

Low Cost Night Vision System for Intruder Detection

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Abstract. The growth in production of Android devices has resulted in greater functionalities as well as lower costs. This has made previously more expensive systems such as night vision affordable for more businesses and end users. We designed and implemented robust and low cost night vision systems based on red-green-blue (RGB) colour histogram for a static camera as well as a camera on an unmanned aerial vehicle (UAV), using OpenCV library on Intel compatible notebook computers, running Ubuntu Linux operating system, with less than 8GB of RAM. They were tested against human intruders under low light conditions (indoor, outdoor, night time) and were shown to have successfully detected the intruders.

1. Introduction

Thermal imaging [1] [2] [3] has been a popular choice of implementation of night vision surveillance systems. In this paper, in contrast to the high costs of thermal imaging systems, we propose a low cost approach for night vision, using low cost cameras such as those equipped with notebook computers, USB web cam as well as wireless web cam, and exploiting the properties of colour histogram under various lighting conditions at night. This approach is increasingly feasible as open source libraries such as OpenCV becomes increasingly popular, as they are deployed on low cost hardware platform such as low cost Intel compatible computers, Raspberry Pi as well as low cost Android devices.

Night vision has been an important field of security and surveillance applications. It has been used by civilian users, enforcement officers as well as the military. Combining the factors of economic growth as well as decreasing costs of computing equipments and popularity of open source software, the demand of night vision in developing countries like Malaysia is increasing. We illustrate two scenarios of using night vision in this paper: static camera and camera mounted on an unmanned aerial vehicle (UAV). We collaborated with civilian users to cater for improving security at home as well as farms, for example, high value swiftlet bird nest buildings in rural areas, with typical investment of over Ringgit Malaysia 100k, and products (swiftlet bird nests) costing over RM 2000 per kg, thus becoming a popular target of theft.

Nowadays CCTV with night vision camera is increasingly popular for capturing intruders on video. Since CCTV is static it could not be used to follow the mobile intruder. Hence it is complemented by camera mounted on Unmanned Aerial Vehicles (UAV). UAV can be also used to fly above and obtain aerial views in dangerous locations [4].

2. Background

Nowadays crime is increasing everywhere. Physically pursuing offenders is dangerous as they may be armed. Informing the authority to track the intruders is usually too late before they escape. This paper proposes a solution by using static night vision camera coupled with Unmanned Aerial Vehicle (UAV)



with night vision camera for tracking intruders. Night vision is a complex problem, with expensive thermal imaging systems as current popular solution. This project uses low cost cameras and open source software. We mainly focus on some limited scenarios where certain amount of ground light is available, and the night vision cameras work within a certain distance from the intruders. We also investigate whether the UAV can detect the intruders with the following path it travels with a specific amount of ground light.

The objectives of this project are as follow:

- (i) To analyze and determine the light intensity needed and the distance of night vision camera to intruder for detection and tracking.
- (ii) To investigate the effectiveness of colour histogram and motion detection algorithms for the purpose of night vision, using low cost cameras.

We employed mostly open source or free software in this project, including: OpenCV [5], Cygwin, Ubuntu [6] and Roborealm [7].

2.1. *OpenCV*

OpenCV (Open Source Computer Vision Library) is an open source for computer vision and computers learning software library. OpenCV was created to give a common infrastructure for computer vision applications and to increase the speed of machine perception in the commercial products. OpenCV has more than 2500 algorithms, which cover a comprehensive set of both state-of-the-art computer vision and machine and classic learning algorithms. These algorithms can be utilized to recognize and detect faces, identify objects, track camera movements, classify human actions in videos, produce 3D point clouds from stereo cameras, stitch images together to produce a high resolution image of an entire scene, extract 3D models of objects, find similar images from an image database, follow eye movements, remove red eyes from images taken using flash, recognize scenery and establish markers to overlay it with augmented reality, etc.

