



# Image processing system for the detection of recyclable solid waste

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**Abstract**— One of the major challenges facing the world today is solid waste pollution, which has spread across vast areas and threatens ecosystems due to the massive accumulation of waste over time. This accumulation has altered the habitats of numerous marine and terrestrial species. These environmental impacts are largely the result of inadequate recycling practices, as only 10% of households worldwide engage in regular recycling activities. In order to help address this issue, this study presents the development of an image processing system for the automatic detection of recyclable solid waste. The methodology involved the use of aerial image acquisition through a DJI Mavic Mini 2 drone, followed by the application of image processing algorithms capable of identifying recyclable materials such as plastic, glass, and cardboard. The results obtained demonstrate a system efficiency rate of 97.99%, highlighting its precision and accuracy in detecting recyclable materials dispersed across urban areas. It is concluded that the proposed system offers a promising technological tool to support solid waste management and promote recycling practices.

**Keywords:** arduino, camera, pollution, drone, matlab, image processing, solid waste.

## I. INTRODUCTION

Today recycling plays a fundamental role worldwide due to the high pollution of solid waste generated on a daily basis [1], putting the planet in a critical situation due to the considerable waste of solid waste that has been developed with materials that decompose in many years [2], such as plastic, batteries and glass that can reach up to 9.3 billion tons worldwide [3], figure that is produced annually. According to that amount of solid waste, only 10% is recycled for reuse by people, while the other amount is distributed in rivers or oceans. [4], affecting all living beings with the contamination of their habitat causing them death by suffocation and showing that the culture for recycling in humanity is very scarce and precarious [5].

Similarly, the accumulation of solid waste leads to contamination of soils and subsoils, which ultimately results in the pollution of groundwater [6], impacting the habitats of animals that are later consumed by humans [7]. Additionally, the buildup of solid waste creates massive piles of garbage that further exacerbate environmental problems. [8]. This situation links human activities to natural processes, as the disasters caused by accumulated waste can be devastating [9], altering their natural course and leading to physical and structural damage to people.

Solid waste pollution can originate in different places such as homes, industries, agriculture, shops, hospitals and constructions [10], being the homes the ones that waste the greatest amount of solid waste, representing more than 50% [11], forcing plastics companies to look for solutions to change their conventional manufacturing materials to biodegradable for rapid decomposition [12], allowing humanity, given little concern for recycling, to be solid waste that biodegrades on its own with the help of natural chemical elements [13]. Although it should be noted that the change of manufacturing material by companies from plastics to biodegradable materials is a lengthy process that will take many years to conduct, so the progressive negative impact on the ecosystem will continue to be affected by conventional plastics [14]. For this reason, the fundamental problem of pollution by solid waste will continue to be present in the environment, being necessary to take the initiative of a system that allows to detect recyclable solid waste for its reuse of the same and prevent it from accumulating by pile of garbage.

The aim of this research article is to develop an image processing system for the detection of recyclable solid waste through automated analysis, enabling the identification of recyclable materials. This will help detect waste that can be reused, preventing its accumulation over time, which could otherwise result in large amounts of garbage and negatively impact both soil and subsoil by contaminating them. For the realization of the system, a drone was used that will take photos through a camera to later perform the image processing through MATLAB and identify solid waste materials that can be recycled. The mathematical software MATLAB is a valuable tool that allows us to perform superior numerical calculations with vectors and matrices, which is especially useful for image processing since it allows us to identify and classify images.

In section II, the literature on previous work will be reviewed. In section III, the methodology of the investigation will be conducted, indicating the design of the system by means of a flow chart and the electronic part of the system. In section IV, system image processing techniques should be performed. In Section V, the results obtained from the recyclable solid waste detection system shall be made. In section VI, the discussion of the system will take place, indicating the importance of the proposed system. In Section VII, the completion and recommendation of the system for detecting recyclable solid waste shall be made.

