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Environmental Sanitation Monitoring System Using Drone and Artificial Intelligence

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Abstract

In addition to indiscriminate waste disposal, non-cleaning of residential, business, and governmental environments is also a major part of the environmental challenges faced by many countries across the globe, especially developing countries in Asia and Africa. Most of these countries have proper environmental laws and policies, but they are inactive. In Nigeria, factors such as corruption, inadequacy of environmental impact assessment, ignorance, limitations of the legal framework, institutional bottlenecks, inadequacy of funding, and insufficient use of technology significantly make the environmental laws ineffective. Some states in Nigeria, like Kano, Lagos, Enugu, e.t.c., are organizing compulsory monthly sanitation exercises on the last Saturday of every month to clean up the streets, commercial, residential, educational, and government environments. Most people, however, did not participate in the exercise, and due to the large size of the cities and an insufficient number of sanitation exercise supervisors, the government, in some cases, found it very difficult to know which places were cleaned up and which were not. In this research, we developed a new environmental sanitation monitoring system using drones, artificial intelligence, and an alert system.

Keywords: Drone, Sanitation, Deep Learning, Artificial Intelligence, Environment

INTRODUCTION

According to Akindutire et al. [1], one of the most commonly accepted indicators for assessing the level of development of any nation is the efficient management of its waste. Ezechi et al. [3] define waste as the useless and unwanted product of human domestic and industrial activities released into the environment. It can be a solid, liquid, semi-solid, or gaseous material container. Therefore, the unlawful manner of dumping solid waste such as garbage, sludge from water supply or manufacturing waste, air pollution control facilities, and other unusable materials without considering the adverse effect on human health is called "indiscriminate solid waste disposal [2]. Most solid wastes are also gotten from industrial chemicals, radioactive substances, and many households make use of open areas, highways, uncompleted buildings, and bushes as their dumping sites. In Nigeria today, illegal dumping of refuse, mostly in industrial and municipal areas, has become a major issue of concern to humanity and the environment [2]. The present environmental pollution derived from solid waste littering has created a lot of health challenges for household residents around the dumping sites. It is evident that most of the people living around the dumping location are not aware of the harmful effects of refuse dumping other than the offensive odors spreading around the untidy environment and also when the waste becomes wet and starts to decay. Urbanization, overpopulation, and the industrial revolution have all contributed to waste generation and inappropriate disposal methods, particularly in Nigeria's urban areas. This unlawful act has triggered more health risks to the populace, which consequently affects their entire livelihood and their major landscape. Lack of appropriate storage facilities, inadequate waste management and planning, wrong perceptions by residents, and nonchalant attitudes towards environmental cleaning and sanitation might be a cause of this problem. When an environment is not hygienic and clean It poses a lot of harm and negative impacts on humans, especially outdoor workers and those producing infectious materials, while young children get easily contacted and are most vulnerable to this act of ignorance and dirtiness [4]. The result of indiscriminate solid waste disposal exposes humans to environmental degradation such as flooding, drainage obstruction, the spread of infectious diseases such as cholera, diarrhea [5], typhoid fever, and waterway blockage, which leads to flies, ticks, and mosquito breeding, which causes malaria and other plagues. In most remote parts of Nigeria like Kano, Lagos, Delta, Oyo, e.t.c., it has been noticed that heaps of litter are dumped in virtually all market areas, the outskirts of the cities and even on roadsides for weeks without any adequate means of waste collection either by the private sector or government. Policymakers in the country have neglected some areas and failed to carry out a thorough inspection during environmental sanitation [2]. Such an attitude is an act of indulgence and negligence on the part of waste workers or supervisors. Or maybe the number of workers and their supervisors was insufficient to carry out the task efficiently, especially in big cities; or they did not have the necessary resources or technology to do so. In many Nigerian states, sanitation is even required on an almost monthly basis, especially on the streets, markets, schools, motor parks, government and non-governmental places. However, the majority of the people, some waste workers and their supervisors, did not participate in the exercise in most cases. The government did not know where the exercise took place and was not due.

In this research, we developed an environmental monitoring system using drones and artificial intelligence with an alert system. The system will fly over the city and send the location and image frames of the places where it observes garbage.

