Optical Sky Scanner

By

Capt Adnan Tariq

Capt Omar Mueen

Capt Hassan Farooq

Capt Malik Ameer Hamza

Supervised by:

Lt Col Dr. Hasnat Khurshid

Submitted to the faculty of Department of Electrical Engineering,

Military College of Signals, National University of Sciences and Technology, Islamabad,

in partial fulfillment for the requirements of B.E Degree in Electrical (Telecom) Engineering.

May 2022

In the name of ALLAH, the Most benevolent, the Most Gracious

CERTIFICATE OF CORRECTNESS & APPROVAL

This is to officially state that the thesis work contained in this report

"Optical Sky Scanner"

is carried out by

Capt Adnan Tariq

Capt Omar Mueen

Capt Hassan Farooq

Capt Malik Ameer Hamza

under my supervision and that in my judgement, it is fully ample, in scope and excellence, for the degree of Bachelor of Electrical (Telecom.) Engineering in Military College of Signals, National University of Sciences and Technology (NUST), Islamabad.

Approved by

Supervisor
Assistant Professor
Lt Col Dr. Hasnat Khurshid
Department of EE, MCS
Date: ___________

DECLARATION OF ORIGINALITY

We hereby declare that no portion of work presented in this thesis has been submitted in support of another award or qualification in either this institute or anywhere else.

ACKNOWLEDGEMENTS

Allah (SWT) is the sole guidance in all domains.

Our parents, colleagues and most of all supervisor Lt Col Dr. Hasnat Khurshid without your guidance.

The group members, who through all adversities worked steadfastly.

Plagiarism Certificate (Turnitin Report)

This thesis has   similarity index. Turnitin report endorsed by Supervisor is attached.

____

Capt Adnan Tariq

NUST Serial no: 280729

____

Capt Omar Mueen

NUST Serial no: 280742

____

Capt Hassan Farooq

NUST Serial no: 280720

____

Capt Malik Ameer Hamza

NUST Serial no: 280749

____

Signature of Supervisor

ABSTRACT

This thesis explores the process of designing a detection system which have the capability to detect Drones, helicopters and airplanes using machine learning and Image processing. The modern world has advanced in technology you can find security cameras of different capabilities having zooming and detection of objects but all of them can zoom the digital image of the object to a certain limit moreover the specifications of those cameras are fix and depends upon its manufacturing company. What if you have the choice to change the specification of the camera as per your own requirement? What if your zooming capability in much more than ordinary security cameras?

In order to introduce a model in which users have the choice to change the specification of camera as required and to enhance the zooming capability of the camera plus providing Optical zoom which is far better than digital zoom we have designed a model which have the capability to scan the area up to 180 degrees in Azimuth and 180 degrees in elevation

A dataset containing 10000 images of helicopters, drones and airplanes have been used to train the model in order to recognize and detect the target object.

Table of Contents

List of Figures .... **x**

Chapter 1: Introduction **1**

1.1 Overview 2

1.2 Problem Statement 2

1.3 Proposed Solution 3

1.4 Working Principle 4

1.4.1 Datasets and annotations: 4

1.4.2 Dataset training and processing: 5

1.4.3 Output Extraction: 5

1.4.4 Decision based upon Outputs: 5

1.4.5 Integration: 6

1.4.6 Live video presentation: 6

1.5 Objectives 6

1.5.1 General Objectives: 6

1.5.2 Academic Objectives: 6

1.6 Scope 7

1.7 Deliverables 8

1.7.1 Hawk eye 8

1.7.2 Object of interest: 8

1.7.3 Special privileges: 8
1.8 Relevant Sustainable Development Goals 8
1.9 Structure of Thesis 9
Chapter 2: Literature Review 9
2.1 Background 10
2.2 Existing solutions and their drawbacks 11
2.2.1 Radar-Based Drone Detection 11
2.2.2 Acoustic-Based Drone Detection 12
2.2.3 Bi- and Multimodal Drone Detection Systems 12
Chapter 3: Interfacing and Detection 13
3.1 Proposed Methodology 13
3.2 System Architecture 16
3.3 Hardware 17
3.3.1 Webcam 18
3.3.2 Pan/tilt platform using stepper motors 18
3.3.3 Laptop 18
Chapter 5: Conclusion 19
Chapter 6: Future Work 19
References and Work Cited 20

List of Figures

Figure 1: Search trend for "drone detection" over the last ten years... 01

Figure 2: The system architecture……………………………………………………………..16

Figure 3: Optical sky scanner…………………………………………………………………..17

Chapter 1: Introduction

Small and remotely controlled unmanned aerial vehicles (UAVs), here in after referred to as drones, can be useful and of benefit for society. Examples of their usefulness are to deliver automated external defib- rollators [1], to fight fires more effectively [2] and for law enforcement purposes. Moreover, the low cost and ease of operation make drones suitable for entertainment and amusement purposes [3].

