CHAPTER TWO

LITERATURE REVIEW

2.1 Review of Related Work

The use of drones for delivering critical medical supplies has gained significant attention in recent years, driven by the need to improve emergency response times and access to healthcare in remote or disaster-affected areas. Several studies and implementations have explored the feasibility, challenges, and benefits of automated drone delivery systems, particularly in the healthcare domain.

One of the pioneering efforts in this field was by Zipline, a company that developed a drone delivery network to transport blood and medical supplies to remote regions in Rwanda and Ghana. Their system demonstrated how drones can reduce delivery times from hours to minutes, significantly impacting patient outcomes. This work highlighted the importance of reliable navigation systems and regulatory compliance for drone operations.

Academic research has also focused on optimizing drone flight paths and delivery logistics. For instance, Amukele et al. (2017) investigated the stability and integrity of medical samples transported by drones, emphasizing the need for maintaining specific environmental conditions during flight. This is critical for first aid supplies such as vaccines and blood products, which require temperature control.

Another study by Dorling et al. (2017) provided a comprehensive review of unmanned aerial vehicles (UAVs) in logistics, identifying key technological challenges including battery life limitations, payload capacity, and autonomous navigation in urban environments. Their work supports the integration of advanced sensors and AI for obstacle detection and dynamic route adjustments, which are crucial for automated systems delivering medical aid in unpredictable environments.

In the context of automation, recent projects have integrated machine learning algorithms with drone systems to enable real-time decision-making. For example, Kim et al. (2020) developed an autonomous drone delivery prototype that uses computer vision to identify safe landing zones and avoid obstacles, minimizing human intervention. This approach aligns with the goal of fully automated delivery systems that can operate efficiently in both rural and urban settings.

Moreover, regulatory frameworks are evolving to support drone deliveries of medical supplies. The Federal Aviation Administration (FAA) and other international bodies have begun issuing guidelines that ensure safe integration of UAVs into national airspace. Compliance with such regulations is an essential aspect of any implementation of an automated drone delivery system.

Despite these advances, challenges remain in scalability, weather dependency, and secure communication between drones and control centers. Many studies suggest that hybrid delivery models, combining drones with traditional methods, might be more effective in the near term.

Overall, the existing literature and practical deployments provide a solid foundation for the development of automated drone delivery systems for first aid supplies. By addressing technological, regulatory, and logistical challenges, this project aims to build upon previous work to create a reliable, autonomous delivery solution that can significantly improve emergency medical response.

2.2 Review of Related Concepts

The implementation of an automated drone delivery system for first aid medical supplies relies on several key concepts spanning drone technology, automation, logistics, and healthcare delivery. Understanding these concepts is essential to design an efficient and reliable system.

1. Unmanned Aerial Vehicles (UAVs) or Drones

Drones are remotely piloted or autonomous flying devices equipped with various sensors, cameras, and communication modules. Their ability to fly over difficult terrains and reach remote locations quickly makes them ideal for emergency medical deliveries. Key drone characteristics relevant to this project include payload capacity, flight range, battery life, and navigation precision.

2. Automation and Autonomous Navigation

Automation refers to the use of technology to perform tasks with minimal human intervention. In drone delivery systems, autonomous navigation is critical and involves the integration of GPS, inertial measurement units (IMUs), and computer vision to enable drones to plan routes, avoid obstacles, and execute safe landings. Machine learning and artificial intelligence techniques enhance the drone's ability to adapt to changing environments and make real-time decisions.

3. First Aid Medical Supplies and Packaging

The nature of first aid supplies—such as bandages, antiseptics, medications, and emergency kits requires special handling during transport. Packaging must ensure the protection of supplies from physical damage, temperature variations, and contamination. Some medical items may need temperature control or shock absorption during transit, influencing drone design and payload mechanisms.

4. Logistics and Delivery Systems

Effective delivery depends on efficient route planning, scheduling, and tracking. Concepts such as last-mile delivery optimization and real-time tracking systems are crucial to ensure timely arrival of medical supplies. Integration with healthcare systems or emergency response centers enhances coordination and prioritization of deliveries based on urgency.

5. Communication Systems

Reliable communication between the drone, control centers, and possibly mobile applications is necessary for command and control, status updates, and emergency interventions. Technologies such as 4G/5G networks, radio frequency (RF), and satellite communication are commonly employed.