## II. LITERATURE REVIEW

Today society takes of great importance the correct handling of recyclable solid waste by the great waste caused by humans that does not allow the preservation of the terrestrial ecosystem, therefore the function of recycling plays a fundamental role throughout the world and has been proposed since before, that is why tool systems have been developed, such as: In [15]. The researchers determined that pollution by accumulation of solid waste garbage is a problem that covers different social aspects with respect to environmental measures, over the years this problem of solid waste becomes more serious in the world and it is necessary to efficiently detect recyclable solid waste by aerial images to give it a second chance with respect to its reuse. Although conventional recycling methods have been used, it is not enough to meet the need for its limited collection on the quantities of solid waste, so they decided to develop an object detector system based on the detection of solid waste by means of aerial images. The methodology used is based on the construction of an asymmetric deep addition network with structural blocks for the extraction of the particularities of solid waste, likewise, to treat blurred images and avoid wasting solid waste remains, they developed another efficient fusion pyramidal network to obtain broader contextual information from a dataset through collections. They achieved as a result an efficiency of 89.14% in the detection of solid waste, concluding that their system surpasses the conventional method of recycling on solid waste.

In [25], it mentioned that clear visualization during shoulder arthroscopy is critical for surgical accuracy and successful outcomes. However, intraoperative bleeding remains a persistent issue, and existing evaluation methods are subjective, inconsistent, and lack standardization. To develop and validate an image processing system capable of objectively quantifying intraoperative bleeding and evaluating surgical effectiveness during shoulder arthroscopy. The proposed system uses color recognition algorithms across multiple color spaces to calculate bleeding scores based on pixel ratios. A total of 200 three-second arthroscopic video clips from prior rotator cuff surgeries were assessed by three senior surgeons trained in the system's color-based evaluation method. Intraobserver reliability was measured by repeating assessments after two weeks. System scores were compared with the surgeons' average ratings. The surgeons' average score was 5.10 (range: 1–9.66), while the system's scores ranged from 1 to 9.46, with an average of 5.08. The mean absolute error between the system and surgeon scores was 0.56, with a standard deviation of 0.50. The system demonstrated excellent agreement with surgeon assessments, achieving an ICC of 0.967 with a 96.7% confidence interval [0.96–0.98]. The developed image processing system provides a standardized and reliable method for evaluating intraoperative bleeding, offering precise detection of blood presence and improving consistency in surgical assessment.

In [26], although automated pavement crack detection systems have evolved with high-resolution imaging and machine learning, image and motion blur continue to pose major challenges, affecting detection accuracy. Research on motion blur mitigation remains limited. To develop an effective image processing system that addresses motion blur in pavement crack images, enhancing both deblurring and segmentation performance. A generative adversarial network (GAN) system was developed, using UNet as the generator and a Wasserstein GAN with

Gradient Penalty (WGAN-gp) as the loss function. Models were trained on sharp and synthetically blurred pavement crack images. Deblurring quality was assessed using segmentation accuracy, PSNR, and SSIM. The WGAN-gp approach achieved superior results compared to other loss functions. UNet demonstrated the best performance among various tested generators when dealing with simulated motion blur. Validation with real motion-blurred images confirmed the system's effectiveness. The proposed GAN-based system significantly enhances the deblurring and segmentation of motion-blurred pavement crack images, offering a promising solution for improving the reliability of automatic pavement crack detection.

In [27], although precision agriculture technologies are improving farming efficiency and sustainability, their deployment is hindered by high computational costs, operational complexity, low image resolution, and limited GPS accuracy, delaying critical decision-making for farmers. To develop a real-time crop monitoring system that overcomes the limitations of current PA technologies by leveraging FPGA-based hardware and RTK-GPS for accurate and efficient field data acquisition and analysis. The system integrated real-time FPGA-based image-processing (RFIP) devices with RTK-GPS to collect, geotag, and process images in real time using Python and a mounted camera. The data were used to generate heat maps representing romaine lettuce leafage on Google Maps. The RFIP system demonstrated a strong correlation ( $R^2 = 0.9566$ ) with a reference system and achieved a Lin's concordance correlation coefficient (CCC) of 0.8292, confirming its accuracy and effectiveness during field testing. The proposed system offers a reliable, real-time monitoring solution for precision agriculture, enhancing farmers' ability to make timely and accurate management decisions, especially for stress-sensitive crops.

