UAV Based Security System for Prevention of Harassment against Woman

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Abstract—**This paper proposes a novel application of using an Unmanned Aerial Vehicle (UAV) for inhibiting physical harassments in public places. The existing surveillance systems are sufficient to monitor crowded areas but are not suitable for monitoring secluded places. The crimes are likely to occur in places with less crowd and make surveillance challenging, which eventually leads to an increase in crime rate. This paper discusses the development of an UAV based security system that responds to a request from a wearable gadget by a user probably a woman who faces a possible threat. The proposed approach focuses on the night time operation the period in which most of the physical attacks would occur. The person, who is facing a possible threat can request for assistance using a primary wearable gadget, which will send the GPS location to the control station. Then a UAV will be deployed to the target location which identifies and tracks the motion of the person using a secondary wearable gadget. This paper also proposes a low cost and lesser computational intensive solution for motion tracking.**

Keywords— **woman harassment, UAV, wearable gadget, GPS, object tracking**

I. Introduction

In India, incidents of physical harassment in public are increasing at an exponential rate [1]. According to a recent survey, an overwhelming majority of 79% woman in India have experienced some form of physical harassment in public [2]. Thirty percent of the entire country's IT and business-process workers are women [3]. Women working during unsociable hours are more vulnerable to harassment or exploitation than men. In a large country like India, existing real-time security systems that require constant human supervision may be ineffective in times to prevent such incidents. Most of the existing solutions to confront this problem use highly sophisticated and costlier components [4],[5],[6]. As a solution to this issue, a real-time UAV based security system is proposed which can provide immediate assistance in rescuing a person who is facing a possible threat. The approach focuses on night time operation, the period in which most of the crimes would occur.

The proposed method also introduces a low-cost solution for tracking the motion of the person under observation. This is done by using a cheaper IR (Infra-Red) based wearable device which provides a novel solution when compared to existing systems. The primary aim of this research is to develop a security system on UAV which responds to a request from the user. The user triggers the request using a wearable gadget. The GPS module in the wearable gadget will update the location to a server, which is used for setting a waypoint for the UAV to navigate to the requested environment. Once the UAV reaches the requested location, the pan and tilt camera mount will rotate and scan for the target or person of interest. The person under observation will be wearing a secondary wearable gadget (head band) with an array of IR LEDs incorporated in it. This could be used for tracking the target in an obscure environment. Real time video would be transmitted to the authorised person. The alarm system mounted on top of the UAV will play pre-recorded warning messages, so as to make the offenders withdraw from their act. Parrot A.R Drone 2.0 was used as UAV platform for experimentation.

The rest of this paper is organised as follows: Section II discusses an overview of work related to this paper. Section III discusses the entire system description and architecture of proposed work. Section IV discusses regarding the results obtained from the research and section V draws the conclusions and future works for this research.

II. Related Work

A Large amount of research was already done in the field of applications of UAV. It has widespread applications in the field of surveillance, first response, aerial mappings, inspections etc. In the research by Anwar Ma'sum, A.R Drone was used for search and recognition of certain objects [7]. In this approach, Adaboost classifier and Pinhole algorithm were used for recognising and estimating the position of an object which works only in a static environment. An Aerial surveillance system proposed in [4] using UAV provides an efficient, convenient and low-cost alternative to the existing surveillance systems. The live streaming feedback enables the operators to monitor the environment from a remote location. This paper gave an intuition for using UAVs for our purpose. An emergency response UAV surveillance system was proposed in [8]. The system provides a real-time video tracking and following of active targets which would be handy in case of emergency situations. The high-flying UAV system

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was used for providing video of the entire scene. Aryo Wiman Nur Ibrahim *et al* [9] proposes a UAV based system that detects and tracks moving an object from the video captured. For achieving this objective, Moving Objects Detection and Tracking (MODAT) framework was developed along with certain image processing techniques. The work from the University of Minnesota described the use of UAV for the application of surveillance in transportation supervision and safety [10]. It demonstrates the use of UAV moving autonomously to a specified location using the decision markers. This gave an insight of using waypoint navigation for our proposed work using GCS (Ground Control Systems).

The paper by Virginia Menezes proposes a surveillance system that uses Raspberry Pi and Simple CV for detecting motion and tracking moving objects in the monitoring area [11]. Streaming real-time camera feed online using MPJG Streamer was also discussed in this paper. Human detection from high altitude image was done based on thermal imaging in the research work done by T.Gitsidis [5]. Optical and thermal sensors along with sophisticated image processing algorithms were implemented for identifying and tracking the presence of a human. In another research, a combination of adaptive background modelling and histogram of oriented gradients for the detection of human motion from surveillance video was introduced [12].

