Literature Review of Automated Waste Segregation System using Machine Learning: A Comprehensive Analysis

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***Abstract* - Waste management is a pervasive problem in today's world and is rising continuously with a rise in urbanization. Waste management has a vibrant part to have an ecological environment. Proper waste disposal at the dumping sites has an essential part in sorting at the base level. Increases in time and more manpower is needed in order to sort waste using the traditional process. Sorting waste can be done in various methods and forms. Analyzing and classifying the garbage using image processing can be a very productive way to process waste materials. This paper aims to analyze existing research presented studies around the globe. This will enable to determine the problems, an algorithm used and method of those cited studies. It can also assess the correct algorithm to be used in a future study. These paper talk about the different methods and proposed systems in which waste segregation took place. These also talk about the drawbacks faced by the already existing systems and algorithms they used. With it, this paper gives a lot of opportunities to produce new knowledge in creating a new system.**

Keywords* - *Convolution Neural Networks, Deep Learning, Image Processing, Segregation, Support Vector Machine, Waste Classification.

I. INTRODUCTION

One of the global problems that affect everyone and all living things is garbage. Plastic outflows into the Philippine oceans are from garbage which was 74% as shown in the study. The Philippines generates about 35,000 tons of garbage daily [21] and the most common garbage thrown are plastic, paper and kitchen waste [4]. In addition, 81% of plastic garbage was thrown from land into the ocean [10]. From this study, there are two reasons why there is leakage of collected garbage: one is the illegal dumping by different companies and another one is through dump sites and located near waterways [15].

Likewise, Manila City the capital of the Philippines grappled with question of what to do with more than 8,600 tons of garbage from its 1.5 million residents generate each day [27]. In detail, the lists of the garbage in the ocean were plastic bags 679,957, paper bags 253,013 and food wrappers 103,226. Also recovered were 38,394 pieces of clothing and shoes, 55,814 tobacco-related items including cigarette butts 34,154, lighters and wrappers, and 11,077 diapers. These can cause poison and toxic in the ocean and you may see these trashes in some body of water like the Manila Bay [28].

Furthermore, despite of strong environmental activism that the Philippines has, it still suffer from a trash problem [26]. From the write ups of Rappler [26] they emphasized on their report that out of the total 178 LGUs in Manila area, there are still 39.89% that don't comply with the 10-year solid waste management plan, 27.53% that don't comply with regulations for segregation at source, 23.03% that don't comply with regulations on segregated collection, 44.38% that do not have a functional materials recovery facilities, and 10.11% that don't have approved disposal facilities [26].

Data shows that the local government was having the hard time in implementing the Ecological Solid Waste Management Act of 2000 [26]. Many programs and projects are done by the Philippine government in the implementation of Reuse and recycle but none of them are successful. Some local government unit instigate the "No Segregation, No Collection Policy" and "No Burn Pilipinas" but still there are municipalities and towns who do not conform with the policy [28] and failed to implement RA 9003.

In today's time, waste management is a very common term and is used to describe the series of activities from waste generation to disposal that can help sort the innumerable problems due to improper waste disposal that includes adverse effects on human health and the environment [17].

Due to rapid industrialization and urbanization causes an extraordinary increase in the origination of unwanted waste. It has been a problem in the community on how to segregate waste. Though, there are lots of program being implemented in order to separate waste from recyclable one. People started waste separating since around 20 years ago, and till today many waste sorting centers have their own automated assembly lines. But this process cycle is not perfect: The current quality control step in waste sorting process requires a lot of manual operations [23].

In the industrial level, the sorted mixed waste is done through the following techniques [24], manual sorting of large items, other materials are sorted through its size with

the help of large rotating drums. It has smaller in size, the diameter has holes in which particles will be dropped and large items will hang in the drum.

Currently, there exist various types of machinery which attempt to sort one material from another with differing degrees of success [19]. In the Philippines, no modern technology has been used to segregate waste. Only the manual process of segregating was then used [28].

The main purpose of this study is to analyze existing research presented studies around the globe. This will enable to determine the problems, an algorithm used and method of those cited studies. It can also assess the correct algorithm to be used in the future study.

The succeeding section will discuss some of the research presented, new technologies used in order to segregate waste and innovations. This will explain as well some studies conducted to eliminate problems in wastes, their advantages and dis advantages.