OpenCV's deployed uses span the limit from stitching street view images, detect intrusions in surveillance video in Israel, monitoring mining equipment at China, helping robots for navigating and pick up objects in Willow Garage, detecting of swimming pool drowning accidents at Europe, running interactive art at Spain and New York, checking runways for debris at Turkey, inspect labelling on products in factories around the world on to fast face detection in Japan [8]. It has C++, C, Java, Python, and MATLAB interfaces and supports Windows, Android, Linux, and Mac OS. OpenCV focuses mostly towards real-time vision applications besides that take advantage on SSE instructions and MMX when it is available. A full-featured OpenCL and CUDA interfaces are being developed now. There are over 500 algorithms and almost 10 times as many functions that generated or support those algorithms. OpenCV is originally written in C++ and has a template interface that works seamlessly with STL containers.

2.2. *Choice of cameras*

Night vision is the ability to see things in low light conditions. Either by biological or using technology, night vision has made possible by a combination of two techniques. Firstly, sufficient spectral range and followed by sufficient intensity range. Human beings have poor night vision compared to animals because the human eye lacks a tapetum lucidum. As for the spectrum range, night-useful spectral range techniques can detect radiation that is invisible to a human vision. Human eye vision is confined to a small part of the electromagnetic spectrum called visible light. It is enhanced with spectral range that allows the viewer to take advantage of non-visible sources of electromagnetic radiation.

Lens plays an important role in night vision systems [9]. To set up the focus in the dark is a challenging task.

An 8V battery is used for the supply for the wireless camera attached to the UAV. The camera transmits the video signals and it is picked up by a receiver connected to the computer. The input video is then processing using OpenCV.



Figure 1. Low cost camera

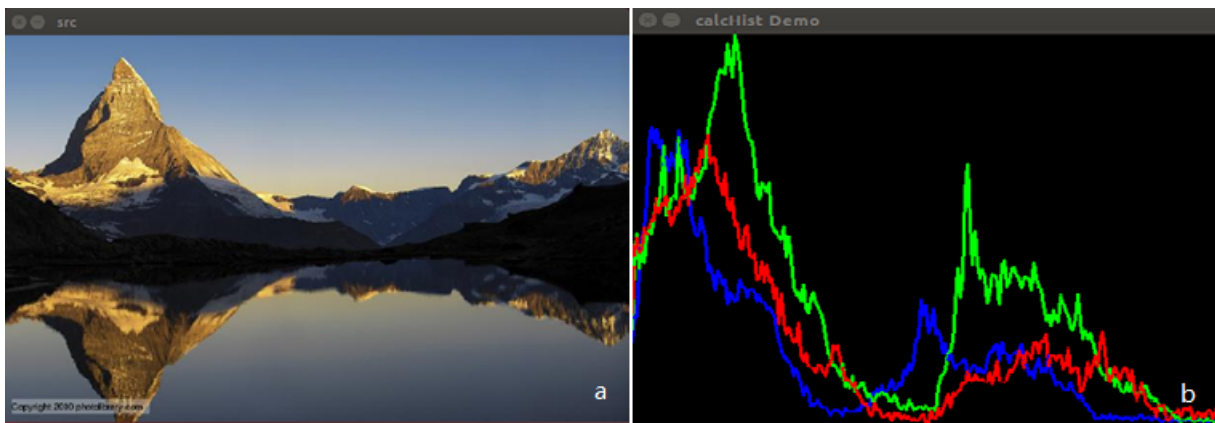


Figure 2. (a) Input image (b) Output calculation of histogram

3. Results

3.1. Experimental Results Using Static Camera

Edge orientation histogram has been applied to detect the sharp changes in digital image at which the image brightness has discontinuities at every point in the image. The points that change brightness sharply is then restructured into a set of curved line segments or edges. Edge detection is one of the fundamental image processing steps to analyse the image pattern so that the important event can be shown in the result of image processing. Besides, the histogram can be calculated by calling the function using OpenCV (Figure 2). This function is to separate the source image in its three R,G and B planes and then configure the histograms for each plane. The intensity of light of each image is ranged from 0 to 255 for every pixel in the image, means that 0 is the darkest intensity value while 255 is the brightest one.