In [16], The researchers determined that solid waste such as plastic, electronic parts, among others, develops impressively and that it is developing countries that take the least precautions about recycling, gathering in piles in garbage and causing a main problem for the environment. Although recycling measures have been taken by the authorities, there is no correct result on the part of citizens in the differences in recyclable solid waste, so it will take many years to make a correct recycling, so they decided to develop the design of an intelligent solid waste management system. The methodology used is based on developing a system capable of managing recyclable solid waste with energy efficiency to be applied in strategic places where piles of recyclable garbage accumulate, for this, they used an Arduino Nano microcontroller along with its modules such as GSM / GPRS for sending information and the ultrasound sensor to calculate the distance in which solid waste is. They achieved as a result an efficiency of 90.44% in the detection of solid waste, concluding that the information sent by the GSM module is of immense help to find the solid waste to be recycled.

In [17], The researchers determined that solid waste is distributed in different places in an erroneous way, combining all recyclable waste with garbage waste generated in different places, causing pollution to the environment, although the population has been warned to recycle and identify the materials to be discarded, These recycling measures are not respected and put the traditional recycling system in defective, which is why several studies have been carried out to find a solution to the waste of recyclable solid waste, therefore, they decided to develop a surveillance system for the storage of recyclable solid waste. The methodology used is based on developing a reliable and robust system that allows monitoring solid waste deposits instantaneously with the use of low-cost components, for this they used sensors in Geiger mode, a PIC microcontroller to control the system and sensors such as SiPM which is a cheap and friendly detector in its handling, necessary for the detection of solid residue. Achieving as a result an efficiency of 92.99% in the detection of solid waste, concluding that its system is completely economical and efficient in the detection of solid waste.

In [18], the researchers determined that the correct management of solid waste plays an important role in the environment, because it will present a healthy domain for people with a solid and cheerful environment, likewise, recycling solid waste such as plastic, cardboard, etc., will maintain a successful environment with a healthy environment, but the reality is totally different, It is not recycled correctly for various reasons, lack of interest on the part of citizens, as well as lack of knowledge regarding recycling solid waste so that it does not affect the environment, so they decided to develop an intelligent solid waste management system applied in garbage containers. The methodology used is based on developing a reliable system that allows staff to detect solid waste and collect it in time to avoid the accumulation of it, managing the collection only when necessary and being able to control the level of filling, for this, they used an Arduino UNO microcontroller for the evaluation of the system, an MQ-6 sensor that detects gases, a rain sensor module, among others. Achieving as a result an efficiency of 91.08% in the detection of solid waste, concluding that its system is distinguished from other systems of others by its wireless module that they use to send information about the filling of garbage containers.

In [19], The researchers determined that the growth of solid waste is generated in each year because the population is constantly growing, mainly in cities, where solid waste management does not work efficiently, making materials such as bottles or cartons are accumulated by a lot, being a problem worldwide due to the lack of awareness regarding the effects generated by the non-decomposition of The materials in the soils and subsoils, being essential to develop a system that allows to identify the recyclable solid waste, therefore, they decided to develop a system of recognition of tactile materials guided by visual performance for the recycling of solid waste. The methodology used is based on developing an efficient system capable of detecting waste such as cardboard, glass or plastic for reuse, for this they used the Python language for the programming of the system, as well as the use of a robotic arm to extract the detected materials and fill it in a specific container with each material detected with the help of a webcam. Achieving as a result an efficiency of 93.34% in the detection of recyclable solid waste, concluding that its system supports copious amounts of recyclable materials, so the arm implemented in the system will work without any difficulty and controlled from the computer.

### III. METHODOLOGY

In the part of the methodology, first, the flow diagram of the image processing system for the detection of recyclable solid waste is developed, as detailed in figure 1, as well as the electronic part that adapts to the system. The aim of this research system is to perform an automatic analysis on solid waste materials and detect those materials that are recyclable, taking into account three main materials: plastic, glass, and cardboard.