6. Regulatory and Safety Considerations

Operating drones in public airspace requires compliance with aviation regulations, which cover flight altitude, no-fly zones, privacy, and safety standards. Ensuring fail-safe mechanisms, such as return-to-home functions and emergency landing protocols, are vital components of the system design.

7. Environmental and Operational Challenges

Weather conditions, geographic obstacles, and electromagnetic interference can affect drone performance. Concepts in robust system design address how to mitigate these factors, such as weather-resistant drone bodies and redundant navigation systems.

By integrating these concepts, the project aims to develop an automated drone delivery system capable of reliably transporting first aid medical supplies to critical locations swiftly and safely.

Understanding each of these foundational areas provides the basis for addressing technical challenges and optimizing system performance.

For this project (and proof of concept), a simple configuration interface is targeted, where the modules are easy to connect and integrate and with a strict low cost requirement (Corcoran, 2019).

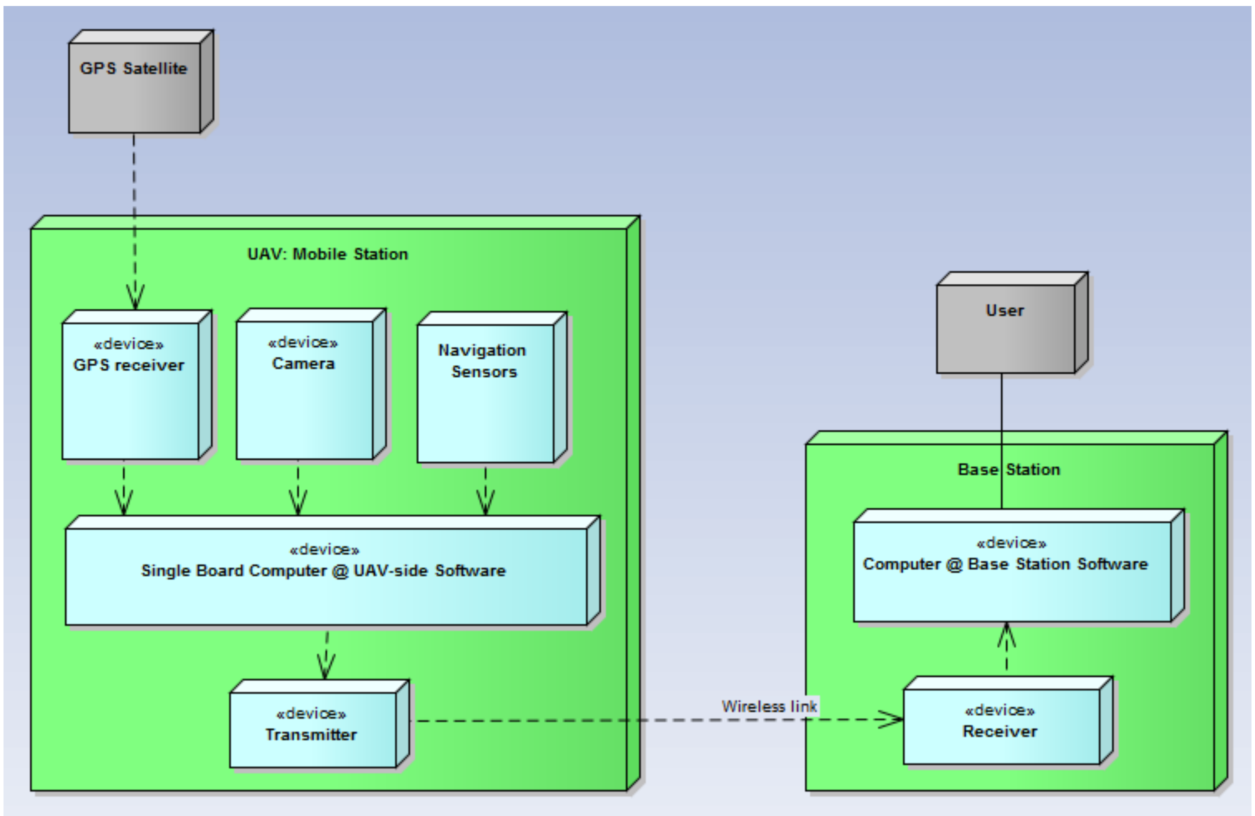

Figure 2.1: System modules: mobile and base stations (Corcoran, 2019)

Ashfaq *et.al.* (2017) produced a nonlinear model and nonlinear control approach for a 6-Degree of Freedom quadcopter aerial robot. The nonlinear model of quadcopter aerial mechanism is based on Newton-Euler formalism.