The histogram graph will be changing continuously from time to time if the source video input received from camera has different intensity of light. The Figure 3 and Figure 4 show that each of the image is taken from the same place and same position but the light source is different. The histogram will change when the light intensity of the environment change. The test has shown that the Edge Detection function needs the minimum of light to be effective.

Figure 7 has shown the experiment is done by using car light while the camera is mounted in front of the car and the object is going to stand in front of the camera. The histogram shows the image has more

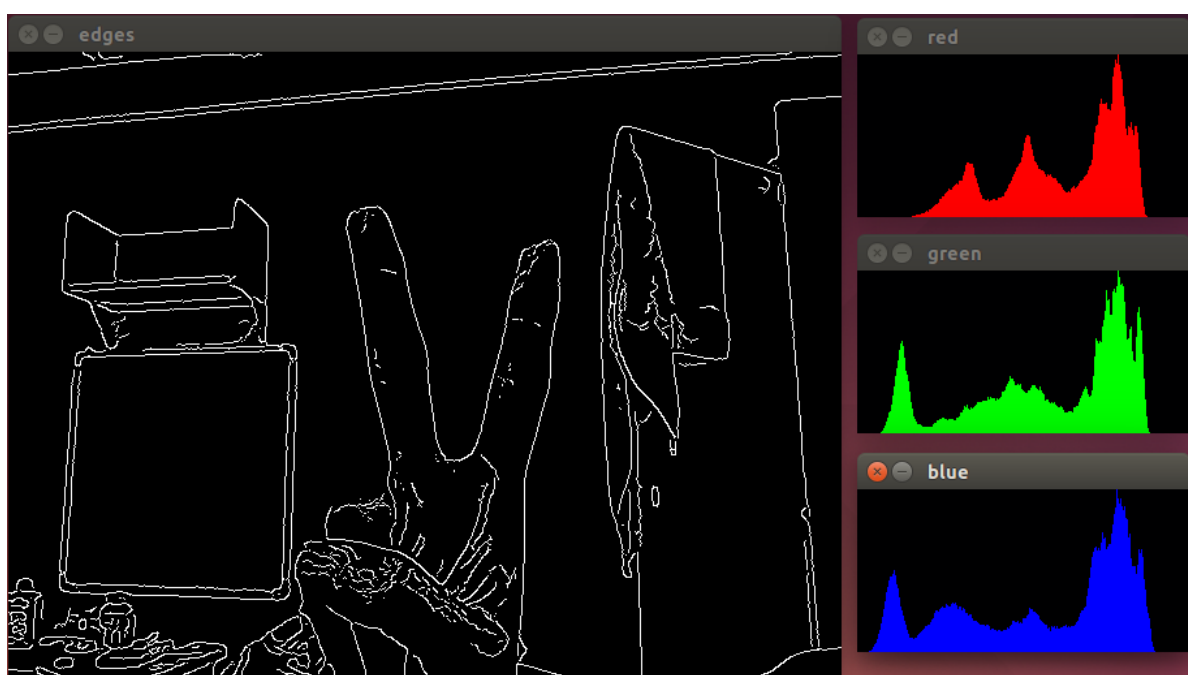


Figure 3. Edge detection in indoor with high intensity of light

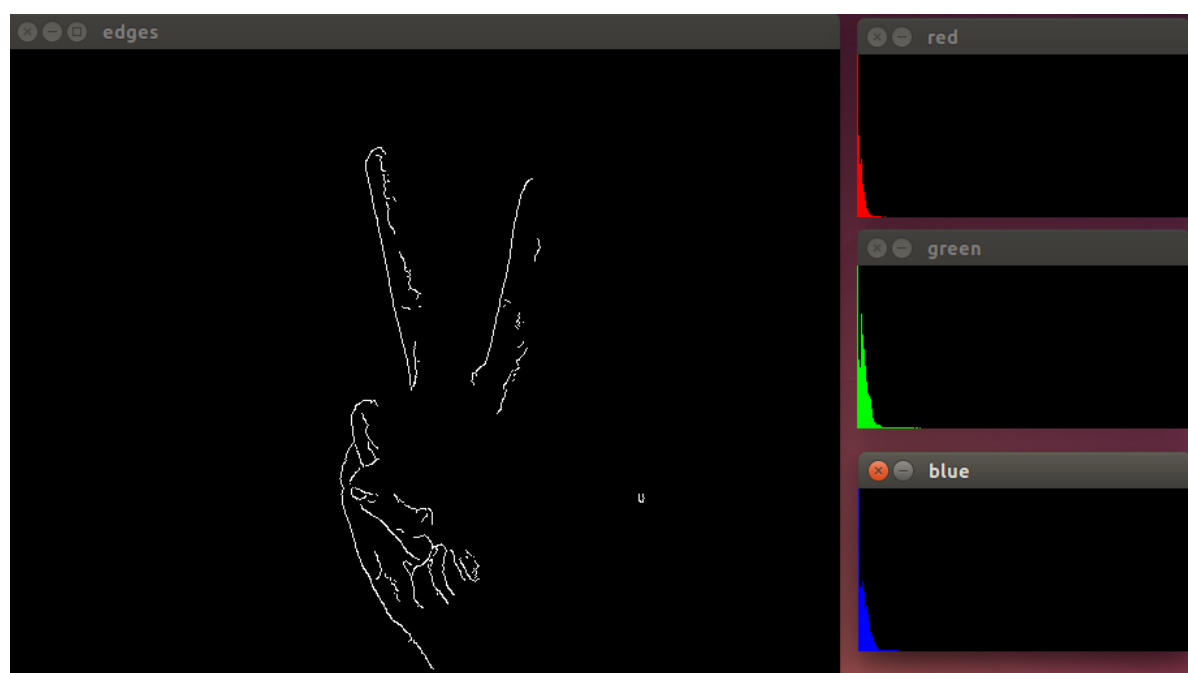