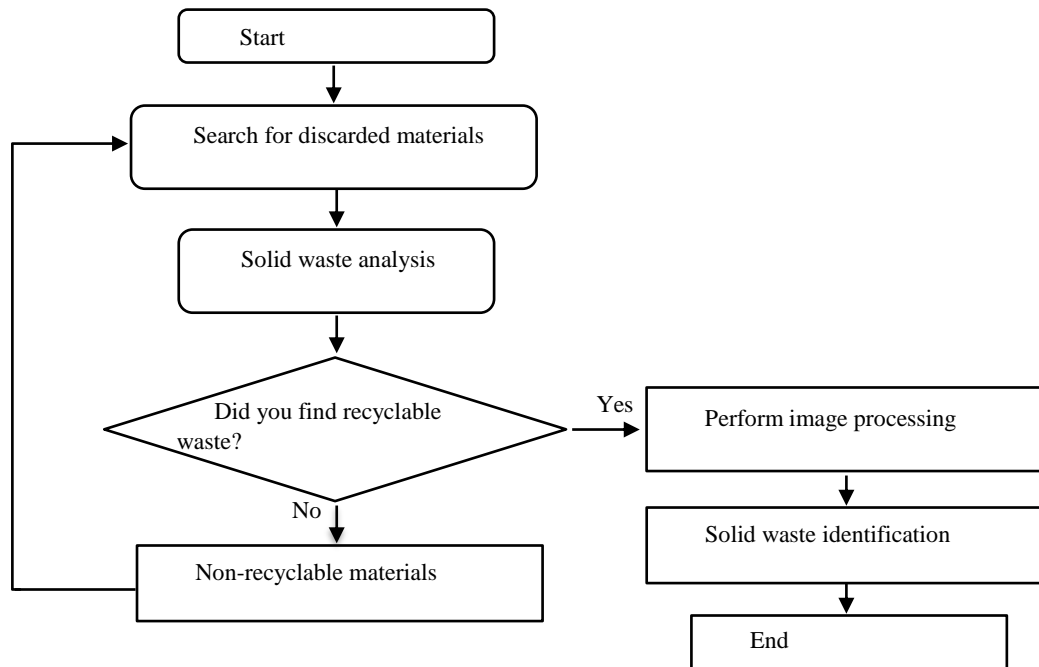


Figure 1: Flowchart of the proposed system.  
Source: Own Elaboration.

## Drone DJI Mavic Mini 2

The DJI Mavic Mini 2 drone is a crewless vehicle that will allow the user to search for a set of discarded materials to find recyclable solid waste, so that it facilitates the user to fly over various places without the need to physically approach the place because this device is characterized by autonomously maintaining a controlled and sustained flight level, showing the following characteristics in the following table I [20]:

Table 1: Drones Characteristics.

DJI Mavic Mini 2 Drone Features	
Camera	4K
Adjustable angle	0-180°
Video Capture	4K
Maximum Distance	10 km
Flying height	400 m
Flight time	31 min
Flight battery	3.7V 1000mAh

Source: Own Elaboration.

As specified in Table I, it was considered to use this unmanned vehicle, as detailed in Figure 2, for the use of the system.



Figure 2: Drone DJI Mavic Mini 2.  
Source: [20].

## Ultrasonic sensor

The ultrasonic sensor is an electronic device that will allow us to calculate the corresponding distance between the drone and the recyclable solid waste by using ultrasonic waves that are sent by the head and receive a reflected wave that returns from the impacted object, counting the time from the moment of transmission and reception. With this, it simplifies the user who manages the system with showing the value of the corresponding distance between both points, on the other hand, the advantages of this sensor are its low operating voltage and its low cost in the market, in addition to presenting a good accuracy that allows measuring distances from 2 to 450 cm [21].

In Figure 3, the HC-SR04 ultrasonic sensor that was used to calculate the corresponding distance in the system can be seen.



Figure 3: Sensor HC-SR04.  
Source: [21].

### Arduino Nano

Arduino Nano is a microcontroller that allows to control the ultrasonic sensor by means of an internal programming that allows the system to detect the corresponding distance between the drone and the recyclable solid waste automatically, storing the information in an external micro SD memory connected to the Arduino through a Micro SD Card memory reader module to receive the determined information and store it according to what is specified in the programming.

The advantage of using Arduino Nano, as detailed in figure 4, is that it provides a free programming platform, developed in a straightforward way by the variety of libraries it presents. [22], as well as its low cost unlike other microcontrollers. Also, Arduino has several modules or components that allow you to develop various tasks without problems, which is why this microcontroller is currently useful for many programmers in various fields.