Doherty (2020), The Wallenberg Laboratory for Information Technology and Autonomous Systems (WITAS) is conducting a basic research project on Surveillance Drone at the Linkoping

University (LiU), Sweden. The project is multi-disciplinary and in collaboration with many Universities in Europe, USA and South America. The aim of this project is to advance technologies for many geographical land comprising road and traffic networks. It involves incorporation of self-sufficiency with digital video and IR cameras, and a communication system.

2.3 GPS Systems

The Global Positioning System (GPS) is a satellite navigation system that provides positioning, navigation and time information (PNT) anywhere on Earth, provided when there is an unobstructed line of sight to four or more GPS satellites (Collier, 2020). The timing service is implemented by incorporating in each GPS satellite a high accuracy atomic clock. The satellites permanently broadcast their own time to the receiver, so they can synchronize themselves. Besides the information about the time of each satellite, the satellites also broadcast their current position. With the information about the time the message was sent and the speed (speed of light), it is possible for the GPS module to calculate the distance between him and the satellites. By knowing the position of the satellites, which is sent in the message and by calculating the distance between the GPS module and the satellite, it is possible for the GPS module to calculate his own position (Collier, 2020). The protocol that is used by the majority of the GPS modules to communicate with other devices is the NMEA 0183, created by the National Marine Electronics Association. The advent of GPS has allowed the development of hundreds of applications, affecting many aspects of modern life. GPS technology is now in almost every electronic device such as cell phones, watches, cars, shipping containers and ATM machines. In order to improve the accuracy of the GPS system a few variations can be considered. The DGPS and RTK-GPS are two methods to improve the GPS system, as described in the following paragraphs.

