Intelligent Outdoor UAV Drone Surveillance

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Abstract- **These days, unmanned aerial vehicles (UAVs) are used for a wide range of civic and military objectives. The UAV is excellent for many sectors where surveillance is crucial since it can carry several sensor devices. When compared to conventional techniques used for surveillance applications, UAVs enable a swift and affordable operation. The current study is based on building a quadcopter and integrating an Arduino Mega 2560 microcontroller with multiple HC-SR04 ultrasonic sensors for obstacle avoidance by utilising the Sense and Avoid algorithm, outfitting it with an analogue FPV camera for obtaining live video feed with minimal latency, providing headcount at a specific location and to track a specific person, automating the quadcopter and integrating it with the Unmanned Ground Vehicle (UGV), etc. The creation of a Ground Control Station (GCS) with a map is also a part of the research. Through MAVLink, the GCS and quadcopter are able to communicate. (Communication protocol for drones).**

***Keywords*— Quadcopter, UAV, Arduino Mega 2560,HC-SR04,UGV, Delivery service GCS, MAVLink.**

INTRODUCTION

The attack of Austrian soldiers on the city of Venice with unmanned balloons filled with explosives is considered to be the earliest example of UAVs (Unmanned Aerial Vehicles), however this practice was not widely adopted as some of the balloons exploded on the Austrian lines.The development of winged air-craft in 1900 changed this perspective and 16 years later Great Britain developed the first pilotless (unmanned) winged aircraft, it was based on radio control as are the UAVs used in today's era. Since then the use of UAVs for military purposes boosted and improved throughout the World War II.As the UAV technology in military sector began to improve, the thoughts about using the same technology for commercial and private sectors also came into being.The nonmilitary use of UAVs begin in 2006 ac-cording to the Wall Street journal and since then the governments used mini UAVs for disaster relief, wild-fire speculation, border surveillance etc. For commercial sector the UAVs are extensively used for photography, video recording, and a large sector is of agriculture which deploys UAVs for a wide range applications which ranges from measuring the water content in soil, spraying of pesticides, to applying computer vision techniques to detect the presence of pests and bugs which harm the crops. However the major interest of this research is based on providing security and surveillance through the use of UAV, which includes the development of a GCS (ground control station) so that a person has full authority over the parameters of UAV, obstacle avoidance system so that while hovering it doesn't crash and put the surrounding in jeopardy, live streaming for surveillance purposes and headcount, moreover another leap that we have taken in UAV automation is it's collaboration with a UGV (Unmanned ground Vehicle) to overcome the issues of facial recognition and battery concerns. This research is divided into sections which includes the information about components we used for building UAV followed by methodologies for development of GCS, obtaining live streaming, obstacle avoidance system, headcount, and collaboration with UGV.

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LITERATURE REVIEW

A. UAV in surveillance

Many researchers have been drawn to employ UAVs for data gathering in the previous decade because of technological advancements, constant decreases in cost, size, and weight, evolution of attached sensors, high-tech cameras, and flexibility in their usage rule [1]. In the age of digital technology, traditional mechanisms are insufficient to assure security. However, UAVs are very necessary to do surveillance, which is a noteworthy option since it will not only reduce effort and provide you a larger geographical area to cover, but it will also give you more information in a shorter amount of time. This is also not a burden on people's life, but rather a simple and cost-effective answer [2] UAVs have become a valuable tool in a variety of surveillance scenarios, including fire surveillance [3], Traffic monitoring [4] [5], Crowd Surveillance [6] [7], wildlife surveillance [8] or looking for missing people [9] [10] [11] [12].

In [13], the authors used SSD's (Single Shot Detector) pyramidal feature extraction for person detection and activity recognition to recognise humans from aerial photos, while in

[14], the authors suggested a model for human detection based on colour and depth data.

In [15] and [16] the author investigated the challenge of piloting surveillance UAVs to monitor a group of moving objects on a regular basis. The authors of [15] suggested a reactive sliding mode control method to steer a team of communicating surveillance UAVs with ground-facing video cameras to regularly monitor a group of moving ground targets on the 3D landscape.