II. EXISTING STUDIES

To better understand the different studies presented and to be able to determine as to what kind of algorithm is to be used best the following are the different studies used the different algorithm and studies where it applies. It also has the strength and weaknesses in which it can be used in deciding as to what algorithm is the right one. There are many systems that can separate waste into different categories. They are the following

- Intelligent Waste Separator (IWS) [9]- can replace the traditional way of dealing with waste; The prototype automatically places garbage in altered basins and accepts inbound wastes by using a multimedia embedded processor, image processing specifically using the image recognition algorithm, and machine learning in order to select and separate waste. It developed prototype consists of a shared trash can, with supplementary basins in it, using multimedia technology [8].

- Spot Garbage [14] is a smartphone-based application. It detects a pile of garbage and identifies the location where the garbage is present by using the location access of smartphones. The app uses the convolutional neural networks architecture for identifying wastes in images.

- IoT based Waste Collection System using Infrared Sensors [16]- This automatic waste segregator uses a modern classification method known as Convolutional Neural Networks to classify the waste into various categories. This system paves the way to better recycling and reuse processes that helps in efficient waste management. By using the concepts of Artificial Neural Networks and Image analyzing specifically the image recognition algorithm, the project is aimed at designing and developing a system that can be effectively utilized to segregate waste.

- Adaptive and Interactive Modelling System (AIMS) [19] that uses induction algorithm to interpret sensor data streams and produce an efficient description of object characteristics which will define material separation strategies.

- Waste Segregation System Using Artificial Neural Networks [18], the project is aimed at designing and developing a system that can be effectively utilized to segregate waste. By applying the concepts of recognition and classification in Artificial Neural Networks, the proposed system can be designed to rightly categorize the different types of waste.

- Automatic Waste Segregator and Monitoring System [2] is a system in which it sorts wastes into three different categories, namely metal, plastic, and the wet (organic) waste. Other wastes are categorized as wet waste, which signifies organic waste which classifies as left-over and vegetable peels [5].

Most of the studies presented used microcontroller and almost all of them are just a prototype system. Variations of wastes cannot be determined. Some of the studies are for special purposes only. Other types and new types of wastes were not able to recognize and determine. In addition, buying and maintaining this kind of study in the microcontroller are proven to be excessively costly. Classifying waste and segregating is a lot helpful in many of the areas such as in the industry, household, company and of course school. No current study was being conducted in automating and segregating waste in school. Using technologies available today in sorting waste and determining which is to be recycled can be very effective techniques to handle garbage.

III. ALGORITHM USED AND THEIR ANALYSIS

The following table shows the systematic review of the literature, an algorithm used by the studies presented, their strength and weaknesses and their findings.

TABLE I. STUDIES PRESENTED AND ALGORITHM (a)

Studies Presented	Algorithm Used	Strength	Weaknesses	Segregated Wastes	Findings
Intelligent Waste Separator (IWS)	Machine Learning	Due to IWS bursting anatomy waste separation do not depend on people. Consequently, avoiding mixing waste in bins has a fewer ratio of error.	The capacities of waste separator do not allow in obtaining information and response is slow.	aluminum cans, plastic cutlery, and plastic bottles	The result shows that it has the possibility to a positioned independent object in classification algorithm that was based with only two of the seven HIMs in differentiating and classifying wastes.
Spot Garbage	Deep learning	A model that can describe the garbage from others. It is 11 times faster than naïve window sliding and can perform prediction. It also uses an Android App	Garbage detection fails in an insufficiently available image. When there is a similar to garbage, it can misclassify the garbage or sometimes lose the distinct attributes when afar.	Plastic Bottles, tin cans, paper, metals some decayed objects	There are outperforms approach with the use of deep learning method, image trusting on image processing increased by 7% for accuracy and specificity was 11%

TABLE II. STUDIES PRESENTED AND ALGORITHM (b)