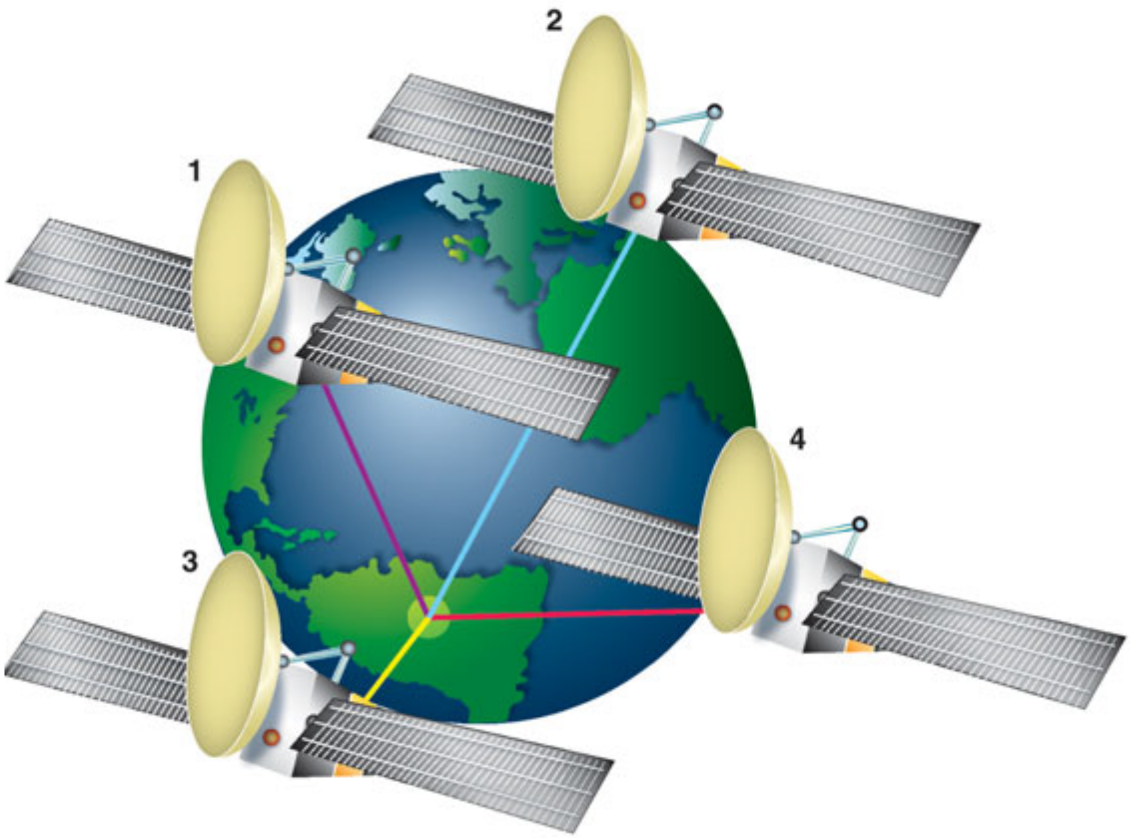

Figure 2.2: GPS Triangulation (Collier, 2020)

2.4 Data Communication

An UAV is able to autonomously fly during all phases of the flight, but has to be monitored from a base station. The communication system should be able to collect the data and transmit it to the base station. The success of UAVs missions is extremely dependent on the availability, high performance and security of the communication channel. As such, a communication channel is essential in an UAV system. The main requirements that should be taken into account, in order to choose the communication channel for this project are: low cost and enough bandwidth to transmit the gathered sensors. To estimate the necessary bandwidth for the data link, a JPEG image with 106 kB (1280 x 720 resolution), was repeatedly set at a rate of 10 fps and the result was a bandwidth of 8480 kbps. The other sensors require a small bandwidth, less than 100 kbps. Thus, the communication channel require a bandwidth, at least, of 8580 kbps. In this section, wireless communication technologies are presented.

2.5 Data Visualisation

After the gathered data (at the UAV) has been received by the base station, it is necessary to convert the data to a user friendly format and display it to the user. The main requirements of data visualization for this project are: low cost; the ability to trace the UAV and display the data from the gathered sensors. In this section, a set of relevant systems and technologies to display the gathered data is presented.

2.5.1 Dedicated Maps

To develop a dedicated application, a data base is necessary with the maps and servers to run the application. The main advantage of such a system is the ability to be fully personalized, fast and secured, since it is developed with one exclusive purpose. On the other hand, this type of system is more expensive, particularly in terms of development and maintenance of the system.

2.5.2 Google Earth

Google Earth5 is a stand-alone program developed by Google, which allows to display the world map through a virtual globe from space and view maps, terrain and 3D buildings. It is possible to zoom in and out for close-up views. In some areas, the close-ups are detailed enough to make out cars and even people. Google Earth has several features such as, find driving directions and measure the distance between two locations. The Google Earth Plug-in (its JavaScript API), provides the ability to embed a true 3D digital globe into web pages. By using the API, one can draw markers and lines, drape images over the terrain, add 3D models, or load KML files, allowing to build sophisticated 3D map applications. The Google Earth API also allows to load KML (Keyhole Markup Language) file which is a XML notation for expressing geographic data, developed for use with Google Earth. The KML files are very useful to load coordinates as a track in Google Earth.

2.5.3 Google Maps

Google Maps6 is a Web-based service, supported by Google, which provides detailed information about geographical regions around the world. Google offers advanced features that powers map-based services, including Google Maps Website, Google Ride Finder and Google Transit. The Google Earth and Google Maps functionalities are similar, Google Earth displays satellite images of varying resolution of the Earth's surface on a virtual globe, whereas Google Maps is a website to access and hover online maps. The Google Maps API is one of the most popular JavaScript libraries on the web and allows to embed Google Maps into a proprietary web, android or IOS application and use the map to search and explore the world. Google Maps comes with three types of maps: street, satellite, and terrain. All Maps API applications load the Maps API by using an API key. Google uses this API key to monitor the application

5https://developers.google.com/earth/

6https://developers.google.com/maps/

Figure 2.3: Google Earth globe

Maps API usage, and if the usage exceeds 25,000 map views a day, Google will contact and present charges. Google Maps API for Business7 is a paid version of Google Maps API and uses the same code base as the standard Google Maps API, but provides the following additional features and benefits:

(i) Greater capacity for service requests such as geocoding.

(ii) Business-friendly terms and conditions.

(iii) Support and service options, with a robust Service Level Agreement (SLA).

(iv) Intranet application support within the enterprise.

(v) Control over advertisements within the maps.