Drone based Solid Waste Detection using Deep Learning & Image Processing

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***Abstract*—** A significant cause of waste generation is littering. Whether intentional or unintentional, littering has an adverse impact on the environment and it also costs municipalities millions of dollars annually to clean up the waste. Traditional systems for waste management include regular waste collection by assigned groups such as the municipal corporation trucks for cities, janitors for an institution etc. Due to the shortcomings of existing waste monitoring and management systems, this paper proposes an alternative and efficient approach for waste monitoring in large. This paper presents a smart solid waste detection system which uses the motion of an Unmanned Aerial Vehicle (UAV) such as drone for waste detection based on image processing techniques which help identify places contaminated with waste and sends the location coordinates as a notification. This system uses the concepts of deep learning, image stitching and image processing through feature extraction. In the last section, we will discuss the future applications of this smart system which will tackle both garbage detection and collection. Finally, the future scope and relevance of this system will be discussed.

Keywords—*solid waste detection, waste management, UAV, drone, image processing, litter, deep learning*

I. INTRODUCTION

Solid waste management has been a major concern for a long time. India produces 42.0 million tons of Municipal Solid Waste (MSW) annually at present. According to a recent consensus, the per capita waste generation in India is increasing at a rate of 1.3% per annum. Garbage generated annually across the globe amounts to billions of tons today, with almost one lakh metric tons of garbage generated in India per day. This can cause a major impact on the environment. With urbanization in India, the scale of cities and the number of residents is rising and with it is increasing the amount of urban waste generated [1][2][3].

Often the presence of litter in a given area results in the intentional throwing of litter at that particular spot as it gives the impression that it is a right place for discarding the waste. Throwing kitchen generated waste out of the window or chucking chewing gum wrappers along the roadside for instance, without realizing the harmful effects it might have on the environment have become a commonplace. It costs residents, local, state and federal governments millions of dollars to pick up litter, reverse the effects of littering and prevent it. Municipal solid waste (MSW) management includes collection, storage, transportation and disposal of solid waste. Poor collection and inadequate transportation leads to heap of MSW at many places, which causes health and environmental problems. Governments across the world are making efforts to improve solid waste management in their respective countries. [4] The accumulated waste causes environmental problems such as the spread of pest species and diseases, marine plastic pollution, damage to wildlife ecosystems and toxicity in the land/waterways.

While most urban waste management systems in place are designed for regular collection of waste from fixed locations at regular intervals, there are certain places (remotely located) which go unnoticed and are therefore, not cleaned. Many solutions have been designed for effective garbage management. There are applications available on the Google Play Store which allow the user to send an alert message to the municipal corporation about the status of the garbage container. However, this process is time-consuming as it relies on human discretion and action and communication via an intermediary. A better solution designed for this problem is to use sensors for obtaining information

about the level of garbage in containers and provide alert messages to the Garbage Collector Truck about the level of waste in a garbage container. Nonetheless, the problem of waste accumulation in remote places persists. Thus, it is crucial to detect and manage litter accumulation at remote and undesired locations with little or no human interference.

Through extensive background study and data collection, it can be concluded that most of the current automated waste management systems rely on IoT and hardware devices such as infrared sensor, ultrasonic sensor, metal sensor, etc. for detection of garbage and subsequent communication of the bin status. Other than this, there are waste sorting systems based on image processing which identify metal materials or other special types of waste. However, these become dysfunctional in case of paper and plastic products. Moreover, there are very few existing artificially intelligent systems which are self-sufficient for waste classification. With a combined approach consisting of the hardware devices such as a drone, Arduino, GPS and GSM module and image processing software algorithms, this paper offers a better and innovative solution to the problem of effective waste detection and management in wide and remote areas.
This system aims to achieve the following:

- To capture Ariel view images using Drone and further process the same to identify solid waste disposed at inappropriate places
- To notify the respective person-in-charge for taking the necessary action to clean the litter/solid waste
- Help maintain cleanliness in places such as beaches, institutions, cities etc.

II. BACKGROUND

A. UAV

Drones are Unmanned Aerial Vehicles (UAV) which operate without a human pilot aboard. They can either be flown using a ground-based remote controller operated by a human or autonomously by onboard computers. They are mostly used in military, commercial, scientific, agricultural, peacekeeping and other applications. They have the ability to navigate through large and remote places which security cameras otherwise fail to cover. The drone that will be used in this project is an assembled flamewheel 450 mm model equipped with first-person-view camera. The utilization of the drone will allow for real-time transmission of video image set to be analyzed by the litter detection deep learning framework.