Figure 4. Edge detection in indoor with low intensity of light

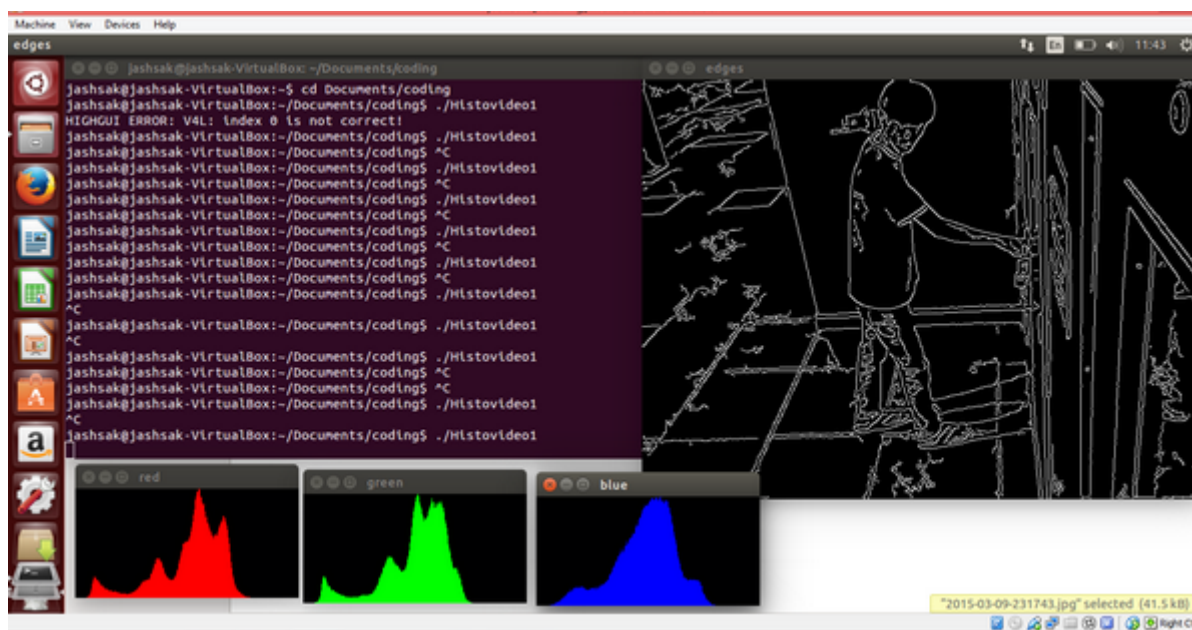


Figure 5. Edge detection in outdoor with high intensity of light



Figure 6. Outdoor environment with car light

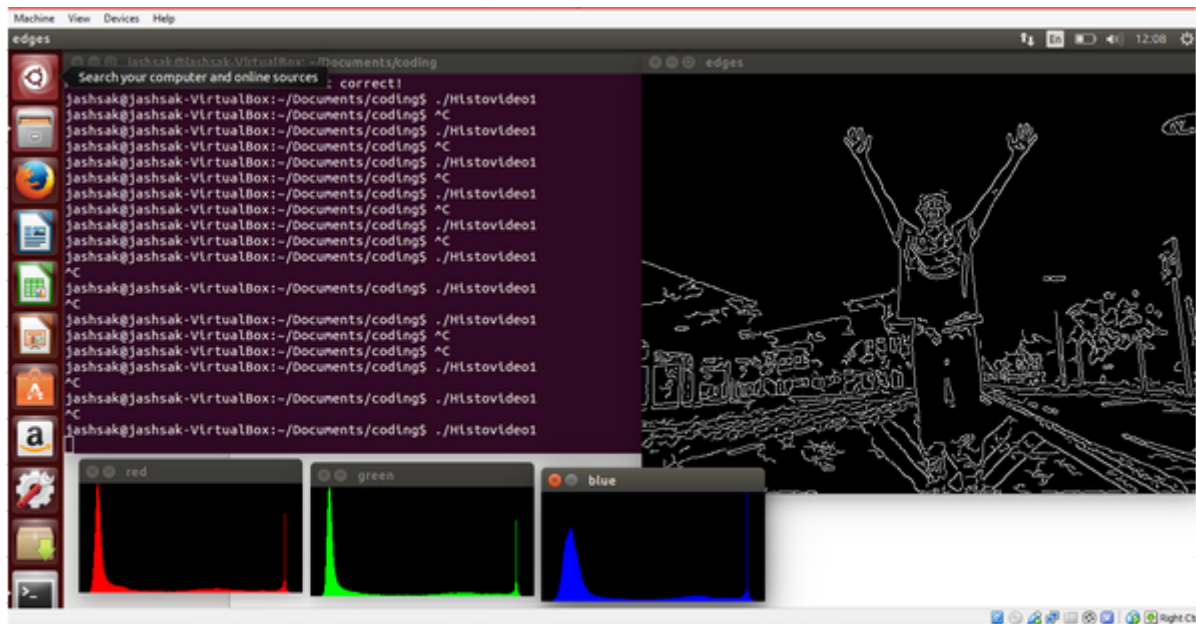


Figure 7. Human detection within distance of 5m.

on dark pixels than the bright one even when the car light is switched on. When the object is 5m away, the edge of the object can be clearly seen. The object's edge started to become smaller when the distance is 10m away. When the object reached 15m long from the camera, the edges of the object is smaller and the image mixed into the environment and cannot be easily detected.

3.2. Motion Detection

The motion detection function is to detect the moving object in the pre-recorded source video. In this function, the background subtraction method is used to detect the background frame which are the right column of pictures. The background frame will keep updating with foreground frame. The background image created is used to compare with foreground image. If there are different in light intensity, the red contour will be drawn out (Figure 8). It means that after the foreground frames subtract the background frames, the differences will be retrieved as a matrix containing points of coordinates and the coordinates will be drawn out using a red colour function. The background image might be very blurry, as it contains the average background statistics. In order to produce a clear background, the camera should be mounted or put at static condition.

