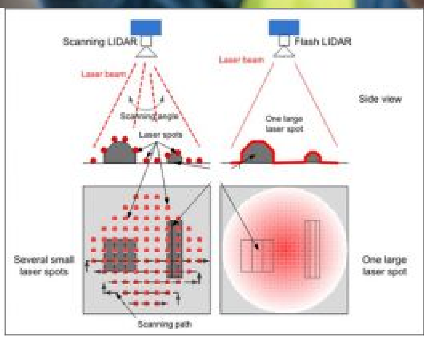
THE STATE OF LIDAR FOR UAS APPLICATIONS

Lidarâ€™s Next Geospatial Frontier

Manufacturer/model	Range (m)	Weight (kg)	Laser (nm)	Multiple Echoes	Pulse Rate (pts/sec)	Method
Velodyne HDL 32-E	100	2.0	905	2	700,000	ToF
Velodyne VLP-16	100+	0.6	905	2	300,000	ToF
Ibeo Lux	200	1.0	905	3	40,000	ToF
Faro Focus 3D S 120	120	~5	905	1	976,000	Phase



Over the past two decades, airborne Lidar has evolved from a developmental technology into a well-established mapping solution, and in the process has revolutionised the surveying and mapping industry. Today, unmanned aerial systems (UASs) represent the next geospatial frontier. With recent advancements in sensor technology, the adoption of Lidar for UASs is rapidly expanding, leading to new industry horizons. Read on for insights into the current state of UAS-based Lidar technology and emerging trends.

(By Michael Starek and Jinha Jung, Texas A&M University-Corpus Christi, USA)

Integration of traditional airborne Lidar mapping technology with UASs has been challenging due to the trade-off between Lidar system performance and size, cost and the effect of flight dynamics on the measurement process. Although large-scale UAS platforms capable of carrying traditional Lidar mapping systems have been in operation for some time, their utilisation is restricted to very niche areas, most notably the military sector (e.g. Northrop Grumman’s Global Hawk). The focus here is on Lidar technology with practical applications for the broader UAS user community. The following weight-based categorisation of UASs by Colomina and Molina (2014) is used here for both fixed-wing and roto-copter platforms to set a basis for the discussion: micro (less than 5kg), mini (less than 30kg), and tactical (less than 150kg). These platform types, particularly in the micro to mini range, represent the largest current user market in the geospatial industry. Over the past few years Lidar sensor technology has been sufficiently reduced in terms of size and weight to enable wider use within this smaller scale of UAS platforms.

The discussion below outlines various examples of UAS-based Lidar technologies based on platform size and application. The division set forth is not black and white, since some systems may fall into more than one category. It is important to state that the authors do not endorse any specific platform or Lidar sensor mentioned in the discussion and that those presented here represent only selection of the available market.

Tactical-grade UAS Lidar

Lidar sensors falling within this category refer to those sensors conducive for integration on tactical to mini UAS platforms with maximum operating ranges exceeding 200 metres above ground level (AGL) and endurance times of up to several hours. These systems are designed to replicate survey-grade performance capabilities of traditional multi-return airborne Lidar mapping systems but at a reduced scale. To do so, these systems utilise advancements in laser technology, receiver sensitivity and enabling technology (IMU/GPS) to provide a fully integrated UAS solution. These systems have trade-offs in achievable ranging distance and flying height compared to traditional Lidar mapping systems on piloted aircraft. However, it is important to mention that this category of UAS Lidar provides the greatest range performance relative to the other sensors types discussed here. Furthermore, these systems tend to be the most costly relative to the other Lidar sensor types discussed (typically more than USD100,000 for the sensor alone) but are priced significantly lower than traditional airborne Lidar mapping sensors.

