Automatic Target Acquisition and Discreet Close Surveillance Using Quad Copter with Raspberry Pi Support

P. Vijayaragavan[1(✉)], R. Ponnusamy[2], and M. Arramuthan[3]

[1] Department of Computer Science and Engineering, Jawaharlal Nehru Technological University, Kakinada 533003, AP, India
vijayaragavanpm@yahoo.co.in
[2] Department of Computer Science and Engineering, CVR College of Engineering, Vastu Nagar, Mangalpalli (V), Ibrahimpatan (M), Hyderabad 501510, Telungana, India
r_ponnusamy@hotmail.com
[3] Department of Information Technology, Perunthalaivar Kamarajar Institute of Engineering and Technology (PKIET), Nedungudi, Karaikudi 609603, Tamil Nadu, India
aramudhanl973@yahoo.com

Abstract. The paper is about making a micro modular drone (MMD) which can be used by armed forces to automatically acquire targets in a wide environment and can maintain discreet close surveillance. A simple quad copter is used to maintain contact with the hostiles. To acquire targets, we use a PI sensor camera which is programmed by Raspberry Pi to automatically acquire targets. For real-time tracking and surveillance, we use a cloud to store coordinates which are continuously sent by the quad copter. A simple application (RM7) is used to acquire data from cloud which can be used by the quick reaction force (QRF) to effectively neutralize threats without taking too much risks and damages. The application is made in a way so that it is compatible with any handheld device and can be used anywhere. Thus, we make a drone which is modular, does not require air eld and much knowledge to operate, and can be used in border with fewer resources.

Keywords: Micro modular drone (MMD) · PI sensor · RM7 · Modular Resources

1 Introduction

Most drones are heavy and large in size, which require resources such as solar cells, maintenance, manpower, and often costly to deploy in border. Most of the time, the borders are not close to air eld which reduces the drones endurance time. To provide a solution to that, we employ a micro modular drone (MMD). The MMD has four basic structural modules. These four modules are aerodynamic and stability augmentation system, target acquisition, cloud data link, and QRF application management, i.e., RM7. The MMD has a lot of advantages over conventional drone due to certain

V. Bhateja et al. (eds.), *Information Systems Design and Intelligent Applications*, Advances in Intelligent Systems and Computing 672,
https://doi.org/10.1007/978-981-10-7512-4_4

characteristics. For combating insurgency in the border, close surveillance has to be maintained 24 ∗ 7. Deploying border staff on regular patrol is inefficient as it is waste of manpower. Other factors would include human error, endurance limits, and of course, great risks of losing life in the border. Instead of placing patrol, a drone can be used to maintain surveillance. A central monitoring team from the control room can control the area from a remote place. If a target does infiltrate through the border, it would be unwise for the QRF to directly confront the intruder, as the intruder maybe armed and may even be hidden in the terrain. The modules of MMD are made in a way to suit the needs of the QRF and central monitoring team in the control room. The systems are made redundant so that even if there is malfunction, the drone may either transfer its function to other MMDs present in the area or can continue to operate with damages. The modules are doubly redundant so that during damages, data and functions can be recovered without any error present in the cloud data link layer [1]. The application RM7 is made versatile. It can be used in any handheld devices such as phone or tablet through which the coordinates of the target can be acquired from the cloud with ease. The data link between the drone and the cloud is secured using an 8-bit encryption system. Ample security is given to the cloud so that, it would be difficult to be hacked and the data inside it cannot be manipulated by the infiltrators. The application can also be combined with auto artillery programs that lie far away to deploy missiles on the targets. The application is extremely useful for the QRF to make effective decisions such as either sending a squad to neutralize the threat or to land smart munitions such as Joint Defense Attack Munitions (JDAM) directly on the hostiles using the coordinates acquired by the MMD [2]. In the following section, the four modules are briefed well in detail. In the final section, the MMD is compared with the conventional drone surveillance to highlight the advantages of MMD.

2 The Basic Modules

The four basic modules are aerodynamic and stability augmentation system, target acquisition, cloud data link, and QRF application management, i.e., RM7. Each of these is designed based on the environment in which the MMD would be functioning. The modules are integral part of the MMD.