3.3. Experiments with Unmanned Aerial Vehicle

A wireless camera is mounted on the UAV and the video stream is processed using OpenCV. When there is a spike in histogram there is a motion at the specific place.

Figure 10 and figure 11 are results of tracking human using colour histogram with camera mounted on UAV. By configuring specific parameter setting, it is able to eliminate noisy output (figure 10 where small boxes appeared. After the improvement done, it only track the human whereas the other objects are neglected (figure 11). As per the objective required, the result is achieved by detecting and track the intruder.

Although the wireless camera could live stream the video as we expected, but the range of the speed and height are limited. Firstly, if the UAV fly too high the video clarity is not good and the speed of the UAV also needs to be monitor so that the live stream video can be viewed. On the other hand, small amount of light source is required for the night vision camera, without the small amount of light intensity



Figure 8. Motion detection.



Figure 9. Design of UAV with night vision camera

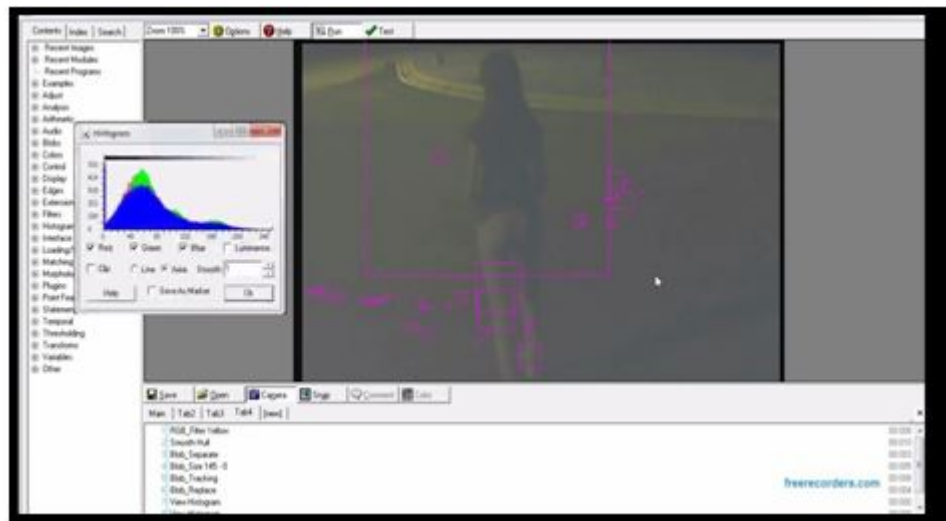


Figure 10. Tracking Human from UAV with histogram

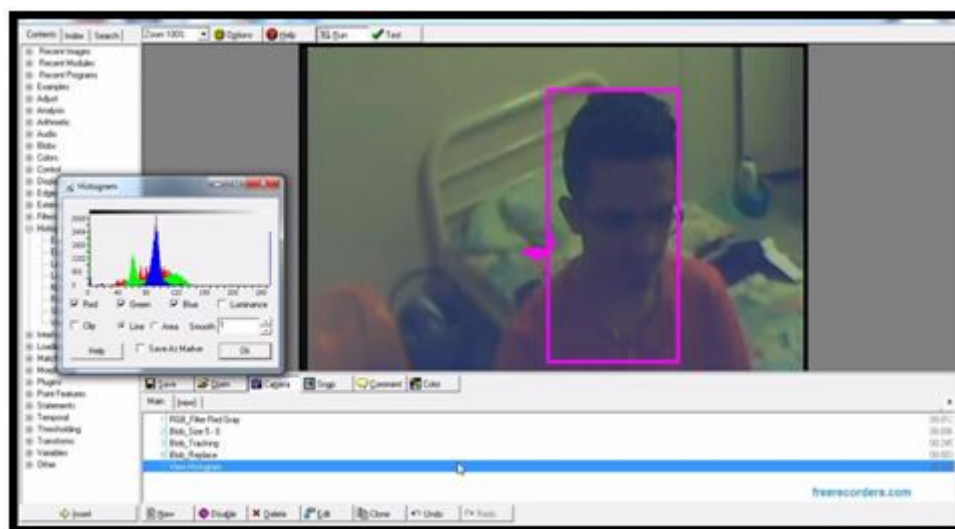


Figure 11. Tracking Human from UAV without tolerance

it will be dark throughout the video and nothing can be seen. Besides that, the camera's resolutions for this project is 2 megapixels with 6 small infrared LED for the camera. This is one of the limiting factor for a good quality of video.

3.4. Recommendations

For future works, some recommendations have been listed based on the problems in order to improve the performance:

- (i) Camera: The improvement that can be made for the camera is maybe can use much better camera than the one used in this project. Better camera is well described as the one has more Megapixels, for instance if 10 Megapixels or more the picture resolution will be much clearer and the video capturing will be fine.

- (ii) UAV: The UAV that used in this project is Syma X5C-1 Explorers 6 Axis 2.4G 4CH RC Quad copter With 2MP HD Camera, this quad copter able to lift small sized object only. In future works, if different type of camera is using maybe it will cause more weight so need much more powerful quad copter so that it can lift the camera and fly, most importantly being stable while flying.

4. Conclusions