Studies Presented	Algorithm Used	Strength	Weaknesses	Segregated Wastes	Findings
IoT based Waste Collection System using Infrared Sensors	Azure Machine Learning System	The proposed IoT-based methodology can easily provide information. It helps the company to efficiently route and effectively scheduled collection of garbage.	It lies in real time generated data and collection of waste.	No specified waste segregated	It uses IR sensors to notified the server if the bin is full and schedule for collection.
Adaptive and Interactive Modelling System (AIMS)	Artificial Intelligence and Induction Algorithm	Using a set of Pareto optimal models for classification is that they provide greater flexibility and ideal behavior under a variety of circumstances.	The error of randomly guessing the class would be 50% and the error of a simple model classifies everything as clear is 40%.	glass, metal, and plastic	They use machine learning techniques that can be effectively applied to container sorting

TABLE III. STUDIES PRESENTED AND ALGORITHM (c)

Studies Presented	Algorithm Used	Strength	Weaknesses	Segregated Wastes	Findings
Waste Segregation System Using Artificial Neural Networks	Classification using Convolutional Neural Networks	Using one of the Machine Learning tools, Convolution Neural Networks was designed and executed. It is devised to achieve segregation of waste thereby reducing human intervention in the handling of waste items.	No physical mechanical device to categorize wastes into different bins. Accuracy rate should be added to train the data set.	Bottles, cans, milk covers, paper bags, and boxes. Spoons, papers, straws, and plastic bags	Using CNN's, the categorization of the waste objects is achieved with the current accuracy rate of 70%. The expansion in the waste categories' database helps in increasing the accuracy rate when training the network for the classification purpose
Automatic Waste Segregator and Monitoring System	An algorithm was not specified except it used ultrasonic sensor and induction sorting	Sorting of waste at the primary stage will make waste management more effective and fruitful.	It is very costly, Waste separation is time-consuming. Size of waste must be less than or equal to the dimension of a funnel	Metallic wastes (paper clip, battery, safety pin), organic waste (leftover foods) and dry waste (paper, small bottle, cartons, tetra pack)	The proposed be able to monitor the solid waste collection process and management of the overall collection process.

Table I clearly depicts the different systematic review of the literature and some studies that prove the strength, weaknesses, and findings of the different studies found. It was also indicated the application to where it was applied and the conclusion in which it further discussed the output of the study. It was noted as well some of the disadvantages of the different studies which help the proponent to identify as to what algorithm and application should she used and why this kind of application be used.

In addition to the study presented, there are studies such as Sakr [22] that used NVIDIA DIGITS for preparing the Convolutional Neural Network, while Support Vector Machine (SVM) was trained through Matlab 2016. The drawback in Sakr's [22] study was the lesser quantity of descriptions and images in the preparation and training set. The training images were scaled down from the original 256 x 256 size to 32 x 32 size. This decreasing interjected to extra other relevant issues. The final implemented model produced in this research had a small average implementation period (0.1s) on a raspberry pi 3.

Yang [23] researched on classifying garbage into six different classes like metal, paper, cardboard etc. The dataset used was hand collected which consisted of 400 plus images for each of the categories considered. Support Vector Machines with a scale of irregular feature transform (SIFT) features and Convolutional Neural Network were the models that were used to classify the images into various categories. Eleven layer CNN architecture was implemented in this, which is very similar to AlexNet. The experiments show that the SVM performs more efficiently than CNN.

In relation, Table IV shows the Garbage Classification models along with their models used and corresponding accuracies [1]

TABLE IV. GARBAGE CLASSIFICATION MODELS

Model	Algorithm Used	Accuracy
Sakr (2016) study	SVM and CNN	94% and 83 %
Spot Garbage	Convolutional Network	87 %
Yang (2016) Research	SVM	63%

IV. METHODOLOGY USED

Various methods has been used in order to analyze and present the studies and researches presented. Considerations were made in searching years it cover, databases to be used for searching, keywords to search and relatedness to the focus of paper. Researcher searched for an updated study ranges from year 2014 up to 2018. To be able to present some innovations, keywords such as Machine Learning, image processing, artificial intelligence and a combination of waste segregation was used in searching in the database from two large databases: Scopus and Web of Science. They were selected because they are the most comprehensive source of scholarly paper and articles.

Upon searching, there are 100 results found. But since some of the study is outdated it was not considered. In addition, some researches were not related in the study,

some of them focused on energy waste such as battery and other electronic wastes, aluminum and others. Since this paper focuses on recyclable materials such as paper, bottles, cartoons, and plastics other wastes was not then ruminated. It is the reason why there are only 6 studies that were just included. As it was the major problem raised in the segregation process in the Philippines.

