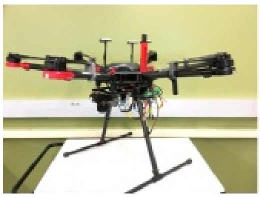
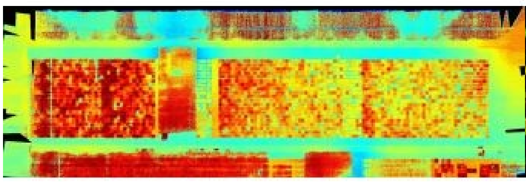
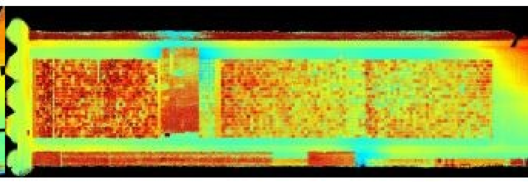
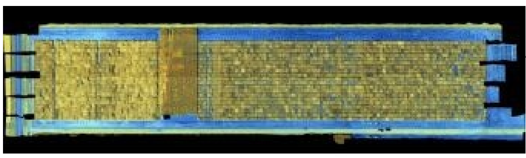
A COST-EFFECTIVE ALTERNATIVE TO AIRBORNE AND TERRESTRIAL MODALITIES

UAV-based Mobile Mapping: Potential, Challenges and Outlook



Accurate representation and 3D reconstruction of the environment using both active and passive remote sensing systems has become essential for non-traditional mapping applications. Due to the excessive cost as well as the required level of technical expertise, the needs of these applications cannot be satisfied by traditional mapping, which is based on dedicated data acquisition systems designed for mapping purposes (e.g. manned airborne and terrestrial mobile mapping systems). Recent advances in hardware and software development have made it possible to conduct accurate 3D mapping without using costly and high-end data acquisition systems. Low-cost digital cameras, laser scanners and navigation systems can provide accurate mapping if they are properly integrated at the hardware and software levels.

In conjunction with recent developments in sensor technology, unmanned aerial vehicles (UAVs) are emerging as a mobile mapping platform that can provide additional economical and practical advantages. The ability of UAVs to fly at lower elevation and slower speed than manned systems allows them to capture data with higher resolution. Moreover, these systems can be economically stored and deployed, which could lead to affordable repeated coverage. In addition, UAVs fill an important gap – in terms of resolution, coverage and repeatability – between manned airborne and terrestrial mobile mapping systems. These characteristics make UAVs an optimal platform for affordable rapid-response mapping applications. The realisation of the UAV's potential as a mobile mapping platform is the main reason behind the current and expected future growth in UAV production and applications. Today's UAV market is estimated at USD13.22 billion (2016), and is projected to reach USD28.27 billion by 2022 at a compound annual growth rate of 13.51% during the forecast period*.

Challenges

In spite of its proven potential, there are still some challenges that need to be addressed for widespread adoption of UAVs as an operational mobile mapping platform, including:

1. *Flight logistics*: The research and professional communities are still facing challenges in terms of securing permissions to operate UAVs equipped with navigation and passive/active imaging sensors. Those challenges are amplified when attempting to fly UAVs in restricted airspace (e.g. in the vicinity of commercial/military airports).

2. *Qualified pilots*: UAV-based mobile mapping represents a paradigm shift in terms of the sensor-to-platform relative cost. For manned airborne mobile mapping systems, the platform is usually more expensive than the implemented mapping sensors/system. For terrestrial mobile mapping systems, the cost of the sensors could be more expensive when compared to the platform, including for UAV-based platforms. However, it is quite feasible for the UAV sensor's payload to be over 30 times more expensive than the platform. This, together with the greater reliability risk of UAVs when compared to other platforms (i.e. manned airborne and terrestrial platforms), increases the demand for professional pilots who can safely and reliably operate the system.
3. *Limited endurance*: For micro/mini UAVs (i.e. those limited to 100m above-ground flight height), the flight duration is still quite limited. The typical average battery life for such UAVs is 30 to 45 minutes. This limited endurance imposes constraints on the extent of the area that can be covered, especially when seeking high-resolution data which requires lower flying altitudes.
4. *Limited payload*: For micro/mini UAVs, the payload capabilities are quite limited (especially when dealing with fixed-wing platforms). Multi-rotor UAV systems have higher payload capabilities, up to several kilograms. However, such an increase in the payload will negatively affect the expected endurance of flights.
5. *Consumer-grade nature of the utilised sensors*: Cost and payload constraints mandate the reliance on consumer-grade sensors (e.g. position and orientation navigation systems as well as passive and active imaging systems). These types of sensors require more attention in terms of the system calibration (e.g. the intrinsic as well as the mounting parameters for the different sensors on board the UAV).
6. *Required system integration expertise*: Due to the wide range of the potential applications, it is impossible to have a single UAV-based mobile mapping system configuration that can satisfy all needs. Therefore, depending on the application in mind, the hardware specifications and configuration should be carefully considered during system development. This in turn would impose an additional requirement for professionals with expertise in both the application area and sensor integration (e.g. synchronisation and communication among the different sensors).
7. *Required data processing expertise*: Tightly coupled with the system integration expertise, high-level data-processing expertise is required while being cognisant of the demands of the different applications. Most importantly, the professional community has a substantial need for the development of reliable guidelines for the quality control of the different stages of data processing up to the final product that meets the demands of the intended application.

