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Features of Household Solid Waste Object Recognition on Garbage Collector Robot (GACOBOT)

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A B S T R A C T

Solid waste or garbage is one of the problems that must be faced by the world's population so that life becomes more harmonious. Through a series of studies, a Garbage Collector Robot (GACOBOT) was created which is expected to help humans overcome this problem in terms of garbage collection. By adding a feature in the form of object recognition, the waste can be sorted by type so that it can be grouped and processed further. In this research, using the Support Vector Machine (SVM) classification method based on the feature extraction of the Histogram of Oriented Gradients (HOG) as the main method. Researchers used 14 pieces of data as training data and 10 pieces of data as test data. From the results of the tests that have been carried out, it has been obtained a success rate of 100% that the system has succeeded in separating waste into 2 types, namely plastic bag waste and glass bottle waste.

INTRODUCTION

One of the environmental problems faced by the community is the existence of garbage [1,2]. When associated with hygiene, health, comfort and beauty (aesthetic) factors, the presence of this waste is undesirable. One of the factors affecting the environment is the problem of waste disposal and management. Waste management that is now done by the world government is to sort the waste by its type [3,4]. Waste sorting aims so that each waste can be processed according to the physical type and the way of disposal and destruction [5,6]. Object recognition feature can be the main solution in sorting objects in the form of garbage. This feature can be applied directly to the robot so that it can produce an efficient and effective system for waste management.

Robots that can recognize objects are an active research area in robotics science [7, 8]. This requires a number of heterogeneous abilities such as the ability to recognize various objects, rapid processing methods, and to be able to perform actions against objects that have been recognized. Currently, robots are being extensively used in a variety of fields that stretch from simple actions to their continued implementation. Each robot implementation implies a specific concept and engineering solution is able to solve the problem that arises at a different level [9].

The system proposed in this study is the addition of object recognition feature in Garbage Collector Robot (GACOBOT) [10]. The robot is expected to recognize the type of debris that has been detected. Once the robot recognizes the garbage, it is also expected to provide feedback in accordance with the design of the program that has been created for each object. The use of computer vision in digital image processing has been widely applied to assist humans in the detection or recognition of an object [11]. To recognize objects in a 2-dimensional image is not easy enough, therefore it is recommended to use computer vision technology in implementing the process of recognition of an object. The process for recognizing or detecting an object requires first separation of parts or segments of the image, this process is commonly known as the segmentation process.

Object recognition is the main feature that must be possessed by a robot, in order to recognize the object to be processed and perform actions that correspond to the object that has been recognized. Object recognition in the form of garbage is one of the smart features that can be owned by Garbage Collector Robot (GACOBOT) so that it can sort the detected garbage and provide

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feedback that corresponds to the form of garbage that has been recognized.

In this research proposal will be designed object recognition feature on Garbage Collector Robot (GACOBOT) against the type of household solid waste. The method used in this research proposal uses the Support Vector Machine Classification Method [12, 13] based on the extraction of the Histogram of Oriented Gradients (HOG) feature [14] as a method to recognize objects in the form of household solid waste so that the GACOBOT system [15] as a whole can run efficiently and effectively.

METHOD

Histogram of Oriented Gradients

Histogram of Oriented Gradient (HOG) is a method used in this study to detect the presence of an object that serves as a feature descriptor of an object, before the object is detected by the camera, there are several stages performed [16, 17].

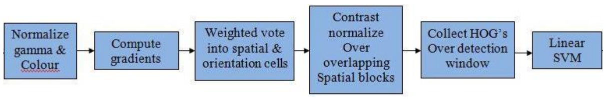

Figure 1. Stage algorithm Histogram of Oriented Gradient

First the image input is processed using the camera which then occurs Gamma Normalization or conversion from color image to gray.

$$f_0(x,y) = \frac{f_i^R(x,y)+f_i^G(x,y)+f_i^B(x,y)}{3} \quad (1)$$

The calculation (1) above serves to change the colored image to a gray image, followed by calculating the gradient value of each pixel. After getting the gradient value, the next process is to determine the number of orientation bins that will be used in the creation of histograms. This process is called spatial orientation binning. But previously in the process of gradient compute images were divided into several cells and grouped into larger sizes called blocks. In the process of normalizing blocks histogram of Oriented Gradient (HOG) algorithm has a windows detector with a size of 64x128 consisting of 8x8 pixels, the process of normalizing this block is the final process of the Histogram of Oriented Gradient (HOG) algorithm that produces features. To determine the object detected, the Support Vector Machine (SVM) stage determines based on the characteristics of the garbage form.

