

Drones at our Service

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ABSTRACT

Drones have been of interest over the past several decades and the level of interest, including research interest, has been steadily growing. Drones are also known as unmanned aerial vehicles (UAVs). With the technological advances in hardware, software, and communication technologies, the size of drones has been shrinking. In addition, the prices of drones have been dropping. These two factors alone have paved the way for many applications of drones in many areas including healthcare, energy, agriculture, transportation, public service, search and rescue operations, and many more. Some of the applications may require a group of drones to work together as a team in a coordinated manner. Drone operations in a group environment require sophistication, being smart, and in many cases being autonomous. A deeper view of drone operations indicates that the opportunities and emerging applications of drones have a clear component of service to us. This paper discusses some of the typical applications of drones and the service aspects of these applications that they provide to us. The paper also discusses the role of artificial intelligence in smart operations of drones.

Keywords: Drones, unmanned aerial vehicles, service aspects of drones, smart systems.

1. INTRODUCTION

Drones are aerial vehicles without a pilot onboard and are also known as Unmanned Aerial Vehicles (UAVs). This category of aerial vehicles has been of interest for many decades. UAVs can fly autonomously or with someone controlling them remotely. Earlier developments of drones or UAVs were primarily for the purpose of military applications [1,2]. Due to the magnificent advances in technologies, the size of smaller drones has been shrinking over the past few decades. With recent developments, the size of drones now varies widely. In addition, the price of smaller drones has been dropping significantly and at the same time their capabilities have been increasing. These factors have paved the way for development of many innovative and entrepreneurial applications of drones. One notable observation is that drones are increasingly being used in augmenting many of our civil recreational, and entertainment services and enhancing our quality of life [3,4]. This paper focuses on non-military applications of drones and how drones are essentially at our service.

UAVs and drones are interchangeably used to refer to the aerial vehicles that fly autonomously or remotely with a controller. Some professionals view them slightly differently. In their opinion, the UAVs should be autonomous whereas drones do not need to be autonomous. With that distinction, all drones can potentially be UAVs, but all UAVs cannot be drones. For the purpose of discussion in this paper, the two names – drones and UAVs – will be used as synonymous [5]. Another term that is also relevant to drones is Unmanned Aircraft Systems (UAS). This term encompasses the drone and other associated components including the controller, the communication systems that connects the controller with the drone, and the person who operates it. The drone or UAV is simply one part of the UAS.

Earlier drones that were larger in size [6] were used for defense applications including intelligence gathering, reconnaissance missions etc. Recent and smaller size drones are useful in many applications such as search and rescue operations, healthcare, agriculture, energy, transportation, and more. Onboard cameras are standard and drone operators see what drones see during flight. Public service applications such as Police and Firefighters can also make very effective use of drones in their activities. Smaller drones can be used as stand-alone or as a group with coordinated operations. Capabilities of these drones or UAVs will increase multifold by linking them with Internet of Things (IoT) and embedding artificial intelligence (AI). Introduction of artificial intelligence in drone services will undoubtedly represent a significant leap forward in drone operations.

In addition to numerous opportunities that drones provide, their operations do pose some challenges. One major aspect that has serious security considerations is potential interference of drone operations with commercial flight operations. Federal Aviation Authority (FAA) is still developing rules, regulations, and policies for drone operations. These policies need to be very comprehensive and must address the smaller drones used by individuals (who are sometimes not adequately trained) for entertainment, hobbies, or even to take some pictures including selfies.

The next section of this paper discusses some of the typical applications and opportunities that drones provide

as service to us. Section 3 discusses some of the challenges associated with drone operations. Role of artificial intelligence (AI) is discussed in section 4. Section 5 presents a summary and conclusions of the paper.

2. SERVICES OFFERED BY DRONES

There have been many technological advances with tremendous societal impact during the past few decades. These include mobile connectivity, Internet of Things (IoT), healthcare technologies, artificial intelligence (AI), sensor networks, image processing, and of course, unmanned aerial vehicles (UAVs) or drones [7].

Drones with their small sizes and affordable prices, are actively being considered for many applications ranging from using as a hobby to more serious applications in many areas including deliveries of shipments that Amazon has been considering. A broad range of entrepreneurship opportunities that drones have created, are being pursued for societal benefits.

Most drones are remotely operated. As cameras are standard piece of equipment in drones of all sizes and operators see what drones see during flight. They can be easily maneuvered away from obstacles and other unpredictable conditions. It is anticipated that drones, in not too distant future, will be able to maneuver on their own using sophisticated artificial intelligence, either onboard (edge) computing or using cloud computing.