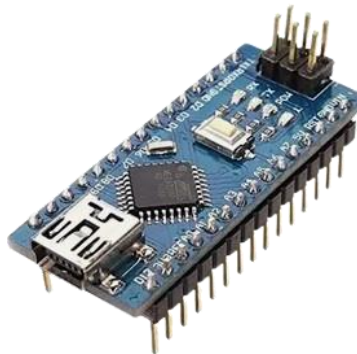


Figure 4: Arduino Nano.  
Source: [22].

### Distance between drone and recyclable material

The corresponding distance between the drone and the recyclable material is a key factor for the user who manages the system because it will accurately determine the value of the distance in which the recyclable material is located. The value of the distance may vary according to the position of the materials, therefore, we take an example value to observe in greater detail how the system will show the distance in which the recyclable materials are located, as detailed in figure 5, highlighting that the maximum distance determined by the ultrasonic sensor is 450 cm, If the recyclable material is outside the range of the sensor, it will suggest zooming in to determine the distance.

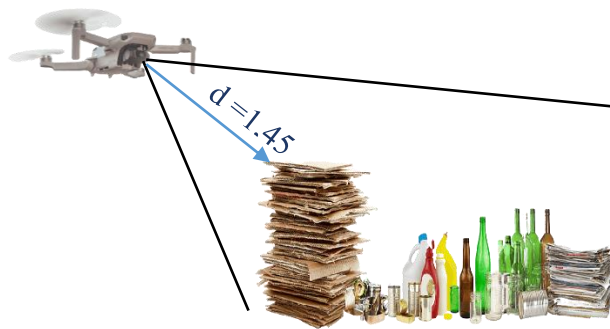


Figure 5: Distance between drone and recyclables.  
Source: Own Elaboration.

#### IV. IMAGE PROCESSING

In the processing part the essential of the system will be explained, perform the image processing after having obtained the images of the discarded materials to specify the step by step the image process, because the part of interest is the recyclable materials (bottles, cartons, and glass) found in the waste. In addition, the drone must be operational to collect the images to later perform the image processing.

MATLAB software is an essential tool for image processing, being used by various professional careers for its various applications that make it a complete and powerful software, and, for that reason, the MATLAB software was used to perform image processing. There are several image processing techniques that are applied to an RGB image, being two most used techniques the grayscale, characterized by using varied shades of gray on an 8-bit image, each pixel in gray scale is comprised with values from 0 to 255, and binarization, characterized by changing the RGB image to black and white by means of a histogram, preserving its important properties [23].

##### Pre Processing

The preprocessing lies in the use of various techniques that improve the quality of the image, in case of obtaining the images by means of a drone camera, it is important to apply various methods for its stabilization. In a similar manner, the processes of enhancement, recovery, compression, or decompression will be applied later based on the system's requirements [24]. These techniques involve the use of filters, histograms, and others, with filters being the most significant method, as they are used in most images to reduce the various types of noise that affect them.

Preprocessing is applied to the image acquisition process, responsible for capturing it by means of the unmanned vehicle (drone), allowing access to places contaminated with waste and having a good camera that will capture the corresponding photos. In this way, the information is acquired in a brief time and then sent to image processing. The block diagram of the image acquisition process is detailed below in Figure 6.

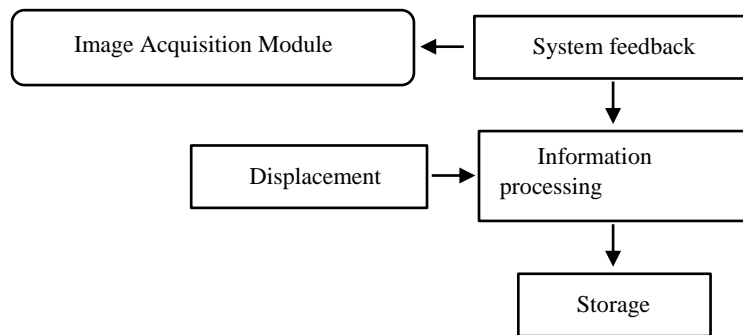


Figure 6: Block diagram of the image acquisition process.  
Source: Own Elaboration.