A. Materials Collection

Research papers ranges from the year 2014 to 2018 were included in this review. The process were as follows:

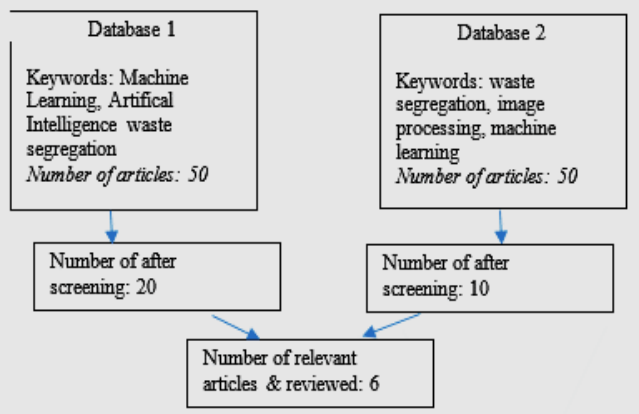

Figure 1. Selection of Articles

Figure 1 depicts how the articles are being validated and quantified.

In addition, material evaluation was made through the categorization of studies which was considered as well base on their focus and process and area of focus.

TABLE V. CATEGORIZATION OF STUDY

Study	Research Area	Focus/Process	Study Type	Area
1	Machine Learning	Waste separation	Prototype	Household
2	Deep Learning	Waste description	Model	Community
3	Azure Machine Learning	Infrared waste segregation	IR Sensor	Industry
4	Artificial and Induction	Waste classification	Model sensor	Industry
5	Convolutional Neural Network	Waste segregation	Prototype / sensor	Community
6	Induction	Waste sorter	prototype	Household

Table V describes the category of the study. The research presented was categorized according to their research area, type focus and where it was applied.

B. System

Not only the studies presented was considered but as well the system they have presented. The system which encompasses the technical aspects used by the research to execute and implement the studies.

TABLE VI. IMPORTANT STUDIES WITH SYSTEM

System	Techniques / Focus	Author / Year
Automated Waste Segregation System	Image Processing / Garbage classification	Garcia A.T. (2015)
Spot Garbage	Detection of Individual Object	Mittal, Yangzik, Garg, & Krishman (2016)
IoT Based Waste Collection System with Infrared	Infrared Obstacle Line Sensor / Garbage Collection and sort	Tarbell (2014)
Adaptive & Interactive Modeling System (AIMS)	AI Sorting Techniques / Sorting wastes	Balakrishnan, Swathy, Rosmi Subha (2016)
Waste Segregation System using Artificial Neural Networks	Acquisition of images of waste material / acquiring image	Xinhua (2017)
Automatic Waste Segregator & Monitoring System	Arduino Controlled Board / Sensor sorting waste	Krizhevsky, Sutskever, & Hinton (2014)

Table VI shows the different systems that was made in the study, their techniques and the focus. Authors was able to indicate and the year it was published. This will help the study to indicate the proper and validate the method used by the researcher in evaluating the paper presented. Moreover, it is useful because the studies presented above are more likely related and relevant to the future work of the researcher.

Furthermore, the following are the different methods used by the different study who successfully relate with the focus of this paper.

C. Image Processing.

The study of Garcia [6], which is called the Automated Waste Segregation System started with converting the image on RGB, followed by using grayscale and binarizing it. At this point, it removes the unwanted features of the image using an ordinary WebCam. They also used the Image Variant Movements in which it patterns to Hu [7] on the object representation and the application of image analysis in the irregular movement. For the purpose of classification, the method used was helpful in selecting a set of numerical attribute extracted from wastes. With the formula they used, they also concluded with the system training and waste classification in which Euclidean distance was used. K-NN Classifier was also utilized in order to classify a new item by searching for its k nearest training items.