Another research was done in the field of real-time object tracking with Raspberry pi 2 [13]. This research basically focuses on the comparison of two object tracking systems, Lucas-Kanade method and Cam-shift method. Several experiments were done with a pan and tilt system with both the tracking mechanisms and their performance were analysed. A research work from Quebec Ministry of Education, Canada shows some extensive work in developing a real-time target tracking using a pan and tilt camera [14]. They proposed an approach to solve problems of occlusion and target shape variations in the image frame. This work is slightly related to our tracking using pan and tilt camera except our proposed approach tries to tracks the IR source.

From the above papers, it is concluded that a number of researches were done in the field of real-time object detection and its tracking from a live video feed. Most of the approaches are costly and computationally intensive. Our proposed system introduces a UAV based security system which is cost effective and simple in construction with no sophisticated components and algorithms.

III. SYSTEM DESCRIPTION

The objective of this work is to develop and implement a UAV based security system that provides assistance to a person probably a woman who will be facing a possible threat in the public. The entire system mainly includes two modules: sending a request for a rescue from the primary wearable gadget (wrist band); tracking the motion of the individual who requested for assistance using an IR source embedded on a secondary wearable gadget (head band). Most likely in the case of a woman, a wearable head band or any convenient smart gadget can be used as a secondary gadget. Since embedding the IR source in the primary gadget may cause occlusion during tracking, the secondary gadget is needed to avoid the constriction.

A. Request for Rescue and Navigation

A wearable device with ESP8266 (aka NodeMCU) [18] is used to receive and transmit GPS sensor data to a server. The device uses tinyGPS for decoding NMEA codes, GPS time and MQTT (Message Queue Telemetry Transport) client for transmitting GPS data [19].

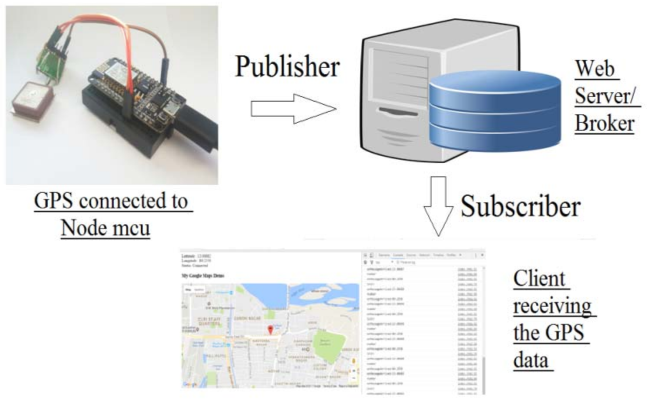

Fig.1: The communication channel for a wearable device with ESP8266.

Fig.1 shows the system architecture for a wearable device which publishes the GPS location to a web server and is accessible to any device which subscribes the web broker in the network. This GPS location from the server is used to navigate the drone to the target location using GCS (Ground Control Station) software. A navigation route is created using waypoint in the GCS to autonomously move the AR Drone to the requested location [15].

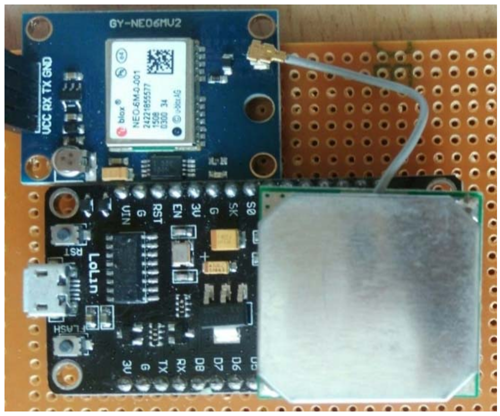

Fig.2: The proposed wearable device with ESP8266 and GPS-Ublox.

Whenever a button in the wearable device is pressed, the device starts sending GPS data sporadically to a server and is available to any device or GUI (Graphical User Interface) which is subscribed to the server. The Fig.2 shows a simple setup of wearable device with ESP8266 and GPS-Ublox module which publishes the GPS location data to a web server.

B. Motion tracking of target individual

An empirical test was conducted to find an optimum height for acquiring a better aerial view. The proposed algorithm for target detection and tracking is shown in Fig. 3, which shows that the UAV after reaching the requested GPS location hovers at the optimum height. As soon as the UAV reaches the requested location, a trigger would be sent to the image processing controller (Raspberry pi 3) which initiates its functioning. The Pi camera fitted on the pan and tilt mounting provides a video feed to the raspberry pi controller.