A pre-processing was performed on the image obtained by the unmanned vehicle (drone), changing the size of the image (1024x1024) according to what is required by the system detector, as detailed in figure 7, where the noise reduction is observed by the denoising Network tool. To preprocess the RGB image obtained by the unmanned vehicle, the code shown below is applied internally.

```

% Upload image
function [Wc]= preprocessing (Image)
Wcolors=imresize(Image,[256 256]);
% Eliminate noise
[WcolorR,WcolorG,WcolorB] = imsplit(Wcolors);
net = denoisingNetwork('dncnn');
WcolorR = denoiseImage(WcolorR,net);
WcolorG = denoiseImage(WcolorG,net);
WcolorB = denoiseImage(WcolorB,net);
WRGB = cat(3,WcolorR,WcolorG,WcolorB);
% Contrast adjustment
Wc= imadjust(WRGB,stretchlim(WRGB));
  
```



Figure 7: (a) Original image. (b) Preprocessed image.  
Source: Own Elaboration.

## Image processing

In the image processing part, the recyclable solid waste of interest is received, prepared, and recognized by means of the images obtained from the image acquisition process. To start with this process, it is necessary to have a fundamental tool such as a powerful computer due to the amount of information to be processed. The image processing part is developed with five important steps, as detailed in figure 8, starting with the reception of the images by the drone camera, then with the preprocessing the noise is eliminated, the pixels of the image are converted to equal size and the contrast of the same is improved, Then it moves on to object recognition with the outstanding features about plastic, cardboard and glass bottles. Once the place with recyclable solid waste is recognized, it continues with the final part where the system makes a report about the identified recyclable solid waste, labeling it in the detected area.

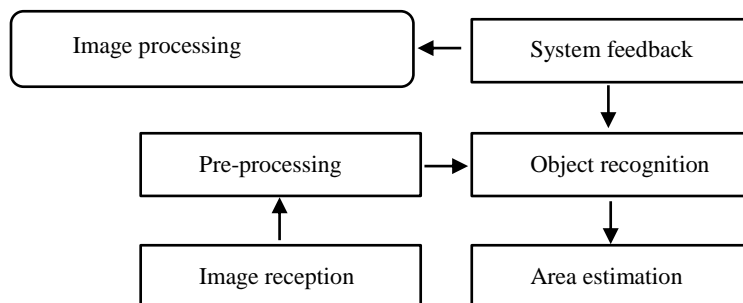


Figure 8: Block diagram of the image acquisition process.  
Source: Own Elaboration.

The software responsible for performing image processing for the detection of recyclable solid waste, must have a structured and object-oriented programming, for this reason, we worked with the MATLAB software that is based on a high-level mathematical language. For the development of this system, we work with tools suitable in Image Processing Toolbox, which facilitates the segmentation and improvement of the image, noise reduction, geometric variations, and image processing.

For the system to detect objects, an N number of images of the drone and the approved training files has to be loaded, the X variable initiated from scratch is generated that will go through all the uploaded images and a solid waste detection table of each image will be developed. The solid waste detection table must be analyzed by means of a new loop that is responsible for observing the detections of the analyzed image and the subsequent image, to avoid repetitions of the recyclable solid waste detected. Then the template detector is applied to determine the recyclable solid waste by means of a true or false, if in the analysis of the image it is detected that the object is present in several it does not count it again.

For the training part, the Cascade object classifier and HOG descriptors were used with various true and false images, from which a training file in XML format is obtained that will be an example for the images analyzed later. At each stage of the sorter, it will be labeled as positive if the bottle is found and negative if the bottle is not found, as detailed in Figure 9, by applying the code shown below.

```

% Load positive images
load('wastetable.mat');
% Select the information from the table.
positiveInstances = wastetable(:,1:2);
% Detail folder negative
negativeFolder = negative images (negative, 'Non-recyclable objects'];
% Preparing the detector
NumStages = 40;
FalseAlarmRate = 0.3;
% Cascading detector XML file named wasteDetector.xml.
trainCascadeObjectDetector ('wasteDetector.xml', positiveFolder, negativeFolder, FalseAlarmRate = 0.3, NumStages = 40);
% Newly trained classifier
detector= vision.CascadeObjectDetector('wasteDetector.xml');
% Read the image
img = imread ('wasteTest.jpg');
% Detect solid waste
wst = step (detector, img)
% Inserting rectangles to the detected residues
detectedImg = insertObjectAnnotation (img, 'rectangle', wst, 'Recyclable waste');
% Show image
imshow (detectedImg);
  
