Small UAS for Geomatics

By Costas Armenakis, PhD, PEng

1. Introduction

We are witnessing a paradigm shift with a new and exciting tool for geospatial data acquisition and 3D mapping. The ever-increasing use of small and light weight Unmanned Aerial Systems (UAS), also known as Remotely Piloted Aircraft Systems (RPAS) or Unmanned Aerial Vehicles (UAV), is transforming geomatics applications and creating new and innovative opportunities for our profession. Small UAS can complement and, in many cases, replace total stations and laser scanners, and operate as low altitude aerial mobile survey systems.

UAS have been mainly developed for military applications, and are commonly known as drones. Long range and expensive UAS have been considered by NASA for fire fighting. In recent years, commercially available UAS have appeared as low-cost platforms to provide aerial real-time surveillance. The idea of user-controlled platforms for mapping purposes is not new. The use of a remotely controlled (RC) helicopter for photogrammetric purposes was reported in 1980. In late 2004, a mini helicopter UAS was used for photogrammetric image acquisition for archaeological mapping and at the same time the generation of a digital surface model (DSM) was reported from a helicopter UAS equipped with a digital camera and a LiDAR. The ability for real-time surveillance with UAS has also started to be investigated in traffic applications. In 2005, a photogrammetric DSM generated from helicopter UAS was compared to a terrestrial laser scanner DSM. In 2007, the use of UAS has been considered here in Canada to acquire imagery for emergency response for disaster management.

The use of small UAS for remote sensing geospatial applications was made possible due to the technological developments in direct georeferencing, photogrammetric image-processing software, sensor and platform miniaturization, micro-electronics and wireless communications.

2. What are UAS?

Small UAS are usually fixed or rotating (multi-copters) wing type aerial platforms. Airships can also be used. They can be remotely piloted or fly autonomously using an autopilot, relying on onboard processors and sensors and having a pre-programmed flying path.

Usually a UAS system for geomatics applications consists of the airborne and ground segments and data processing software. Typical components of the airborne segment are: aerial platform, avionics (autopilot, GNSS, IMU, altimeter, compass, navigation cameras), telecommunications (command and control, downlink telemetry and sensor data), power generation (for propulsion, avionics and sensors) and mapping sensors (still/video optical cameras, thermal, multispectral sensors, LiDAR; usually with onboard data storage). The ground segment comprises the command and control unit, communications, power unit and optionally, launch and landing systems for the fixed wing platforms. The data processing module consists of photogrammetric software for flying, route planning, image matching, bundle adjustment, generation of digital surface models (DSM), 3D point clouds and orthoimages. Obviously we should not underestimate the role of a well-trained human operator, not only when it comes to operating the UAS but also to ensure that the legal requirements are met and to ensure the safe operation of the aerial platform - for example in case of unexpected system failure.

Julien Li-Chee Ming, PhD graduate student, Geomatics Engineering program, York University carrying the fixed wing UAS he is working on.

UAS can be easily deployed as they do not require much mobilization for preparation and flying. They can fly in environments that are unfriendly to humans, and thus gather geospatial data in in dangerous environments without risk to flight crews.

Canadian manufacturers of UAS include the Brican and CropCam Micropilot fixed wing platforms, the Aeryon Scout quad-copter and the Draganflyer double helix tri-copter, while Trimble US markets the UX5 fixed wing aerial imaging rover.

3. Applications, products and accuracies

Aerial data collection is a way to obtain a better perspective and coverage over an area, and also has the ability for targeted coverage at flexible visiting times. The emerging low-cost small UAS are an effective aerial platform carrying imaging and ranging sensors for geospatial data collection. Usually UAS are used for generating rapid 3D mapping products over relatively small, remote and inaccessible areas.

UAS can be used in many and diverse applications. They include mapping (3D point clouds, DSM, orthoimages), cadastral surveys, land cover/land use monitoring, corridor mapping (inspections of pipelines and power lines), volumetric surveys, landslides, mining, precision farming, forest fire fighting, disaster management, search and rescue oper-

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Aeryon Scout

ations and emergency response, traffic and accident monitoring, conservation and monitoring of biodiversity including wild life and forest tree diseases, mapping and monitoring of remote arctic areas (glacier studies and ice flow), geophysical exploration, surveillance, border patrol, and archaeology.

Currently the most common sensor used for data collection is a small format digital camera. The air survey conducted by the UAS is similar to the one used by the higher altitude airplanes. The autonomous operation of the UAS is based on a predefined flight path determined by waypoints using the onboard GNSS/IMU autopilot system. The flying height, rate of taking images, flying speed and the interval between flight lines need to be entered. A 70/70% forward and lateral overlap is recommended to ensure complete coverage of the survey area. Due to the small format of the camera a large number of images are collected, thus we have to deal with a high volume of data. Payload capacity and battery life are currently the weak points of the small UAS. Privacy is also a debatable issue.

