which in this case are the images. In this context, the proposed project is a fundamental research, and its effect will be used as the basis for the research of other scientists.

Every year in Poland millions tons of municipal waste is created. According to Eurostat data, in 2012, households produced over 9.3 million tons of waste [3] with only slightly more than 10% of the total collected municipal waste was recycled. A huge amount of mixed waste ends up in waste management plants, which later is sorted in order to extract recyclable materials, high-energy waste, and organic disposal, which can be biodegraded through composting. This selective method for processing the input materials is a widely recognized as a way of reducing the amount of waste going to landfill. In the currently operating waste management plants the sorting process is realized in a manual-automatic way with very different amounts and kinds of devices. What also varies is the order of deployment of these devices

in production lines. Depending on the degree of automation of the sorting and segregation facilities, magnetic or electromagnetic, inductive, optical and electrostatic separators are being used. However, the sorting of the waste is a complex process, and difficult to implement, due to the mechanical deformations and contaminants of delivered waste. Most modern waste collection trucks use a compaction mechanism and waste carried by such vehicles have been affected by mechanical stress and blending, which leads to considerable difficulties in distinguishing individual objects during sorting process [4]. It is estimated that, despite a few years of the new Polish rules of selective collection and waste management, far more than half of waste still going to landfills. Meanwhile, the European Union Directive 2008/98 / WE on waste management [5] and applicable Polish law [6] show that besides prevention of waste generation, the process of waste material recycling should have priority over the energy production as a result of high-energy waste combustion. It is assumed that successively in 2020, 2025 and 2030 recycling of packaging must achieve levels respectively 60%, 70% and 80%. Specialists, dealing with the issue of waste processing and disposal, agree, that increasing the level of automation and reducing the amount of work carried out manually will increase the efficiency both currently running waste management plants and plants built in the future, and also improve the purity of recyclables [7]. In the case of searching for new solutions, which can improve the processes of sorting the municipal waste and recovering the secondary raw materials, the Computer Vision technology seems to be perspective. One example of successful implementations of those techniques is biometrics, which uses human biological characteristics for identification. Those characteristics are extracted from images of human faces, fingerprints, irises, etc. [8]. The dynamic development of biometric methods, however, was possible thanks to the creation of common access databases, like eg. the face database [9, 10]. Using these databases, the scientists could test their method and compare the results. By using the same data, the comparison of different methods appeared to be credible and objective. The same mechanism could be applied to another specific group of objects such as packaging, containers or other articles of daily use, which should be properly identified in municipal waste streams - in order to ensure its effective segregation. At this point emerged the idea of creating, within the proposed project, a professional database of "valuable" objects (at least from the perspective of environmental protection), on which, as in the case of biometrics databases, various CV techniques could be tested.

2 The plastic waste image database

The WaDaBa database of plastic waste images have been created. Acquisition of the minimum of 100 objects is planned, and for each of them forty images will be done in different conditions. In the future database will be expanded because it will still appear new types of waste.

We created the research position for acquiring images of waste. To comprise it will be from: the platform, on which will be put objects - wastes, the stand with a camera, the light sources of two type: the fluorescent lamp and LED. Objects of waste used in the project were acquired from households. Everyday type of plastic waste have been used - see Fig. 1. Waste have been acquired and photographed by four months in order to recruit as the most typical kinds of the municipal waste.

Fig. 1. Plastics type marks

The object will be put on the research position and next photographed with first and second type of light. There were series carried out of 10 photographs with differ in the angle of the turnover for every object (in the vertical axis). Next the object was damaged to varying degrees: small, medium and large. For each type of destruction have been made 10 photographs. So considering all variants for every object 40 photographs were taken, multiplying it by the number of objects, 4 000 of photographs were created in the database. The parameters of photographs:

- size 1920x1277 of pixels
- resolution 300 dpi
- colour palette RBG 24 bits
- file format JPG

Concerning parameters of photographs, single images have size about 1 MB, and the entire database of 4 GB. The acquired image have been saved onto the disk under the standardized name determining parameters of acquiring the image and type of waste. The database of images is available at address `http://wadaba.pcz.pl` with free access. In addition, the portal will be published the results of research into automated sorting techniques that use image recognition. Sample images are shown in Fig. 2

It was assumed that the name of the each acquired picture should describe of photographed object in a simple form. In this way the easy choice of some iteresting objects will be possible in later stages of the research. For instance, objects with the medium level of damage or all bottles with a screw caps.
It was decided that the name of the photographed object will be coded as follows:

0004_**a**01**b**05**c2d**0**e**1**f**0**g**1**h**1.jpg

Fig. 2. Sample images fro WaDaBa database.

where first four digits denotes the order number of the object and the next sections (a to h) described its properties such as:

a - a number denoting the plastic type;
b - colour;
c - type of light;
d - the deformation level;
e - the level of a dirt;
f - presence of a screw cap or a lid;
g - presence of a ring - characteristic for the bottles with a screw caps;
h - order number of a random position of a photographed object.