B. Image Stitching

Image Stitching is a technique used for attaining high-resolution panoramic image from multiple images combined together. Image stitching techniques can either be direct intensity-based or feature based. This project focuses on using feature-based image stitching algorithms such as Scale Invariant Feature Transformation (SIFT) to determine a relationship between the images through distinct features extracted from the processed images. Snapshots from the live video feed captured with the help of the drone will be taken at regular intervals and stitched together for further analysis.

C. Deep Learning and Computer Vision

Concepts of Deep Learning and Computer Vision have been used in this project to achieve the automated detection of litter. Deep learning is a subpart of Artificial Intelligence (AI) which is concerned with emulating the learning approach that humans use to gain knowledge from data patterns. In contrast to machine learning algorithms, deep which are supervised and linear, deep learning algorithms are stacked in a hierarchy of increasing complexity and abstraction. The advantage of deep learning is that the program builds the feature set by itself without any sort of

human supervision and hence are generally faster and more accurate. A Deep Neural Network (DNN) is a neural network with a certain level of complexity, they have multiple layers between the input and output layers. The DNN finds the correct mathematical manipulation to turn the input into the output. Deep learning within the field of Computer Vision is concerned with the automatic derivation of useful information from visual data. Image Processing can be done using 'TensorFlow', a dataflow framework developed by Google for high performance computation. Tensor Flow object recognition algorithms are used to classify and identify arbitrary objects within larger panoramic images obtained from multiple datasets. TensorFlow is well suited for deploying deep learning models.

D. Python

Python is a high-level object-oriented programming language with emphasis on code readability and built-in libraries to provide various functionalities. Being a general purpose programming language, it provides powerful implementations to facilitate large data and advanced calculations with libraries such as TensorFlow, Scipy, Scikit-Learn, and NumPy. Tensorflow and Scikit-Learn are libraries that provide various machine learning frameworks and algorithms, such as neural networks and support vector machines. TensorBoard is a suite of visualization tools that make it easier to understand, debug, and optimize TensorFlow programs. NumPy is a library for applying various advanced mathematical functions with arrays and matrices, both key components of machine learning algorithms. Scipy is the optimized core package for scientific routines in Python; it is meant to operate efficiently on NumPy arrays, so that Numpy and Scipy work hand in hand. To use computer vision, Python was also implemented with Scikit-Image and OpenCV. These libraries provide important image manipulation tools computer vision techniques, such as feature extraction and image classification.

E. Hardware Components

Arduino is a programmable controller which can be used for handling file transfer operations. It can "talk", (transmit or receive data) via a serial channel, so any other device with serial capabilities can communicate with an Arduino. The drone will be fixed with an arduino to facilitate the interfacing of other hardware components such as a Global System for Mobile Communication (GSM) and Global Positioning System (GPS) modules. The GSM can be integrated with the Arduino to connect with the computer system over a network and communicate. A GPS module integrated with the drone will fetch coordinates (latitude and longitude) of the places that the drone will fly through.

F. Cloud Platform

A cloud platform allows for data storage, remote access and encapsulates various tools for data analytics and machine learning. A cloud platform such as Amazon Web Services (AWS) Elastic Cloud 2 (EC2) instance will be used to store the serially transmitted location coordinates (recorded by the GPS module) sent via the GSM module integrated with the drone. The use of cloud is to allow remote file transfer and further processing of the data recorded for comparison purposes.

III. EXISTING SYSTEMS

A. Waste Monitoring and Management Systems

In the past decade, many smart solutions for waste detection and management involving the use of IoT have emerged. These systems use mechanisms to check for the status of garbage containers and eventually indicate the same to the respective in-charge. RFID technology is used for collection of

data regarding garbage container in [5]. RFID tag works to detect within the frequency range and when any tag comes to the range of RFID reader, it automatically reads data from RFID reader, then filters collected data and arranges it into specific formatted SMS. Subsequently, the data is sent to central server sends the information to the web server as well as authorized person's mobile phone. A similar system design is described in [6] is which uses RFID technology to avoid overflow of the bin by sending an alert message. It uses Arduino Uno R3 as a microcontroller for reading data from sensors. When RFID tag interrupts the RFID reader, the sensor will check the status of the bin and send it to the web server.