Nevertheless, such drones can also be intentionally or unintentional- ally misused, so that the safety and security of others are affected or threatened. In the worst case, this can cause severe structural damage to an aircraft if it collides mid-air with a consumer-sized drone even when flying at moderate speeds as shown by researchers at the University of Dayton [4].

Due to the rapid development of commercial and recreational drones the research area of drone detection and classification has emerged in the last few years [5] and, as can be seen in Figure 1 below, the Internet search trend for web pages with drone detection related content has been increasing over the last ten years.

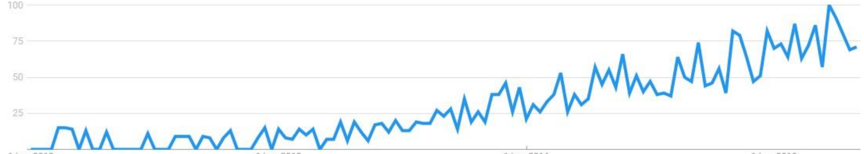

Figure 1: Search trend for "drone detection" over the last ten years.

This thesis explores the process of designing a detection system which have the capability to detect Drones, helicopters and airplanes using machine learning and Image processing. This will also include the collection and annotation of the necessary dataset to accomplish the training and evaluation of the system. Three different consumer-grade drones are included in the dataset together with birds, airplanes, and helicopters.

1.1 Overview

Recently, the interest and demand in drone are higher than ever. With this popular demand, new types of drone merchandise have been designed and manufactured. As for this shift, the commercial drone industry keeps on growing. Although commercial drones have been massively produced to satisfy the military needs, there has been some downsides to this. As it became easier to spot drones outdoors, more safety issues have been brought up as concerns. These are not merely about accidents regrading to drones harming individuals, but include drones invading government restricted areas. Additionally, considering that a coordinated fleet of drones is capable of more various tasks [6], drones can be a bigger threat than people could imagine. As there are more drones out in public, it became harder to regulate them legally and safely. For regulation, it is essential to detect and identify drones up in the sky. So, there is a need to counter such illegally entering drones and this problem direly needs to be solve in order to remain aware and alert as there has been no proper solution to this problem till date.

1.2 Problem Statement

Pakistan is a third world underdeveloped country. For drone detection, traditionally radars and acoustics systems are used, but it has many limitations that lead to ever-increasing drone detection threat on borders. Following are some highlights of the existing problems due to lack of technical advancement in drone detection system.

1. Increased use of drones in modern times
2. New technological threat on border that limits the awareness of enemy surveillance mechanism
3. Absence of Automated drone detection technology causes surveillance problems.
4. Existing detection mechanisms (Radar and acoustics) do not fulfill the requirement to detect small drones.
5. Wastage of manpower on border by applying temporary measures on borders.

1.3 Proposed Solution

The major goal of our proposed solution is to continuously monitor the drones in air that are small and cannot be detected by traditional means for all the borders of Pakistan. Traditional Radar detection and using of manpower on border to detect drones must be replaced by smart optical drone detection devices. The proposed Optical Sky scanner drone detection system is capable of scanning the area up to 180 degrees in Azimuth and 180 degrees in elevation and detecting the drones, helicopters and airplanes using image processing.

1.4 Working Principle

The project mainly works on the principles of image processing amalgamated with machine learning algorithms. The project is divided into different modulus and every module is inter-woven with the next module. The list of modules is as under:

- Datasets and annotations
- Dataset training and processing
- Output extraction
- Decision based upon Output
- Integration
- Live video presentation of detected object

1.4.1 Datasets and annotations:

An integral part of the project is the preparation of datasets. The dataset comprises of images of various type of objects present on the air: drones, airplanes, helicopter. Known Enemy Drone dataset is of pivotal important in our project. birds

1.4.1.1 COCO Dataset:

Common Objects in Context (COCO) is a labeled dataset comprising of vast sets of common life objects, mainly 4 different types. The objects of interest in COCO data set for this project are air moving objects, the proposed project extracts 4 such objects (drones, airplanes, birds, helicopters).

