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Research Article

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Delivering Medical Products to Quarantined Regions Using Unmanned Aerial Vehicles

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Abstract

Unmanned aerial Vehicles (UAVs) possess the capacity to transport goods quickly, safely, and inexpensively across both accessible and inaccessible terrains such as to stranded mountain climbers or boats adrift. Medical supplies are typically delivered by ground transport as well as aircraft, both fixed and rotor wing. During emergencies, the availability of blood products and pharmaceuticals is often limited at critical access hospitals, and conventional channels of supply may become disrupted. This article aims to demonstrate the feasibility of using small UAVs to transport pharmaceutical products to epidemic-stricken regions.

A Syma X5-c quadcopter was loaded with a sample drug. Using its accompanying transmitter, the drone was flown from a base location to a pre-determined delivery location. Upon successful delivery of the drug, the drone was navigated back to base by the operator. Future improvements to the drone model include facial identification system to verify recipients before delivery, auto-pilot control of drone with the aid of an on-board computer program and a GPS unit, real-time picture, and video relay/transmission back to control station, and autonomous delivery of drug without requiring physical contact from the recipient.

Keywords: Unmanned Aerial Vehicles; Automated pharmaceutical delivery; Quadcopters

Introduction

Unmanned Aerial Vehicles (UAVs) are aerial vehicles or drones that operate without a human operator on-board. They are either controlled through radio frequency from a remote control or through a computer program installed on a computer on-board the drone. Initially used primarily by the military sector (e.g. for missile deployment during war), applications of UAV have extended to the civilian sector. Some of the current applications for UAV include: agriculture [1] surveying [2], wildlife monitoring and conservation [3], real estate assessments [4], surveillance, meteorological studies, such as taking geographical samples at extreme heights, and courier services, such as Amazon CEO Jeff Bezo's announcement in 2013 that the company would use drones for package delivery [5]. Advances in technology and decreasing costs have led to an increased use of unmanned aerial vehicles (UAVs) by the military and civilian sectors. The use of UAVs in commerce is restricted by US Federal Aviation Administration (FAA) regulations. The FAA continues to demand that drones be controlled by a human pilot and stay within that pilot's sight line. These regulations forestall implementation of a large-scale drone delivery fleet. The FAA also has established a no-fly zone, which lies between 400 and 500 vertical feet, to ensure that drones remain distinct on radar from human-piloted aircraft. However, such restrictions do not necessarily apply to other countries [5]. In fact, 57 countries and 270 companies were producing UAVs in 2013 [6].

The use of UAVs in the medical industry is relatively new. UAVs have been used for medical product transport [7]. Drones delivered care packages in the aftermath of the 2010 Haitian earthquake and have been deployed in various disasters, such as the category 5 cyclone that struck the islands of Vanuatu, the Nepal earthquake, and Super-storm Sandy. In 2014, a medical drone delivery of medication was undertaken by Deutsche Post DHL AG from Norddeich, Germany to Juist, a remote, car-free island in the North Sea. The drone flew for approximately 12 km off the German coast and landed on the island. Doctors without Borders also used drones to transport dummy tuberculosis (TB) test samples from a remote village to the city of Kerema, Papua New Guinea in 2014. The country has a significant TB burden and an increasing burden of multidrug-resistant TB, as well as inaccessible roads and generally poor weather conditions that moor transport boats 5 months of the year [6,7].

Singer et al. [8] have proposed the use of small UAVs for transporting laboratory samples for early infant diagnosis of HIV in Malawi. Transportation of laboratory samples for HIV (EID and Viral Load), tuberculosis and other diseases is a tremendous barrier in Malawi due to limited transportation infrastructure, poor roads (some of which are impossible during the rainy season), and the high cost of fuel (approximately USD 1.40 per liter). There are several companies specializing in UAVs for the health sector and a consortium of non-profit, for-profit, academic, and international organizations working together on developing UAVs for health [9] UAVs have been considered for delivering health commodities, and have been tested for transporting laboratory samples in Haiti, Lesotho, Papua New Guinea, and South Africa [10].

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The goal of this research project is to test and explore the possibility of using UAVs to provide medical assistance to remote, inaccessible regions undergoing epidemic outbreaks, such as the Ebola virus that affected over four countries in the West African sub region. Under such circumstances, the virus responsible for the disease can be transmitted by physical contact either in person or body fluids of an infected person, with death almost certain to occur within days. This makes it very hard for medical attention to be given to people in the epidemic stricken region. In the case of the Ebola epidemic in West Africa, several health-care providers were infected while trying to offer medical assistance, while some lost their lives. The use of UAVs for drug delivery to quarantined regions experiencing this epidemic outbreak could potentially reduce the cases of infection and mortality among health care workers wishing to provide medical assistance to these regions. This project explores and demonstrates the practical feasibility of utilizing UAVs in the transportation of medical drugs to quarantined regions experiencing cases of epidemic outbreaks.

