GROSTLOG 2018
Global Research on Sustainable Transport & Logistics

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/atlr

Mechanism For Drones Delivering The Medical First Aid Kits

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Abstract

Transportation plays vital roles in lives. Its connections are associated with almost everything, from postal deliveries to multi-million cargo shipments. Currently, transportation of medical goods during critical need is limited to wheeled motor vehicles and manned aircrafts, which can be costly, slow, and sometimes impossible when emergency site is out of reach. Nowadays, drones revolutionise healthcare by transporting lifesaving medical supplies such as medical aids and blood. Unfortunately, with current technology, drone's battery lifespan is a limitation that can hinder the delivery process. This paper describes our study that concerns with design of mechanism that prolongs drone's battery life and offers effective delivery of medical first aids. The mechanism is attached to the drone and carries medical aids safely while decreasing the number of take-off and landing by deploying the kits from air to land (using parachute method). The main objective of this study is to design a mechanism that can carry and release the medical kit with care at the targeted area. Based on the results, the mechanism was proven to be able to carry and release medical first aids securely during flight and landing.

Keywords: drone, release mechanism, medical first aids kit, Arduino

Introduction

Whenever a medical emergency occurs, quick response time is critical in terms of life saving. However, currently, the transportation of medical aids in times of critical need is limited to wheeled motor vehicles and manned aircraft, options that can be costly and slow (Thiels, Aho, Zietlow, & Jenkins, 2015), and sometimes is impossible when the emergency site is out of reach. Furthermore, traffic congestion is a major problem in big cities and ambulances can be stuck in a traffic jam and may not be able to arrive within the targeted emergency response time. Drones can be seen as the innovative alternatives in enabling immediate

ISSN: 2622-5778 (online)
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help to victims suffering from health emergencies or traffic accidents before professional medical personnel arrive. By speeding up emergency response, possible harms can be avoided and healthcare providers can prevent potential deaths and accelerate patient treatment.

Drones are commonly known as unmanned aerial vehicles (UAVs) that are remotely or automatically controlled. Nowadays, drones revolutionise the healthcare by transporting lifesaving medical equipment and supplies such as medical first aid kits, telemedicine or medical support such as diagnostics, drugs, or tools, blood, life-saving drugs, vaccines or anti-venom, defibrillators to patients in cardiac arrest, prescriptions and even organs for transplantation. Drones are also capable of delivering medical supplies quickly and effectively to people in remote medical centers, disaster areas, and offshore vessels. Thus, as stated in Scott and Scott (2017), drones are useful for medical supplies delivery when the delivery involves small items, remote locations with difficult access, timely delivery, poor transportation infrastructure at destination, or roads blocked by severe weather, disasters or traffic congestion.

The use of small drones is subject to several limitations in relation to load capacity, flight duration, power supply, and other technical features. The flying range of small drones is between 1.5 km to 3 km per complete flight (LaFay, M., 2015) while a long distance drone can fly up to a maximum of 80 km. According to Hasan and Jouffroy (2017), drones are powered by lithium-ion batteries, which offer the highest power and energy density. According to Scrosati, Croce, and Panero, (2001) and Salameh and Kim (2009), the drone batteries represent one of the most troublesome and potentially hazardous components of drone operations. The battery's power determines the drone's flight time and a more powerful battery keeps the drone in the air for a longer period. The flight time of normal drone ranges from 15 minutes up to 60 minutes. It can also last between two to four hours if the batteries are of military grade quality. Thus, a notable drawback of drones is the high power consumption, which is dependent on the batteries that influence the flight duration of the drone's mission. With the current technology,

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
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the drone's battery lifespan is a limitation that can hinder medical aids delivery process.

The drone's battery lifespan also usually depends on the usage of the drone itself. Corral, Fronza, El Ioini, and Ibershimi (2016) states that the maneuvers, movements and general aspects of the flight profile (load, altitude, speed) that involve more energy investment will result in faster battery discharge that leads to shorter drone autonomy. Therefore, it is important to optimise the flight time of drone by reducing the number of drone's take-off and landing since taking off and landing increase the flight time and consume more energy. Optimising the batteries lifespan for the drones has then become the main motivation for us in conducting our study.