1.4.1.2 Custom Drone Dataset:

This project uses a custom build dataset of known enemy drones for its use. The images are gathered, filtered, and annotated to obtain coordinates of the object of interest.

1.4.2 Dataset training and processing:

The prepared dataset is used as input to train object detection models using machine learning.

1.4.2.1 YOLO algorithm:

YOLO is an abbreviation for the term 'You Only Look Once'. This is an algorithm that detects and recognizes various objects in a picture (in real-time). Object detection in YOLO is done as a regression problem and provides the class probabilities of the detected images. Our project uses YOLO (you only look once) algorithm to train the dataset, this prepares object detection model.

1.4.3 Output Extraction:

The outputs are extracted based on objects (drones, helicopters, birds, airplanes) detected, these objects are counted and stored to keep a record.

1.4.4 Decision based upon Outputs:

The extracted outputs, the count of drones in the air are used in decision making.

1.4.4.1 Range based decision:

The primary decision is based upon the range of the drones present on the air prioritization based on closer range.

1.4.5 Integration:

The different modules are then integrated in to one stand-alone entity. This stand-alone entity is essential for a compact solution.

1.4.6 Live video presentation:

The visual demonstration of the detected object is done on laptop.

1.5 Objectives

1.5.1 General Objectives:

"To build an innovative state of the art software integrated hardware prototype powered by Machine Learning (ML) and Image processing techniques, providing a Optical Sky Scanner as an object detection tool to cope up with mainly drone detection problem."

1.5.2 Academic Objectives:

- Development of a Optical Drone Detection System
- To implement Machine Learning techniques and simulate the results
- To increase productivity by working without involving man force
- To design a project that contributes to the welfare of Pak Army

1.6 Scope

The scope of this thesis is twofold: First, to explore the possibilities and limitations of designing and constructing a mount which have the capability to rotate the camera up to 180 degrees in Azimuth and 180 degrees in elevation.

The second object of the thesis is to collect, compose a dataset that contains all possible images of drones, helicopters and airplanes. This dataset should contain images of as many drones as possible. The data and the associated annotations should be in standard formats, so that the data can be imported, reviewed and even edited by others.

Thus, this thesis can be seen as incorporating all phases of designing an embedded and intelligent system. From the initial literature study, the subsequent assessment and procurement of suitable hardware components, the design and 3D-printing of parts that are not available, the programming and training of the system, and finally evaluating it and reporting the results. In this case, the thesis also includes the collection and composition of the required dataset.

A key doctrine and principle of this thesis will be that to effectively detect the sought after drones the system must also, by all possible means, detect and keep track of other flying objects that are likely to be mistaken for a drone.

1.7 Deliverables

1.7.1 Hawk eye

It serves as a hawk eye to observe and detect the drones by using a combination of image processing and machine learning techniques with the help of camera and a pre-fed data set in real time. Moreover, if we use Nikon p-900 than the zooming capability can increase up to 85x.

1.7.2 Object of interest:

It can detect the object of interest by using the same combination of image processing and machine learning techniques. By detecting the object of interest, we mean detecting the drones, helicopters, airplanes and birds especially already known drones of enemies.

1.7.3 Special privileges:

It provides the special privileges to the workforce on borders because it can cover larger area by scanning it for drones and helicopters. It will definitely reduce the employment of forces in border areas for the said purpose.

1.8 Relevant Sustainable Development Goals

Make cities and human settlements safe, resilient and sustainable.

This project is totally based on providing security to the people by detecting the objects which can harm the humanity in many ways.

1.9 Structure of Thesis

Chapter 2 Contains the literature review and the background and analysis study this thesis is based upon.

Chapter 3 Contains the design and development of the project.

Chapter 4 Contains the conclusion of the project.

Chapter 5 Highlights the future work needed to be done.

Chapter 2: Literature Review

In this section, we introduce various research relevant to our research. The content of this paper can be summarized as a drone detection and identification system based on image processing and machine learning.