The drugs required by the quarantined region are loaded on the drone at the base station (a region free from the epidemic outbreak). The drone is then navigated to the quarantined region by an operator until it gets to the quarantined region. After successfully arriving at the quarantined region, the drone lands at a specific location where the intended recipient for the drug is waiting. The recipient retrieves the drug from the drone. After successful delivery of the drug to the intended recipient in the quarantined region, the drone is then navigated back to the base station by the operator. Details about the drone utilized in this study, and the methodology that would be employed in aerial drug delivery for quarantined regions are presented in the Materials and Methods Section. The results section show the outcome obtained after implementing the previously described methodology. The challenges encountered and possible improvements to the system are explained in the results and discussion section.

Materials and Methods

Materials

Syma X-5c drone: The Syma X-5c is a remote-controlled quadcopter with an on-board camera (Figure 1). A quadcopter, also called a quadrotor helicopter or quadrotor, is a multi-rotor helicopter that is lifted and propelled by four rotors. Control of vehicle motion is achieved by altering the rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics. There are several advantages to quadcopters over comparably-scaled helicopters. Quadcopters do not require mechanical linkages to vary the rotor blade pitch angle as they spin. This simplifies the design and maintenance of the vehicle. Second, the use of four rotors allows each individual rotor to have a smaller diameter than the equivalent helicopter rotor, allowing them to possess less kinetic energy during flight. This reduces the damage caused should the rotors hit anything. For small-scale UAVs, this makes the vehicles safer for close interaction. Some small-scale quadcopters have frames that enclose the rotors, permitting flights through more challenging environments, with lower risk of damaging the vehicle or its surroundings. Due to their ease of construction and control, quadcopter aircraft are frequently used as amateur model aircraft projects. Moreover, due to the fact that they are unmanned, there is a reduced risk of loss of lives in the event of a crash. These characteristics make drones very useful and would therefore be harnessed by the project to fulfil its aim. Some key features of the Syma X-5c quadcopter include:

1. 360° roll.

Figure 1: Syma X-5c and transmitter.

2. 6-axis gyroscope.
3. Hover capability.
4. HD camera for video/image capture.
5. 100x faster radio control.
6. Further remote distance with spectrum technology.
7. Modular design.
8. Indoor /outdoor flight.
9. 2 pounds in weight.
10. 50 meter remote distance.

Transmitter/remote controller: The drone is accompanied with a remote controller (Figure 2). The remote controller interfaces with an on-board receiver that in turn controls the motion of the rotors and the speed of rotation as the case may be. It works with a radio frequency with a range of 2.4 GHz.

High/low speed switch: This button regulates the speed of directional transit of the drone. Basically it throttles the speed of sideways transition of the drone.

Left control accelerator lever: The accelerator lever is used to the control the speed of rotation of the fan. The speed of rotation is directly proportion to the height of flight of the drone; therefore the accelerator is used to control the height of flight of the drone. The acceleration is controlled by moving the joystick upwards and downwards. The accelerator is also used to synchronize the signal of the transmitter with that of the drone.

Hover up and down trimmer: This trimmer is used to fine-tune the default height of flight of the drone. In some cases when the drone is switched on, it moves higher without controlling it to do so. In cases

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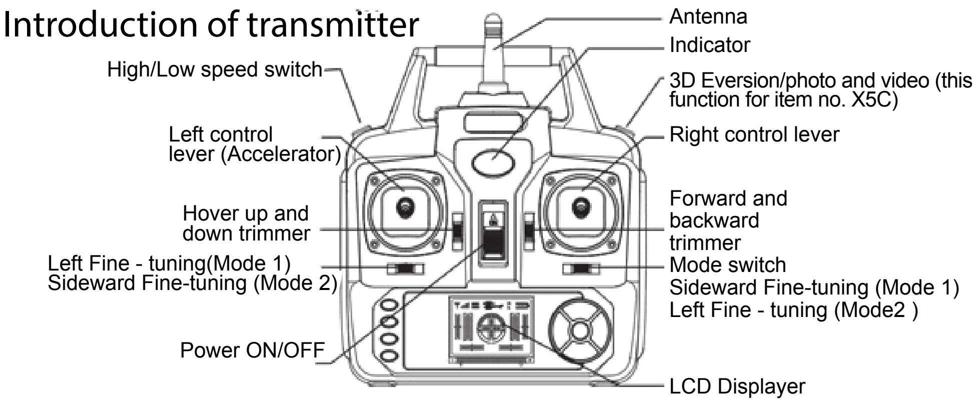

Figure 2: Transmitter for Syma X5-c Quadcopter.

like that the trimmer can be used to ensure that the drone is stabilized and restore it to a default height of hover as specified by the position of the accelerator.