Huang et.al. Investigated the navigation of a group of solarpowered UAVs in urban areas for periodic surveillance of a collection of distributed movable ground objects. Because the number of targets in the scenario is more than the number of UAVs, the UAVs must conduct periodic monitoring. In addition, the authors took into account the presence of tall structures in metropolitan areas, which might obstruct the Line-of-Sight (LoS) between a UAV and a target. Tall structures may also cast a shadow, preventing the solar-powered UAV from harvesting energy from the sun and rendering surveillance ineffective [16].

The authors of [17] suggested a sliding-mode control algorithm for monitoring a moving disaster area using UAVs equipped with ground-facing cameras, which navigates the UAVs to monitor the faster-moving portion of the disaster area's frontier.

Based on artificial intelligence (AI) platforms for data processing, Nguyan [18] presents an effective method to improve data transmission and reception in UAV-CSS (camera surveillance systems) systems. The method generates an initial backdrop frame before updating it to the full background and sending it to the server. It divides the scene's zone of interest (moving objects) and only broadcasts the changes. As a result, the CSS can considerably minimise data storage or transmission. Furthermore, the systems' complexity might be greatly decreased.

B. Object Detection & Object Tracking

Object Detection is basically detecting objects that belong to a certain class. Since 1990, many researchers have been drawn attention towards object detection and recognition systems. The today's strategies may be classified into two major types: one-stage techniques and two stage-techniques. Onestage technique focuses on inference speed, examples of which include Single Shot Detectors (SSD) [19], You only Look Once (YOLO) [20] and RetinaNet [21]. Two-stage technique focuses on detection accuracy, examples of which include Mask R-CNN [22], Faster R-CNN [23], Cascade R-CNN [24]

The standard technique is to extract the features of the detected object using SIFT [25] or SURF [26] for training the classification models like ANN [27] or SVM [28]. However, with the advancements in deep learning has replaced the previously used approaches by providing low efforts and high accuracy.

The author in this paper [29] presented a novel perspective for Localization Quality Estimation (LQE) which is based on the four parameters of the bounding box. The author has performed close correlation between real localization quality and distribution statistics. They have successfully developed a lightweight Distribution-Guided Quality Predictor (DGQP) for the reliable object detection. The author has achieved 46.2 AP at 14.6 FPS efficiency in both inference and training.

Xiang Dai et.al. [30] Improved the previous research in lieu of performance in counting object detection heads. The author has presented a unified way of detecting object heads in a dynamic head framework. The proposed framework improves the ability of detecting objects without any hassle of computational work. The framework was found to be more effective and efficient on COCO benchmark with a standard ResNeXt-101-DCN backbone. The overall performance of the object detectors was found to be 54.0 AP.

The author in this paper [31] addresses the shortcomings of SIAM Mask [32], which is commonly used for single object tracking and segmentation. SIAM Mask requires the bounding boxes to be drawn manually around objects to be tracked. This is not however gives the better solution, the author has overcome this dependency by using YOLOv4 [20] and Detectron2 [33], which automatically detect the object in a frame and gives better efficiency.

METHODOLOGY

A. Development of GCS Automation

The ground control station is the main platform for monitoring and controlling the parameters of UAV whether ying in auto mode or controlling the UAV manually.The GCS includes a map using Google maps API to show the live location and heading of the UAV obtained from the GPS with compass mounted to it, and for providing the user with a exibility to control the automated missions performed by the UAV such as making the UAV circle at a certain position on a map.Other than a map the GCS shows various important parameters of UAV such as battery percentage, altitude, speed, latitude and longitude. C is used as a basis for the development of UI and for connection with the UAV so that we can send certain commands and receive the required information from the UAV. However, automation of the UAV is done through making the use of MAVLink protocol. The implementation of connecting to UAV and automation using MAVLink protocol is described as follows.

1) Connection with UAV: It is important to first establish a connection with UAV and GCS. Following is the C code

snippet required for connection with the UAV.
Setting the port on which telemetry is connected.

SerialPort port = new SerialPort(); port.PortName = ¨(Name of Com port)";

Setting Baud rate to 5600 and opening the port.

port.BaudRate = 57600; port.Open();

Reading packet from the port.

