D.R.D.O. SASE's UAV Fleet Challenge

Mid Evaluation Report
IIT (BHU), Varanasi

Introduction

Our nation's military faces significant challenges in a strategic environment that are becoming more threatening with each passing day. This calls for the intervention of technology in the defence sector. The sophistication of operations has also dramatically increased, and new technologies are enabling new ways of conducting military operations at an accelerating speed. Disruptive innovations in the defence sector are required to enhance military capabilities.

As the role of unmanned aerial vehicles continues to grow in all sectors of society, new applications for drones in security and defence continue to emerge. Advancements in drone technologies have resulted in an increased capacity for unmanned vehicles to take on a range of dangerous tasks, especially in emergency response, that would traditionally have been performed by humans. A new technology - drone swarm - is emerging in defence. The ability of drones to autonomously make decisions based on shared information has the potential to revolutionize the dynamics of the defense sector. An important application of swarm in the defence sector is perhaps the search-and-rescue operation. Drones can search large areas, identify a soldier in distress, assess their status, and communicate in real-time to ground resources the location of the soldier.

A UAV fleet is being developed by the students of IIT (BHU) Varanasi, which will enable a quick search-and-rescue operation for military personnel in distress.

Technical design

1. **Multicopter UAV design optimization**
   The multirotor has a simple construction design and consisting of a frame with a given number of arms, motors, propellers, a battery and a control system. The optimization is able to increase the flight time and to increase the flight dynamics.

   UAV design parameter selection:

   1. **Frame** - Q450 with integrated PCB, 450mm in diameter, 320gm, Polyamide Nylon arms, highly tough and durable
   2. **Propeller -** HD Propeller 1045(10x4.5) ABS:- 15° angle at the end of the propeller stabilising flight
   3. **Brushless Motors** - Emax MT2213 BLDC 935 kva motor:- powered by highest grade neodymium magnets, gives the best efficiency of the motor
   4. **ESC -** 30A blheli esc :- compatible with 18A motors for appropriate current
   5. **Battery -** 6200 mah battery:- 25c, for minimum 15 minutes flight time

2. Control

1. **Framework - ROS**
   ROS (Robot Operating System) is used for the autonomous working of UAV. Being an open-source, meta-operating system for robots, it enables hardware abstraction, low-level device control, implementation of commonly-used functionality etc.
2. **Simulation - Gazebo**
   In ROS Gazebo is an inbuilt simulation software it offers the ability to accurately and efficiently simulate populations of robots in complex indoor and outdoor environments.
3. **PX4 and MAVLink**-
   Px4 flight controller is being used and simulation of pixhawk is made. The individual UAV is controlled and coordinated by a central ground station, which in this case is the Mission Planner Software. The communication protocol being used is MAVlink (Micro Aerial Vehicle Communication Protocol). MAVlink proves to be a robust, efficient and versatile communication protocol for both onboard and offboard communications.
   To make node between ROS and Ground Station with Mavlink, ROS has an inbuilt package called MAVROS that serves as a MAVLink extendable communication node for ROS with the proxy for Ground Control Station.

3. Localisation

GPS Technology has been used to calculate the longitude and latitude coordinates of the UAV system. In an outdoor environment, GPS provides a reliable method for positioning. The other existing methods for positioning like Ultra-Wideband (UWB), Infrared (IR), Wireless Local Area Network (WLAN), Bluetooth etc. are not suitable for this problem due to range and signal constraints.
GPS is perfect for our outdoor operation with fairly accurate values and a worldwide coverage area.

