Drone Detection Experiment Based On Image Processing And Machine Learning

Giao N. Pham, Phong H. Nguyen

Abstract: Drones are widely used in the field of information gathering and tracking, even they could be used to attacked targets. Therefore, the drone detection for the restricted areas or special zones is important and necessary. This paper focuses on the drone detection problem based on image processing for the restricted areas or special zones where used cameras for monitoring. The proposed solution detects drones from the captured images based on training the Haar-like features. The dataset of drone images is used in the Haar training process to generate a Haar-cascade model of drones. This model is then used to detect drones from images captured by the camera. The proposed solution is implemented and experimented with single cameras installed for any place including indoor environment and outdoor environment. Experimental results proved that the proposed solution could exactly detect drones for any zone or the restricted areas. The average accuracy of the proposed solution in the experimented environments is 91.9 %, and it provides an easy and economical solution for user.

Index Terms: Drone applications; Drone Security; Haar features; Haar training; Object detection.

1. INTRODUCTION

Drones are known as Unmanned Aerial Vehicles (UAV) is an aircraft without a human pilot aboard. Drones may operate with various degrees of autonomy either under remote control by a human operator or autonomously by onboard computers [1], [2]. Drones are originally used for missions too dirty or dangerous for humans while they originated mostly in military applications [3], [4]. Compared to the manned aircraft, drones are easily maneuverable and can be operated from anywhere. They provide greater visibility for the pilots operating them because they are guided by satellites and have highly advanced cameras. Nowadays, drones are rapidly used expanding to commercial, scientific, recreational, agricultural, and other applications such as policing, peacekeeping, surveillance, product deliveries, aerial photography, agriculture, smuggling, and drone racing [5]-[7]. Although drones are used to replace human in dangerous missions but they are also used for evil purposes. First of all, drone can scout targets and collect information from special zones or track moving objects as car, human for spying purposes without any detection. Secondly, drone can bring weapons to attack targets or bring bomb to terrorize public places without prevention as shown in Fig. 1. Thus, drone detection problem is important and necessary to ensure security for the restricted areas or special zones. In order to respond to above issue, we would like to propose a drone detection solution for the restricted areas or special zones based on image processing. The key content of the proposed solution is to use a dataset of drone images and non-drone images to create a Haar-cascade model for drones by the Haar training process. The trained Haar-cascade model of drones is then used in an image processing to detect drones by a Haar-cascade classifier from frames if drones appear in those -frames. To clarify the proposed solution, we organize our paper as follow. In Sec. 2, we would like to explain the related works as Haar feature, Haar-cascade classifier, and drone detection. In Sec. 3, we present the proposed solution in detail. Experimental results and the evaluation of the proposed solution will be described in Sec. 4. Sec. 5 shows the conclusion.

***Fig. 1**. Drone brings weapons to attack targets.*

2 RELATED WORK

2.1 Drone Detection

Currently, to detect drones or UAVs we have to use a drone detection system based on complex radar systems [8], [9]. This system is a complex combination of radars, sensors and other complex devices [10]-[12]. Drone detection systems use complex radars and sensors to detect drones based on detecting the signal of drones or using the scan wave of radars as described in Fig. 2a. These systems need a group of people to operate them, and they are often used in military purposes or special applications. Moreover, the price of drone detection systems is very expensive, and the maintenance process consumes a lot of money. So, they are unsuitable for small zones or personal purposes.