A. Aerodynamics and stability augmentation systems

A quad copter has four rotors. To make it airborne, all the four rotors rotate to produce lift in a horizontal direction [3]. The environment it would be facing would be heavy rains, dust, snow, sleet, and of course, enemy fire if detected by the hostiles. For heavy rains and winds, we increased rotor speed and the thrust is applied to counter to the wind direction. Another way for protection against wind is applying translation force by tilting the axis thus maintaining attitude equilibrium [4]. Snow does not possess much problem as the rotor produce torque force to withstand enough snow and air. The mainframe is made of carbon materials which are lightweight and can withstand heavy amount of damage. The drone is RF-controlled [5]. It can work autonomously and can be overridden using RF control if the command center feels the need to. The MMD is made fault-tolerant [6]. Even if one or two rotors completely fail due to enemy fire or

due environment fault, an automatic augmentation system tilts the quad copter to maintain attitude equilibrium [5]. The augmentation systems programmed automatically and do not need to be manually engaged during failure (Fig. 1).

Fig. 1. Quad copter in controlled fight despite losing one rotor. Stability augmentation system is based on this model

The payload of the copter consists of:

1. Rashberry pi—300 g
2. Solar panels—50 g
3. 5000 mAh battery—1000 g
4. PI camera—100 g.

Total weight = 1450 g.

The thrust-to-weight ratio is ample enough to make it maneuverable.

The payload is enclosed in a carbon box to protect it against snow, rain, sleet, and enemy fire. However, the MMD cannot protect itself against heavy explosives such as SAMs, anti-aircraft artillery (AAA) guns, and 40-mm bullets.

B. Target acquisition

To acquire targets, we use PI sensor in the Raspberry Pi. The PI sensor captures an area and converts it into digital image. The digital image is processed by the Raspberry Pi. Raspberry Pi has its own processor and RAM to quickly scan for targets [7]. The targets are acquired using color differentiation method. Once a target is acquired, the PI sensor changes from search to tracking mode automatically. While in track mode, preset settings such as distance, altitude are programmed so as discretion is maintained in the hostile area [8]. If the target is lost due to LOS or terrain or signal interference, then the PI sensor goes back to search mode. It searches back in the same last location. While automatically acquiring target, an alert message is already given to the central command. For overriding, the basic controls are replaced by RF commands given by central command. The drone has a built-in GPS system which simultaneously calculates the coordinates [9]. The coordinates and digital image data are multiplexed and sent to the cloud.

C. Cloud data link

The data link from the cloud and drone is made using 3 g or a 4 g connection. If a tower is nearby then 3 g connection is enough, if it is not there then 4 g is available for data transmission [10]. The digital image and coordinates are sent to the cloud. The central command is able to maintain close surveillance to the target by acquiring data from the cloud [11]. The data link is protected by 8-bit encryption. The cloud is configured using cloud tools and thus does not require much maintenance. A central command has systems to which the cloud is connected through a pipe [12]. Real-time surveillance is maintained by the control panel via the cloud (Fig. 2).

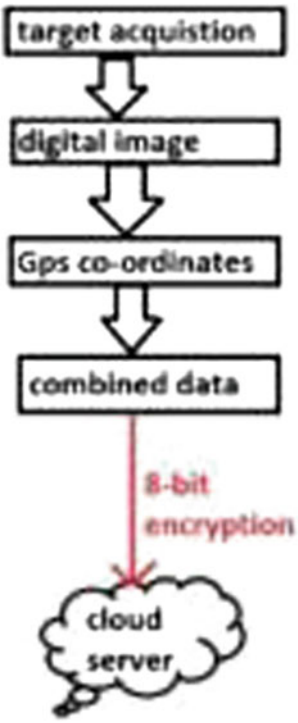

Fig. 2. Data link from drone to the cloud for maintaining real-time surveillance

D. QRF application management RM7

The QRF application, i.e., RM7 is an application that gives real-time coordinates of targets. It is a simple smartphone app that downloads the coordinates from the cloud. The app works in a very simple way. Coordinates from the cloud are plotted on a map application, and thus the location of the targets is known. The app focuses on acquiring target location only. RM7 is designed to work with many different systems. It is extremely versatile as the application is based on Java (Fig. 3).