Haar Feature based Cascade Classification [7] is applied for object detection. This technique has three key characteristics. One is that by using Integral Image, features used by the detector can be computed very quickly, making its computation complexity O (1). Two is the method constructing the classifier by selecting a small number important feature using a learning algorithm, yielding a very efficient classifier. Three is the method for combining increasingly more complex classifiers in cascade fashion, making it dramatically fast. Recently, deep learning has been applied in many studies in image processing field. Among the deep neural network structures, Convolutional Neural Network (CNN) has been gaining great interest because it automatically detects the important features during its learning phase. It has already shown performance breakthroughs in image classification [8] and object detection [9]. The reason why

CNN shows great performance in extracting feature is its capability in extracting abstract features. This allows it process with greater accuracy and speed [10]. In this paper, drone identification is based on supervised learning. Supervised learning is a systematically more adjusted CNN and has been applied in [11] and [12].

It has been gaining recognition by showing better performance than unsupervised learning [13]. Based on the research, we have chosen CNN to increase speed and efficiency. The two modules implemented in this system requires learning based on images. As it heavily relies on machine learning, with careful calibration and sufficient learning, the system can show better performance.

2.1 Background

In today's era, one of the major issues faced across the world is use of drones without ample procedure to tackle them. Usage of drones has led to many further problems, as discussed in Problem Statement, which increases need for a smart system. Ultimately, results in a milestone achieved by having a system to detect even the smallest drone.

Initially, Pakistan technical advancement was barren. Then, these started exporting under liberal policies resulting in increase in industrial growth due to the rapid expansion of domestic demand and encouragement for export. Despite of declination of growth, Pakistan managed to make progress and growth in the new century. And now we are inclining towards smart industries, automation, based on new technologies (Internet of

Things (IOT), Machine Learning `camera sensor attached provides good surveillance as it is a fully automated system.

2.2 Existing solutions and their drawbacks

Different solutions are previously being provided for this problem like detection through heat, sound, or metal detection via radars, but every product has some pros and cons. Following are some solutions which are already being prepared and being implemented.

- Radar-Based Drone Detection Systems
- Acoustic-Based Drone Detection
- Bi- and Multimodal Drone Detection Systems
- UAV Detection and Classification

2.2.1 Radar-Based Drone Detection

Radar is a traditional sensor that provides the robust detection of flying objects at long-range distances and almost uninfluenced performance in unfavorable light and weather conditions [14]. As radar sensors are mostly designed for detecting high velocity ballistic trajectory targets such as military drones, aircrafts, and missiles, they are not suitable to detect small commercial UAVs that fly with relatively lower non-ballistic trajectory velocities [15]. While radar sensors are well-known as reliable solutions for detection, their classification abilities are not optimal [16]. Since UAVs and birds have key characteristics that often make them difficult to distinguish, the above-mentioned drawback of radar sensors makes it an unprofitable solution for the classification task of UAVs and birds. The complexity of installation and high cost of radar sensors are other reasons that necessitate a relatively low-cost anti-drone system2.2.2 Systems using edge detection techniques

2.2.2 Acoustic-Based Drone Detection

Relatively low-cost acoustic detection systems use an array of acoustic sensors or microphones to classify specific acoustic patterns of UAV rotors, even in low visible environments [17]. However, the maximum operational range of these systems remains below 200–250 m. Additionally, sensitivity of these systems to environment noise, especially in urban or noisy loud areas and wind conditions, influences detection performance.

2.2.3 Bi- and Multimodal Drone Detection Systems

As we can see, each of these modalities has its specific limitations, and a robust anti-drone system might be complemented by fusing several modalities. In order to develop a cost-efficient drone monitoring system, some researchers [18] considered composing a sensor network with different types of sensors. Depending on the number of sensors used for the detection task, bimodal and multimodal drone detection systems can exist . To improve detection accuracy, a bimodal drone detection system can combine two different modalities such as camera array and audio assistance, camera and radar sensors, and radar and audio sensors [19]. Meanwhile, a multimodal drone detection system can be performed with the simultaneous use of acoustic arrays; optical and radar sensors; or simple radar, infrared, and visible cameras—as well as an acoustic microphone array [20]. Therefore, a maximal system performance can be achieved by fusing several drone detection modalities. However, our focus is the approach that uses camera images and computer vision algorithms.