```

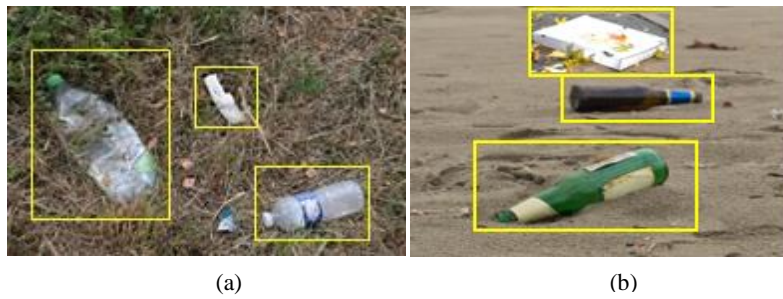


Figure 9: (a) Image with plastic detection. (b) Image with glass and cardboard detection.  
Source: Own Elaboration.

It should be noted that there may be false positives or false negatives, for this, the system has feedback that will correct errors in later stages of the analysis.

## V. RESULTS

The development of the solid waste detection system meets the specified objective of automatically analyzing the images of the waste thrown and identifying the recyclable materials to avoid the accumulation of solid waste that manages to contaminate the various areas of the environment, helping with recycling that is a problem worldwide due to lack of awareness.

Table II shows the fundamental characteristics of the solid waste detection system, mentioning the values of each parameter displayed in the operation of the system, being convenient for the detection of plastic, cardboard and glass bottles, so that it replaces conventional recycling that is vulnerable for people who practice it by direct contact with contaminated areas.

Table 2: Solid waste detection system.

Solid waste detection system	
Power supply	AC: 220V DC: 5V - 12V
Travel distance	10 km
Sensor distance	2 cm - 450 cm
Materials of interest	Bottles, cardboard, and glass
Operating time	Minimum: 31 min

Source: Own Elaboration.

When developing this system, the various recyclable materials that are thrown on the street or in landfills will be identified, based on easily accessible electronic devices with exact properties for the good identification of recyclable solid waste. Likewise, the operation time is important for this system, which can last much longer than specified when implementing an external battery.

According to those specified in Table II, the system conducts the detection with an efficiency of 97.99% in its operation, being a system that stands out for its high efficiency value, in addition to having the necessary precision for identification when analyzing the images automatically with the MATLAB software.

If this system is implemented, all the electronic devices that complement the system must be taken into account, being selected for their correct characteristic and for their accessible cost so that it can be developed by any person or institution. If in case in their implementation they vary in the choice of another drone, they should take into account the camera and the battery life to speed up the operation.

The importance of developing the image processing system for the detection of solid waste is that it will facilitate recyclability without putting the user at risk because it will not have any direct contact with contaminated garbage waste at the time of locating it, making it an important system that will help the environment in not contaminating the soil and subsoil.

To locate recyclable materials, the drone is responsible for automatically moving the camera to obtain the images to be processed, without presenting any limitation in its operation. In addition, the Arduino microcontroller helps determine the distance from the drone's location point to the point where the recyclables are located.

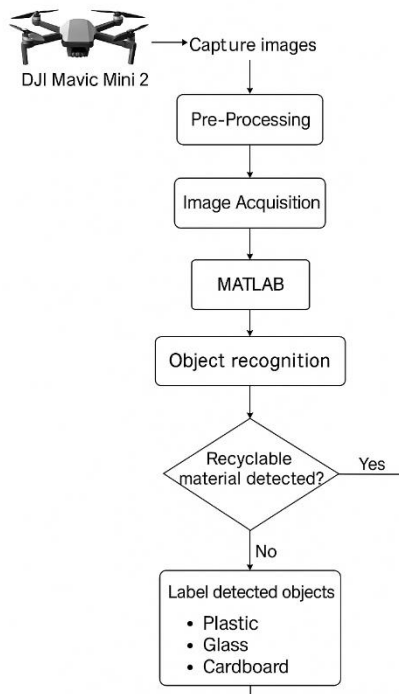


Figure 9: Flow Diagram of the System.  
Source: Own Elaboration.