To effectively process the large number of images for the derivation of the final geospatial products, a high level of automation is recommended to ensure rapid data processing and product delivery. Fast data processing with fully automatic workflow for operations such as multi-view image matching, bundle adjustment, 3D point clouds, DSM and orthoimages can be performed with both Internet accessible and commercially available software. For example, the Canadian SimActive, the Swiss Pix4D and Trimble US offer photogrammetric solutions for UAS.

Microdrone MD 4 -1000

The low flying altitude, the high resolution data, the use of ground control points and the geometrically strong photogrammetric block create the necessary conditions to achieve high positional accuracies of the determined 3D object coordinates despite the possible instability of the UAS platform. Using aerial triangulation, an absolute accuracy of 0.5-pixel ground spatial distance (GSD) in planimetry and 1 pixel GSD in height is possible. This translates to accuracies in the 5 cm level. The quick launch of the UAS together with the rapid capture of the aerial images and the automated data processing result in significant time and cost savings compared to the field surveying methods.

Draganflyer-X6

4. Regulations

In Canada, Transport Canada governs the uses of UAS which have been operating commercially since 2008—from aerial photography and mapping to supporting the police and the RCMP with surveillance and search and rescue operations. According to the Canadian Aviation Regulations (CARs), UAS are treated differently than model aircraft. "Model aircraft" means an aircraft with a total weight that does not exceed 35kg, that is mechanically driven or launched into flight for recreational purposes and that is not designed to carry persons or other living creatures. Although some small/micro unmanned air vehicles may weigh less than 35kg, if they are operated by research institutions and commercial operators for non-recreational purposes then they do not fall in the category of model aircraft.

For every flight, commercial operators are required to obtain a Special Flight Operation Certificate (SFOC) and receive approval. Section 623.65 of the CARs outlines the information that should be submitted when making an application for a SFOC. The request has to be submitted as early as possible and as much information as possible must be provided. The predictability and reliability of the unmanned air vehicle must be demonstrated; essentially that it has the ability to perform in the desired environment. The requirement for a SFOC is intended to ensure the safety of the public and protection of other users of the airspace during the operation of the unmanned air vehicle.

5. Outlook

UAS fill the space between terrestrial and aerial mapping systems and their popularity is continuously increasing. Already Canadian companies are operating successfully in this field. For example, Accuas Inc. specializes in aerial surveys and mapping using UAS equipped with compact digital cameras. They use a fleet of 10 unmanned aircraft ranging in size from small, multi-rotor helicopters to much larger fixed-wing planes.

Transport Canada is changing the process of SFOC application for small UAS. Applicants complying with the regulatory requirements would have greater assurance of SFOC approval, and the regional inspector workload would be reduced when reviewing renewal applications from organizations that have been determined to meet the regulatory requirements. National mapping organizations in Europe have started investigating the use of UAS in their operations. The U.S. Federal Aviation Administration (FAA) is planning the full integration of Civil / Commercial UAS into the National Air Space (NAS) by 2015. In the meantime two types of unmanned aircraft for civilian use have been certified in the US: the Insitu's Scan Eagle X200 and the AeroVironment's PUMA. A major energy company plans to fly the Scan Eagle off the Alaskan coast to survey ice floes and migrating whales.

According to the 2013 Association for Unmanned Vehicle Systems International (AUVSI) Economic Report "The Economic Impact of Unmanned Aircraft Systems Integration in the United States", the economic impact of the integration of UAS into the National Air Space (NAS) will total more than \$13.6 billion in the first three years of integration and will grow sustainably for the foreseeable future, cumulating to more than US\$82.1 billion between 2015 and 2025. The integration into the NAS will create more than 34,000 manufacturing jobs and more than 70,000 new jobs in the first three years. By 2025, total job creation is estimated at 103,776, while the manufacturing jobs created will be high paying (US\$40,000) and require technical baccalaureate degrees.

The UAV-g 2013 conference focusing on the use of UAVs in the geomatics sector was held in Rostock, Germany from 4 to 6 September 2013. More than 200 participants attended the event. One particular highlight was the UAV air show, where a total of 15 companies demonstrated various operational systems, payloads and technologies. The Geomatics Engineering program of York University will host the UAV-g 2015 conference. The Unmanned Systems (US) Canada conference fostering success in unmanned vehicle systems will be held in Vancouver from 12-14 November 2013.

We foresee endless uses of UAS. It is time to refresh our photogrammetric knowledge!

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