Chapter 3: Interfacing and Detection

This chapter describes the proposed methodology and the automatic drone detection system is also outlined. First, on a system-level and thereafter in deeper detail, both regarding hardware components, how they are connected to the main computational resource, and the involved software.

As pointed out in “Most of the research in visual drone detection fails to specify the type of the acquisition device, the drone type, the detection range, and the dataset used in their research. These details are key to validate the work and make it comparable with related literature”. Hence the hardware used is initially specified in detail.

After that follows a description of the software running in the drone detection system when it is active, including the graphical user interface. The support software used for such tasks as to collect data, to set up the detectors and to evaluate the performance after training is also described. For all parts that include a machine learning feature, the training process is also presented.

Finally, the methods used for the composition of the drone detection dataset are described, including the division of the dataset ac- cording to the sensor type, target class and sensor-to-target distance bin.

3.1 Proposed Methodology

An efficient drone detection system must have the capability to both cover a large volume of airspace and at the same time have the resolution enough to distinct the drone from other objects. Combining wide and narrow field of view-cameras is one way to accomplish this. Another way, shown in [21], is to use an array of high-resolution cameras. Since this thesis incorporates only one infrared sensor, with a fixed field of view, there is no possibility to have neither a wide-angle infrared sensor or an array of such sensors. The proposed way to achieve the desired volume coverage is to have it on a moving platform. This platform can then either have objects assigned to it or search by itself, at moments in time when the sensors on it are not busy detecting and classifying objects.

To be able to react to moving objects and also to have the ability to track those, the combined time-constraints of the detection cycle and the control loop of the moving platform means that the system must work in close to real-time. Hence, all the detection and classification processes must be done efficiently and with as little delay as possible. The feedback loop of the moving platform must run at sub-second speed.

To be able to put together such a system, involving both several sensors and mechanical part makes the importance of choosing the right methods critical. While reviewing the theoretical foundations of machine learning techniques, and at the same time look at the practical results reported such methods can be found.

This thesis will utilize three machine learning techniques. Two of these are supervised, and one is unsupervised. First, it has two detectors and classifiers build around the YOLOv2-architecture [22]. Both these can be seen as a form of transfer learning since the feature extraction parts build on an already-trained network. The YOLOv2- networks are trained using a dataset with an annotated ground truth. Hereinafter, in this thesis, by detection we mean the process of both detecting the area where the object is in an image and the classification that assigns it to one of the labels or classes found in the ground truth of the training dataset.

Finally, an unsupervised technique is also used in the drone detection system. This is based on the segmentation of images using GMM background subtraction By employing this image segmentation, the system can find moving objects in the field of view of the wide-angle camera. This will also be referred to as detection even if it does not involve a classification of the object seen as in the YOLOv2- case. Since we are not providing the detector with any ground truth of what is foreground and background, this process falls under the category of unsupervised machine learning techniques.

One of the conclusions found in the related work is that to be able to detect the drones with high enough efficiency, the system must also recognize and keep track of other flying objects that are likely to be mistaken for a drone. For some of these drone-like objects, this is indigenous hard, e.g., birds. For others, it is technically possible since some of them announce their presence and location via radio. The technical system for this is the ADS-B, over which most aircraft regularly transmit messages with varied content.

Combining the data from several sensors under the time constraints described above must be kept simple and streamlined. This together with the fact that very few papers are exploring sensor fusion techniques is the motivation to have a system where the inclusion and weights of the sensors can be altered at runtime to find a feasible set- ting.

To be able to accomplish the necessary training of the detectors and classifiers, a dataset is also collected. The annotation of this is done so that the dataset can be inspected, edited, and used by others. The fact that the datasets for the thermal infrared and the visible video sensors are collected under the same conditions, and using the same targets ensures that a comparison between the two sensor types is well-founded.