## VI. DISCUSSION

As there is a diversity of systems that aim to detect solid waste to recycle it, applying various work strategies to achieve its specific objective and contribute to the care of the environment, as well as the care of people because the amount of waste such as plastic, batteries, etc., continue to be produced in enormous quantities and take many years to decompose.

In addition, it should be noted that this system applies a unique work strategy to detect recyclable solid waste and help avoid pollution or accumulation of garbage. Likewise, this proposed system differs from other systems conducted by its methodology, for example, the research work developed by [15], where the researchers proposed to develop an object detector system based on the detection of solid waste by means of aerial images. Reaching as a result an efficiency of 89.14%, but this system does not run the tests in real situations but has only evaluated it with images that have been acquired online, limiting its use, and losing confidence in its use by people.

We also have the research work developed by [16], where the researchers proposed to develop the design of an intelligent solid waste management system. Reaching as a result an efficiency of 90.44%, but this system does not use equipment that allows controlling the system remotely, likewise, the information sent about solid waste does not determine the precise location because the module used is not characterized by sending coordinates accurately, also, the calculated distance has errors with respect to solid waste.

We also have the research work developed by [17], where the researchers proposed to develop a surveillance system for the storage of recyclable solid waste. Reaching as a result an efficiency of 92.99%, but this system performs early monitoring, which does not allow to accurately determine the amount of solid waste that may be in a recent or a pile of discarded waste, this completely limits its operation because it does not meet its stated objective, not to monitor storage full of recyclable solid waste.

We also have the research work developed by [18], where the researchers proposed to develop an intelligent solid waste management system applied in garbage containers. Reaching as a result an efficiency of 91.08%, but this system does not specify the type of sensor used to measure the level of the container, likewise, the infrared sensor is with an erroneous threshold level that does not do what is specified in the programming, as well as the motor drive that does not control its operation accurately on the system.

We also have the research work developed by [19], where the researchers proposed to develop a system of recognition of tactile materials guided by visual performance for the recycling of solid waste. Reaching as a result an efficiency of 93.34%, but this system does not have good accuracy for the recognition of recyclable materials, likewise, its handling is not practical for the user and has limitations in dynamic environments where there is solid waste. A comparison will then be made in Table III of this system (a) with our proposed system (b).

Table 3: Comparison of Detection Systems.

	A	B
Process	Manual	Automatic
Information acquisition	Webcam	Drone
Image processing	Python	MATLAB
Detection	Recyclable solid waste	Recyclable solid waste
Accuracy	93,34%	97,99%
Process	Manual	Automatic

Source: Own Elaboration.

## VII. CONCLUSION AND RECOMMENDATION

Regarding system development. It is concluded that Operation is efficient, helping to recycle recyclable materials that over the years generate a lot of garbage, causing pollution to the environment. Identifying recyclable materials by means of labels and visualizing it through the computer screen.

From the development of the system, it is concluded that this system can be used in different circumstances, specifically by the drone that allows the user to reach places without access to have knowledge about the location of recyclable materials. In addition to having the necessary devices that allow development in the best way on any circumstance.

From the development of the system, it is concluded that the image processing system for the detection of solid waste is completely reliable and safe for users who handle it, due to the zero physical contact that exists with the surface when locating recyclable materials, that is why there is no risk of catching any of the viruses that are in garbage waste.

The development of the system, it is concluded that the performance of MATLAB software was essential for the development of the solid waste detection system, for its various tools and functions applied in the preprocessing and in the processing of the image when applying this software. Although it is a high-level software, a user-friendly algorithm was made for the user's ease in understanding.

From the development of the system, it is concluded that its performance of the image processing system for the detection of solid waste is beneficial due to its various characteristics that it presents, such as its low cost, the prudent time of search and location, which allow the system to stand out unlike other systems developed.

In the future, a GPS locator will be added to the system so that they can send the coordinates of the exact point where the recyclable materials are and can be displayed on the computer to have more complete information.

The recommendation given to the user is to respect the characteristics of each electronic device used for the system, to avoid inconveniences in its detection operation, such as with the ultrasound sensor that covers a corresponding distance.

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