2.2 Haar-Cascade Classifier-Based Drone Detection

Haar-cascade classifier-based object detection method is an effective object detection method. It is a machine learning based approach where a cascade function is trained from a set of positive and negative images. It is then used to detect objects in other images. The core basis of the Haar-cascade classifier is the Haar-like features [13]-[17]. These features

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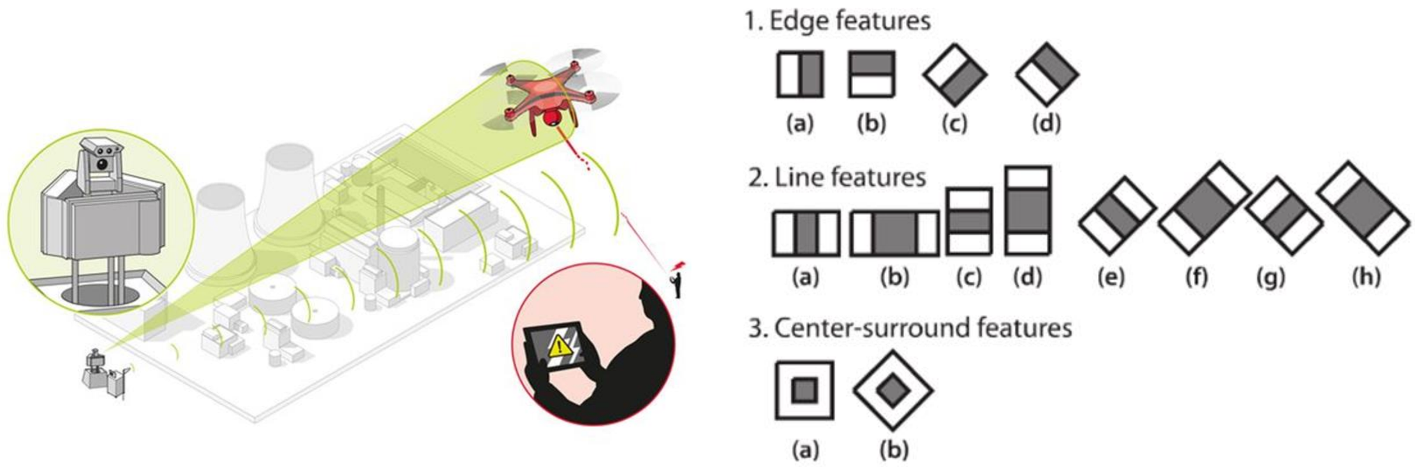
use the change in contrast values between adjacent rectangular groups of pixels. The contrast variances between



(a) (b)

Fig. 2. *(a) A drone detection system using radars [18], and (b) Common Haar features.*

-values between adjacent rectangular groups of pixels. The contrast variances between the pixel groups are used to determine relative light and dark areas. Two or three adjacent groups with a relative contrast variance form a Haar-like feature. Fig. 2b shows common Haar-like features that is used to detect objects in an image. The Haar-like features can be easily scaled by changing the size of the pixel group being examined. This allows features to be used to detect objects with various sizes. Therefore, we could use Haar-cascade classifier to detect drone objects with various sizes in frames captured by the camera.

3 THE PROPOSED METHOD

3.1 Overview

The proposed solution includes two parts as shown in Fig. 3. First part is the training process. Second part is the drone detection. The input of training process is drone images (called positive images), non-drone images (called negative images), and training parameters. In the training process, a dataset of images (including drone images and non-drone images) and training parameters are used in the Haar training process to obtain a Haar-like features model of drone. The format of the Haar-like features model of drone is ".xml" file. In the drone detection, the frame is captured by the camera and then converted to the gray image. This gray image will be equalized histogram [18] and used to extract the Haar-like features. Finally, the Haar-like features of the captured frame and the trained model are used as the input of the Haar-cascade classifier to detect drones.

3.2 Training Process

In order to train Haar features model of drone, two sets of images are needed. One set contains images or scenes that do not contain drone object, which is going to be detected. This set of images is referred to as the negative images. The other set of images, the positive images, contain one or more instances of drone object. The location of the objects within the positive images is specified by: image name, the upper left pixel and the height, and width of the object. The training process obtains the final model in XML format by using Intel's Open Computer Vision (Open-CV) library. The training parameters and the steps of the training process using Open-CV library is shown in [19], [20]. Fig. 4 describes the stages of the training process for a drone image.

