Chapter 11
Drones in Healthcare

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Abstract Unmanned aerial vehicles (Drones) were first used in the 1990s by military organizations. However, the decline in cost due to technological advancements has allowed drones to become viable options for a diverse range of services including health services. Currently, health services and medical resources in underserved communities are limited to motor transportation and in-person interactions; however, drones may be a feasible option in providing these services in a more effective manner. Current research has explored the use of drones for natural disaster relief, search and rescue missions, and transfer units. However, there is limited research on how drones could be used as telemedicine and transfer units. This chapter discusses the current research on the use of drones in the health field and presents a pilot research project on drones as telemedicine and transfer units.

Keywords Unmanned aerial vehicles • Drones • Rural medicine • Telemedicine

11.1 Introduction

Drones have generated great interest in recent years due to their industrial, commercial, and recreational potential. Drones have locomotion capacities, the ability to move from one side to another. However, drones are differentiated from

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other air vehicles in that they do not need to be manned by a human. Their remote pilots can control them from varying distances, dependent on their automation and autonomy. Therefore any unmanned aerial vehicle that has the capacity to be autonomous even with various functions and uses is considered a drone.

The most common term used in the media today to describe an "unmanned aerial vehicle" is a drone. Unfortunately the term drone often carries a level of stigma inherited from its controversial military applications on the battlefield. A more preferable and descriptive term used by proponents of the industry is unmanned aerial vehicle (UAV). Drones and UAVs are considered synonymous, although some argue that a drone can be differentiated by a level of automation that makes it flight dependent on pre programmed behaviors as opposed to a UAV that is a remotely piloted aircraft flown by "stick and rudder," with a pilot in control. This point of differentiation, however, remains debatable. On the other hand, unmanned aerial systems (UAS) is a term of reference that by definition is clearly distinguishable from a drone or UAV. A UAS is a description that encompasses the aircraft or the UAV, the ground controller, and the communication system that connects the two. In this chapter the term UAV and drones will be used interchangeably.

Current technological advancements have made drones more efficient. Drones contain cameras, GPS, and diverse sensors that allow greater autonomy and efficient flights (Scott and Scott 2017). Additionally, new lithium batteries are allowing drones to cover greater distance (Scott and Scott 2017). Furthermore, mobile phone or tablet software increases accuracy in tracking and navigation (Scott and Scott 2017). These mobile applications also make it increasingly intuitive and easy for all audiences to pilot a drone.

Civilian drones with commercial-grade low-cost technology have already been used for various rescue tasks and natural disasters around the world. However, this technology's potential has yet to be fully explored and used. In fact this technology's use is limited for public services around the world due to regulatory issues in airspace (DeBusk 2010). Although this technology is already available and ready to be used, technology advances much faster than the laws themselves. One of the main reasons that airspace regulatory agencies block or restrict certain uses of these aircrafts is to preserve air safety of manned aircrafts and people on the ground by gradually analyzing the risks and knowing the modes of operation and then slowly deciding restrictions and operating laws (DeBusk 2010). Due to these limitations, there is very limited research on the use of drones in the health industry. This chapter will present the current uses and research of drones in the health industry and then present a pilot study on the use of drones as telemedicine and transport units.

11.2 Drones and Natural Disaster Relief

The systems used in civilian-grade UAVs can provide effective assistance in natural disaster relief and make emergency response increasingly effective and timely (DeBusk 2010). The optimum design of aerial systems for these applications is regularly improving with the use of rapid prototyping techniques including 3D printing, laser cutting, and new light-weight and resistant materials (DeBusk 2010).

Successful examples of the use of drones in natural disaster relief are with tornados (DeBusk 2010). There are many regions in the world including Europe, the United States, and South America, where tornadoes are very active (DeBusk 2010). Drones can be used to advance tornado and storm warnings (DeBusk 2010). Different institutions have created diverse techniques and process to maximize the accuracy of storm warnings. A research study by Georgia Institute of Technology examined the use of micro-radars called MiniSAR (miniature synthetic aperture radar), a form of radar that is used to create images, to observe the shape and composition of the clouds in greater detail, and to analyze the atmosphere with greater precision (DeBusk 2010). Current micro-radar systems such as MiniSAR are small enough to be inserted into unmanned aerial vehicles as they weigh only a few hundred grams (DeBusk 2010), but advances in the near future could put radar systems in smaller aircrafts.