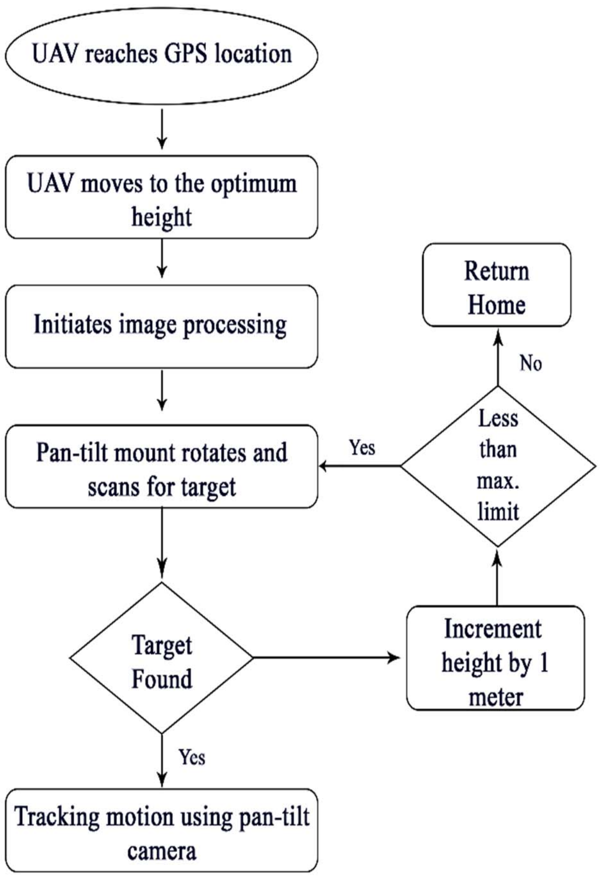

Fig.3: The proposed algorithm for target detection.

The pan and tilt mount with Pi cam executes a rotation and scans the environment for the target IR source. Once the IR source is located by the Pi camera in the image processing unit, the pan and tilt mounting stops rotating and UAV aligns itself parallel to the pan and tilt direction. The pan-tilt system will then start tracking the motion of the target and provides motion commands to the AR Drone via raspberry pi. If the IR source is not visible from the current height, UAV will increment its height by 1 meter, provided the height is within the permissible limit otherwise returns to its home position.

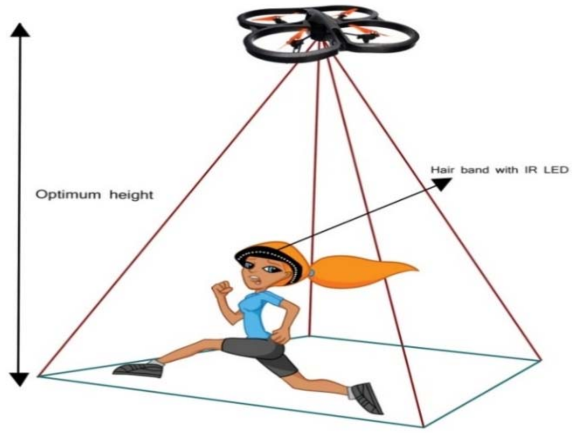

Fig.4: Aerial view from AR Drone, tracking the motion of woman under observation

To minimise the chances of occlusion, the secondary wearable device of choice is a head band. The IR source is embedded in the head band as shown in Fig.4 which is tracked using the pi camera. Human eyes are insensitive to IR rays which make it unnoticeable for the attackers. On the other hand, the cameras usually made of silicon sensors are sensitive to IR rays even in dark, which eventually makes the system work properly during night. The pi camera mounted on the UAV has an Infra-Red (IR) filter, which gives the output as an image with only the IR source as a bright blob. There might be multiple sources of IR in the background due to which we derived a mechanism for uniquely identifying the person under observation. The IR source on the band blinks with a frequency of f_1 which is a unique feature that can be identified. The baud rate at which the frames flow into the image processing unit from the camera is f_2 frames per second. The effective frames per second recognized by the system is $f_3$which will be the effective down-sampled frequency. The choice of f_1, f_2 and f_3 was made in such a way that the down sampling does not give high aliasing and the effective frequency $f_3$is in a desired range. The system first detects the high intensity point in the image and tracks it by the method of optical flow. Across frames the region of interest is tracked and the displacement vector of the same is given out as the output of the algorithm. This displacement vector is given into the control system which in turn controls the pan and tilt unit. Hence the object always appear at the center of the frame. The pan and tilt mount is operated by means of a PID controller. The output of the optical flow is the displacement vector in the polar coordinate system. We map the displacement vector as an error correction into the pan and tilt system. Error gains for pan and tilt controls will be calculated and used separately for keeping the point of interest in the center of the frame.