In the following subsections, we discuss a few typical services offered by drones that enhance our quality of life.

Drone services in healthcare

The field of healthcare has always been at the forefront of employing the latest technologies and the trend continues [8,9]. Robotic surgeries, smart diagnostics using artificial intelligence, and sophisticated image processing are being utilized regularly. With the growing deployment of Internet of Things (IoT), the approach to healthcare is shifting. Smart medications and smart healthcare are becoming common. Population is becoming comfortable with telemedicine and has become more common with the onset of COVID-19 pandemic. It is obvious why the characteristics of healthcare ecosystem are changing. This is also moving the healthcare model from being reactive to being proactive (preventive). In such a dynamic environment, use of drones is enhancing the healthcare delivery system. If we consider drones as “Things” in the context of IoT, then Internet of Drones (IoD) is expected to play a major role in healthcare [10].

One of the most effective use of drones in healthcare is when efforts are made to bring the care to the patient at his or her location in the event of an emergency or even otherwise [11]. In such situations, speed and response

time are very important and can literally mean a difference between life and death.

Another anticipated use of drones in healthcare is to deliver medications and healthcare equipment to rural areas that do not have healthcare infrastructure, or located in areas that are not so easily accessible. Drones can cut through the hurdles such as traffic congestions, and make these deliveries with speed. Use of drones, therefore, saves time and hence saves lives. Similarly, drones can also be used to collect medical specimens including blood and tissues, from remote medical facilities and transport them safely to a laboratory for testing. Drones can also be used to transport blood for transfusion or human organs for transplant, from one healthcare facility to another making these deliveries safely and with speed to deal with serious health conditions.

Research laboratories are experimenting use of drone ambulances. These drone ambulances are dispatched in case of an of emergency to the location of the incident, with necessary equipment, and with appropriate payload. The drones can arrive quickly with the necessary equipment/supplies and directions to administer first aid. Further guidance can be provided through audio and/or video communication. Initial results of these experiments have been remarkable and very encouraging [12].

Drone services in energy

It is anticipated that, based on the current trends, the world population will reach 10 Billion by year 2050. That will certainly increase the worldwide energy consumption. It is estimated that energy consumption will increase by 40% during the next 25 years. To meet that demand for energy, it is of paramount importance to develop and maintain the energy infrastructure. It is also important to know that as a result of this increased demand for energy, the energy sector is going and will continue to go through transformational changes. This is creating a shift towards utilizing renewable energy sources, and use of emerging technologies. Use of windmills, solar panels, and natural gas are on the rise and this trend is expected to continue and grow. Processes are being automated and operational efficiencies are expected to increase. Energy generation is rapidly becoming geographically distributed. Development of microgrids is emerging and integrating those with the national energy grid is an important aspect. Remote monitoring and management of assets is an integral part of the energy operations [13].

Drones and Internet of Drones can play a major role in improving the operational efficiencies in the energy sector. Safety of personnel is always a major concern in operating, inspecting, and maintaining the energy infrastructure facilities. Energy facilities are commonly located at remote places. The windmills are located away from the cities and at remote locations. Electrical transmission lines run through rough terrains such as

deserts, swamps, and over the mountains. Oil rigs are located offshore and far from shores. Solar panels/farms are usually located far and spread over large areas. Drones can be used very effectively to safely inspect the energy facilities, perform preventive maintenance, and improve reliability. Teams of drones (also called drone swarms) can work collectively to complete these missions much more effectively, efficiently, and in less duration of time.

There are many other effective uses of drones in the energy sector. In addition to doing inspections, drones can carry tools to unsafe places. The tools can perform a variety of tasks including thermal imaging, assessing equipment vibrations, and assessing fatigue. As we know, efficiency of solar panels degrades as dust and other debris deposit on their surface. Drones can be used to inspect and even clean solar panels. In larger solar farms, a team of drones can work in coordination to accomplish the task. Similar inspections can be performed on power transmission lines, power plants, and windmills in less time and using less resources.

Another possible use of drones in energy sector is to assess the damage to power distribution system in the aftermath of disasters such as hurricanes or earthquakes. Drones can perform these tasks quickly and safely even before personnel can be allowed in the area. That can certainly help speed the restoration process of services to consumers.

Drone services in agriculture

As the world population is on a rapid growth trajectory, the demand for food is expected to increase significantly. In parallel, the agricultural land continues to shrink and so does the agricultural workforce. A shift towards urban living is also on the rise. It is anticipated that in not too distant future, 70% of the world population will be living in urban areas.