MAVLink.MAVLinkMessage packet; packet = mavlink. ReadPacket(port .BaseStream);

Requesting the data stream

req stream id=(byte) MAVLink.MAV DATA STREAM.ALL;

2) Heartbeat Message: The basic information about the UAV is received through Heartbeat Message.

Reading the heartbeat message (readsomedata is a function developed to read the messages which are being received from the UAV).

Requesting the data stream

var heartbeat=readsomedata¡MAVLink. mavlink heartbeat t¿(sysid, compid);

Getting the flight mode of UAV uint custom mode=heartbeat. custom mode;

3) Arming the Quadcopter: The UAV can be armed by using the MAV COMPONENT ARM DISARM command.

MAVLink.mavlink command long t req=new MAVLink. mavlink command long t() req.command=(ushort)MAVLink. MAV CMD .COMPONENT ARM DISARM

4) Waypoint Navigation: The latitude and longitude of a certain location is required to make the quadcopter move to that location, when the user clicks on a certain point on a map, the latitude and longitude is obtained which are then used in MAV CMD WAYPOINT command to make the quadcopter move to that location autonomously.

req.command=(ushort)MAVLink.MAV CMD .WAYPOINT

B. Live Streaming

One of the main objectives of this research is to achieve low latency live streaming for image processing on off board desktop PC or laptop. However, to fulfill the objective following options were considered.

1) Raspberry pi for Live Streaming: Raspberry pi along with a pi camera seems to be a better option for on board image processing however for off board image processing the latency and the reliability of a Wi-fi connection are the major drawbacks of using Raspberry pi with a pi camera. When the pi camera was used to transmit the live video feed to the remote PC or laptop, the latency was found to be increasing at every instant and reached to an approx value of 5 seconds. To make a tradeoff between high video quality and high latency streaming can be problematic when using quad copter due to its speed.

2) FPV Camera for Live Streaming: FPV camera is a light weight, small and reason-ably priced camera which can provide real time video with very low latency. However, the video quality of an FPV camera is relatively low due to its transmission technique. FPV camera transmits video in analog format which can be either NTSC or PAL. When the FPV camera was used the latency was found to be of approx 22ms 3) IP Camera for Live Streaming: An Internet Protocol camera is a digital camera which sends its signal through the internet. An IP camera can be easily used with the quad copter if there is a Wi-Fi module attached to it. How-ever the Wi-Fi connection needs to be fast and reliable.

TABLE I LIVE STREAMING METHODS COMPARISON

Method	Latency	Quality	Dependency
pi Camera	(sec (approx 5	Good	WIFI
FPV Camera	ms 22 (approx)	Average	Video Transmitter and Receiver
IP Camera	ms(ap- 140 (prox	Good	WIFI

By analyzing the pros and cons of each method as shown in table 1 and by evaluating our limitations we preferred the used of FPV camera to obtain live video feed from the quad copter. Live streaming is obtained using python programming language and OpenCV library.

Following code is used for obtaining the live stream directly from the receiver.

cap=cv2.VideoCapture(0) ret,frame=cap.read()cv2. imshow('frame',frame)

C. Obstacle Avoidance

We connected the Pixhawk 2.4.8 with the Arduino Mega 2560 and connected multiple HC-SR04 ultrasonic sensors. The sensors are used to measure the distance be-tween the obstacle and the UAV. By testing and experimenting we set the distance to be 100cm in order for the obstacle to be avoided. MAVLink library for C++ language is used to control the UAV while avoiding the distance. We used the Sense and Avoid algorithm which is used in [34] with some modifications. *1) Sense and Avoid Algorithm:*

- The UAV continuously checks the distance from obstacles from front,right,back and left.
- If the distance measured is less than 100cm then the manual control from the user is disabled through the Arduino mi-crocontroller as the UAV is set to break mode.
- The UAV moves in the opposite direction by using the mavlink RC CHANNELS OVERRIDE command until a safe distance is measured i.e, greater than 100cm.