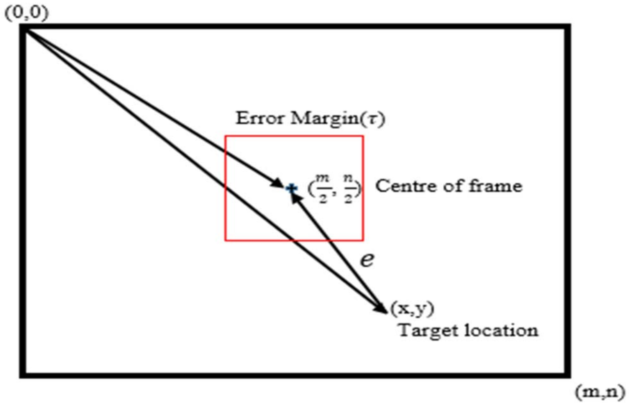

Fig.5: Image frame with significant points of interest

Fig.5 shows the image frame obtained by the Raspberry Pi Cam with the target location, the centre of frame and error margin (τ). Assuming the frame size be m*n center of the frame will be at ($\frac{m}{2}$,$\frac{n}{2}$). Let the point of interest be at point A(x, y). In order to track the point A, pan-tilt system should be moved such that it would come to the center of the frame. For smoother motion of the pan-tilt system, we have given a permissible margin τ of error near the center of the frame ($\frac{m}{2}$,$\frac{n}{2}$). Euclidean distance between point the the of interest in the frame and center of frame, e will be [20]:

$$e = \sqrt{\left(x - \left(\left|\frac{m}{2} - \tau\right|\right)\right)^2 + \left(y - \left(\left|\frac{n}{2} - \tau\right|\right)\right)^2} \quad (1)$$

Let (x_i,y_i) be a point within the permissible margin of error. Difference in x and y coordinates of the target location and point within the error margin (x_i,y_i) can be defined as x_{error} and y_{error} respectively.

$$y_{error} = y - y_i \quad (2)$$

$$x_{error} = x - \left|\frac{m}{2} \pm \tau\right| \quad (2.1)$$

$$x_{error} = x - x_i \quad (3)$$

$$y_{error} = y - \left|\frac{n}{2} \pm \tau\right| \quad (3.1)$$

The tracking of the target will be done by controlling the pan-tilt motion using PID controller. The motion of the pan and tilt system will be controlled by the gains values PID_{tilt} and PID_{rot} respectively [21], [22].

$$PID_{tilt} = K_P * x_{error} + K_I * \int x_{error} dt + \frac{K_D * dx_{error}}{dt} \quad (4)$$

$$PID_{rot} = K_P * y_{error} + K_I * \int y_{error} dt + \frac{K_D * dy_{error}}{dt} \quad (5)$$

The PID parameters K_P, K_I, K_D were calculated based on trial and error method. After finding the PID parameters, the motion commands based on tracking algorithm is sent to the AR Drone using LabVIEW. The Command VI (Virtual Instrumentation) created for drone's motion allows it to move autonomously according to the motion of target (person of interest). The wireless communication between Raspberry pi and LabVIEW was achieved using ESP8266 NodeMCU which sends motion commands to a server accessible for LabVIEW.

IV. RESULTS AND DISCUSSION

The result from the wearable device is presented in the Fig. 6 below which shows the GPS location getting updated in the server using MQTT protocol. These coordinates from the server would be used for the waypoint navigation of the UAV. From the empirical test for the optimal height, it was found that UAV when operating at a height of 3 meters gives a wider and better aerial view of the environment. The IR filter placed in front of Pi camera, filtered out most of the other sources of light from the environment. The IR source flickering at a rate of 14 Hz was used to clearly differentiate it from all the possible outliers in the environment.