To meet these challenges, there have been many significant advancements in the field of agriculture based on the emerging technologies during the past several decades [14]. Agricultural processes have continued to be automated and adoption of the latest technologies has significantly improved efficiencies of agricultural processes and improved crop yields. In the current climate of growing world population and increased demand for food, use of the latest technologies can help close the gap between food demand and food supply.

It is anticipated that the global use of smart technologies in agriculture will increase rapidly. Among many technologies being deployed for automation of agricultural processes, use of drones and sensors takes a dominant role. These sensors monitor the crops and the soil to make sure their health and optimal conditions. The sensors provide the data to a central data storage. The data is either transmitted to that locations or collected by

drones that fly over the sensors and collect the data to bring it back to the central data storage. The data is then analyzed, and decisions are made and implemented through appropriate means. In implementation of the decisions, drones become very practical.

If a crop is observed to be not doing so well in a certain area (patch) of a farm, a drone can be dispatched to remedy the condition. That specific area may require additional fertilizer, water, or pesticide. Instead of applying the remedy to the entire farm, only specific area (patch) can be treated. This is essentially a scaled down approach to remedy an agricultural condition on a farm. This demand-based approach to treat a patch (and not the entire farm) by using drones, will certainly produce healthy food products. This proactive approach will also reduce challenges and issues to become bigger and thus results in a higher quality produce. Drones can also be deployed to harvest certain crops that usually require manual labor [15].

Along with many other applications of drones in agriculture, an interesting application is using drone swarms in cross pollination of crops [16]. If the size of drones continue to shrink, it is possible the robotic bees will be replaced by swarm of drones to do the job of cross pollination. Capabilities of image processing and artificial intelligence will be on full display in these applications.

Drone services in transportation

Among other prominent industries that have changed significantly with emerging technologies, transportation industry is one of those. Transportation companies are heavily investing to meet the competitive challenges of autonomous driverless cars. The vehicles of future are expected to be pervasively connected. They will be able to communicate with each other (vehicle-to-vehicle or V2V, vehicle-to-infrastructure or V2I, and vehicle-to-everything or V2E). The infrastructure will need to be technically enhanced to support autonomous vehicles. Irrespective of how autonomous and technically advanced vehicles become, their mobility will still be limited by the infrastructure such as roads, bridges, and other supporting elements of transportation infrastructure.

We also know that air transportation such as airplanes can provide travel but only between the airports. Sea transportation such as cargo ships and cruise ships can provide travel but only between the seaports [17]. That raises the question of providing transportation to areas where there is a lack of infrastructure, the infrastructure is not accessible due to flooding or other disasters, or no infrastructure. That is where drones come in handy and can fill the transportation needs. An ordinary drone does not fly too high and, if all the rules and regulations of Federal Aviation Authority (FAA) are observed, they can travel from one point to another using the shortest path. Drones can also avoid difficult terrains and reach their

destinations in a much shorter time than other vehicles can. They are already being used in healthcare for delivering critical items such as insulin in hard-to-reach areas in underdeveloped countries that severely lack transportation infrastructure. Drones can also be used for delivering much needed supplies (foods, clothes etc.) to areas, in case of a disaster.

Drones can also play a pivotal role in handling traffic accidents. In such incidents, it is difficult to reach the accident site because of traffic conditions. That delays delivery of critical help that may be urgently needed in such situations. Drones can be used to bypass the traffic conditions and deliver some of the critical medical supplies that may translate into saving lives. Drones can also be used in shipping industry to quickly scan and document a stack of containers that may be hard to reach or too time-consuming otherwise.

Drones or swarm of drones can also be used for inspection and maintaining transportation infrastructures such as bridges, roads, railroads etc. Frequent inspections of infrastructure elements and preventive maintenance can help prolong the life of infrastructure and improve safety and resilience.

Drones in public service

Public services are one of the major sectors that can use drones to enhance the services offered to improve quality of life of citizens. These services include law enforcement, fighting fires, search and rescue missions, and managing disaster situations. They can also be used in surveillance, construction projects, and wildlife tracking. Drones are expected to be extremely attractive for use in many services offered in smart cities.

A typical use of drones in law enforcement is to assist police in tracking individuals, and managing suspicious activities. They can effectively mark the boundaries of the crime area, document the suspicious activities, track suspects, and guide the police until the suspects are apprehended. During the process, a live video feed from drone(s) can also be sent to the law enforcement agencies [18].