This paper describes our study that concerns with the design of mechanism that prolongs drone's battery life and offers effective delivery of medical first aids. The mechanism developed is attached to the drone. It will carry the medical aids safely while decreasing number of take-off and landing by deploying the kits from air to land (using parachute method).

Methods

Our study has three objectives. The first objective is to identify the main features for suitable deployment mechanism for holding and releasing the first aids. The second is to design a mechanism that can be attached to the drone and can carry medical aids with care. Meanwhile, the last objective is to test the mechanism using real experiments with an actual scale prototype.

As mentioned earlier, drones have a notable limitation in terms of high power consumption which influences the flight duration. Thus, strategy or mechanism that leads towards efficient power consumption must be sought. In drones operations, the most important quality requirement is airworthiness, which refers to an aircraft's suitability for safe flight. Based on Corral, Fronza, and El Ioini (2015), a drone is considered airworthy if it is able to take off, conduct its mission and land safely. Therefore, in this study, when designing the mechanism

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for the drones, the energy efficiency towards airworthiness has been the prime concern.

Prior to designing the mechanism for the drone, the type of drone to be used in delivering the medical first aid kits has to be selected. Basically, there are two main types of drones (UAVs) in the commercial market, which are the fixed-wing and the multi-rotor ones. Both have their advantages and disadvantages including their suitability for certain applications. Fixed-wing UAVs normally have longer flight endurance capabilities while multi-rotors can provide stable image capturing and easy vertical take-off and landing. Fixed-wing UAVs can cover large areas in one flight, however they require a suitable landing area and some skills of the pilot to land them softly to avoid damage to the craft and sensors. On the other hand, multi-rotor drone is easy to control and maneuver. The multi-rotor drones are easy to fly, to take off including landing, and they can easily perform autonomous flights (Thamm, et al. 2015). Thus, with some training, one can control this drone without much difficulty. Another big advantage is that a landing strip is not required for this kind of drones, making them suitable to be used in fields, forests or in urban environments. However, the multi-rotor drones have to create their lift during the complete flight actively, hence their endurance and their operation speed is restricted and they can only cover limited areas (Cai, Dias, & Seneviratne, 2014).

In this study, a multi-rotor drone is considered as a more suitable aerial vehicle for transporting the first aid kits. It is easy to handle and it has the ability of multi-rotor to hover in a more stable manner as compared to the other type of drone. These advantages can help the developed mechanism to release the medical kits in stable condition during in the air, which may contribute towards safe and accurate landing of the kits at the targeted area. For our study, the DJI Phantom 3 drone has been used. Its main specifications include: weight (battery & propellers included) is about 1216g, maximum flight time is approximately 25 minutes, GPS for satellite positioning system, uses LiPo 4S as intelligent flight battery and 2600 mAh LiPo 18650 battery for the remote controller.

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The conceptual design is the first phase of the design process, where it outlines the features and structure of the preliminary stage. The process flow steps are as the following:

i. The drone will be equipped with the mechanism that is able to carry the medical first aid kits (30 items with max. weight of 500 grams).

ii. The drone will be able to fly and maintain hovering at the altitude of 30, 50, 70, 80 and 100 meters from ground.

iii. The drone will be able to fly to the selected area

iv. The Wi-Fi module will receive the input from the browser to release the medical box from the air.

v. The medical first aid kits box will be dropped on the targeted area with the assistance of the parachute.

vi. The time of the medical kit landed based on different altitude will be recorded.

vii. The distance deviation of the medical kit landed from the target point will be recorded

Figure 1 shows the conceptual design for method of this study. The first aids box holder has two main functions that are essential during the flight test. First, this box holder is installed with a parachute and thus the holder will fall down with decent downward velocity and land without harm to the medical kits. Second, this box holder is appropriate for the mechanism that will be designed. When it is released to the air, the left and right sides of the holder have a slot that will be controlled by two servos which will carry and release this handle when arriving at the drop destination.