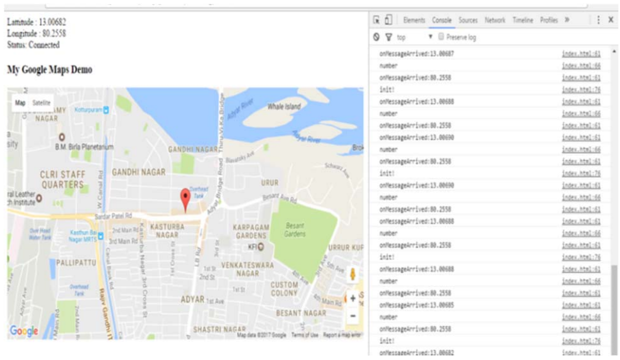

Fig.6: The server receiving the GPS location from ESP8266 NodeMCU

Fig.7: The image processing unit used for the motion tracking of the target

Fig. 7 shows the image processing unit consisting of Raspberry Pi 3, pan-tilt camera mount and 8 MP pi camera with the IR filter.

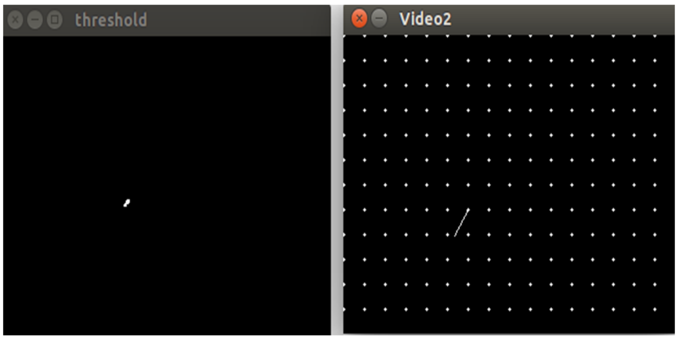

Fig.8: IR filtered image and tracking of IR source from distance of 3 m.

The left-hand side of Fig.8 shows the IR filtered image in which the influences from other lighting sources were removed. The entire frame was divided into regions. These regions are mapped into points as shown in figure 8. The movement of the target in the image frame was mapped to these points. Whereas the right-hand side of Fig.7 shows the motion of the target between the mapped nodes. In order to reduce the risk of jittery movement, an error limit of 20 pixels was permitted for the PID controller. The PID controller for the pan-tilt motion was calibrated based on trial and error method.

TABLE.I. PID controller parameters calibrated for the motion of the pan-tilt camera mount.

PID parameter	Final calibrated value
K_p	0.03
K_I	0.001
K_D	0.0015

Table I shows the PID parameters calculated for the tracking of a target with the pan-tilt system. The image processing unit was tested independently in low light conditions with varying distance between camera and target.

TABLE. II. Test results of the detection and tracking of target using pan-tilt camera from different distances

Distance from camera to target (m)	Number of trials	Number of correctly identified and tracked	Success Percentage (%)
1	20	19	95
2	20	19	95
3	20	19	95
4	20	18	90
5	20	17	85
6	20	16	80
7	20	12	60
8	20	7	35

Table. II shows the results of detection and tracking of the target using Raspberry Pi camera from different distances. 20 trials were taken at each of the distances considered.

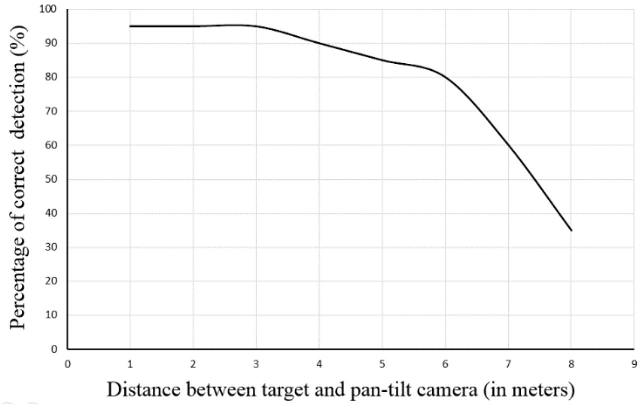

Fig.9: Graph showing the relation between distance from pan-tilt camera to target and the percentage of correct detections

Fig.9 shows the relation between the distance from the camera to target and the level of accuracy in its identification and tracking. It was observed that, within a distance of 6 meters, the image processing unit successfully detected and tracked the motion of the target with an appreciable accuracy of 80%. Beyond that point, the accuracy in the detection and tracking falls down considerably. For the same reason, the maximum permissible height the UAV hovers during its mission was set to 6 m. The algorithm was then implemented on AR Drone platform and also while tracking the IR source, delays were abridged by adjusting the video frame settings in LabVIEW.

V. Conclusions and Future Work

From the above results, we can conclude that the AR Drone with pan and tilt mount was able to detect and track the target when operated within the permissible height. With the proposed approach, it was found that the applicability of UAV based assistance was realisable .The intermediate phase with waypoint navigation using GCS and pre-recorded warning system was considered to be the future work.

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