As far as is known, there are only a few commercial sensors presently available that fall under this category. The most notable is RIEGL's VUX-1, which was released in February 2014 (Figure 1). The VUX-1 weighs less than 4 kilograms, has a 300-degree field of view with a rotating scanning mirror and provides internal storage with several hours of data collection. It has a 550kHz laser pulse repetition rate operating in the near infrared and utilises time-of-flight measurement with echo signal digitisation and online waveform processing for multi-return capability. At a 50kHz pulse repetition rate, system specifications state a maximum range of 920 metres for targets with reflectivity higher than 60% and a maximum operating altitude of 350 metres AGL. Accuracy at the 150-metre range is quoted as 10mm (1 sigma). Applications for tactical-grade UAS Lidar such as the VUX-1 include wide-area topographic mapping, coastal zone mapping, defence and forestry, among others.

Mini-grade UAS Lidar

Lidar sensors within this category refer to sensors conducive for integration on UASs no larger than mini UAS platforms (less than 30kg total weight) with operating ranges of less than 200 metres AGL. Typical weights of the entire scanning system including the Lidar sensor and enabling technology range from 2kg up to 20kg. It is important to note that tactical grade UAS-Lidar like the VUX-1 mentioned above could also fall under this category based on sensor weight, but the single distinguishing factor here is the reduced maximum range and operating altitude. The majority of these systems are integrated on roto-copter platforms due to their greater payload capacity. However, such systems are limited in flight endurance due to roto-lift inefficiency and current limitations in battery endurance for electrically powered UASs. Typical endurance is much less than an hour for a standard platform, but total endurance for a given platform will depend on payload weight and ambient wind, among other factors.

Lidar sensors within this category consist mostly of short-range laser scanners originally developed for robotics and mobile/terrestrial applications that have been successfully integrated onto mini-grade UAS platforms. This includes several different sensors from manufacturers such as FARO, Velodyne, SICK and Hokuyo. Examples of commonly integrated sensors include the Velodyne HDL 32E, Ibeo Automotive Solutions IBEO Lux, and the FARO Focus 3D S 120. More recently, manufacturers have been developing Lidar sensors specifically designed for mini-grade UAS integration. One example is the recently released and very lightweight Velodyne VLP-16 (Figure 2).

Several companies provide complete turnkey systems for mini-grade UAS integration by coupling a short-range Lidar sensor with a light-weight, high-performance INS and data logger as well as post-processing software. Typically, these are portable units that can be mounted onto any appropriate UAS platform or are provided integrated with a specific UAS platform. Example of turnkey systems include Routescene's LidarPod (Velodyne HDL 32E; Figure 4), YellowScan (IBEO Lux), Phoenix Aerial System's Scout Series (Veoldyne HDL 32E or VLP-16), 4D-IT's Scan-Copter 2.0 (Faro Focus 3D S120) and the SABRE SkyPod (Faro Focus 3D S120). Lidar systems falling within the mini-grade UAS category are best suited for localised mapping applications including inspection surveying, stockpile monitoring, mining operations, landslide mapping or vegetation monitoring.

Micro-grade UAS Lidar

Lidar sensors within this category refer to very low-cost and lightweight laser ranging and depth imaging sensors that are conducive for integration onto micro-grade UAS platforms. For example, the recently released Lidar-Light by PulsedLight is an extremely compact (21 x 48.3 x 35.5mm) and lightweight singlebeam ranging sensor (up to 40 metres) which costs less than USD90 at the time of writing (Figure 5). It uses an interesting ranging method based on correlated waveform signatures. Structured light-imaging sensors of Microsoft Kinect fame also fit into this category. Micro-grade sensors like the Kinect are popular among do-it-yourself (DIY) enthusiasts and academic researchers for developing creative UAS solutions. Examples of applications include sense and avoidance and interior mapping. For instance, back in 2010, researchers at the University of California Berkley equipped a micro-grade quadcopter with a Kinect to develop a UAS capable of autonomous flight, and many other such examples exist in the research literature and DIY community.