Another paper on waste management [7] uses ultrasonic sensor to detect the level of garbage in the bin and communicates to control room using GSM system. Four IR sensors are used to detect the level of the garbage bin. When the bin is full the output of the fourth IR is active low and this output is given to microcontroller to send a message to control room through GSM. A similar system [8] consists of waste bins equipped with ultrasonic sensors which are interfaced with Arduino Uno and a Wi-Fi module which collect the waste fill level status and upload the data to database. This data appears on the android application which notifies the appropriate collector client based on their location once the bin gets filled up. [9] introduces an Android app, SpotGarbage that can automatically detect and localize regions containing garbage in user-clicked unconstrained geo-tagged real-world images. The app utilizes the proposed fully convolutional network, GarbNet for coarsely segmenting image regions containing garbage and the locations of the images classified as garbage are marked and plotted on Google Maps.

In this paper [10] ZigBee, GSM and ARM7 controller is used to monitor the garbage bin level. When garbage bin is full, this message of garbage level is sent to ARM7 controller. Then ARM7 will send the SMS through GSM to authority as to which bin is overflowing and requires cleaning up. [11] uses a Raspberry Pi to capture images and performs image processing using edge detection algorithm to identify waste. The detection is based on computer vision and is carried out with the help of camera and opt couplers. Waste is then collected by a vacuum unit which takes all the garbage and cleans the area. A related framework is described in [12] which consists of two parts, one of which is the hardware platform with Raspberry Pi as the core module and the other is the software platform based on SURF-BoW and multi-class SVM algorithm. This paper demonstrates the effectiveness of Bag of Visual Words algorithm in image processing.

B. Surveillance Systems

Drones are unmanned aerial vehicles which often find their application in surveillance and monitoring of wide areas and remote places which are otherwise inaccessible. [13] describes a smart transport infrastructure system based on drones and feature extraction techniques to determine the level of traffic congestion on roads and also indicates vacant parking slots in a particular area. This system is an instance of the accuracy and feasibility of using drone based image processing to achieve useful results. A similar approach is discussed in [14] where a custom-built drone is used to capture images of large fields, crops in particular, to determine the type of soil present in a specific area. Image processing is used for classification of images with reference to a predefined train dataset. This paper suggests the possibility of using a GSM integrated drone for instant processing of captured images on a system upon retrieval. Using a GSM would be beneficial as it has no range limit of transmission which is useful for real-time processing. This paper [15] presents the design and implementation of SkyStitch, a multi-UAV-based video surveillance system that supports real-time video stitching implemented using commercial off-the-shelf hardware. It addresses two key design challenges: (i) the high computational cost of stitching and (ii) the difficulty of ensuring good stitching quality under dynamic conditions. Deriving valuable insights from the past works, we aim to build a system which takes live video feed recorded by drone as input which can be retrieved by the system in real-time for image processing and feature extraction to identify and classify images of

garbage into various categories. The presence of a GSM (communication) and GPS (georeferencing) module allows for real time communication and location tracking.

IV. PROPOSED SYSTEM

As part of the proposed solution, the focus of this project is to build a system which takes a live video feed (or multiple images) captured by a drone as its inputs and extracts information from the images in order to identify places contaminated with solid waste/litter. The drone would capture a wide area such as a college campus or a locality and provide an aerial view of the location. The drone will be made to transfer the visual data recorded by it to the local server which is a computer system performing the processing operations. Arduino will be used for handling file transfer operations which will allow for real time retrieval of captured images. GSM and GPS module placed over the drone would provide the functionality of mobile communication and real time location referencing. With the help of image stitching techniques, the live video feed will be stitched based on similar features producing panoramic images of a place. This data can then be processed using Deep-Learning image processing algorithms coded in Python. The predefined dataset would encompass images of litter such as waste metal cans, bottles, crumpled paper, plastic bags etc. By testing the input data against the classes/categories of the predefined dataset in Tensor Flow framework, the algorithm will produce an output which assigns a distinct class to the given input image. The end goal is to send a notification which contains geographic coordinates (GPS based location) of the place contaminated with garbage to the respective person-in-charge prompting him/her to take the necessary action. The place coordinates corresponding to the timestamp of the output image (where litter was detected) will be fetched and subsequent message will be sent. The key components for this system include the following:

- Remote controlled Drone for surveillance and capturing images
- Arduino for managing the captured images and handling file operations
- Python IDE to run Python based programs
- Interfacing circuitry for making the connections
- GPS and GSM module for position tracking and communication respectively

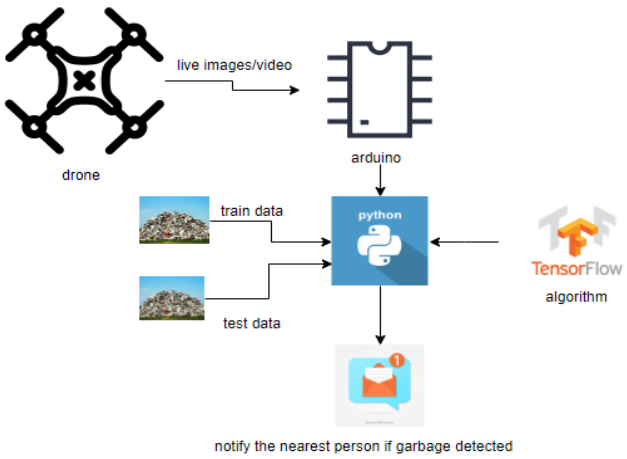

Fig. 1. Working of the proposed garbage monitoring system

The general working of the proposed system containing the hardware and software components has been shown above in fig 1.

V. EXPERIMENTAL PROCEDURE

The popular machine learning techniques such as SIFT and Bag of Visual Words (BoVW) have been used extensively for image processing through feature extraction over the past decade.

TensorFlow based algorithm on the other hand is relatively new as it was developed by Google recently. Being specialized for numerical computation and large-scale machine learning, TensorFlow provides a convenient front-end API for building applications with the framework. After performing image processing using both BoVW (which includes SIFT for feature extraction and BoVW for vocabulary formation) and TensorFlow, it was concluded that Tensor Flow is more efficient and performs better among the two for image processing and classification. The algorithms were tested using a sample dataset of images of trash taken from GitHub. The output images of TensorFlow algorithm are shown in fig 2.