Next, the drone in Figure 1 refers to the selected drone of this study, which is the DJI Phantom 3. Because of its credibility, this drone is the best option for this prototype testing.

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Advances in Transportation and Logistics Research
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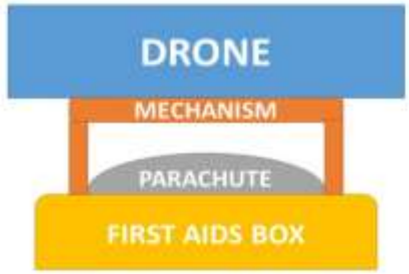

Figure 1. The conceptual design of drone and first aids box holder

DJI Phantom 3 is able to carry a heavy payload (maximum of 2.5 lbs. or 1.134 kg) as compared to others drones. This drone is also extremely user-friendly. It is equipped with interface that can ease the flying process. Meanwhile, the built-in GPS track the location of the drone during delivery of the medical kits to the targeted area.

In realizing the idea of the mechanism intended in this study, which is the medical kits holder, and transform it into reality, this research used the 3D printing method. The advantage of the 3D printing is the speed at which part can be produced compared to the traditional method. Transforming a CAD model into a printed product will only take a few hours to complete. With the time constraint, the ability to produce functional end parts at low to mid volumes offers a huge time-saving advantage when compared to traditional manufacturing techniques.

The selected material for the medical kits holder is Acrylonitrile Butadiene Styrene (ABS). ABS is best suited for this application where it has the required strength, ductility, machinability and thermal stability. ABS is more prone to warping thus; the medical kits must not be too heavy to be carried by the drone. In this study, the weight of the medical kit box is limited to a maximum of 500 grams only. Therefore, the most important setting here is the fill density, which defines the amount of plastic inside the print. In general, a fill density between 10% and 20% will be strong enough for most objects. In this study, the medical kits holder infill density is 15%. Figure 2 shows the CAD model of the medical kit holder and the medical kit holder produced through 3D printing.

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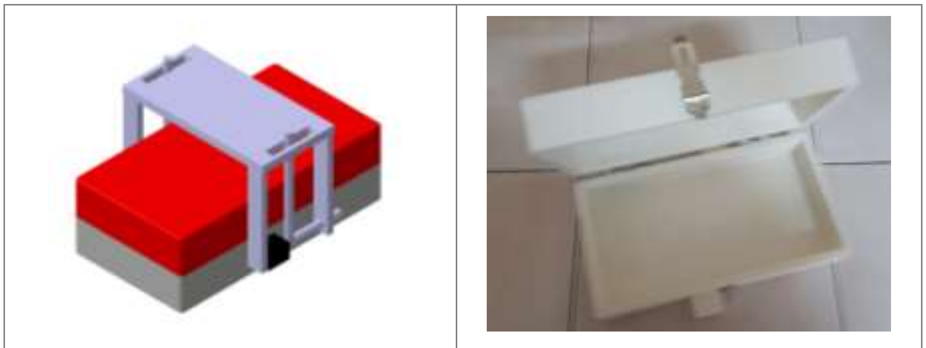

(a)	(b)

Figure 2. (a) CAD model of medical kit holder and (b) the medical kit holder produced by 3D printing

Parachute is one of the mechanisms that enables medical first aid kits to reach the targeted area safely and the paramedic or medical personnel is going to be able to use the kits. The function of the parachute is to slow down the speed of medical kits falling to the ground. The selected material to be used for the parachute in the prototype testing is nylon (refer figure 3).

Figure 3. The parachute

The Arduino UNO is a widely used open-source microcontroller board based on the Microchip ATmega328P microcontroller developed by Arduino. In this study, the Arduino UNO for the drone has been set up according to the schematic diagram, equipment, modules and coding. Basically, this system is used to unlock the first aid kits holder in mid-air. The Arduino UNO will act as a brain to translate the input that has been sent by a user based on the output that is desired by the study.