3.3 Drone Detection

Assume that M is the Haar features model of drone after the Haar training process. It will be used to detect drones from frames captured by the camera in application part. Firstly, a configured camera captures frame from the restricted areas or special zones. Given $\mathbf{F}_t$ is the current frame captured by that camera. The current frame $\mathbf{F}_t$ is converted to the gray image $\mathbf{G}_t$ as shown in Eq. (1).

$$\mathbf{G}_t = RGBtoGRAY(\mathbf{F}_t) \quad (1)$$

Due to the proposed solution is based on the Haar-like features which is based on the contrast adjustment of image, we have to equalize the histogram of the gray image $\mathbf{G}_t$. This means we have to convert the gray image $\mathbf{G}_t$ to the equalized histogram image. Assume that the equalized histogram image is $\mathbf{F}_t^H$, and it will be obtained from the gray image $\mathbf{G}_t$ by the "Equalize Histogram Function" as shown in Eq. (2) with the $EqualizeHist(.)$ is the "Equalize Histogram Function" to convert the gray image $\mathbf{G}_t$ to the equalized histogram image $\mathbf{F}_t^H$.

$$\mathbf{F}_t^H = EqualizeHist(\mathbf{G}_t) \quad (2)$$

The equalized histogram image $\mathbf{F}_t^H$ is then used to extract the Haar-like features. Actually, the Haar-like features of the equalized histogram image $\mathbf{F}_t^H$ is a set of parameters and stored in XML file as the Haar feature model of drone M. So, to brief, we defined the Haar-like features of the equalized histogram image $\mathbf{F}_t^H$ by the $\mathbf{H}_{\mathrm{F}_t}$, and the feature extraction process is performed by the feature extraction function $E_H(.)$ as shown in Eq. (3).