Emergent Trends

One current area of development not mentioned previously is in bathymetric Lidar. Traditional systems are very heavy, costly and have excessive power requirements, thus severely restricting their utility for wide-scale UAS integration. To address this current limitation, a team at the Georgia Tech Research Institute (GTRI) has designed a new approach that could lead to bathymetric Lidars that are much smaller and more efficient than the current full-size systems. The new technology would allow modestly sized unmanned aerial vehicles (UAVs) to carry bathymetric Lidars equivalent to current piloted aircraft systems, which would substantially reduce costs.

Another emerging technology of interest in terms of UASs is an innovation called 'flash Lidar'. 3D flash Lidar cameras have 3D focal plane arrays with rows and columns of pixels, similar to 2D digital cameras but with the additional capability of recording the 3D depth and intensity. Each pixel records the round-trip time of travel of the camera's laser flash pulse from the sensor to the scene and back (Figure 6). 3D flash Lidar has some advantages over conventional Lidar scanners for UAS integration including lightweight composition, no need for precision-scanning mechanisms, low power consumption and higher altitude operation. For an example of flash Lidar targeted at mini to micro-grade UAS integration, see Advanced Scientific Concept's Peregrine 3D Flash Lidar.

Developments in GNSS-inertial solution technology for efficient, high-accuracy mapping from small-scale unmanned platforms are greatly progressing the applicability of Lidar technology in the UAS market. Finally, simultaneous localisation and mapping approaches commonly applied in robotics are making their way into UAS-based Lidar mapping systems. These techniques use automated feature extraction and cloud-to-cloud registration approaches with limited or no aiding sensors to derive near-real-time seamless 3D point clouds of the scanned scene (see for example XactMap's GPS Lidar).

Conclusion

This is an exciting time for Lidar technology, and the coupling of the technology with UASs is still in its infancy. As UAS capabilities continue to evolve and flight regulations open more doors, Lidar will find a much wider audience which lead to unforeseen new developments, applications and opportunities.

Further Reading

Colomina, I. and Molina, P. 'Unmanned aerial systems for photogrammetry and remote sensing: A review' *ISPRS Journal of Photogrammetry and Remote Sensing* 92 (2014): 79-97.

Georgia Tech Bathy Lidar: http://gtri.gatech.edu/casestudy/smaller-lidars-could-allow-uavs-conduct-underwater

XactMap's GPS Lidar: http://www.gim-international.com/news/mapping/uas/id7926debut_for_gpsless_uav_lidar_surveying_and_mapping_system.html

Figures

Figure 1, RIEGL VUX-1 mounted on the RiCOPTER platform (photo: www.rieglusa.com)

Figure 2, Mini-grade UAS Lidar system being developed by researchers at Texas A&M University-Corpus Christi that integrates a DJI S1000+ platform with a Velodyne VLP-16 Lidar scanner. The system will use an Applanix APX-15 high-accuracy INS (weighing 60 grams) and employ a Zenmuse Gimbal Z-15 for mounting a Sony Alpha Nex 7 camera.

Figure 3, Short-range Lidar sensor specifications for mini-grade UAS platforms; ToF = Time of Flight.

Figure 4, Example of a turnkey mini-grade Lidar system developed by RouteScene that utilises a Velodyne HDL-32E scanner (photo: www.routescene.com).

Figure 5, Micro-grade UAS equipped with Xbox Kinect for autonomous flight developed by researchers at University of California, Berkeley, back in 2010 (photo: Liz Hafalia, The Chronicle).

Figure 6, Scanning Lidar compared to flash Lidar (photo: adapted from http://www.fosternav.net).

Authors

Dr Michael Starek is an assistant professor of geospatial surveying engineering and GISc with the School of Engineering and Computing Sciences at Texas A&M University-Corpus Christi, USA.
michael.starek@tamucc.edu

Dr Jinha Jung is an assistant professor of civil engineering with the School of Engineering and Computing Sciences at Texas A&M University-Corpus Christi.
Jinha.Jung@tamucc.edu