Nowadays, we see many smart drones being developed in the market for aerial footage of land. We use these aerial video frames to perform the classification algorithm in real time and send alerts to nearby local authorities. In the last decade, there has been an exponential rise in data on the internet and in addition, the past decade has seen huge improvements in GPU hardware. These algorithms are trained on big GPUs to perform detection and recognition tasks better.

In recent years, artificial intelligence algorithms [6, 7] in the domain of computer vision. In this research work, we developed a smart surveillance system to monitor the sanitation in local streets. To accomplish this task, we have used a few computer vision techniques and algorithms. Recent work in the field of deep learning, especially with convolutional neural networks, has shown significant results in and recognition. In this task to perform garbage and clean recognition, we trained the classifier model of Resnet50 [8]. After the recognition, we perform post processing, where we collect the location GPS data for further use in alert systems. We have performed this task using a smart drone. This program was developed to be installed directly on smart drone so that the drone not only just records but also performs an alert whenever any garbage is recognized. Various challenges are present in object recognition. A few of the major issues are: partial occlusion, lower resolution cameras, inaccurate recognition, and less annotated data. Keeping all of the challenges in this task in mind, we proposed a method to address the problem and perform the detection task as efficiently as possible.

LITERATURE REVIEW

In deep learning, convolutional neural networks [9] are one of the types of neural networks that have proven great performance in areas such as image recognition and classification. ConvNets have been useful in the detection and recognition of objects. To solve computer vision tasks, various convex architectures are available, including LeNet [9], VGG16 [11], ResNets [8], and AlexNet [12]. All the architectures consist of four main operations: convolution, non-linearity activation functions, pooling, and classification (fully connected layer). ConvNets derive their name from the convolution operator. The purpose of convolution in the case of a convNet is to extract feature maps from the given input image. Convolution preserves the spatial relationship between pixels by learning image features using small squares of input data. Every image is forwarded multiple layers by performing convolutions to learn the feature maps. The size of the feature map is controlled by the number of filters, padding, and strides. After every convolutional layer, an activation function is used to introduce non-linearity in our ConvNet, since most of the real-world data we would want our ConvNet to learn would be non-linear. The most widely used activation function is ReLU. It stands for Rectified Lin-ear Unit. ReLU is an element-wise operation applied per pixel and replaces all negative pixel values in the feature map by zero. Pooling, also called subsampling or downsampling, is used to reduce the dimensionality of each feature map, but it retains the most important information. Pooling is of various types, such as max, average, and global average pooling. In the case of Max Pooling, we define a spatial neighborhood, for example, a 2x2 window, and take the largest element from the rectified feature map within that window, discarding all the other minimum values. Instead of taking the largest element, we could also take the average of the elements in the window by average pooling. In practice, Max Pooling has been shown to work better to learn discriminative features for image recognition. Finally, the FC layer, as the name implies, connects every neuron in the previous layer to every neuron in the next layer. It uses a softmax function in the output layer. The outputs from all the convolutional layers and pooling layers that have learnt deep features are forwarded to the fully connected layer to classify the given input image. Here, a softmax layer at the end of fully connected layer gives the probability scores of the input image identity.

Object classification algorithms

In this section, we will discuss various object classification algorithms and reasons for choosing a specific algorithm. There are various deep learning models like LeNet, VGG16, ResNets, and AlexNet. Let's discuss in brief each of them.

In the year 1998, Yann LeCun and et al. proposed Lenet-5 in the research paper titled "Gradient-Based Learning Applied to Document Recognition". They used this architecture to recognize handwritten and machine-printed characters. This was all about the Lenet-5 architecture. Finally, to summarize, the network has five layers with learnable parameters. The input to the model is a grayscale image. It has three convolution layers, two average pooling layers, and two fully connected layers with a SoftMax classifier. The number of trainable parameters is 60000.

VGG16 is a convolution neural net (CNN) architecture which was used to win the ILSVR (Imagenet) competition in 2014. It is regarded as one of the best vision model architectures available to date. The most unique thing about VGG16 is that instead of having a large number of hyper-parameters, they focused on having convolution layers of a 3x3 filter with a stride 1 and always used the same padding and maxpool layer of a 2×2 filter with a stride 2. It follows this arrangement of convolution and max pool layers consistently throughout the whole architecture. In the end, it has 2 FC (fully connected layers) followed by a softmax for output. The 16 in VGG16 refers to it having 16 layers that have weights. This network is a pretty large network and it has about 138 million (approximate) parameters.