D. Detection of Individual Objects

As stated in the study of Mittal [11], they have used 2 ways in perceiving an image and segregating them. One deals with the detection of individual objects in which they extract patches and combine predictions of an object. They have used patch generation, wherein images from the

Garbage in Images (GINI) dataset are processed in order to generate stable size. They also created GarbNet Model in which it permits the loads and heaviness of the images were modified by means of the pre-trained prototype. After the pre-trained model was done, they are optimizing the GarbNet Model. As they optimize the model, fewer neurons were used with a fully associated level resulting to radical change reducing of 87.9% in size which the help of convolutional neural network (CNN) as they compute the redundant with the intersecting amenable fields. In addition, the assistance of Image Processing helps the extracted image from patches were used as a baseline.

E. Infrared Obstacle Line Sensor

The system features an Infrared Obstacle Line Sensor that is fitted on the dustbin. The sensor system is connected to Raspberry Pi 2 board, in which it was fitted with a Wi-fi or GSM Module that connects to the internet. As the dustbin has filled-up, a notification was sent to the server using the Python (Django Framework) to schedule the collection of garbage. Using Azure Machine Learning System wastes can be collected from the various dustbin and obtain predicted times this will improves the scheduling process [16].

F. AI Sorting Techniques

The specific area of interest in this project is machine learning in which little or no a priori knowledge is assumed available for the construction of knowledge bases. Such learning-based algorithms are more robust than their counterparts, which rely on hardwiring physical features into a control circuit. The machine learning induction algorithm is able to adapt to changing situations through integrating new conditions and findings with those it has already seen. The study conducted used a prototype system in which AIMS is the model used for the recursive splitting into the sorting mechanism. There is a conveying system that enables the container to transmit, radiate and convey. Acoustic hardware was integrated for the sensor interrogator and database assimilator to be able to define and segregate waste [19]

G. Acquisition of the Images of Waste Materials

This study defines the waste first. To be able to do that, the researcher used to categorize the waste into six (6) parts. After considering the waste category, the also determine the database wherein about 500 images of an item was collected [18]. The code to train the CNN trims the number of images in each category. Thus, they train the CNN that is the machine learning tool that consists of several layers in a network which was the Deep Networks (Alex). Determining the label of the new input image was conducted by AlexNet a trained CNN with 25 layers. They transfer the learning which involves the modification of a pre-trained network. The accuracy rate of the network can be further increased by training a Linear SVM Classifier [5]. By training the SVM Classifier [5] using the extracted features from the re-trained network, a multiclass classifier of high accuracy can be achieved.

H. Controlled by Arduino Uno Board / Ultrasonic Sensor

This study was made possible through the use of parts like ultrasonic sensors, inductive proximity sensor, DC motors, blower, and electromagnet are interfaced to the Arduino board [2]. There is an ultrasonic sensor that is fixed in the inlet to detect the falling of waste. The echo received from the waste is received by the microcontroller to calculate the delay [4]. This will be placed on every outlet in order to check whether the bin is filled or not. A notification is being sent to the server whenever the bins are filled through the help of GSM Module.

V. RESULTS AND DISCUSSION

As the related literature and studies were carefully analyzed and reviewed the following are the results of this study.

TABLE VII. TABLE OF REVIEWED ALGORITHM AND ACCURATENESS

Algorithm	Accuracy	Author
Deep Learning	On Image Processing Increased By 7% For Accuracy And Specificity Was 91%	Google developers
Azure Machine Learning System	91%	Dille, 2019
Artificial Intelligence and Induction Algorithm	91%	Shavlik, Mooney, & Towell, 1991
Classification Using Convolutional Neural Networks	Current Accuracy Rate of 99.68%	Xin And Wang, 2019
SVM and CNN	94% And 83 %	Sakr 2016
SVM	Current Accuracy Rate 89.41%	Yang, 2016

Table VII shows the different algorithms presented in the study. The researcher only choose the most commonly used algorithm in the different studies presented. As the researcher analyzed, it was discovered that among the six(6) most commonly used algorithm classification using the Convolutional Neural Network has the highest accuracy level in terms of classifying an objects. Although, all of them are classified as the machine learning algorithm there are still an algorithm that will stand out amongst them. It was noticed as well that most of the algorithm used were above 90% for their accurateness. This means that this kind of algorithms to be used in the classification and segregating waste are most reliable one.

On the other hand, having the convolutional neural network alone as being used in one project can have the most accurate level of classifying an image. From the table

as well, it can be noted that using the combined effort of an algorithm makes it an algorithm cannot perform its duty.