Fig. 3. RM7 application functioning

3 Drone Operation and Functioning

The drone is launched by the border force and sent on a routine patrol mission. A predefined path is already specified toward which the drone scans for target using its PI sensor. The target-found message is given to central command once the intruder has been acquired by the drone [13]. The central command then overrides the control function to RF control to gain control of the drone [14]. The target is tracked, and live stream video of the intruder is acquired via the cloud. The coordinates are obtained in the phone app using the RM7 application.

Some of the characteristics of MMD drone are as follows:

A. Equipment

The equipment required for MMD is very less. They cost less and can be used anywhere. Only cost would involve buying cloud and optimizing it for application purpose.

B. Modular

Every part of the drone is modular. Even if any part or modules get damaged, they can immediately be replaced. The parts cost very less. Turnaround time is very less, and the MMDs can be made combat-ready in a very short time.

C. Accuracy

The data obtained from the drones are extremely accurate as they are taken immediately after coverage. The data link speed depends on the type of connection maintained from cloud to the MMDs (Fig. 4).

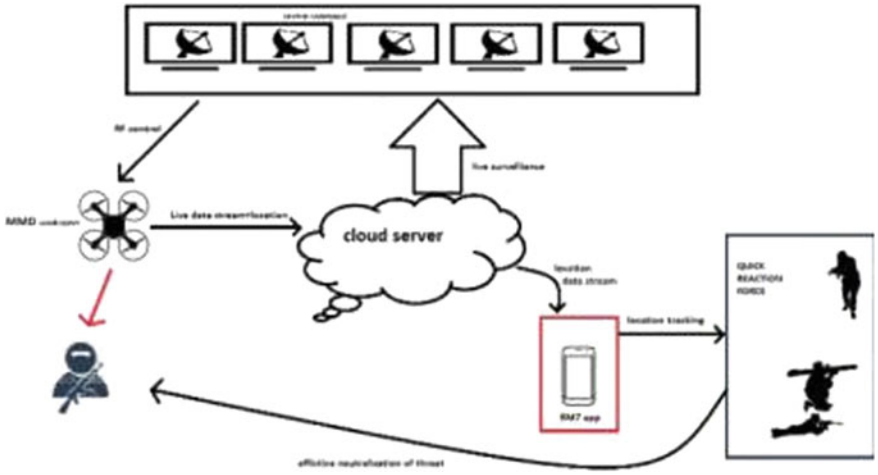

Fig. 4. Using drone in a border

D. Resources

MMD is a drone that operates without fuel. It does not require huge air force bases for taking off and landing. The MMD is solar-powered. It uses only 5000 mAh battery to perform all functions. The running costs of MMD are extremely low. Many MMDs can be inducted to maintain a fleet of drones for surveillance. All of them can be tracked and controlled by a specific set of drone pilots from a remote central command.

4 Comparison of MMDs to Conventional Drones

Drone versus MMDs

5 Conclusion

The paper discusses making a micro modular drone that can be used in many places. Here, we compare with conventional drone for making MMDs application border security area. We see that MMDs have a lot of advantages over conventional drone. The only drawback in a MMD is that it lacks armament.

In future, we hope wide number of MMDs would be deployed in the border which would reduce huge amount of defense spending and would lower the risks of border security force. We hope the RM7 app would help commander to make effective tactical decisions that would lower risks of QRF fighting around the borders (Table 1).