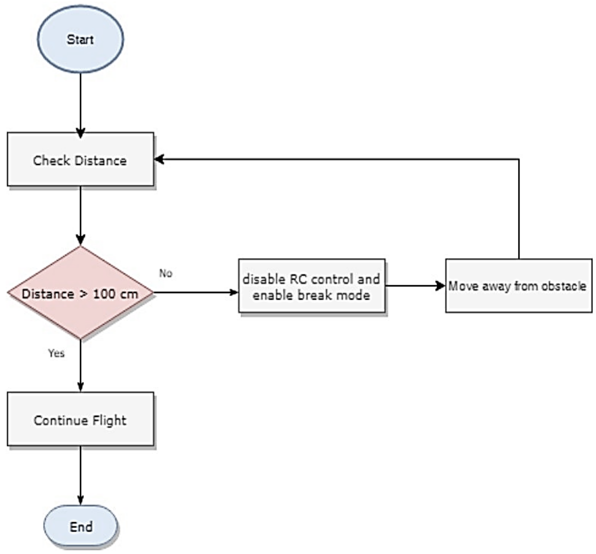

Fig. 1. Sense and Avoid Algorithm Flow

D. Headcount

The method for headcount we applied is a modified version of people counter proposed in [2]. The working of our model is divided into three parts and can be observed as follows.

1) Detection: In order to count people in a live stream it is first important to detect them. However there are multiple methods used when it comes to object detection. The three most commonly used are.

- R-CNNs as proposed in [35]
- You Only Look Once (YOLO) as proposed in [4] and
- Single Shot Detectors (SSDs) defined in [5]

The R-CNN [35] algorithm is quite slow when it comes to detecting objects in live stream there-fore it is not used in our model. The YOLO [4] object detection method provides much better speed however the accuracy achieved is not desirable for our application as the UAV hovers over a specific location and needs to detect people with at least 65%-80% accuracy.

The SSD [5] provides balanced accuracy and speed between the two methods defined above. The SSD is much easier to implement and the algorithm is faster (depending on the net-work we use) than R-CNN and accurate than YOLO. Various networks for object detection can be used including MobileNets [6], VGG [7] or ResNet [8]. However VGG and ResNet can be a burden to use for resource constraint devices, considering the environment in which our application may be deployed the VGG and ResNet net-works are omitted and MobileNets is used. The MobileNets as defined in [6] is computationally inexpensive and can be used easily on resource constraint devices.

2) Tracking: Once the object is detected it is tracked by using the centroid tracking algorithm [9] [36]. Which works as follows.

The object is detected by using the methodology described in Detection section above, SSD can detect up to 20 different objects, and our interest is in detection of person only. In figure 2 the object is referred to as a person.

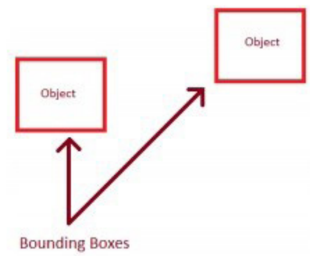

Fig. 2. Sense and Avoid Algorithm Flow

- After person is detected the centroid of bounding box is calculated. As shown in figure 3.

The centroid on X-axis can be calculated by.

$$X-axis = Length/2 \quad (1)$$

The centroid on Y-axis can be calculated by.

$$Y-axis = Width/2 \quad (2)$$

- The respective IDs are assigned to each detected object as depicted in figure 4

3) Counting: We first draw a horizontal virtual line on the screen as proposed in [2], once people cross this line moving downward they are counted. It is important to determine the direction in which people are moving with respect to the virtual line, hence to find the direction we take difference of Y coordinate of the centroid and the mean of previous centroids. If C be current centroid and mean (Ci) be the mean of previous centroids and D be the direction then,

$$D = C - \text{mean}(Ci) \quad (3)$$

If D is positive then it is considered that people are moving downward hence the counter is incremented.