Support Vector Machine

SVM (Support Vector Machine) is one of the classifiers that is now widely used to perform various classification requirements. In addition to classification [18], SVM is also used for regression. SVM is a binary classifier that divides data into two classes with a hyperplane [19]. This hyperplane is right in the middle of both classes with a distance of d to the nearest data point for each class. d is called margin, and data points that are exactly at the d distance from the hyperplane are called support vectors. Hyperplane SVM is expressed with the following equation (2).

$$w \cdot x + b = 0 \quad (2)$$

where w is the normal of hyperplane, and $\frac{b}{\|w\|}$ is the distance of the hyperplane to the point of origin. Figure 2 shows a hyperplane dividing two classes.

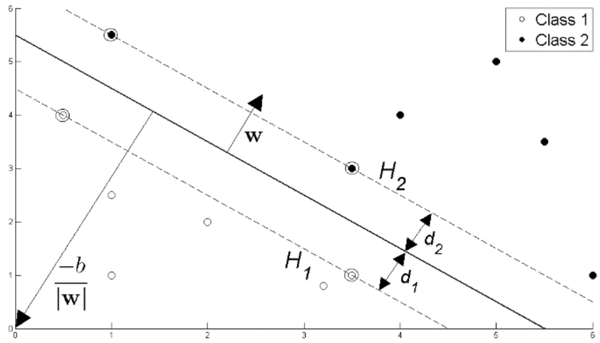

Figure 2. Hyperplane divides two classes [20]

The data points that go into class 1 are the data points that meet the equation (3).

$$w \cdot x + b \leq -1 \quad (3)$$

and the data points that go into class 2 are the data points that meet the equation (4).

$$w \cdot x + b \geq 1 \quad (4)$$

In SVM retrieval information is also widely used, especially in the process of data classification. Its ability to process large-dimensional data is an advantage of SVM compared to other classifiers. In text data retrieval information, SVM advantages to process large-dimensional data can be utilized, because of the nature of text data that is usually large-dimensional.

Object Recognition Feature

The GACOBOT system is built using python programming language and several data processing library packages. The Framework on GACOBOT system in classifying the type of waste can be seen in figure 3 below.

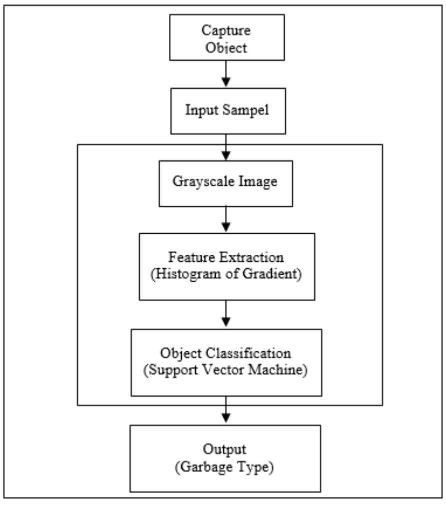

Figure 3. Research Framework

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Based on figure 3, GACOBOT has three stages in recognizing the type of garbage. the first stage of the garbage sample is converted into a grayscale image. Grayscale images will be calculated histgram of Gradient (HoG) values to get a feature value on each sample. The HoG value of the sample will be analyzed to distinguish the type from the sample image. The HoG value of each type of garbage will be used as the input value of SVM to be used as training data. The HoG value of each type of garbage will be used as the input value of SVM to be used as training data. The SVM model used is the SVM Linear Model which classifies data types directly without using a specific carnel. The extraction stage of Histogram of Gradient can be seen in figure 4 below.