In conclusion by using the OpenCV software which installed in Ubuntu platform, the colour histogram is generated with few coding. The colour histogram is depend on the light source at the environment. In bright environment the histogram will be wider on the X-axis. After some experiment conducted, the suitable ground light intensity needed for this project is the street light. Followed by, few experiments have been conducted under the street light condition along the street of kolej kediaman 5 UMP Pekan campus during the night time. By using Roborealm software it is able to detect and track the intruder with a purple colour box within the height of 20m. The height of the UAV is depends on the limitation of the night vision camera's manufacturer datasheet. The limitation of the signal for the night vision camera was 20m, thus all the experiment are tested with the distance of 20m height. Moreover, the UAV with the night vision camera can detect and track the intruder as per stated in the objective.

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References

- [1] Salleh N A S M, Ghazali K H and Azman F I 2014 *Proceeding of the Electrical Engineering Computer Science and Informatics* **1** 380–384
- [2] Zweng A, Beleznaï C and Sulzbachner C 2015 Reliable intruder detection using combined modalities of intensity, thermal infrared and stereo depth *Advanced Video and Signal Based Surveillance (AVSS), 2015 12th IEEE International Conference on* (IEEE) pp 1–6
- [3] Ojha S and Sakhare S 2015 Image processing techniques for object tracking in video surveillance-a survey *Pervasive Computing (ICPC), 2015 International Conference on* (IEEE) pp 1–6
- [4] Chiang A 2014 *Intruder Detection System* Ph.D. thesis School of Engineering and Applied Science, Washington University in St. Louis
- [5] Puttemans S, Howse J, Hua Q and Sinha U 2015
- [6] Wu J T, Der Lee J, Chien J C and Hsieh C H 2014 Nighttime vehicle detection at close range using vehicle lamps information *Computer, Consumer and Control (IS3C), 2014 International Symposium on* (IEEE) pp 1237–1240
- [7] NIHAR A and KUMAR D R U 2015
- [8] Jeong M R, Kwak J Y, Son J E, Ko B and Nam J Y 2014 Fast pedestrian detection using a night vision system for safety driving *Computer Graphics, Imaging and Visualization (CGIV), 2014 11th International Conference on* (IEEE) pp 69–72
- [9] Kimura M, Shibasaki R, Shao X and Nagai M 2014 Automatic extraction of moving objects from uav-borne monocular images using multi-view geometric constraints *IMAV 2014: International Micro Air Vehicle Conference and Competition 2014, Delft, The Netherlands, August 12-15, 2014* (Delft University of Technology)