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The setup of the complete mechanism prototype consists of Arduino UNO, a servo motor, and power supply. This mechanism is placed directly underneath the drone, followed by the parachute and lastly, the medical first aid kits. The mechanism prototype testing was done by having the drone flown at the altitude of 30m, 50m, 70m, 80m and 100m above the ground. Note that the maximum height for a drone to fly at the urban area is 100 meters. The data recorded from this research are; the time taken for first aids to reach the ground, the coverage area of the parachute when landing, and the condition of the first aid kits after landing. The prototypes testing experiments were conducted, mostly during noon in May 2018. The ideal situation for the prototype testing experiments is the day with moderate humidity and not windy. The prototype testing experiments were carried out at a public field at Taman Bukit Bandaraya, Seksyen U11, Shah Alam, Selangor. This location has been a strategic place for conducting the testing because it is quite isolated and away from main roads. It was chosen as a precaution step to avoid any injuries on people that may occur either during the flight duration or when the medical first aid kits fall to the ground at high acceleration.

Figure 4 displays the location where the prototype testing experiments were conducted. Meanwhile, Figure 5 shows that the mechanism was able to release the medical first aid kits box without any problem.

Figure 4. The test location in Shah Alam

Figure 5. Deployment of medical kits

The achievement also includes the parachute fully open successfully, which reduces the impact when landing on the ground. Therefore, this parachute is able

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to deliver the medical first aid kits safely without damage or any other problem.

Results and Discussion

The time taken for the first aids to reach the ground, the coverage area of the parachute when landing, and the condition of the first aid kits after landing were recorded when the medical first aid kits box was deployed at different altitudes. The various landing points of the medical first aid kits box provide the data on distances from the targeted landing spot. Then a graph of these distances versus the altitudes from where the medical first aid kits box was released is plotted (see Figure 6). Figure 6 shows that the relationship between the altitude and the distance deviation from the target point has a linear trend. Figure 7 presents the graph that shows the relationship between the time taken for the box of medical kits to reach the ground versus the altitude at which the medical first aid kits was released. Figure 7 shows that the relationship between the altitude and the time taken to hit the target point fluctuates. The plotted data do not seem to demonstrate any clear trend although the time taken increases along with the increase in vertical elevation during release of the medical kits box. The results as shown in Figure 6 and Figure 7 were then compiled, and the mean and median of the readings were calculated and tabulated in Table 1 to analyze the best altitude to release the medical aid box.

Based on Table 1, the lowest time for the medical kit to hit the ground after being released is 11.5 s when released from 30 m, and the mean and median of nearest distance from landing point to the target point is 13 m and 14 m, respectively, which is also at 30 m altitude. This support the theory that the lower the altitude, the shorter the time taken to reach the ground, and the deviation from the target point will also be smaller. However, the time for the medical kits box to hit the ground when released at 70m was found to be the second lowest, which is at 21.5 s. Meanwhile, the median of distance of deviation from target point for the medical kits box, which was released at 70 m altitude (16.5 m), is almost the same as that from 50 m altitude (16 m).

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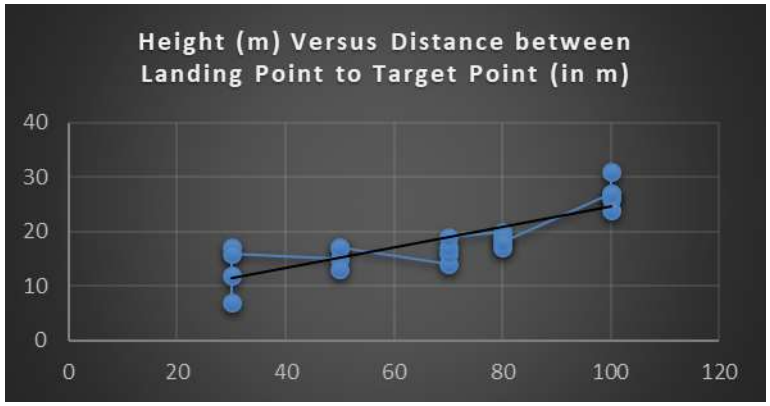