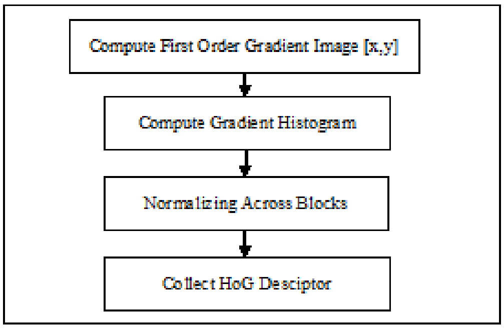


Figure 4. HoG Extraction Stage in Sample

HoG Feature Extraction on this system uses package library skimage. The calculation stages of the Histogram of gradient value are generally explained in figure 2 above. Compute Gradient Image [x,y] stage is the calculation stage of first order image gradient. at this stage the sample image will be searched for the contour border of the image and its texture information. The next stage of the sample will be divided into several cells each cells will be searched for the value of 1-D histogram of gradient or orientations integral images. Normalizing Across Blocks is the normalization stage of each block resulting from the calculation of histogram og gradient. the final stage is to collect each HoG descriptor of each block to visualize into a final image of the Histogram of Gradient processing. The classification stage of the object uses SVM linear method as shown in the following figure 5.

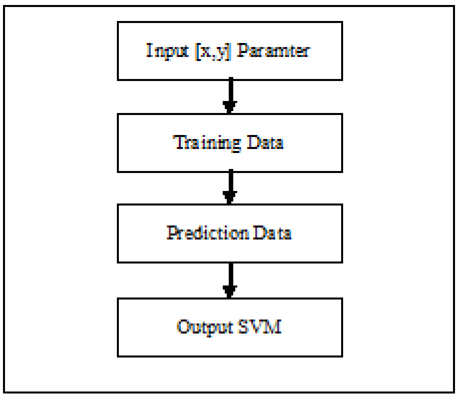


Figure 5. Stages of Classification of Garbage Types Using Linear SVM

Based on the picture above the initial stage in classifying the type of object is to enter the value input x, y. value x is the value of the extracted feature of the object on this system parameter value x is the value of HoG. While the value of parameter y is the target output value. In this system the output is distinguished into two main classes namely: plastic bag waste and glass bottle waste.

RESULTS AND DISCUSSION

At this stage, testing of object recognition features in robot garbage collectors (GACOBOT) is performed. Data retrieval using Raspberry-Pi Version 4 and Pi-camera. In this study the system was tested to recognize 2 types of garbage, namely: plastic bag waste and glass bottle waste. The object that has been tested can be seen in figure 6.

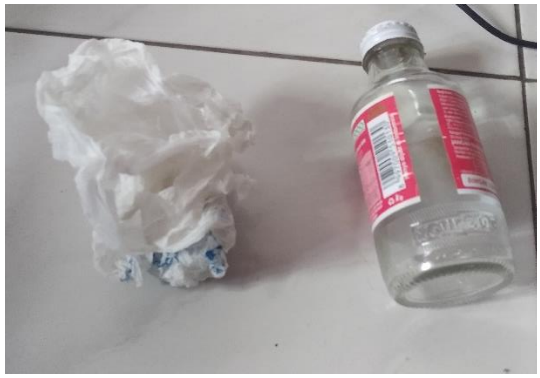


Figure 6. Garbage Object

The waste will be stamped using a raspberry system with a remote mechanism via a smartphone WiFi. The concept of data retrieval can be seen in figure 7.

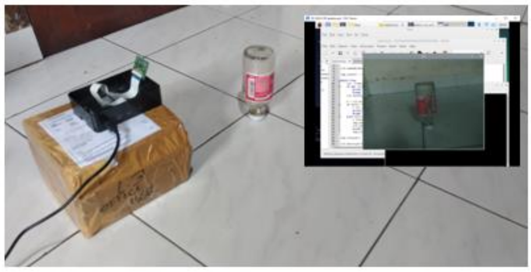


Figure 7. Data Retrieval

It can be seen in figure 7, that the object is approximately 20 cm away from the raspberry and placed in front of the system. In the window box display at the top right is a remote view of raspberries. The object image will be captured alternately against the background of the static or unchanged object. At this stage, 24 test data will be collected which will be distinguished as data for training and data for testing. The data capture results can be seen in figure 8.