4. Object Detection

To detect the object as described in the problem statement, Computer Vision, Object detection techniques and Haar Cascades are being used. The process takes place in the following steps-

1. **Canny Edge Detection**
   Canny edge detection is run using a range of threshold values. It uses kernel convolution to detect edges in a given image. The Canny edge detection a fast straightforward method uses high and low thresholds to determine edges and all possible combinations of threshold values are used limited by a step size between the values. The resulting binary images are processed for contours in linear time.
2. **Detecting and Filtering Contours**
   Some of the contours resulting from Chang’s Contour detection are filtered out based on a minimum number of pixels that can be used for prediction. Various techniques like comparing the ratio of perimeter squared to the area, filter the contours that are approximately close to being square-shaped.
3. **Rotating and Converting to standard size-**
   Contours resulting from Chang’s contour detection are represented by a set of vectors c and each component vector ci. By rotating these candidates into alignment before extraction of the Haar features, the features become more discriminatory and result in an increase in accuracy of the trained classifier. Each output image is scaled to a standard size before extracting the haar features.

4. **Extracting the Haar Features**
   Various features are inspected and compared to previously trained classifiers to distinguish between the target object and the extra contours that might have crept in. By aligning buildings and adding padding to expose its edges, which have high contrast, contrast patterns between candidates is obtained. For example, the Haar features being extracted will statistically expose higher contrast in candidates which contain the target object due to the edges of this object appearing in the same location across examples. Also, upper texture and the surrounding area texture may also be consistent enough to provide linear separable distributions of values with respect to the target object and false contours.

Swarm Implementation For Search Using UAVs

All the UAVs are connected to a central master system over telemetry links. UAVs are equipped with onboard cameras for detection of targets.

Arena distribution and mapping:

1. The whole search arena is divided into grid cells. Each cell can contain one or more targets.
2. As the altitude of UAV increases, the UAV can have a large field of view at once but that will decrease the efficiency of the target searching algorithms. There is a tradeoff between altitude and target searching algorithm efficiency. So an optimum height is found depending upon the conditions and each is carried out.
3. A grid-based probabilistic map is generated where each grid cell contains the probability of finding the targets. Every time a UAV completes a grid cell, it will update the probabilistic map with the target finding probability value.
4. The waypoints are dynamically calculated for all the UAVs in such a way that UAVs cover the whole area in the least possible time.

Our Work Till Now

1. We have built 4 quadcopters of the stated specifications and tuned them for a good manual flight.
2. Simulations have been done using Gazebo and ROS environment has been developed to connect the 4 UAVs via telemetry to the master computer to implement navigation.
3. For box detection we have started to test the method on Jetson Nano Board using a logitech C270 camera.

Scalability and Economic Feasibility

All the design parameters of the UAVs have been optimised. This ensures that the system is compatible with the environment it is to be used in. The battery, propellers, and frame size, all have been selected to ensure a successful performance for long durations. Using batteries of a higher power, for real-life scenarios, we may even extend the flight time. All the materials used in building the UAV are cost optimised.

The communication between the UAVs will be done using the telemetry devices which are highly reliable and have very long ranges, up to 300 metres. Using Swarm technology ensures that the task of detection is done by UAVs as a group and not individually. Thus, the risk of failure decreases.
Although the current algorithm deployed is for 4 UAVs and 5 objects, it can be very easily modified for hundreds of UAVs and objects, thus making it highly scalable. Using GPS allows us to expand the use to a much larger arena with minimum error in the output.

Impact

The deployment of swarm UAVs in the military brings the necessary sophistication and strategic requirements. The idea of a single, large, expensive military drone with onboard sensors and capabilities is rapidly becoming obsolete. With the advent of swarm technologies, it is becoming easier to deploy multiple with collective interactions between them and the environment. Swarm UAVs provide support functions such as intelligence, surveillance, and reconnaissance. They prove to be incredibly useful for search and rescue operations. SAR operations were traditionally conducted by military personnel themselves, endangering multiple lives, or by primitive devices which were slow and inaccurate. Every second is of utmost importance in a SAR operation.
Multiple drones can span a large area over a short period of time and enable quick response from the ground forces. Swarm UAVs eliminate the need of personnel for conducting on-ground SAR operations. Deployment of swarm UAVs in various domains of national defence will prove to be a huge asset.