3.2 System Architecture

In the Architecture we are using a webcam as a primary Optical sensor which will act as an eye to capture the image of the objects during scanning process. The live feed of the webcam would also be visible on laptop. In this project we are using laptop for image processing on python using YOLO V5. The live feed would undergo processing for which the model is trained, it will then extract the objects if any using the data base. Another part of this system is the microprocessor which is Arduino Uno in our case. Arduino is controlling the Stepper motors allowing them to rotate the webcam while scanning. The block diagrams of two systems involved in the architecture of this model are shown below

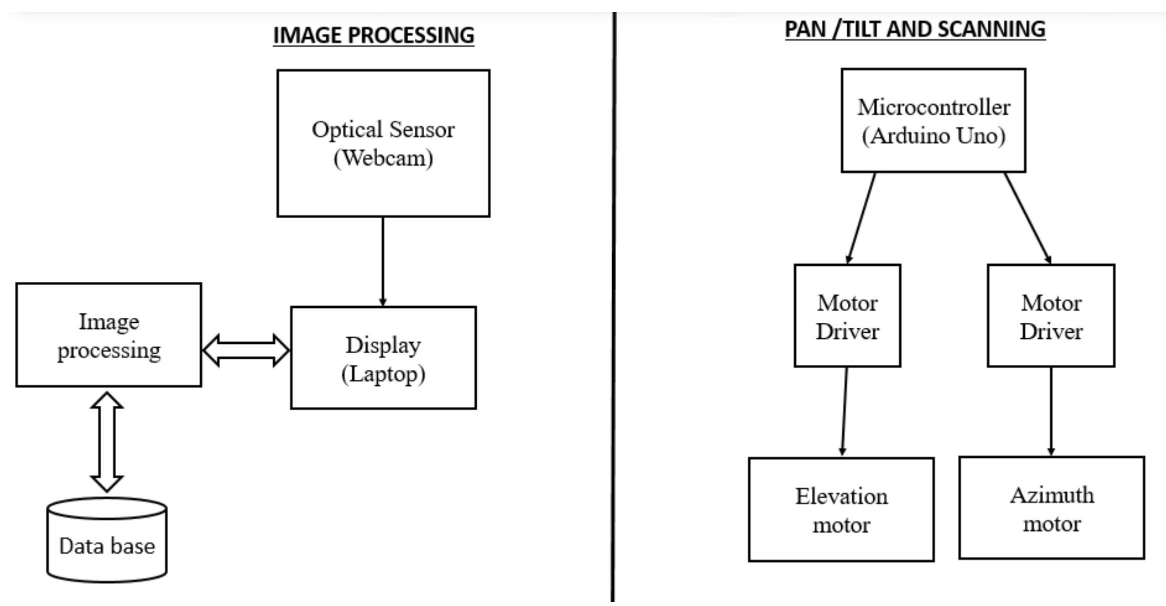

Figure 2: The system architecture

3.3 Hardware

The base of the mount is made up of Acrylic which is hard enough to bear the weight of Camera. The stepper motors are fixed with the help of screws the mount have sufficient ventilation to keep the electronic devices cool. The size of the mount is 1 square foot which makes it very handy and easy to be carried and deployed on different high locations.

Figure 3: Optical Sky Scanner

Just as in the design of any embedded system, the power consumption of the system components has also been taken into consideration, battery along with a power adapter as a standby is arranged for this purpose.

3.3.1 Webcam

A webcam is used scan the area in the visible range. While scanning the camera would read the frames and as soon as a drone comes in its way it will start highlighting its presence which would be live and can be seen on the laptop.

3.3.2 Pan/tilt platform using stepper motors

In order to detect targets in a wider field of view up to 180 degrees in azimuth and 180 in elevation, Nema 23 Stepper motors are providing pan and tilt for the camera. Both motors are connected with motor-drivers separately which are then connected to the Arduino Uno. Since Nema 23 stepper motors have 200 total steps so these are further divided into 3200 steps to increase the accuracy and make the motion of the camera free of jerks.

3.3.3 Laptop

The final presentation of the scanning and detection of the objects after the image processing of the live feed is shown on the laptop.

Chapter 5: Conclusion

In this paper, we propose an optical sky scanner for the detection and identification of objects especially Drones by making decision based on image processing and machine learning. This system has shown that even with simple artificial intelligence, the performance is very promising. All systems were actually implemented and training data were collected from the different sources. With small amount of easily collectable training data, the system still showed great accuracy, which makes it more appealing

Chapter 6: Future Work

For future work, we would like to integrate sensors which can accurately pin point the location of object in the air. We are also looking forward to introduce tracking of object by the camera once the object is detected. We will further more integrate sensors which can give continuous feedback about the current position (in form of angles) of camera while the it is in scanning mode.

References and Work Cited

1. Drone delivery of an automated external defibrillator – a mixed method simulation study of bystander experience. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 27, 2021.