$$\mathbf{H}_{\mathrm{F}_t} = E_H(\mathbf{F}_t^H) \qquad (3)$$

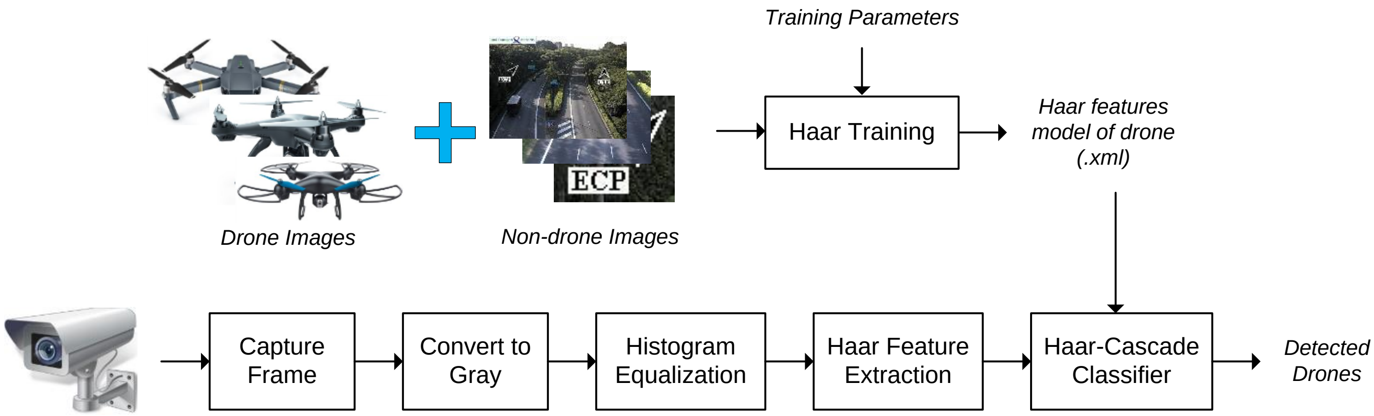


***Fig. 3**. The proposed method.*

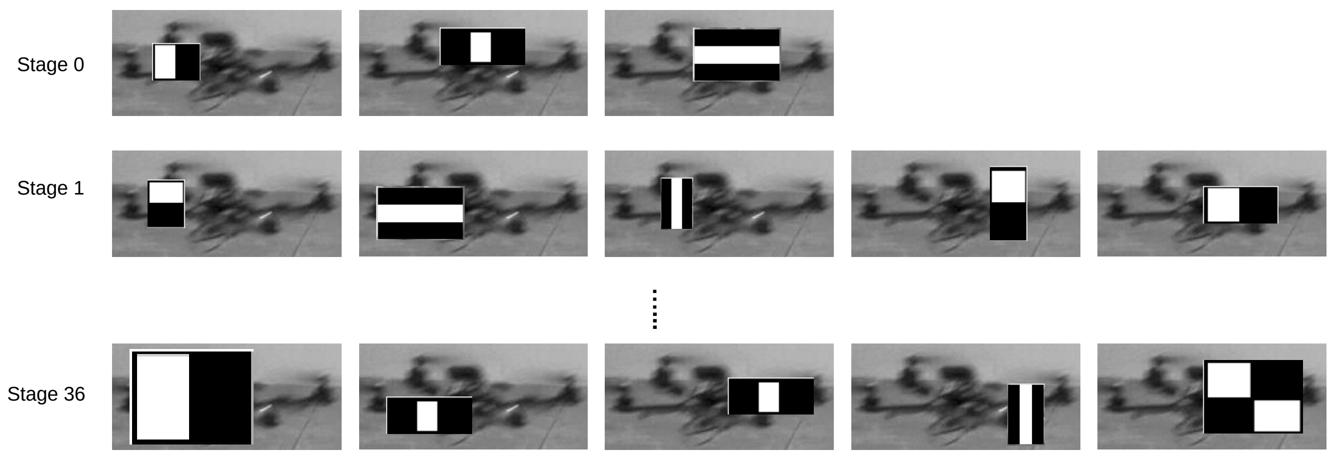


***Fig. 4**. The training process for a drone image.*

Finally, the Haar-like features $\mathbf{H}_{\mathrm{F}_t}$ and the trained model M are used as the inputs of the Haar-cascade classifier for the drone detection process. We firstly computed the error between the Haar-like features $\mathbf{H}_{\mathrm{F}_t}$ and the trained model M the "Classifier" function as described in Eq. (4) with the Δ_D is the error between the Haar-like features $\mathbf{H}_{\mathrm{F}_t}$ and the trained model M. After that the error Δ_D will be compared to the threshold θ to determine that image contains drone or not drone as shown in Eq. (5).

$$\Delta_D = Classifier(\mathbf{H}_{\mathrm{F}_t}, \mathbf{M}) \qquad (4)$$

$$\begin{cases} if \Delta_D > \theta, drone\ is\ detected \\ \quad if\ \Delta_D \leq \theta, not\ drone \end{cases} \qquad (5)$$

4 EXPERIMENTAL RESULTS

We implemented the proposed solution by using the image processing library OpenCV 3.4 and Visual Studio C++ 2017. Our experiments are setup and run on an Intel Core i7 Quad 3.5 – GHz, 8 GB of RAM, Windows 7 64-bits. A single cemara is setup and configured to monitor special zone and to record videos for experiments. We collected 2000 drone images from many types of drone with various colors and various sizes; and 2000 non-drone images in real conditions as birds, kites, airplanes, helicopters for the Haar training process. The accuracy of the training process is 96.1 %. This result is relatively high. Because the proposed solution is based on the conventional techniques of image processing. The accuracy of the training process result is dependent on the accuracy of the training dataset. In order to increase the accuracy of the training process, we can standardize and increase the number of images in the training dataset. For applications using the Haar training process, we can increase the accuracy of the Haar training process by using the background images of the fixed environment that will be install applications.