ResNet, short for Residual Network, is a specific type of neural network that was introduced in 2015 by Kaiming He, Xiangyu Zhang, Shaoqing Ren, and Jian Sun in their paper "Deep Residual Learning for Image Recognition". The ResNet [3] models were extremely successful It has won first place in the ILSVRC 2015 classification competition with a top-5 error rate of 3.57% (an ensemble model) and won first place in the ILSVRC and COCO 2015 competitions in ImageNet Detection, ImageNet localization, Coco detection, and Coco segmentation. Replacing VGG-16 layers in Faster R-CNN with ResNet-101 They observed a relative improvement of 28%. Efficiently trained networks with 100 layers and 1000 layers also.

AlexNet famously won the 2012 ImageNet LSVRC-2012 competition by a large margin (15.3% vs 26.2% (second place) error rates). The major highlights of the paper are that it used ReLU instead of tanh to add non-linearity. It used dropout instead of regularization to deal with overfitting. Overlap pooling was used to reduce the size of the network.

Above all the above models, ResNet was used for this work to develop garbage recognition. One of the problems ResNets solve is the vanishing gradient. This is because when the network is too deep, the gradients from where the loss function is calculated easily shrink to zero after several applications of the chain rule. This results in the weights never updating their values, and therefore, no learning is being performed. With ResNets, the gradients can flow directly through the skip connections backwards from later layers to the initial filters. Therefore, we have chosen Resnet for better accuracy and speed.

METHODOLOGY

For this task to be performed, we need a drone equipped with a high resolution RGB camera along with GPS sensors, and a local computer with any operating system installed to process all the video streams captured from the drone equipped with a camera and also collect GPS data simultaneously in order to send email alerts via an API (Application Program Interface) running on the local computer.

Proposed Pipeline

In order to achieve the goal of this work, we proposed a pipeline shown in fig. 1:

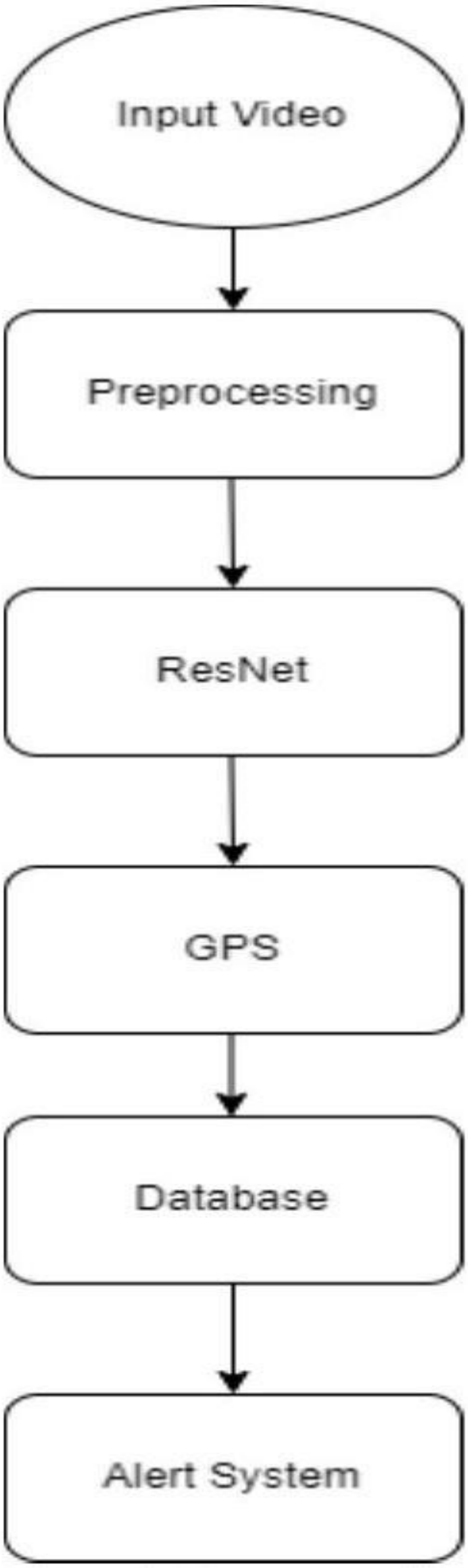

Fig. 1: Proposed Pipeline

Pre-processing - Before sending the video frames to the Resnet classification model, we perform a few preprocessing steps for better results. In our task, we have smoothened the frames using a gaussian filter and further resized the images according to the input shape of the model.