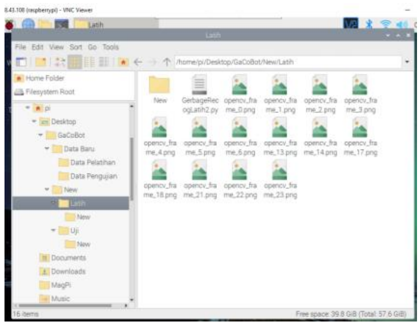


Figure 8. Training Data

Based on the data information in figure 8, there are 12 amounts of training data where the data is distinguished against 2 types of garbage. One type of garbage will be trained with 6 types of data. The amount of test data can be seen in figure 9.

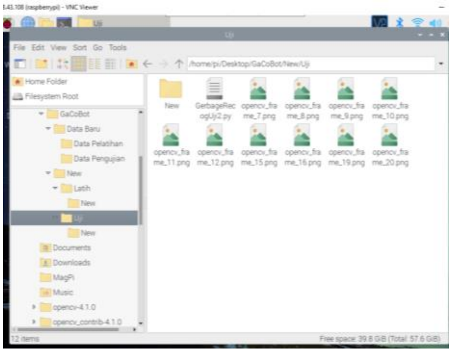


Figure 9. Test Data

In figure 9, there are 10 pieces of test data that are categorized into 2 types of garbage, so that one type of garbage is tested 5 times as many times as testing. Each training data will be extracted from the accumulated value of the white pixels which is a visualization of the histogram of Gradient (HOG) imagery. So that the pixel accumulation value of the 12 data will be saved into the program as training data. Then the training data will be entered into the SVM system by implementing the Gamma value automatically using the Scikit-Learn library. The training data that has been written in the program can be seen in figure 10.

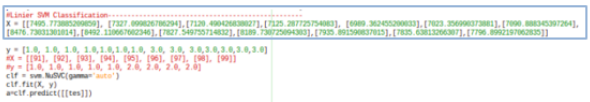


Figure 10. Training Data in The Program

The process of retrieving values in the program is done by testing each sample and collected data as shown in figure 11.

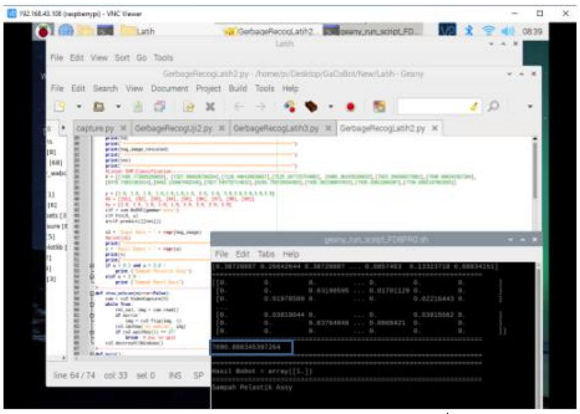
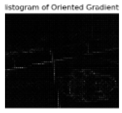
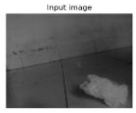
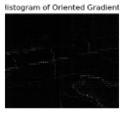
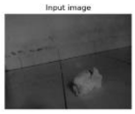
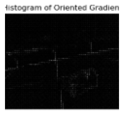
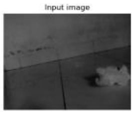
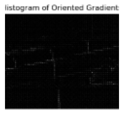
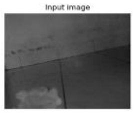
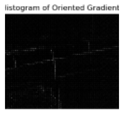
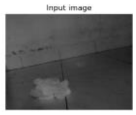
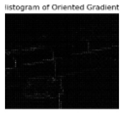
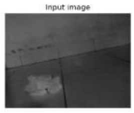
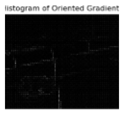
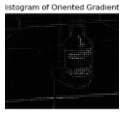
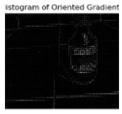
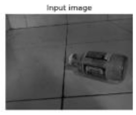
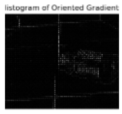
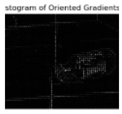
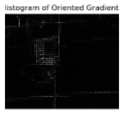
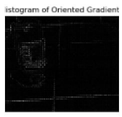
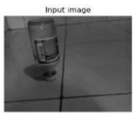
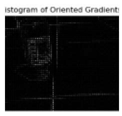


Figure 11. Feature Value Retrieval Process

The process of retrieving the value of the feature is done as much as the training data. Then the value will be entered into the program and classified according to the type of garbage. The data training table can be seen in table 1.