***TABLE 1**. DRONE DETECTION RESULTS*

Video Name	Size of Frame	Frame Rate	True Detection	Total Detection	Accuracy (%)
Video 1	640x480	25f/s	360	390	92.30
Video 2	640x480	25f/s	130	144	93.70
Video 3	640x480	25f/s	115	129	91.40
Video 4	640x480	25f/s	26	30	90.33
Video 5	640x480	25f/s	150	161	93.60
Video 6	752x480	25f/s	143	161	90.08
Average Accuracy = 91.90 %					

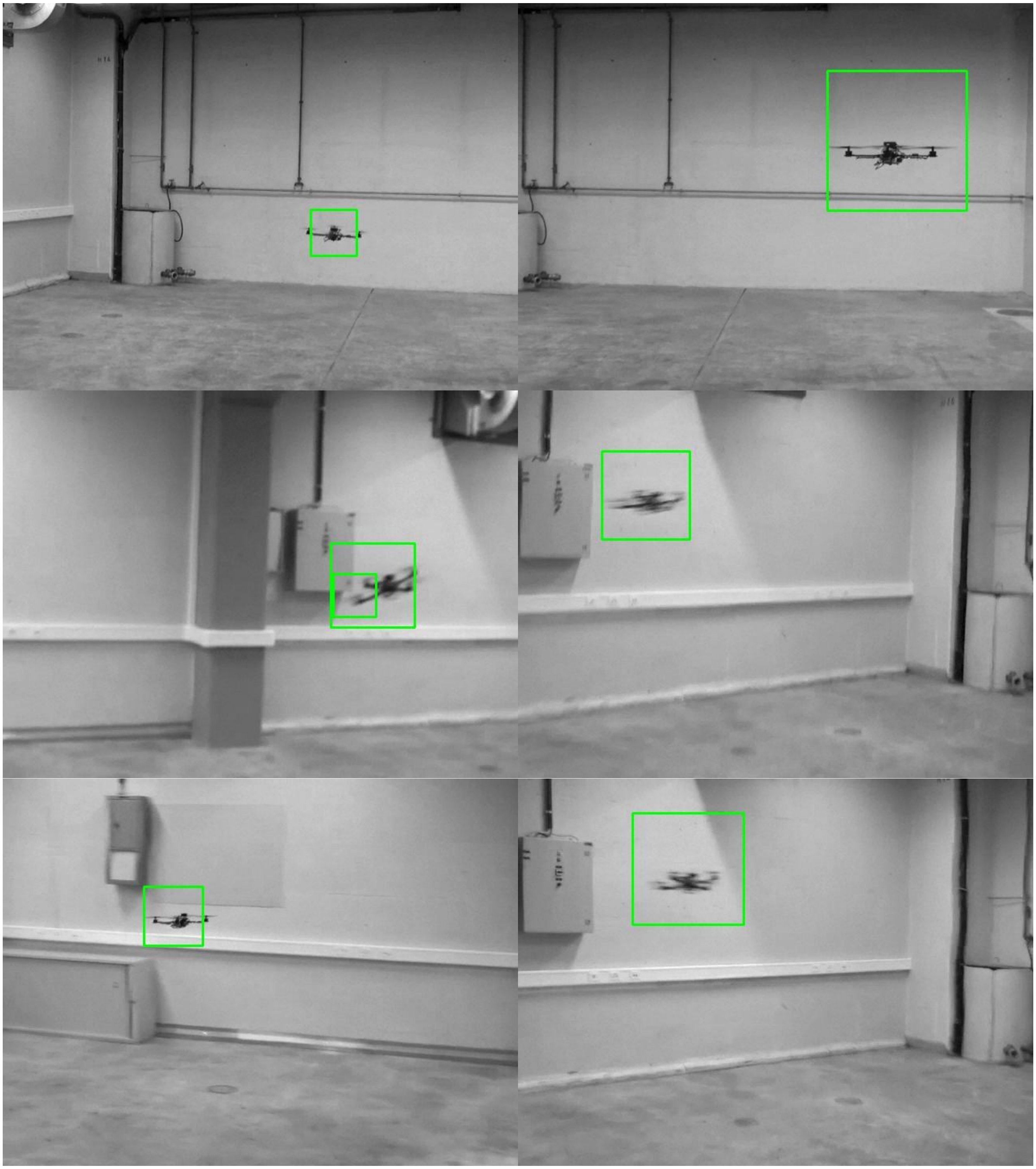


Fig. 5. *Drone detection result for indoor environment.*

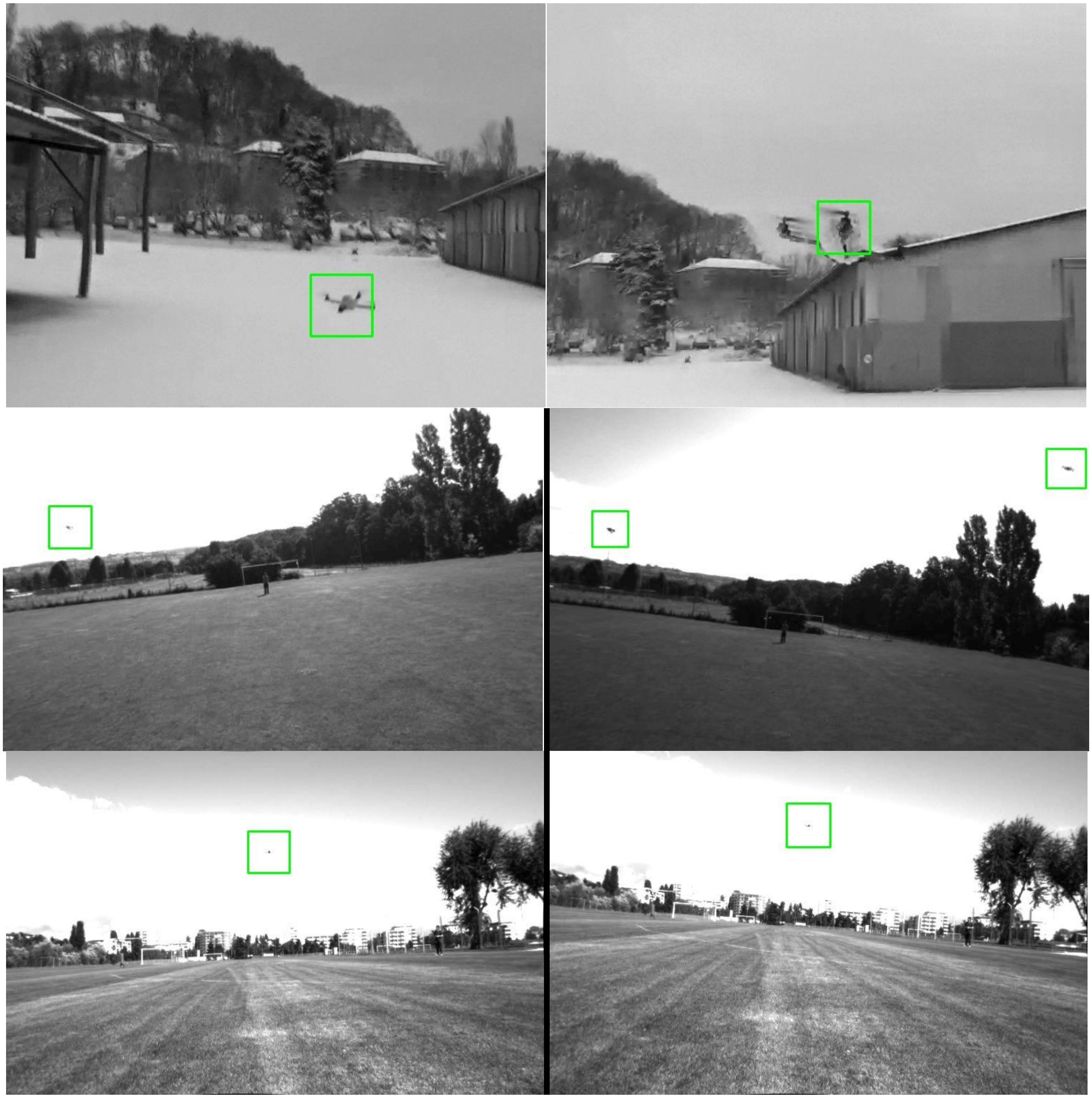


***Fig. 6**. Drone detection result for outdoor environment.*

We used a single camera to record videos for our experiments. The detail of videos is shown in Tab. 1. The experimental environment for the proposed solution is both indoor environment and outdoor environment. The drone detection results are shown in Fig. 5 and Fig. 6. Fig. 5 shows the drone detection results for indoor environment, and Fig. 6 show the drone detection results for outdoor environment. Based on Fig. 5 and Fig. 6, we could conclude that although it still have false detections but the proposed solution detected drones in test videos well. The accuracy of the proposed solution is computed by Eq. (6) and shown in Tab. 1. With test videos in Tab. 1, the accuracy of the proposed solution is formed 90.08% to 93.70 %. The average accuracy of the proposed solution is 90.05% as