Outlook

Realising its huge potential, the research and professional communities have been actively addressing challenges pertaining to system development and manipulation of acquired data by passive and active digital imaging systems on board micro/mini UAVs. Some of the promising developments in this area include:

1. *Position and orientation systems (POS)*: The continuous hardware and software developments in global navigation satellite systems (GNSS) and inertial navigation systems (INS) have led to the availability of lightweight (i.e. less than 100g) POS units that are capable of providing position and attitude accuracy in the range of 2 to 5cm and 0.025° to 0.08°, respectively. Such developments are having tremendous impact on reducing the required ground control for passive imaging systems as well as the derivation of more reliable products from Lidar units on board UAVs.
2. *Low-cost digital cameras with GNSS/INS synchronisation capabilities*: It is now feasible to equip UAVs with off-the-shelf digital cameras that have more than 40 megapixels while providing capabilities for precise time tagging of the acquired images. Such capabilities are having huge impact on reducing the ground control requirements for the production of accurate orthophoto mosaics and digital surface models.
3. *Low-cost Lidar units*: Recent developments in the laser-ranging and scanning technologies have made it possible to have reasonably priced (i.e. less than USD10,000) Lidar units that weigh less than one kilogram while providing more than a quarter of a million pulses per second with range accuracy at the centimetre level. Such moderate weight and cost characteristics make it possible to augment the system with a digital camera without excessively increasing the overall payload cost/weight.
4. *Lightweight multispectral and hyperspectral imaging systems*: Advances in digital imaging technologies have led to the availability of lightweight multispectral and hyperspectral cameras. Such cameras allow current UAV-based mapping systems to provide solutions to applications that require higher spectral resolution and wider spectral range than is offered by RGB digital cameras.
5. *Commercially available image-based data processing software*: Thanks to recent advances in integrating photogrammetric and computer vision tools, the mapping community has access to several commercial packages that are capable of processing hundreds and even thousands of images to produce accurate orthophoto mosaics and dense digital surface models. Such packages have made it possible to process acquired data using a wide range of digital imaging systems in a short time while providing products that meet the needs of several applications.
6. *Innovative system calibration capabilities*: The research community has been successful in providing tools for accurate system calibration to simultaneously provide the intrinsic parameters of passive/active imaging sensors and the mounting parameters relating to such sensors to the onboard position and orientation unit (e.g. GNSS/INS). These advances are also coupled with strategies for quantitative evaluation of the stability of the calibration parameters.
7. *Innovative approaches for multi-sensor/multi-platform data integration*: The research community has been developing solutions for the integration of active and passive sensors operating in a wide range of the electromagnetic spectrum (e.g. RGB, multispectral and hyperspectral sensory data together with Lidar-based point clouds).

Summary

Recent technological advances coupled with developments in data processing activities are allowing UAV-based mobile mapping systems to address the needs of a wide range of applications. Surveying, infrastructure monitoring and agricultural management are starting to implement UAVs equipped with GNSS/INS-assisted passive/active digital imaging systems operating in different bands of the electromagnetic spectrum. In illustration, Figures 1 to 5 provide examples of multi-rotor UAV platforms that are equipped with directly georeferenced RGB/Lidar/shortwave infrared (SWIR) imaging systems together with generated orthophoto mosaics and digital surface models from such modalities.

For wider adoption and acceptance within the professional community, it will be necessary to establish standardised pre-acquisition best practices as well as post-acquisition guidelines. This will ensure the validity of the collected data in meeting the needs of the intended applications while reducing the required level of technical expertise. While UAV-based mobile mapping systems are unlikely to replace manned airborne and terrestrial modalities, there is no doubt that the former will play an important role in a wide range of applications that cannot be cost-effectively addressed by the latter. Moreover, it is expected that imagery and Lidar data from UAVs could be integrated with acquired geospatial data using traditional mapping platforms to offer more cost-effective solutions (e.g. providing local control to improve the positional accuracy of the latter).

* *Unmanned Aerial Vehicle (UAV) Market, by Application, Class (Mini, Micro, Nano, Tactical, MALE, HALE, UCAV), SubSystem (GCS, Data Link, Software), Energy Source, Material Type, Payload and Region – Global Forecast to 2022.* By: marketsandmarkets.com; publication date: November 2016; report code: AS 2802.