Table 1 Comparision between Micro Modular Drone and Conventional Drone

Characteristics	Micro Modular Drone	Conventional drones
Size	Very small in size	It is very big wings
Airfield	Does not require airfield	Requires airstrip to take off and land
Shootdown chances	The radar cross section is lesser for SAM's system to fire missiles	The RCS is enough for SAMs to acquire it in their radars to send a missile
Cost	Costs around $5000 approx	Costs around 1.8 million
Fuel	It runs on solar power maintenance	It runs on solar power and the panels need maintenance
Turnaround time	Turnaround time is less	Turnaround time is high
Tracking	Close surveillance is possible	Close surveillance is not possible
Pilot requirement	Does not require much experience	Flying experience is required
Altitude limits	Can fly at any altitude to track	It has to fly high to avoid detection. It has to fly in circle over the target area
Application	Application support is available	Application support is available
Camera and sensor	It uses PI sensor and can be replaced easily	It uses close CCD which is very large
Weight	The weight of the MMD is around 2–5 kg	The weight of conventional drone is very high, i.e., in tonnes
Armament	It provides no support for armament	The payload mostly consists of A–G missiles
Discretion	Discretion can be maintained as rotors do not produce much sound	Very high discretion can be maintained. However at lower altitude, detection is very much possible
Airspace requirements	Requires very less airspace	Requires lots of airspaces

Acknowledgements. The MMDs' creation is possible with the module drawn idea. I thank the Aurora project team for formulating the ideas and deploying them.

I thank Mr. Mark Weller (IEEE) for providing research paper on stability and control of quad copter despite the loss of one or two rotors.

References

1. R. Mahony, V. Kumar, and P. Corke, Aerial vehicles: Modeling, estimation, and control of quadrotor, IEEE robotics & automation magazine, vol. 19, no. 3, pp. 20–32, 2012.
2. P. Martin and E. Salaun, The true role of accelerometer feedback in quadrotor control, in IEEE International Conference on Robotics and Automation, 2010, pp. 1623–1629
3. P. Pounds, R. Mahony, P. Hynes, and J. Roberts, Design of a four-rotor aerial robot, in Australasian Conference on Robotics and Automation, vol. 27, 2002, p. 29.
4. A. Chamseddine, Y. Zhang, C. A. Rabbath, C. Join, and D. Theilliol, Flatness-based trajectory planning/replanning for a quadrotor unmanned aerial vehicle, IEEE Transactions on Aerospace and Electronic Systems, vol. 48, no. 4, pp. 2832–2848, 2012.

5. http://yingmachinearena.org/wp-content/publications/2014/mueIEEE14.pdf.
6. D. P. Bertsekas, Dynamic Programming and Optimal Control, Athena Scientific 2007, Vo-II, 2007.
7. Y. Zhang, A. Chamseddine, C. Rabbath, B. Gordon, C.-Y. Su, S. Rakheja, C. Fulford, J. Apkarian, and P. Gosselin, Development of advanced FDD and FTC, techniques with application to an unmanned quadrotor helicopter testbed, Journal of the Franklin Institute, 2013.
8. D. P. Bertsekas, Dynamic Programming and Optimal Control, Vol. II. Athena Scientific, 2007.
9. N. A. Chaturvedi, A. K. Sanyal, and N. H. McClamroch, Rigid-body attitude control, Control Systems, IEEE, vol. 31, no. 3, pp. 3051, 2011.
10. J. Fink, N. Michael, S. Kim, and V. Kumar, Planning and control for cooperative manipulation and transportation with aerial robots, The International Journal of Robotics Research, vol. 30, no. 3, pp. 324–334, 2011.
11. M. Ranjbaran and K. Khorasani, Fault recovery of an under-actuated quadrotor aerial vehicle, in IEEE Conference on Decision and Control. IEEE, pp. 4385–4392, Year-2010.
12. D. Scaramuzza, M. Achtelik, L. Doitsidis, F. Fraundorfer, E. Kosmatopoulos, A. Martinelli, M. Achtelik, M. Chli, S. Chatzichristo, L. Kneip et al. Vision-controlled micro ying robots: from system design to autonomous navigation and mapping in gpsdenied environments. [online] http://robotics.ethz.ch/scaramuzza/DavideScaramuzzales/publications/pdf/IEEERAMsubmitted.pdf, Year-2013.
13. Ravello Darea, Rosela d cruz, Stability of quadcopters using RF, IEEE, 2014.
14. J F. Fraundorfer, L. Heng, D. Honegger, G. H. Lee, L. Meier, P. Tanskanen, and M. Pollefeys, Vision-based autonomous mapping and exploration using a quadrotor MAV, in IEEE/RSJ International Conference on Intelligent Robots and Systems. IEEE, pp. 4557–4564, Year-2012.