Table 1. Data Training

No	Name	Image input	HoG Result Pixel Accumulation Value	Output Image	Class Type
1	opencv_frame_0		7495.77		Plastic Bag Waste
2	opencv_frame_1		7327.09		Plastic Bag Waste
3	opencv_frame_2		7120.49		Plastic Bag Waste
4	opencv_frame_3		7125.28		Plastic Bag Waste
5	opencv_frame_4		6989.36		Plastic Bag Waste
6	opencv_frame_5		7023.35		Plastic Bag Waste
7	opencv_frame_6		7090.88		Plastic Bag Waste
8	opencv_frame_13		8476.73		Glass Bottle Waste
9	opencv_frame_14		8492.11		Glass Bottle Waste
10	opencv_frame_17		7827.54		Glass Bottle Waste
11	opencv_frame_18		8189.73		Glass Bottle Waste
12	opencv_frame_21		7935.89		Glass Bottle Waste
13	opencv_frame_22		7835.63		Glass Bottle Waste
14	opencv_frame_23		7796.89		Glass Bottle Waste

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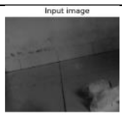
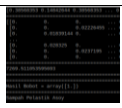
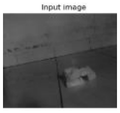
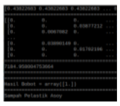
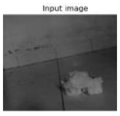
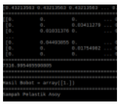
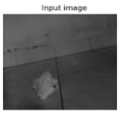
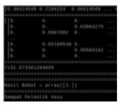
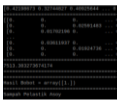
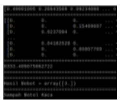
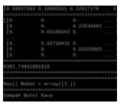
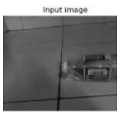
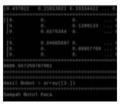
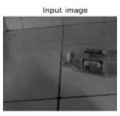
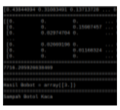
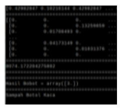
Based on the data in table 1, the accumulated value of HoG for plastic bag waste ranges from 6989 – 7495. While the accumulated value of HoG for glass bottle waste is about 7796 – 8492. The training data will be used as a reference for the training stage. Tests have been conducted on all 10 garbage object data that differ from the training data. The test data consists of 5 plastic bag waste data and 5 glass bottle waste data, the results can be seen in table 2.

Table 2. Data Testing

No	Name	Image Input	HoG Result Pixel Accumulation Value	Output Result	State
1	opencv_frame_7		7269.51		Detected
2	opencv_frame_8		7184.95		Detected
3	opencv_frame_9		7316.99		Detected
4	opencv_frame_10		7131.57		Detected
5	opencv_frame_11		7513.38		Detected
6	opencv_frame_12		8333.40		Detected
7	opencv_frame_15		8382.74		Detected
8	opencv_frame_16		8606.55		Detected
9	opencv_frame_19		7716.20		Detected
10	opencv_frame_20		8074.17		Detected

Based on the results in table 2, it appears that the 10 data consisting of plastic bag waste and glass bottle waste can be recognized all with a 100% success rate. This high success rate is influenced by the value of hog pixel accumulation features that have significant differences between the two objects. This is due to the difference in shape between different objects. In the next study it is necessary to combine the extraction of color-based and shape-based traits. In fact, HoG is a form-based feature extraction.

CONCLUSIONS

Based on the results of the tests conducted it can be concluded that the object recognition feature has been successfully implemented in GACOBOT. With supporting data that the accumulated value of HOG for plastic bag waste ranges between 6989 - 7945 and the accumulated value of HOG for glass bottle waste is about 7796 - 8492. The 100% recognition success rate influenced by the value of hog pixel accumulation features has significant differences between the two objects.

The system will then be integrated into the GACOBOT system as a whole and perform serial connections in real-time to recognize garbage and perform maneuvers

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