shown in Tab. 1. The accuracy of the proposed solution is dependent on the training dataset. In our experiments, we used a small training dataset, thus the average accuracy of the proposed method is understandable. The accuracy of the proposed solution can be increase by increasing the number of images in the training dataset, and for a fixed environment we can use the background frames of that environment to increase the accuracy of the Haar classifier.

$$Accuracy = \frac{Number\ of\ True\ Detections}{Number\ of\ Total\ Detections} \qquad (6)$$

Due to the fact that there are previously some object detection methods based on the Haar-like features, the training datasets and experimental environment of those methods are

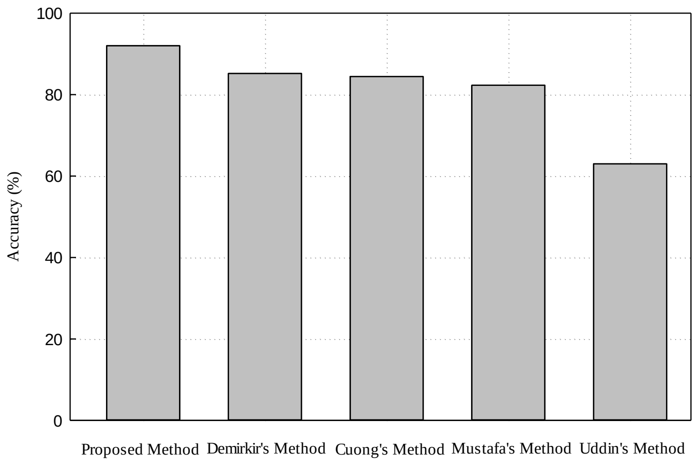


Fig. 7. *Accuracy of the proposed solution compared to previous methods.*

-different, we will not compare the detail of the proposed solution to previous methods. We only compare the accuracy of the proposed solution to the accuracy of previous methods. In Demirkir's method [21], they proposed an object detection using the Haar feature selection optimization and achieved max accuracy 85.2 %. In Cuong's method [22], they proposed a face detection method using variance based Haar-like feature and support vector machine, and achieved average accurracy 84.48 % with two databases of faces. In Mustafa's method [23], they used Haar-like feature and gentle adaboot classifier to detect obscenity. The average accuracy of their method is 82.89 %. In Uddin's method [24], they used Haar-like feature for horse detection and the accuracy of their method is 63 %. In our solution, the average accuracy of the proposed solution is 91.90 %. This means the accuracy of the proposed solution is better than previous methods. Fig. 7 shows the accuracy of the proposed solution compared to previous methods.

5 CONCLUSION

In this paper, we proposed an effective solution to detect drones based on image processing. The proposed solution used the Haar-like features to detect drones from frames captured by a single camera. The proposed solution is implemented and experimented with both indoor environment and outdoor environment. It could exactly detect almost cases. The proposed solution is simple and easy to implement for personal purpose applications for any place. The proposed solution is also flexible to developers. Because developers can use their training dataset to develop their applications for specific purposes. This is an advantage of our solution. In future, we collect big datasets to improve the accuracy of the proposed solution and experiment the proposed solution with many place.

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