Climate monitoring is a key aspect of storm classification and early detection of tornadoes. Obtaining information about speed and direction of the wind directly from the source increases the accuracy of climate monitoring. Drones have the ability to get readings of wind speed and direction as the aircrafts can fly near the storms (DeBusk 2010). Drones use sensors that can distinguish the type and composition of clouds that then use software to process them as images (DeBusk 2010). Therefore drones provide more accurate readings compared to indirect traditional methods (DeBusk 2010). The type of drone that this data can be obtained from is a fixed wing (Figs. 11.2, 11.3, and 11.4); that is to say, it is an airplane very similar to those used in the aeromodelling but larger with dimensions ranging from 4 to 26 m of wingspan (DeBusk 2010). Making some structural modifications to the fixed-wing drone allows it to withstand rain, low temperatures, severe winds, and turbulence while caring the measuring instruments (DeBusk 2010). The current aircrafts that meet these technical specifications include Textron's "Aerosonde" and General Atomics' "Altair/Ikhana" (DeBusk 2010).

Additionally, drones can be used to respond to a natural disaster. For example, in Nepal after the earthquake (2015) and in the Philippines after typhoon Haiyan (2013), drones were used by humanitarian organizations to collect real-time information (Htet 2016). Specifically, these drones were used to evaluate the damage and map which areas were affected (Htet 2016). This information was used to assess what areas needed help and determine which roads were still okay to use (Htet 2016). This information proved to be useful responding to natural disasters and can be used in any emergency situation.

11.3 Drones as Search and Rescue Units

What if instead of sending personnel to dangerous situations, authorities could send a drone? The Autonomous Unmanned Aerial Vehicle Technology Laboratory at Linköping University in Sweden is conducting research on how to integrate artificial intelligence in distributed software architectural frameworks (Burdakov et al. 2010). This allows for greater autonomy and functionality in complex operational environments.

Other research at Linköping University in Sweden has focused on the combination of drones and human operators to provide emergency service assistance (Doherty and Rudol 2007). First, drones explore the affected areas and try to identify wounded individuals by means of specialized area photos (Doherty and Rudol 2007). Then, medical instruments and other resources (food, water, etc.) are delivered to the previously identified individuals (Doherty and Rudol 2007).

These drones use different video sensors including thermal and conventional RGB spectrum, which transmit the images captured to software involved in image recognition for detection and geo location of human bodies (Doherty and Rudol 2007). This is a complicated process as technology on these UAVs involves the development and manufacture of new flight hardware and aircraft design. The sensors that are continuously developing and improving are the vision sensors (Doherty and Rudol 2007). These sensors are crucial for the use of drones in search and rescue missions and are continuously being developed to provide advanced synthetic vision and offer a clearer picture of what is on the ground (Doherty and Rudol 2007). The incorporation of night and infrared spectrum vision allows these operations to extend at night and continue search operations in conditions with less visibility (Doherty and Rudol 2007).

11.4 Drones as Transfer Units

Currently, there are organizations in different parts of the world that have implemented and are continuing to develop uses for drones in the health sector. Organizations such as WeRobotics have made strategic alliances with robotics manufacturers, technology companies, and research institutes to co create, with local universities, non profits, community, or government innovation labs, drones called “Flying Labs” (We Robotics, 2017). These “Flying Labs” are implemented in developing countries and allow local communities to use robotics for their own improvement (We Robotics, n.d.). These labs provide training, equipment, data-processing experience, and other services depending on the community’s identified needs (We Robotics, n.d.).

A research study by the Department of Pathology at Johns Hopkins University School of Medicine found that drone transportation of laboratory tests including chemistry, hematology, and coagulation testing did not affect the accuracy of the test results (Amukele et al. 2015). This provides evidence that there are no systematic differences between the laboratory test results of samples due to transportation (Amukele et al. 2015). This provides support for using drones as a means to transport laboratory tests.

Inexpensive drones (approximate cost of $10,000) can fly 20–60 miles with a 5-lb cargo load (Lippi and Mattiuzzi 2016). Drones can transport biological samples including blood derivatives and pharmaceutical specimens (Thiels et al. 2015). The transportation of medical devices and medical supplies can be valuable in natural disasters, when roads are blocked or when other forms of transport are unavailable or not timely. Although there is concern about the risk of collision, regulations for healthcare usage, and areas for safe takeoff and landing (Lippi and Mattiuzzi 2016), with technological advancements, research, and trials, these concerns can be minimized and outweighed by the benefits.

11.5 Drones as Telemedicine and Transfer Units

Drones can be used to facilitate access to medical care in marginalized communities. Drones are particularly useful in marginalized communities as these communities lack infrastructure and transportation to allow for the delivery of necessary health services and supplies in a time-effective manner. Drones are able to travel quickly with a speed of 40–60 miles/hour (Lippi and Mattiuzzi 2016) and can overcome topographic challenges that would be very challenging to overcome by other forms of transportation.