Side-ways fine-tuning button: This applies in cases where the drone flies sideways without controlling it to do so. The side-ways fine-tuning button is used to adjust the default sideways movement of the drone.

Antenna: This is used to transmit radio frequency that controls the drone and also receives feedback signal from the drone as the need be.

Indicator: This indicates when the transmitter is powered on and also blinks when the transmitter operates.

Power button: The power button is used to switch the transmitter On/Off.

3d eversion/photo and video button: This button controls the drone to display some stunt in air. The photo/video button is used to actuate the on-board camera for photo and video capture.

Forward and backward trimmer: Like the other trimmers it is also used to adjust the default position of the drone.

Direction control lever: This is used to direct the drone forward, backward, leftward and rightward.

LCD display: This gives a visual display of the controls and operational state of the drone, showing the acceleration and direction.

Methodology

Figure 3 shows the flow chart operation of the drone for drug delivery in an epidemic-stricken area. An order is made for medical supplies that are needed urgently in the region. The GPS coordinates of the delivery point is made available. The drone is loaded with the required drug. For demonstration purposes, a single tablet of a malaria drug is secured to the drone. The navigation of the drone is a basic responsibility of the operator, i.e. it is done with no programming code involved. The drone was controlled in an open field with sufficient space to prevent collision with humans or structures. Once the drone reached the delivery point, it was lowered to ground level. A picture of the recipient was snapped using the on-board camera. The recipient retrieved the drug. The drone was then flown back to the base. It should be noted that FAA regulations demand that drones be controlled by a human pilot and stay within that pilot's sight line. However, these regulations do not exist in the African countries where the Ebola epidemic outbreak occurred, and so the navigation of the drone could

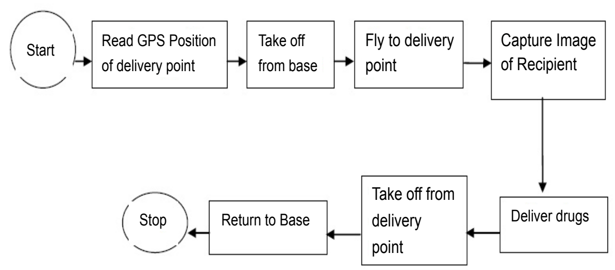

Figure 3: Flow chart for drug delivery using UAV.

eventually be done autonomously, enabling the drone to travel further distances and away from the operator's line of sight. It would also require less input from the operator.

Discussion and Conclusion

The drone was successfully controlled to deliver the specified goods to the delivery point and to fly back to its base. Figure 4a shows the drone prior to take off. The malaria drug is being loaded on the drone. Figure 4b shows the operator manning the drone during flight. Figure 4c shows the drone navigating to the delivery point. Figure 4d shows the recipients retrieving the drug from the drone at the delivery location. Figure 4e shows the drone navigating back to base. Figure 4f shows the drone back at the base.

Several challenges were encountered during this project. The mechanical force imposed by direction of breeze distorted to an extent the positioning of the drone while hovering in air. The effect of the wind was taken into consideration during the control of the drone. The battery life of the drone has a rating of 3.5v 500mAh, which is quite low. The drone takes about 3 hours to get fully charged but only has an operational time of about 10-15 minutes. However, this drone was sufficient to demonstrate the feasibility of using UAVs for drug delivery.

There are still many things that can be added to this drone make it more efficient. Future improvement to the drug delivery drone includes inclusion of a facial identification system to verify recipients before delivery. Control of the drone will be upgraded from the transmitter to auto-pilot mode with the aid of an on-board. computer program and a GPS unit. Real-time picture relay/transmission back to control

(a) (b) (c)

(d) (e) (f)

Figure 4: Drug delivery using UAV (a) Loading drug on UAV at base.(b) Controller manning UAV after take-off from base. (c) UAV en route to delivery point. (d) Recipients retrieving drug from UAV at delivery point. (e) UAV departing after delivering drug (f) UAV arriving at home base.

station would also be included in the upgraded model. The battery life of the drone will be upgraded to increase the flight time of the drone. Additionally, an automated drug release mechanism (such as a small robotic gripper) could be integrated into the drone so that the recipient has no cause to physically touch the drone. With this feature, once the drone arrives at the destination point, it would automatically deposit the drugs on the ground before taking off and flying back to the base station. This would ensure that the epidemic does not spread beyond the quarantined region.

This research project has successfully demonstrated that UAVs can be used for drug delivery in quarantined regions undergoing epidemic outbreaks. Future work will include autonomous navigation of the UAV, developing an efficient power supply for the UAV, photo identification of recipient prior to drug delivery, and automatic delivery of drug at destination point without requiring physical contact from the recipient.

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