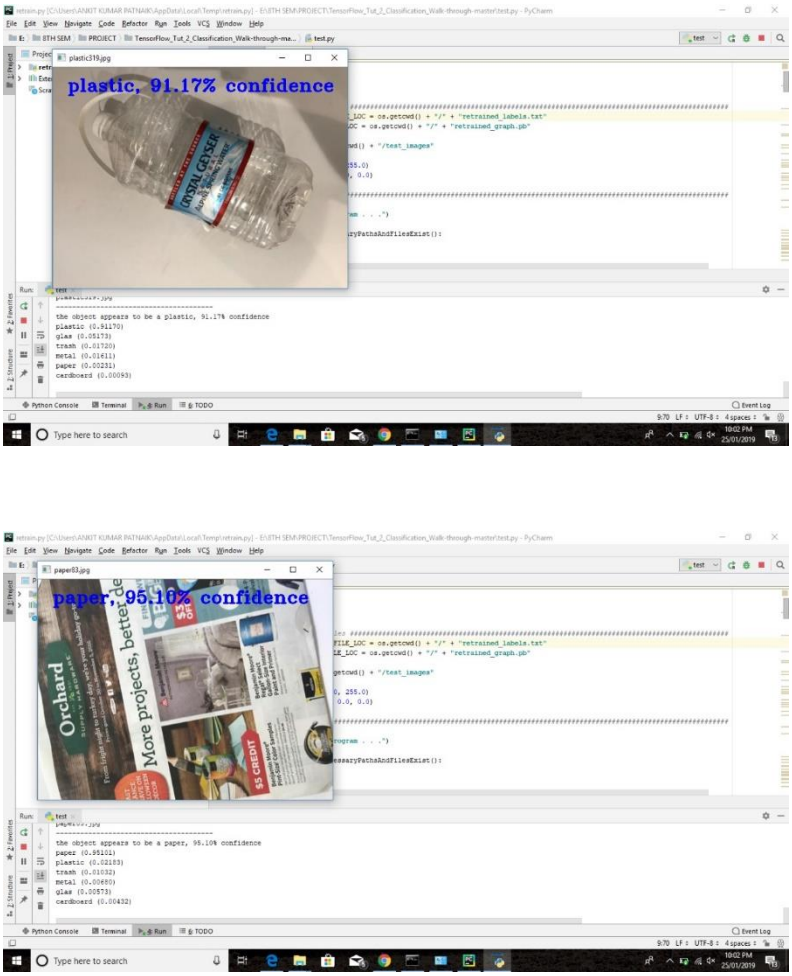

Fig 2: Output images of TensorFlow algorithm, displaying the classification of the given objects as trash with the confidence percentage

In a similar manner, Image Stitching algorithm was implemented using sample aerial images taken using first-person view (FPV) camera. OpenCV is an image and video processing library present in Python with SIFT functionalities which are used for feature extraction and image classification. Based on opencv_contrib's SIFT descriptor, the images are stitched together into a single panorama. The input images are shown in fig 3. Fig 4 shows the output of the image stitching algorithm which is a stitched image. Image stitching is needed in order to stitch the images taken by the drone in order to provide a 180 degree panoramic view of a specific location which will be used for detecting the presence of waste in the location. Real-time implementation of the algorithms will be done using images taken from the drone.

Fig 3: Input aerial images (left, centre, right) taken from FPV camera

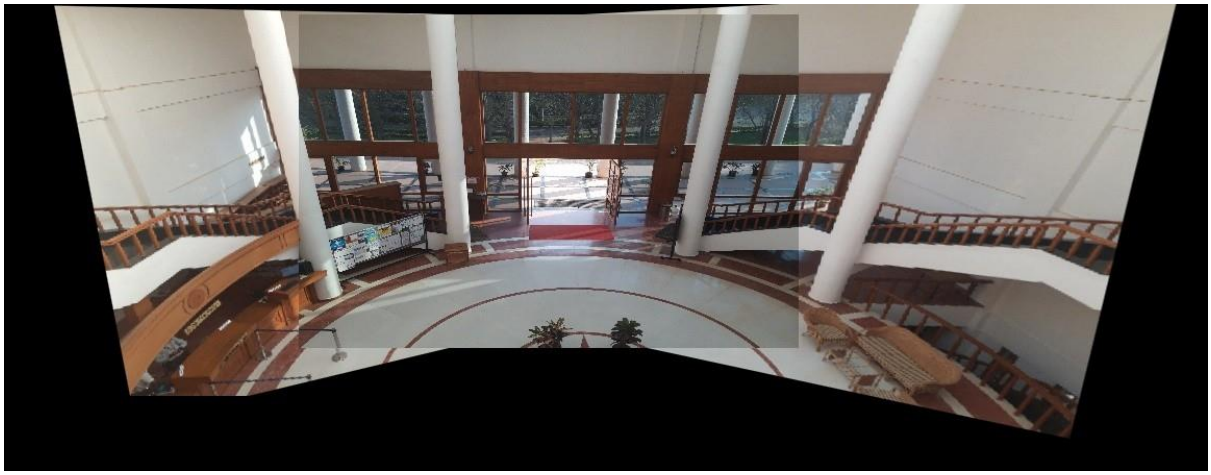

Fig 4: Stitched image output

VI. CONCLUSION

As this system is entirely automated, it will be efficient and applicable to all environments. The use of a drone adds to effective monitoring of waste as it removes the need for humans to manually travel to places for surveillance. This system offers the benefits of maintaining cleanliness in the surroundings and the environment. Waste accumulation in undesirable places can be minimized, even eliminated and waste management can be improved to a great extent. The implementation of this system will also assist organizations in effectively managing waste in remote places.

However, despite its benefits, this project specifically focuses on waste monitoring while waste disposal and cleaning remain out of its scope. Therefore, future works can be based on developing an automated robotic system to handle the waste detected. A robotic garbage collector can be integrated

with the drone. The collector can be essentially be programmed to receive inputs from the drone about the type of garbage detected upon which the collector will clean up the litter, segregate the waste into recyclable and non-recyclable materials. Disposal of this waste will also be looked after by the robotic garbage collector. Such an integrated system would complete the entire process of waste detection and collection single handedly without requiring human interference.

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