TABLE VIII. SYSTEM REVIEWED AND FINDINGS

System	Techniques / Focus	Findings
Automated Waste Segregation System (Intelligent Waste Separator)	Image Processing / Garbage classification	This system created a prototype which can replace traditional way of dealing waste. It used machine learning specifically image recognition which use both pattern and digital analysis.
Spot Garbage	Detection of Individual Object	It relies on smartphone. The created app used convolutional neural network architecture in identifying wastes which makes the study become more accurate and strong.
IoT Based Waste Collection System with Infrared	Infrared Obstacle Line Sensor / Garbage Collection and sort	With the use of infrared sensors the server was able to notify if the bin is full and the collection is being scheduled.
Adaptive & Interactive Modeling System (AIMS)	AI Sorting Techniques / Sorting wastes	This study applies machine learning strategies to the task of material segregation using an induction algorithm. It was shown that recursive splitting techniques show promise and will be compared with results from neural network representations in an attempt to maximize processing efficiency
Waste Segregation System using Artificial Neural Networks	Acquisition of images of waste material / acquiring image	It used Convolutional Neural Network to achieve segregation. This was designed to reduce human intervention in segregating waste.

Table VIII shows the system reviewed and findings of the researcher. Since there are also system reviewed included in the study, it was noted that most of them were used devices and hardware to have an even image processing and classification such as camera then process the image. The system presented used different kinds of algorithm but most of them were from the machine learning such as convolutional neural network that makes the classification and segregation much easier.

It was clearly noted that having used of neural networks makes it easier for a certain system to make a classification and sorting. It is notable as well that three (3) of the presented system used convolutional neural network (CNN) which makes CNN as the most algorithm being used in classifying and segregating waste. To enable a segregation, they used machines and hardware.

VI. CONCLUSION AND FUTURE WORKS

Various steps and methods of efficient waste management and disposal have already been researched and carried out by many researchers and research enthusiasts. Many devices have also been designed in order to carry on this process efficiently. Hardware components such as raspberry pi have been used along with various algorithms to achieve the goal. Images of objects are scanned using the device in order to classify them accordingly.

But a major shortcoming of such devices is that all these devices work with maximum accuracy only on images containing single objects to be recognized and classified. Convolution Neural Networks is considered to play a very important role in the process of object recognition and classification and can be said to be the major step towards the development of such methods. Methods and steps that consider the shape and size of objects for their recognition and classification have also been developed, but they can be used only on objects that can be said to stay in a specific shape or size, which seems to be a bit difficult when it comes to wastes and scraps. Physical reflectance properties of various objects and also a classification of objects based on their materials have also been used earlier to propose methods to classify images accordingly. Previous researches have been more about single object recognition and classification, and moreover, different algorithms were implemented on the same datasets in order to calculate and evaluate the precision and accuracy of the algorithms used to demonstrate the importance and application of the specified algorithm with respect to the kind of datasets used.

The major drawbacks of these already existing systems are that they aim to classify an only single object in an image. In a real-world scenario, it is very difficult to separate individual objects from a garbage pile and then classify them as the amount of garbage present will be in the magnitude of millions of tons and it will be very time-consuming. Hence there is a need to recognize and segregate multiple objects in a single image. Also in the current models, the number of categories in which wastes are classified is very less. Wastes are usually classified as recyclable and compost. Recyclable materials consist of paper plastic metal etc. and each of it is recycled separately in a different way.

Hence to classify the recyclable materials from garbage and wastes into different categories would make the recycling process better and easier. From the past decade, there is a huge increase in the use of electronic gadgets, which can be attributed to the explosive growth in computer and technology. The average life of an electronic gadget like a smartphone is around 2 years. In the next few decades, the number of electronic wastes generated will increase drastically. It will be very difficult to recycle these components as each part are made of made of different materials and each of these materials has to be recycled in different ways.

Therefore an efficient method to recycle electronic gadgets and their spare parts is needed. With this, a study to conduct new wastes segregation is a must.

Research opportunities can be worth considering in which the time it response in determining the waste being thrown must be quick, waste classification in bulk should also be in consideration and determining and sorting waste

produce in school should be focus on. Image processing capability must be high in order to determine and segregate recyclable materials.

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