Currently, some organizations are attempting to develop drones that can deliver a range of health services to underserved communities. For example, Aidronix, Mexico (Aidronix, 2017), is developing a high-value light-duty unmanned aerial transport system, which aims to reach out to marginalized communities with medical assistance. One of the projects is to develop aerial bridges from distribution centers installed at strategic locations to supply medical supplies to rural communities. These distribution centers would load the drones with the supplies needed, and the drones would deliver them and return to the distribution center for more. The distribution centers can be built with shipping containers, camping trailers, or low-cost thermal booths and be equipped with all the necessary medical supplies including medications, vaccines, antibiotics, and antidotes (Fig. 11.1). Fixed-wing drones may be used for this project (Figs. 11.2, 11.3, and 11.4) due to their higher performance, carrying capacity, and speed compared to the multi-rotor drone (Fig. 11.5). These low-cost aircrafts are currently in the prototype stage, and further field testing is required. This would allow Aidronix to effectively supply rural communities with any medical supplies needed.

Additionally, Stanford University with funding provided by the Stanford Center for Innovation in Global Health and in collaboration with Aidronix will begin a study in 2017 to create and evaluate the feasibility of drone telemedicine units. This pilot study will be conducted in Mezquital, a highly marginalized municipality of Durango, Mexico (Fig. 11.6).

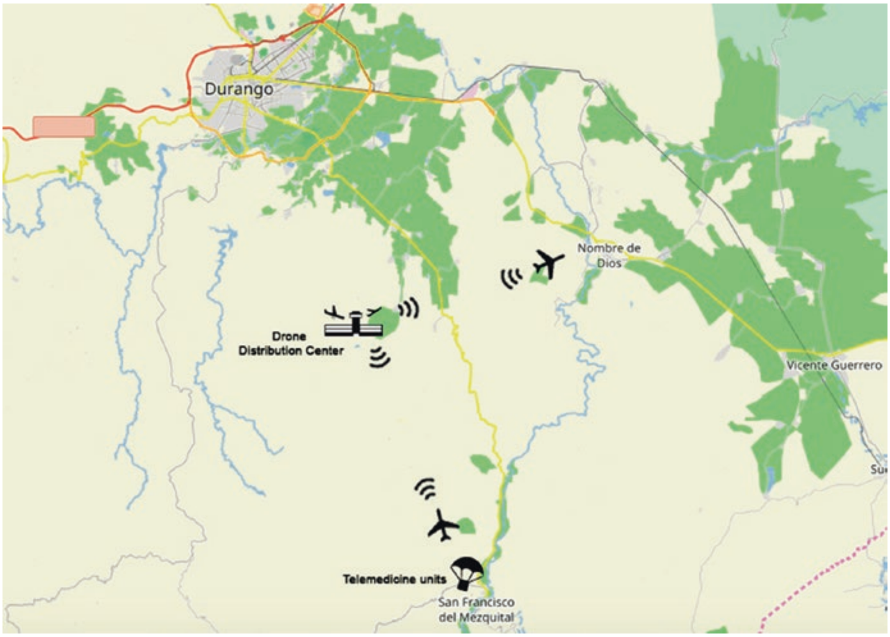

Fig. 11.1 *Map of distribution centers*. Map illustrating the idea of developing distribution centers. These distribution centers would load the drones with the supplies needed, and the drones would deliver them and return to the distribution centers for more. Map adapted from © OpenStreetMap contributors, and this data is available under the Open Database License

Fig. 11.2 *Fixed-wing drone*. Picture taken from the tip of the wing of a fixed-wing drone, during an aircraft test on stress, battery life, and carrying capacity. This unit is equipped with video cameras that transmit video to the remote pilot, so they can see where it is flying (first-person view, FPV) and at the same time sends the telemetry of the aircraft

Fig. 11.3 *Manual launch of a fixed-wing drone*. Manual launch practice of a fixed-wing drone built by Aidronix. Manual launch of a drone can be very complicated as human error can compromise the aircraft. Additionally, the operator is at very close proximity to the propeller, which can be dangerous. In larger units this technique is impractical due to the total weight of the aircraft

Fig. 11.4 *Delta fixed-wing drone*. This is a delta fixed-wing drone of 2-m wingspan. Due to its heavy weight, it is released by means of a catapult. This is one of the prototypes used to transport medical supplies to rural communities. Its approximate flight time is 45 min and cruising speed is 70 km/h

Geographically isolated areas have limited financial resources and low access to immediate medical care and specialized medical centers. Mexico is a clear example of a country where inequalities exist and provides a development platform for a disruptive solution. Durango is the fourth largest state in Mexico with the second lowest population density with a population of 1,754,754 in its 123,317 km^2 (National Institute of Statistics and Geography, n.d.). Durango is prone to inequalities in access

Fig. 11.5 *Multi-rotor drone*. This image was taken during the search for a missing person in a canyon in Mexico. This 8-motor multi-rotor drone incorporates a video camera that transmits to the operator. However, the range of operation is short. This is an ideal platform when takeoff space is limited or when there is not enough space for the operator to move around

to care due to its vast territory and diverse geographical landscape that creates isolated areas. Of the 39 municipalities, 5, Canelas, Mezquital, Otáez, Tamazula, and Topia, are considered by the SEDESOL Micro-Regions Program as highly marginalized with regard to access to education, living condition, population density, and income (Consejo Nacional de Población (CONAPO), n.d.).