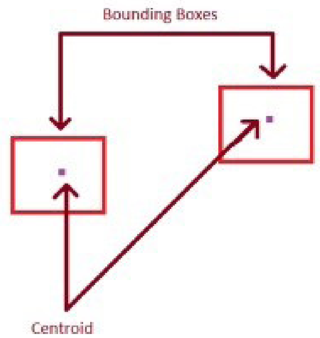

Fig. 3. Centroid Calculation

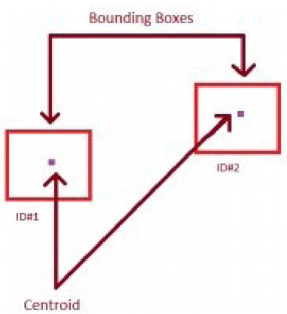

Fig. 4. ID Assignment

4) Collaboration with UGV: It involves the following steps

- The GCS is used as a platform for collaboration between the UGV and UAV.

- Latitude and longitude of the UGV is obtained from the GPS mounted on it.

- Through latitude and longitude provided by the GPS of UGV its location is derived on the map embedded in the GCS as shown in figure 5, the green marker shows the location of UAV whereas the blue marker shows the location of UGV[37].

Fig. 5. ID Assignment

- When the UGV signals for aerial support, the latitude and longitude of UGV is used as a waypoint for the UAV.

- By using MAV CMD NAV WAYPOINT command the UAV autonomously moves to the location of UGV

RESULT & DISCUSSION

During the development of GCS the rate of mes-sages was increased which included the relevant information about the Pixhawk 2.4.8 flight controller such as the Heartbeat message in order to achieve low latency in retrieval of information. The different functions related to the messages received from the UAV need to be in a BackgroundWorker thread.

For the purpose of waypoint navigation it is important for the Pixhawk 2.4.8 flight controller to be calibrated with GPS 3D fixed. If not, the UAV denies to switch to auto mode properly. The Ublox M8N GPS with compass delivers accuracy of about 2 meters reference when applied to outdoor environments, For indoor the use of GPS is inappropriate and shows the UAV moving even when it has landed.

In the Live Streaming method we adopted,it was observed that the latency was unmatched when compared to other methods as shown in section B of Methodology. However the quality of footage obtained was observed to be less when compared to streaming methods of pi camera and ip camera[38].

Obstacle avoidance system for UAV which is proposed in section C of Methodology was tested in an open area as UAV switches to break mode while it confronts an obstacle in its path, in the break mode the UAV can not be controlled by the RC transmitter. However after adjusting factors which affected the speed of UAV while using the MAV RC CHANNELS OVERRIDE command, the results obtained can be observed in table II.

TABLE II OBSTACLE AVOIDANCE RESULTS

(Distance (cm) (approx	Avoidance Accuracy
20>	Good
80>	Good
100	Good
100<	Average
170<	Bad

The Headcount method mentioned in section D of Methodology was tested in an indoor environment and within close range in absence of wind which affects the overall outcome of the specified method. When tested without optimizing the speed of the UAV the error can be clearly observed as shown in figure 6 in which it assigns an id to an object which is not a person and the status is waiting rather than tracking.

However after optimizing the speed of UAV the result was accurate enough that it tracked and as-signed the ID to a

Fig. 6. Error in testing Headcount

person than any other object and the counter was incremented as shown in figure 7.

Fig. 7. Result after optimizing the speed parameters

As far as Collaboration with UGV is concerned it is important to first calibrate the UAV and have the GPS 3D fixed in order for the waypoint navigation to work effectively.

CONCLUSION

The prime objective of conducting this research was to build an automated UAV with GCS specific to be used in security systems to improve their efficiency through integrating the autonomous characteristics of UAV with computer vision techniques and to take a leap towards the already modernized technology of UAV systems by collaborating it with a UGV.

- The live streaming method proposed in this re-search can be used effectively if HD quality footage is not a requirement.

- The obstacle avoidance system using Arduino Mega 2560 defined in the Methodology section is a low budget solution as compared to using Raspberry pi for achieving such purpose.

The integration of obtaining headcount in a UAV system is not only advantageous to security systems but it can also be applied to count the number of people in protests and in any other such situations to address any required purpose.

To conclude, this research provides a minor fore-ground for other researchers to build and automate their own UAV systems integrated with computer vision techniques to implement their ideas for the improvement of not only the security and surveillance systems but also to address the domains which autonomous UAVs can be of use for the sake of making lives better and easier to manage.

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