Figure 6. The distance between medical kits landing point and the target landing spot versus the altitude at which the medical kits box was released

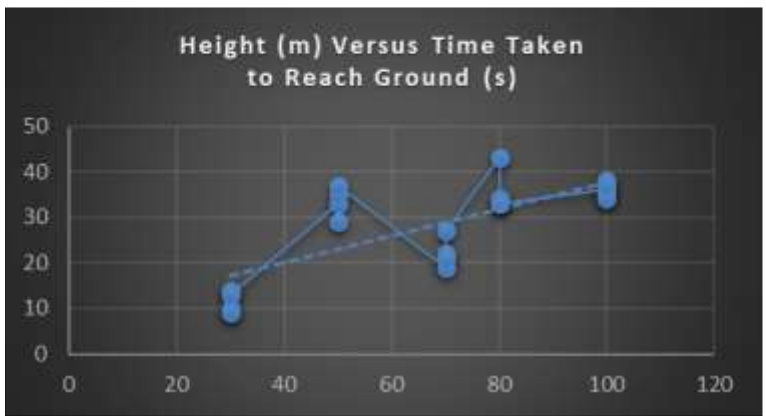

Figure 7. The time taken for medical kits box to reach the ground versus the altitude at which the medical first aid kits was released

External factors such as time of day and wind speed might also have an effect on the time taken by the medical kits box to land on the ground and the deviation of distance from target point. For the case of 70 m altitude, probably the time when the medical kit was released, there was no wind, which can cause drag, thus this makes the time to reach the ground faster. It is difficult to control the external factors due to the uncertainty of the weather condition.

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Table 1. Summary of Mean and Median Time to reach the ground and distance diverted from target point

	Height (m)	Time taken for object to reach the ground (Mean)	Time taken for object to reach the ground (Median)	Distance of the object deviates from target spot (Mean)	Distance of the object deviates from target spot (Median)
1.	30 m	11.5 s	11.5 s	13 m	14 m
2.	50 m	33.5 s	34 s	15.5 m	16 m
3.	70 m	21.5 s	21.5 s	16.5 m	16.5 m
4.	80 m	35.7 s	33.5 s	18.5 m	18.5 m
5.	100 m	36 s	36 s	27 m	27 m

Conclusion

This study has shown that the drone was able to carry the medical kits with weight of 500 grams safely using the developed mechanism. The medical first aid kits consist of 30 items such as bandages, plasters, antiseptic cream, alcohol wipe and scissors. The mechanism was built using Arduino UNO, servo motor, power supply (6 volts) using a custom made 3D printing. The mechanism acts as the lock and release mechanism for the medical first aid kits box. Besides that, the parachute deployed for the medical kits delivery performed perfectly. It was able to support the medical kits with 500 grams weight and released from different altitudes during the deployment. Releasing the medical kits box at certain altitude and the use of parachute through the mechanism designed reduced the number of take-off and landing, thus contributes towards batteries power saving, which can prolong the batteries' lifespan. The first aid kits has also been successfully and safely delivered to the target destination throughout the experiments. The medical kits also landed in good condition when released from the selected heights. These results indicate the potential for a low-cost drone and mechanism to perform the delivery of the first aid kits as required by circumstances.

In addition, the medical kits box does not land on the targeted spot. Most of the times, the box reached the ground in more than 10 meters away from the target. Thus, it can be deducted that external factors may have influence on these

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distances especially when weather conditions are unpredictable. Nevertheless, the study has achieved its objectives. For future studies, drone with higher specifications (longer flight time or longer life batteries) can also be used for testing the mechanism as well as for testing with heavier payloads. In addition, more reliable transmitter and receiver can be considered such that data can be transmitted at long range where the receiver can also read it. This recommendation may enable the drones that deliver the medical first aid kits to work more efficiently and effectively.

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