Specifically, this project will focus on acute, subacute, and chronic medical problems in geographical locations with a shortage or absence of healthcare providers and lack of adequate infrastructure to provide immediate medical care when needed.

This pilot project will use UAVs as telemedicine units, which will incorporate basic but technologically advanced digital health systems. For example, these telemedicine drones will incorporate FDA-approved digital health devices including devices able to monitor EKG activity, pulse, blood pressure, temperature, oxygen saturation, and ultrasound (Rhythm Technologies, Inc., n.d.; Sotera Wireless, Inc., n.d.; Zhao et al. 2015). These devices can be incorporated into the drone via small stand-alone devices or a mobile phone. These UAVs will use highly secure networks that will allow patients to connect to healthcare providers immediately in a HIPPA compliant manner with limited broadband.

Overall, this study will evaluate the feasibility and scaling of prompt access to care via drones through the use of digital health, telemedicine, and transportation of necessary health equipment and medication. We hope that this study will provide insight on how to create systems of air bridges with unmanned aircrafts between

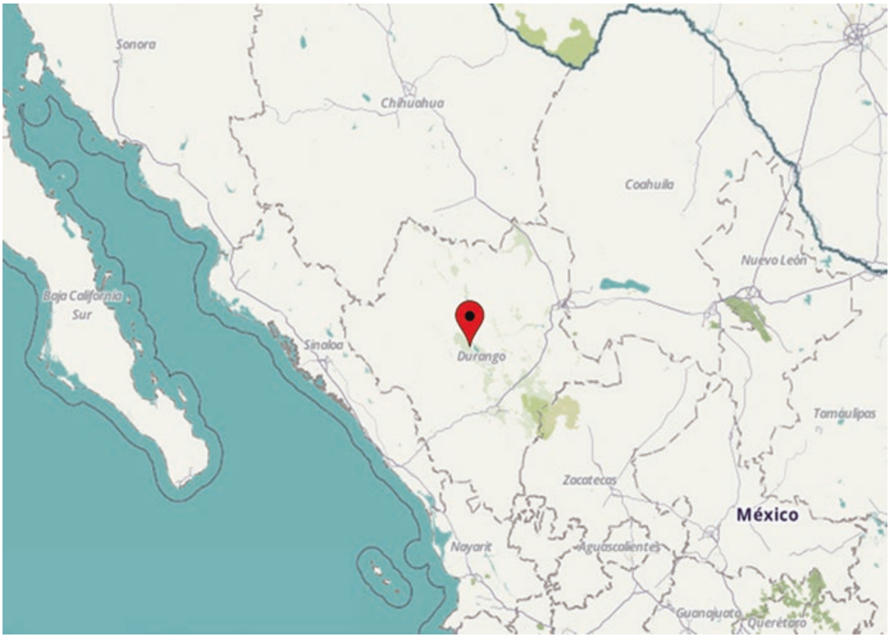

Fig. 11.6 *Map of Durango*. Map showing the location of Durango in Mexico. Map adapted from © OpenStreetMap contributors and this data is available under the Open Database License

marginalized regions and a distribution center offering health equipment and services. Additionally, we hope that this study will provide evidence that drones can be used as effective telemedicine units. If so, we hope that this model will be replicated in the rest of the world.

11.6 Conclusion

If we were to compare drones to the invention and boom of personal computers in the 1980s, at that time computers were expensive, large, and of rustic design. In addition to their operating systems having many errors, few people knew how to use them. People did not imagine that computers would become an integral part of day-to-day life and be able to complete so many diverse and complex tasks. Nevertheless, technology began to develop and mature exponentially. Now, everyone has a computer and it has become an essential tool.

Just like with computers in the 1980s, we have now developed an understanding of drones as an aircraft. However, we have yet to fully develop the use of this technology.

Technology is reaching a point of maturity. This opportunity will allow drones to become viable options for a diverse range of services including health services. Drones can have a large social impact. Drones can be used for natural disasters, search and rescue missions, and transfer units. And if our hypothesis is correct, drones can also serve as telemedicine units. Currently, health services and medical resources in underserved communities are limited to motor transportation and in-person interactions; however, drones have the ability to change communities, access to health all over the world. Drones can make medical services readily available and take road infrastructure out of the equation.

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