2. M. Innocente and P. Grasso. Self-organising swarms of firefighting drones: Harnessing the power of collective intelligence in decentralized multi-robot systems. Journal of Computational Science, 34:80–101, 2021.

3. The World Air Sports Federation FAI. World drone racing championship. https://www.fai.org/world-cups/ drone-racing-2020, April 2020.

4. Aviation International News. What happens when a drone hits an airplane wing? About the University of Dayton research institute. https://www.youtube.com/watch?v=QH0V7kp xg0, April 2020.

5. B. Taha and A. Shoufan. Machine learning-based drone detection and classification: State-of-the-art in research. IEEE Access, 7:138669–138682, 2020

6. S. Yoo, J. Jung, A. Y. Chung, K. Kim, J. Lee, S. Park, S. K. Lee, H. K. Lee, and H. Kim, "Empowering drones teamwork with airborne network," in Advanced Information

Networking and Applications (AINA), 2017 IEEE 31st International Conference on. IEEE, 2017, pp. 678–685.

7. P. Viola and M. Jones, “Rapid object detection using a boosted cascade of simple features,” in Computer Vision and Pattern Recognition, 2001. CVPR 2001. Proceedings of the 2001 IEEE Computer Society Conference on, vol. 1. IEEE, 2001.

8. K. He, X. Zhang, S. Ren, and J. Sun, “Deep residual learning for image recognition,” in Proceedings of the IEEE conference on computer vision and pattern recognition, 2016, pp. 770–778.

9. S. Ren, K. He, R. Girshick, and J. Sun, “Faster r-cnn: Towards real-time object detection with region proposal networks,” in Advances in neural information processing systems, 2015, pp. 91–99.

10. W. Shi, J. Caballero, F. Husz´ar, J. Totz, A. P. Aitken, R. Bishop, D. Rueckert, and Z. Wang, “Real-time single image and video super resolution using an efficient sub-pixel convolutional neural network,” in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 2016, pp. 1874–1883..

11. Parthasarathi, V., Surya, M., Akshay, B., Siva, K.M. and Vasudevan, S.K., (2015). Image processing. Indian journal of Science and Technology, vol.8, no.16, p.1.

12. Ravish, R., Shenoy, D.P. and Rangaswamy, S., Camera Based object detection System. In *Proceedings of the Global AI Congress (2019)* (p. 207-221). Springer, Singapore.

13. Chattaraj, A., Bansal, S. and Chandra, A., (2009). An intelligent image processing system. *IEEE potentials*, vol.*28*, no.3, p.40-43.

14. Mohammadi, S., Rajabi, A. and Tavassoli, M., (2012). Technology and neural network. In *Advanced Materials Research*, vol. 433, p. 740-745. Trans Tech Publications Ltd.

15. Rajesh, G., Raajini, X.M. and Dang, H. eds., (2021). Industry 4.0 Interoperability, Analytics, Security, and Case Studies. CRC Press, p. 96-262.

16. Masurekar, O., Jadhav, O., Kulkarni, P., & Patil, S. (2020). Real Time Object Detection Using YOLOv3. International Research Journal of Engineering and Technology (IRJET), p. 3764-3768.

17. Lu, J., Ma, C., Li, L., Xing, X., Zhang, Y., Wang, Z. and Xu, J., (2018). A object detection method on YOLO. *Journal of Computer and Communications*, vol.*6*, no.11, p.98-107.

18. Shindel, P., Yadav, S., Rudrake, S. and Kumbhar, P., (2019). Smart object detection system using YOLO. *Int. Res. J. Eng. Technol.(IRJET)*, vol.*6*, p.966-970.

19. Biswas, D., Su, H., Wang, C., Stevanovic, A. and Wang, W., (2019). Bimodal drone detection system. *Parts A/B/C*, vol.*110*, p.176-184.

20. N. Srivastava, G. Hinton, A. Krizhevsky, I. Sutskever, and R. Salakhutdinov, "Dropout: a simple way to prevent neural networks from overfitting," The Journal of Machine Learning Research, vol. 15, no. 1, pp.1929–1958, 2014.

21. H. Liu et al. A drone detection with aircraft classification based on a camera array. IOP Conference Series: Materials Science and Engineering, 322(052005), 2018.

22. J. Redmon and A. Farhandi. YOLO9000: Better, faster, stronger. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2017.