We also decided to use characters (as a name of a parameter) and digits (as a parameter value) to make the easier to understand it for the human - quickly, without a computer. In the table 1 the established values of defined parameters are presented.

3 PET classification method

Amongst home waste they are dominating PET. Many-months observation of household rubbish confirmed it. On that account we decided that one should first select this type of plastic. With additional argument behind it, there is a fact that it is possible again to process PET and to obtain a textile e.g. fleece material [11]. At developing the algorithm developing the simplest and fastest method for it to be possible to use it in the sorting plant of rubbish on the transport belt in the real time possibly was an important establishment. In the first step, we load the image and converts it to grayscale. The edge detection is then performed to allow the object to be located. A standard mode of operation using the Canny filter was used for the detection of the edge. After locating we are allocating the image area containing the object. Next we are calculating the histogram for this part of the image. Analysis of the histogram consisting in adding up is a further step first one hundred and

Table 1. Values of parameters used encoding of the names of photographed objects

parameter	parameter values
a (plastic type)	**00** - missing or unreadable identifier, **01** - PET - polyethylene terephthalate, **02** - PE-HD - high-density polyethylene, **03** - PVC - polyvinyl chloride, **04** - PE-LD - low-density polyethylene, **05** - PP - polypropylene, **06** - PS - polystyrene, **07** - Other.
b (colour)	**00** - transparent, **01** - white, **02** - red, **03** - green, **04** - blue, **05** - yellow, **06** - orange, **07** - purple, **08** - brown, **09** - grey, **10** - black, **99** - other.
c (light)	**1** - scattered light of fluorescent lamp, **2** - warm LED light reflector.
d (deformation)	**0** - undeformed, **1** - small deformation, **2** - medium deformation, **3** - high deformation.
e (dirtiness)	**0** - clean, **1** - small dirt, **2** - medium dirt, **3** - hight dirt.
f (screw cap or lid)	**0** - lack, **1** - occurs.
g (ring)	**0** - lack, **1** - occurs.
h (random position)	**0, ... , 4.**

of one hundred last elements of the histogram. Considering the fact that PET is transparent material but the background of images it is black (similarly to the transmission belt in the sorting plant) we are comparing received earlier values of sums. For PET the value of the first sum will be greater, while for other non-transparent materials the second sum will be larger (Fig. 3). After all on this base a decision to categorize the object for the PET collection or nonPET collection are being made.

Algorithm:

- load photo
- convert to gray scale
- edge detection
- object localization
- select object
- calculate histogram
- analyse histogram
- decision: PET / notPET

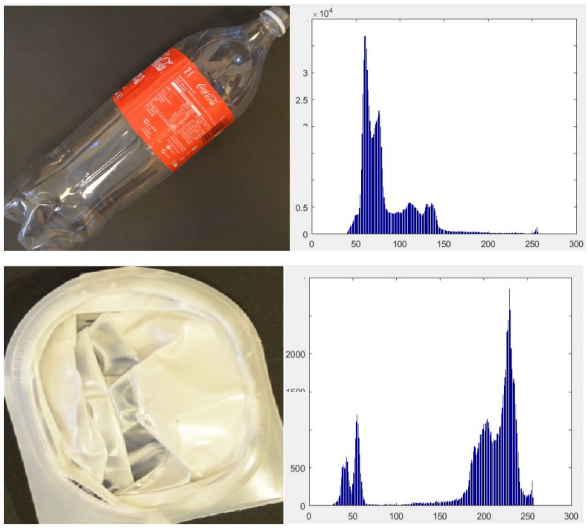

Fig. 3. Comparison of histograms

4 Experiment

The experiment was carried on our databese WaDaBa. We used ten sets of data with 200 pictures each that means we used two thousand images. Table 2 presents results of experiment. These results have preliminary character for developing advanced waste selection techniques based on computer vision techniques. Analysing the current condition of the knowledge in this field we didn't come solutions of this type. From a review of the methods of waste sorting presented in [12] shows that so far computer vision methods arent adopted in the automatic selection of wastes. In addition, we cannot compare our results to other existing methods.

5 Conclusion

The research results presented seem promising. Therefore, further research is planned on the development of more advanced methods using computer vision techniques. We analyse the types of errors we have found to improve the selection results by more accurate object extraction techniques. Improvement of the recognition level of objects can be sought by improving the feature extraction technique and operation on complex sets of features. The resulting database will be useful for testing new methods and will allow you to compare results on the same data. Therefore, it is appropriate to further expansion of the base in the future.

Table 2. Results of experiment

Name of set	No. of images	Recogn. rate [%]	FAR [%]	FRR [%]
Set A	200	92.0	0	8.0
Set B	200	92,5	7.0	0.5
Set C	200	61,0	25.0	14
Set D	200	74,0	25.0	1.0
Set E	200	54,0	46.0	0
Set F	200	88,5	11,5	0
Set G	200	51,5	48,5	0
Set H	200	57,0	42.0	1.0
Set I	200	88,0	11.0	1.0
Set J	200	80,0	14.0	6.0
Set K	200	94,0	6.0	0
Average		75,68	21,45	2,86

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