Unmanned Aerial Systems for Geological Survey

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Introduction

With the advent of commercially viable unmanned aerial systems (UAS) they have made cost effective rapid accumulation of data for individuals, government agencies, and universities. The data collected by UAS can be applied to a multitude of applications such as petroleum exploration, disaster relief, and hazard planning, hazardous conditions, and many others (Austin, 2010; Gupta *et al*., 2013) . Various UAS platforms exist in fixed and rotary wing configuration in sizes from handled to full size aircraft, all capable of carrying various sensors for specific mission profiles (Austin, 2010; Gupta *et al*., 2013).

Advantages of UAS:

UAS are available in sizes ranging from handheld to full-size aircraft (for military and government agencies) with associated cost. UAS are not subject to all of the maintenance regulations of conventional manned aircraft in the United States.

UAS operators do require licensing in the United states in most circumstances per 14 C.F.R. § 107 Part C, commonly referred to as Part 107 in aviation circles, the Federal Aviation Administration (FAA) issues licenses for commercial operators. The process for obtaining a UAS license is less costly and less time consuming than the commercial pilots license that a manned aircraft operator would be required to hold.

UAS can be constructed by private individuals or educational institutions using hobby grade equipment and techniques. This can be a way to integrate different course programs to demonstrate project management between disciplines.

Disadvantages of UAS:

Though UAS are lower cost than manned aircraft, they are not free and still do require a licenced operator in most circumstances when not being used by a hobbyist. In the United States, UAS operation is regulated by the

There is no federal or commercial standard for UAS construction methods, they may be constructed of materials ranging from paper laminated foam, balsa wood, 3D printed plastic, fiberglass or other composites, or conventionally constructed using metals by common aviation techniques. Having no standards also applies to the electronics and power plants that are commonly used.

In the United States, Part 107 restricts UASs to 55 pounds, must remain within visual line of sight of the operator, must remain below 400 feet or within 400 feet of the highest obstacle, and are restricted to 100 MPH. Temporary waivers can be applied for on a case by case basis from the FAA to operate outside those restrictions provided they can be justified, though they are not guaranteed to be issued.

Due to the size of UASs, they tend to be affected by the weather to a greater extent than manned aircraft, this could be an issue in areas subject to rapid changes in weather conditions. Their size may also limit their flight time and range.

Applications

The availability of and ease of use of UAS makes them an ideal solution for a multitude of applications that might otherwise be cost prohibitive, time consuming, or dangerous if manned aircraft or other methods would be used. UAS can be procured and operated for less than the hourly cost of a manned system and be operated on relatively short notice, not having to wait for the availability of a rated pilot.

-need to add the examples once I finish reading the papers-

Infrastructure inspection:
(Gillins *et al*.,2016)

Wildlife management and tracking:
(Linchant *et al*., 2015)

Mapping and geological survey:
(Casagli *et al*., 2017)
(Singh and Frazier, 2017)

Agricultural monitoring:
(Allred *et al*., 2020)

Natural and manmade hazard analysis and prediction:
(Casagli *et al*., 2017)
(Šipoš and Dušan, 2020)
(Watts *et al*., 2010)
(Wood *et al*., 2016)

Types of UAS:

There are two common types of UASs that are operated, that being fixed wing and rotary wing. Each type has unique characteristics suited for different purposes that may be useful for geological survey.

Fixed wing UASs have a conventional airplane layout and use their wings for lift and moving control surfaces for directional control. They may use an electric motor or internal combustion engine and propeller for propulsion, some use electric ducted fans or fuel burning turbines as well. An autopilot system may be used to provide automated capabilities such as orbiting around a fixed point on the ground or following GPS coordinates in a programmed flight plan, or be manually controlled for simplicity. Fixed wing UASs have the longest range, heaviest payload capacity, and longest flight time compared to rotary wing UASs, this comes at the disadvantage of requiring a flat area clear of vertical obstructions for takeoff and landing, though additional equipment can be used such as a catapult launch system for takeoff and a net or cable arresting system for recovery. Fixed wing systems excel at tasks that require coverage of a large area or long periods of time.

Rotary wing UASs are subdivided into two categories: helicopters and multicopters. The biggest advantage of rotary wing systems is that they are able to take-off and land vertically, and their ability to hover, allowing for a stable sensor platform.

Helicopter type UAsS have a rotor system where directionality is controlled by changing the pitch of the rotor blade. Helicopters typically have a single large main rotor that is aligned parallel to the ground to provide thrust that can be used for lift, roll, and pitch; and a smaller tail rotor aligned perpendicular and radially to the main rotor disk that is used for yaw authority and to counteract the torque produced by the main rotor. A variant of the helicopter type has two counter-rotating main rotors in a stacked or tandem configuration with no tail rotor. Helicopter type UAS are mechanically complex and are difficult to maintain. They can offer longer flight times and heavier payload capacity than a similar sized multicopter UAS, additionally, the larger rotor disk can pose a hazard. Helicopter UAS may be powered by electric motors or internal combustion engines.

Multicopter UASs typically have four or more motors and fixed pitch propellers, though some versions have two or three motors with mechanical components to alter the thrust line of the motor for directional control. Multicopters with four or more motors do not use any mechanical components for directional control, the motors are fixed and all movement is caused by changing motor RPM to alter torque and thrust vectors in relation to the airframe. This makes them mechanically simple at the expense of being electronically complex by requiring a flight computer system (FCS) to maintain flight. The requirement of an FCS lends multicopters to programmed flight patterns along GPS points and tasks that require a spatially stable platform for sensor employment, having all operator input filtered through an FCS also reduces the aeronautical knowledge and skill required to effectively use a multicopter, making them usable to a wider audience. Multicopters are almost exclusively electric to maintain mechanical simplicity and easier control by the FCS though some have been built to be powered by an internal combustion engine and very complex mechanical systems.

Sensor packages:

UAS can carry a multitude of sensor packages for geological survey Virtually any sensor system that can be reduced enough in size to fit into the platform and does not require physical contact (in most cases, ex. taking water samples) can be utilized. Visual sensors, be it infrared, near infrared, color, or ultraviolet spectrum, are by far the most utilized sensors in UASs. Other types of sensors that may be carried are magnetic sensors (Wood *et al.*, 2016), ground penetrating radar (Šipoš and Dušan, 2020).

Conclusion:

UASs provide educational institutions, corporations, and government agencies a flexible platform for rapid data collection for a variety of purposes in a cost effective manner. With the continuing development of better electronics for control systems and sensors, and more robust regulations, UASs are set to become the preferred method for easy data acquisition.

References

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