ResNet - In this step, each processed image from Step 1 is forwarded to the trained ResNet model. The output of the model is an image with classification labels.

GPS Location - Since we have an alert system that sends an alert to the appropriate local authorities, we need a GPS location that will be sent to the local authorities. So, when unhygienic garbage is detected, the system will send an email alert to the appropriate authorities. The email alert contains the GPS location of the detected unhygienic garbage and is attached with an image frame of the detected garbage.

Database - All the data captured by the drone during the flight is streamed through WIFI to a local computer. These frames are stored in a local database and they are used as an input to classification algorithms. GPS data is saved in a local database for future use by the alerting system to send alerts.

Alert System - We have an API that sends email notifications to the nearest local authorities whenever garbage is detected. This specific image frame, along with its respective location coordinates, is attached and sent to the nearby local authorities via email.

RESULT

In this section, we will discuss the results. Our model was trained with two labels, namely "clean" and "garbage." Fig. 2, Fig. 3, Fig. 5, and Fig. 6 are the confusion matrix, training and validation accuracies, ROC curve, and result outputs respectively.

Fig. 2 is the confusion matrix of our trained model. A confusion matrix, also known as an error matrix, is a specific table layout that allows visualization of the performance of an algorithm, typically supervised learning. Each row of the matrix represents the instances in an actual class, while each column represents the instances in a predicted class or vice versa.