Drones can serve as a very effective tool for saving lives in disaster situations such as accidents, tornados, flooding, earthquakes, and hurricanes etc. This is commonly referred to as search and rescue missions. Due to their small sizes, drones can travel in tight spaces, identify locations where critical help is needed, and even deliver much needed supplies. They can also be used to assess the damage and help plan restoration of services as fast as possible [19].

Similarly, drones can be used in fighting fires and carry supplies to places where it may be dangerous for professional firefighters to go. Drones can also assist in

searching people that are trapped and need assistance. They can work as a team and coordinate their action plan. This helps in performing these tasks safely to save lives.

Insurance agencies are already using drones to document damage and to decide about the consumer claims. This reduces efforts and save times as the client claims are settled. Use of drones make the process expeditious and based on facts.

We have discussed only a few of the typical applications of drones in our society. It is expected that the applications of drones will continue to grow rapidly including helping individuals with physical disabilities such as blindness, deafness, or lack of mobility. Drones can also find applications in education, construction, mapping, and many more. It is anticipated that drones will coordinate their tasks and work in teams to handle bigger and complex tasks. For instance, for constructing a typical dwelling, a team of drones can work with the construction supplies and the construction plans to complete the tasks faster and with precision.

3. CHALLENGES IN DRONE OPERATIONS

Drones operate in an environment which is constrained at many levels. Communication bandwidth is constrained, battery life is constrained, and that limits the range and the duration of their missions. Establishing and maintaining the communication with the drones is a challenge due to mobility and unpredictable disruptions and obstructions. When drones are working in a team (or drone swarm), the communication with the operators and among the drone team members become even more complex. Fluidity of topology adds to the communication complexity. The routing and scheduling of drone path, particularly, in a team environment is quite complex. It is particularly so, when multiple drones originate from different locations and have different destinations. In addition, one of the bigger challenges among the drone team members is coordination among the team members and having a mechanism to avoid collisions [20].

Another challenge in drone operations is security, which is also common in computing and communication environments. The weight of drones is purposely kept light and hardware is limited. Constrained battery power limits the implementation of sophisticated information security algorithms. These limitations combined with pervasive presence and ubiquitous connectivity of drones, makes them vulnerable points of unauthorized accesses. Physical security of drones is also a challenge, particularly when they carry some expensive and sensitive payloads [21,22].

Personal privacy is another concern that public feels very strongly about. This is particularly so because drones, no matter how small in size, have cameras as a standard piece of equipment onboard. That breeds fears

that drones may invade personal space and privacy of individuals. Some of these challenges will be addressed as the Federal Aviation Authority (FAA) develops policies and procedures for drone operations [23,24].

4. ROLE OF ARTIFICIAL INTELLIGENCE

The main objective of artificial intelligence (AI) is to make devices (drones in the context of this paper) smart and to help them make autonomous decisions. Smart drones, equipped with AI software, use available data to establish past trends, learn from that, and make efficient/effective smart decisions for their next move. The process of edge computing combined with cloud computing can be utilized by drones. However, due to constrained battery power and absence of sophisticated AI algorithms onboard, the decision-making abilities of drone may be limited [25,26].

Use of artificial intelligence can be applied to almost all the drone applications discussed earlier and more. Typically, image processing and AI will be used together. For instance, use of AI is harvesting fruits from trees or cross pollination is a practical and interesting application. A drone can use image processing and AI to recognize fruit and to decide if it is ready to be harvested. Once that decision is made, the fruit can be harvested by the drone before it moves to the next fruit. Similarly, image processing and AI can be used effectively in search and rescue missions and other applications.

5. SUMMARY AND CONCLUSIONS

This paper has discussed the use drones or unmanned aerial vehicles (UAVs) in a variety of service-oriented applications that enhance the quality of life for us. With the advances in hardware, software, and communication technologies, the size of drones has been shrinking and that paves the way for many innovative applications. The applications of drones are anticipated in almost all fields including healthcare, agriculture, energy, search & rescue, transportation, surveillance, and even in communications to extend the reach of Internet. We have discussed some of these applications that provide service to us and various (but limited) operational details. Some of the applications may require a group of drones or swarms to work together in a coordinated manner. In general, all drone operations need to be sophisticated, smart, and autonomous. This is particularly so for coordinated operations that involve multiple drones. The opportunities and emerging applications of drones are numerous and so are the challenges. This paper has also discussed some of the challenges they pose. In addition, the paper has discussed the role of artificial intelligence in smart operations of drones.

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