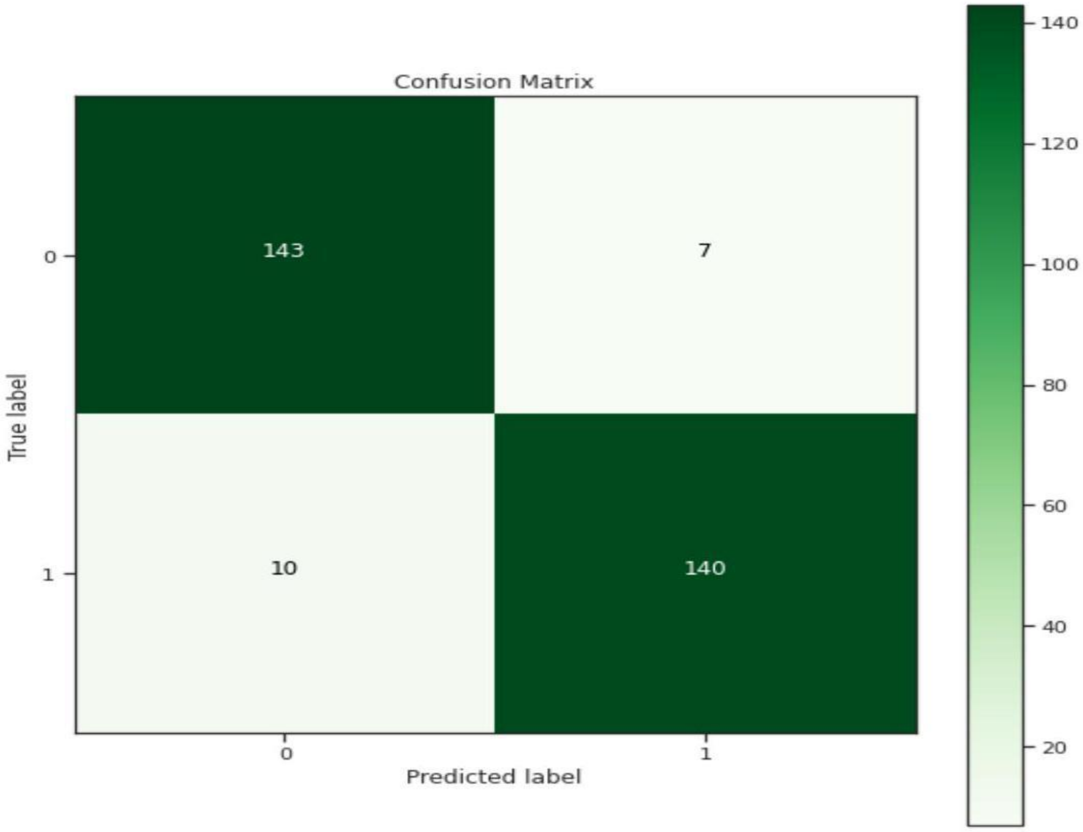

Fig. 2: Confusion matrix

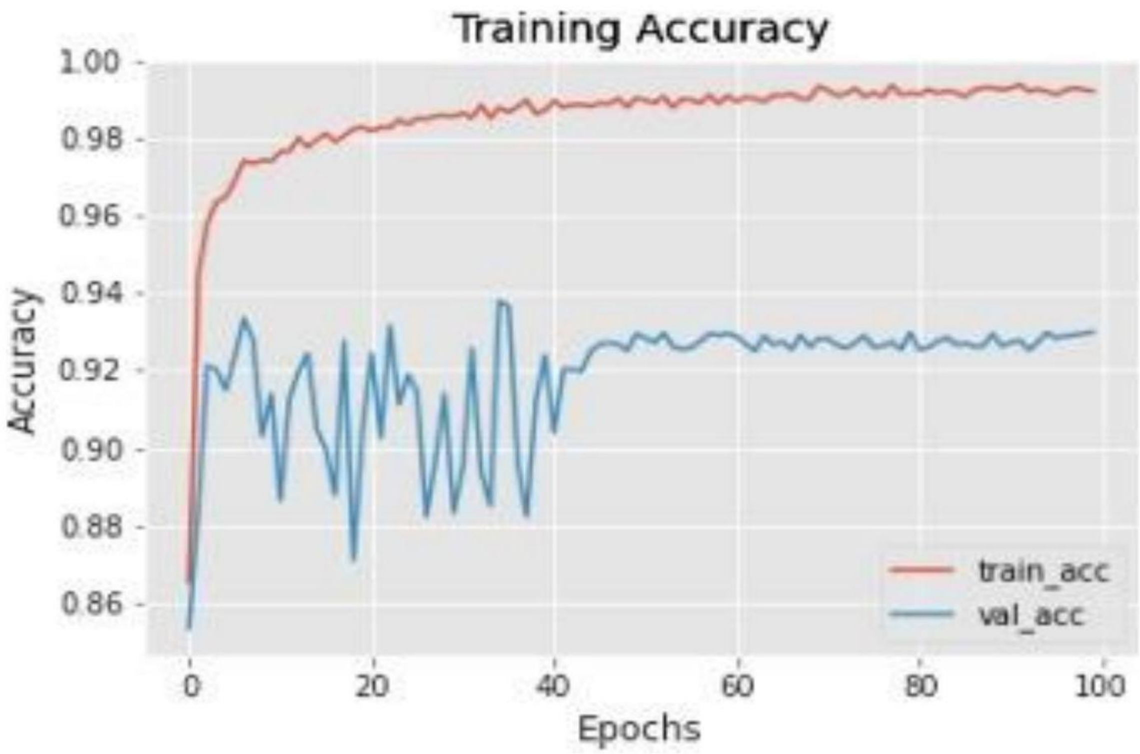

Fig. 3: Training curves and Validation Accuracies

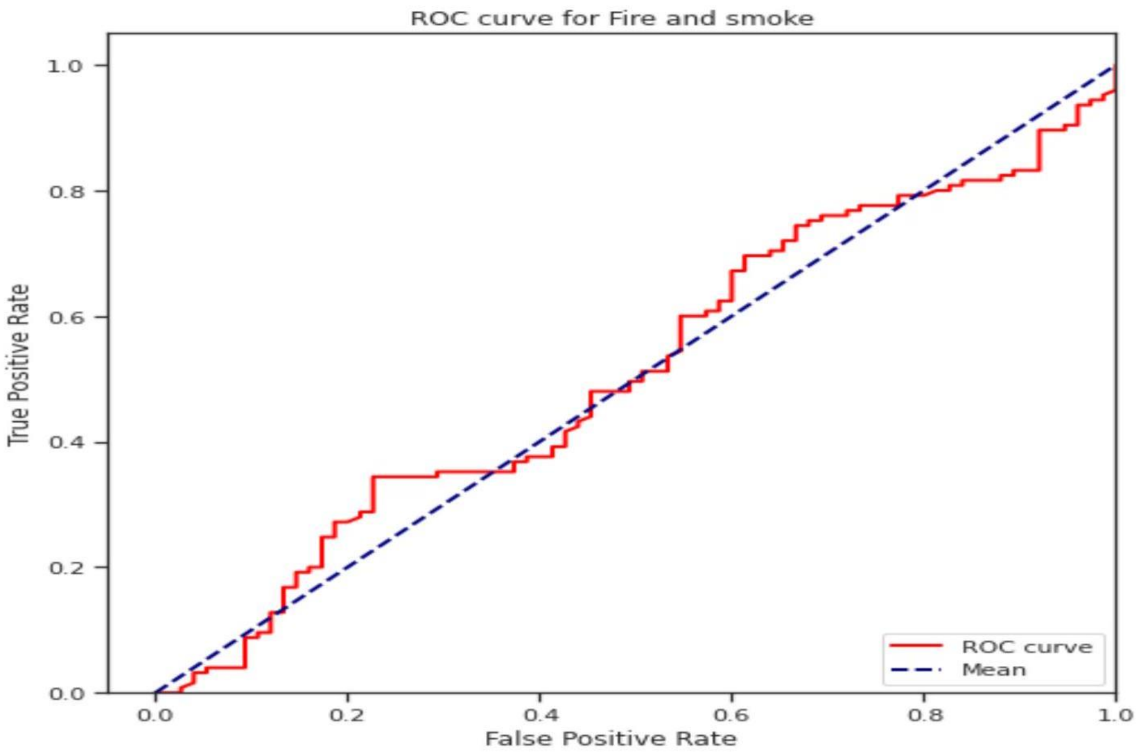

Fig. 4: ROC curve

The Receiver Operating Characteristic curve (ROC curve): is a graph showing the performance of a classification model at all classification threshold. This curve plots two parameters:
True positive rate
False positive rate
True Positive Rate (TPR) is a synonym for recall and defined as:

$$\mathrm{TPR} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}$$

False Positive Rate (FPR) defined as:

$$\mathrm{FPR} = \frac{\mathrm{FP}}{\mathrm{FP} + \mathrm{TN}}$$

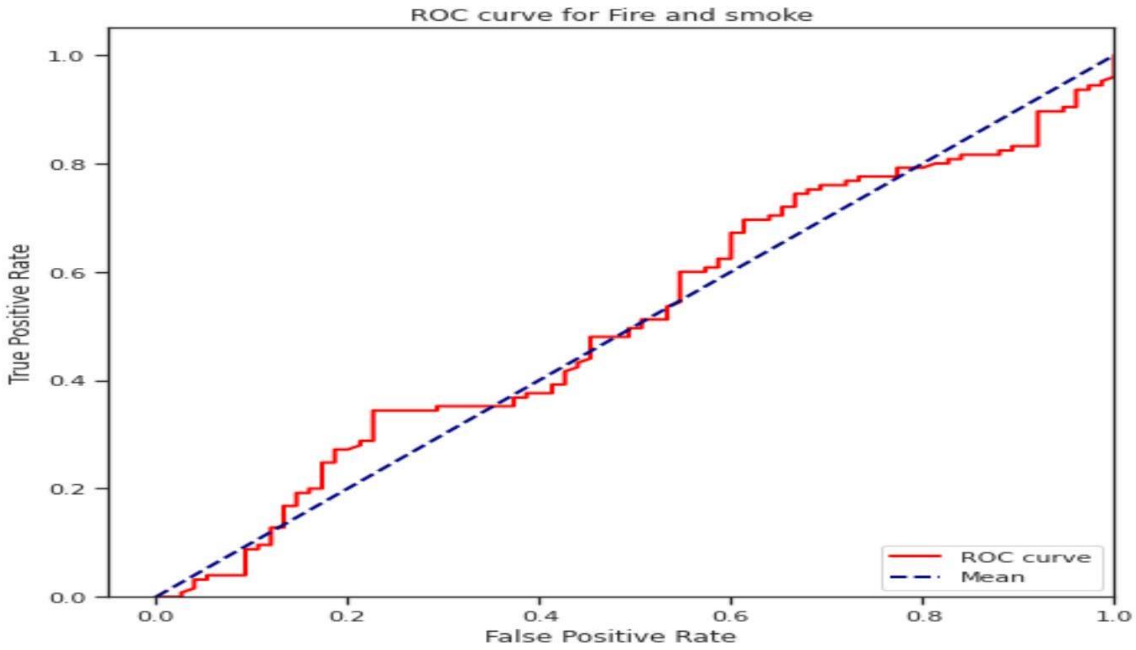

Fig. 5: ROC curve

Fig.7: Clean and Garbage results

Discussion

Over all, this project performs clean and garbage recognition and sends alerts to appropriate authorities. Although our system performs recognition tasks, due to the huge data of aerial images, the real-time scenario needs huge computation power. As we all know, most drones are lightweight and have less powerful hardware. As a result, in the future, we would like to stream aerial data directly to clouds, compute in the cloud, and transmit the results via cloud technologies. In this work, we have used Wi-Fi to stream the data from the drone to our local computer, but as we know, Wi-Fi has a short range, so the data cannot stream when the drone takes further flight from the local station. For that, in our future work, we will stream the aerial data directly to the cloud, compute in the cloud, and transmit the results via cloud technology in real time.

Conclusion

In this work, we have developed a garbage and clean alerting system that performs garbage and clean recognition using drones and artificial intelligence and sends alerts to the local authorities for taking necessary action.

ACKNOWLEDGMENT

In this work, we acknowledge the various datasets that used and have annotated them manually with labels. Some of the datasets we have used are from Kaggle, such as the garbage and clean [13, 14] datasets.

References

1. Akindutire, I. O., and E. O. Alebiosu. "Environmental risk factors of indiscriminate refuse disposal in Ekiti State, Nigeria." IOSR Journal of Research and Method in Education 4.5 (2014): 54-59.
2. Ifeoluwa, Ogunniran Blessing. "Harmful effects and management of indiscriminate solid waste disposal on human and its environment in Nigeria: A Review." Global Journal of Research and Review 6.1 (2019): 1-4.
3. Ezechi EH, Nwabuko CG, Enyinnaya OC, Babington CJ (2017) Municipal Solid waste Management in Aba, Nigeria: Challenge and Prospects. Environ Eng Res 22: 231-236.
4. Yan X, Sankoh FP, Tran Q (2013) Environmental and Health Impact of solid waste disposal in developing cities: A case study of Canville Brook Dumpsite, Freetown, Sierra Leone. J Environ Protection 4: 665-670.
5. Yongsi HBN (2008) Environmental Sanitation Risks on Tropical Urban Settlings: Case Study of household refuse and diarrhea in YaoundeCameroon. Int J Human Soc Sci.
6. Fujita, Hamido. (2022). Advances and Trends in Artificial Intelligence. Theory and Practices in Artificial Intelligence. 10.1007/978-3-031-08530-7.
7. (2022). Intelligence of Artificial Intelligence: Philosophy. 10.31219/osf.io/d9fe3.
8. He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep Residual Learning for Image Recognition. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR).
9. Alex Krizhevsky, Ilya Sutskever, and Geoffrey E. Hinton. Imagenet classification with deep convolutional neural networks. In F. Pereira, C. J. C. Burges, L. Bottou, and K. Q. Weinberger, editors, Advances in Neural Information Processing Systems 25, pages 1097– 1105. Curran Associates, Inc., 2012.
10. El-Sawy A, El-Bakry H, Loey M. CNN for handwritten arabic digits recognition based on LeNet-5. IInternational conference on advanced intelligent systems and informatics 2016 Oct 24 (pp. 566-575). Springer, Cham.
11. Simonyan K, Zisserman A. Very deep convolutional networks for large-scale image recognition. arXiv preprint arXiv:1409.1556. 2014 Sep 4.
12. Iandola FN, Han S, Moskewicz MW, Ashraf K, Dally WJ, Keutzer K. SqueezeNet: AlexNet-level accuracy with 50x fewer parameters and< 0.5 MB model size. arXiv preprint arXiv:1602.07360. 2016 Feb 24.
13. https://www.kaggle.com/code/kneroma/clean-planet-trash-detection-dataset
14. https://www.kaggle.com/datasets/rodrigolaguna/clean-dirty-containers-in-montevideo

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