Point Clouds and Pixels – New Technology Solutions for Imaging and Scanning Sensors

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ABSTRACT

Airborne Sensors, both imaging and LIDAR, continue to develop rapidly, responding to user needs in a variety of applications. An overview of new applications for both imaging and LIDAR systems is given, along with a description of technology advances responding to these applications. A review of products incorporating these technical advances is presented, illustrating the current state of the art.

1. EVOLUTION IN USER APPLICATIONS AND REQUIREMENTS

Inasmuch as we are all scientists at some level, the users or our technologies are very much driven by business needs rather than the desire for scientific discovery. The desire to develop a competitive advantage and/or run efficient operations is the engine that drives the transition from technology to product. Competitive advantage can be the result of acquiring a technical capability suitable for some specialized need. Technology can also be applied to produce existing end products (i.e., data) at lower cost. Both these motivations have been seen over a significant period of time in the history of airborne sensor development.

In the intervening years since the last Photogrammetry Week, both influences above can be seen. The effect on sensor requirements of these two influences has been subtle yet, at the same time, distinct. For instance, we have been witness to the rise of airborne systems designed for specific applications, such as corridor mapping or remote sensing. We have also seen advancements in productivity, even in systems designed to handle a wide range of activities (e.g., both engineering scale and wide-area data acquisition).

1.1. Applications and requirements for airborne imaging systems

Within the users of large-format imaging systems one can find examples of novel applications and also examples where greater efficiency is desired. Some examples of applications for airborne imaging, along with the implied technical requirements are shown in Table 1 below.

Airborne Imaging Application	Implied Requirement(s)
Remote sensing in the near-shore marine environment[1]	Consistent color radiometry
Forestry	Consistent color radiometry, including in the near infrared band and color/false-color CIR stereo imaging
Large-area projects	High data production efficiency / low cost per pixel by (1) being able to fly more hours per day (i.e., greater latitude in lighting condition), (2) more pixels per hour and (3) faster processing speed
Automated filtering and classification	All bands acquired simultaneously, and at high resolution

Table 1: Applications and implied requirements for airborne imaging systems.

1.2. Applications and requirements for airborne LIDAR systems

Like the case for airborne imaging, airborne LIDAR systems have seen new applications as well as demands for increased productivity. Some examples of applications for airborne LIDAR, along with the implied technical requirements are shown in Table 2 below.

Airborne LIDAR Application	Implied Requirement(s)
Large-map-scale data collection (land development and engineering)[2]	High point density, high scan rate, high accuracy
Forest inventory	High penetration
Large area mapping[3]	High measurement rate
Use by non-traditional practitioners (e.g., ground survey firms)	Ease of use

Table 2: Applications and implied requirements for airborne LIDAR systems.

Two points should be made regarding the implied requirements on system design. First, high point density should not be confused with high measurement rate. High point density applications such as site development, corridor mapping or urban modeling require ground surface measurements at small post spacing, with only secondary regard to the actual rate at which the points are acquired. In these cases, point density and accuracy outweigh measurement rate (i.e., points per second), since the site size might be quite small compared to the mobilization time. On the other hand, high measurement rate is just that; more points per second. This is most important in large area mapping, where the total number of points to be collected is large, particularly in comparison to mobilization costs.

The second point is that system scan rates and data accuracy must keep pace with increases in desired point density. Failure of scan rates to keep pace with increases in point measurement rate will result in high cross-track point density without a corresponding increase in along-track point density. Ideally, every quadrupling of measurement rate would be accompanied by a doubling of scan rate. In the case of delivered data accuracy, it too must keep pace with increases in point density. The mathematics are fairly similar to that of the scan rate-measurement rate relationship. If the point density is quadrupled (and if scan rate is doubled), then the typical point spacing is cut in half. If the maximum slope of any relatively flat TIN surface is not to increase beyond the slope of prior (lower-point-density) data, then the accuracy (or at least elevation jitter) must be cut in half in order to avoid an appearance of greater “roughness” on otherwise flat surfaces.

2. IMAGING SOLUTIONS

2.1. ADS80

Since the 2007 Photogrammetry Week, the Leica Airborne Digital Sensor has evolved into its third generation. The new ADS80 retains the patented tetrachroid design, which allows perfectly co-registered imagery in all color bands (including NIR). It continues to be offered in two sensor head variations, the SH81 and SH82. The SH81 is allows natural color and CIR data collection from the nadir orientation, making it an ideal instrument for orthophoto production. The SH82 allows for true stereo viewing of both natural color and CIR imagery, and is ideal for feature collection, even in CIR mode, and with no pan sharpening. It should be noted that one of the key advantages of the parallel line-scan format is often overlooked. The line-perspective images, when viewed in stereo for feature collection, result in less operator fatigue. This can have measureable benefits in terms of feature collection productivity.

The ADS80 instruments have responded to the requirement for high productivity through several advancements. The improved signal-to-noise ratio in the third-generation system allows for flights in less optimal lighting conditions, accommodating more flying hours per day and an extended flying season. This same advancement allows the sensor to operate at higher line rates, accommodating higher aircraft speeds and/or smaller ground sample distances. Improvements in data handling allow these higher line rates (and the accompanying higher data rates) to be recorded accurately. These advances effectively lower the "cost per pixel" during data acquisition.

The ADS80 has also been enhanced through the use of removable solid state disk (SSD) recording. The advances in SSD recording technology have allowed the use of high-capacity removable SSD modules in the ADS80 Control Unit. This results in a significant decrease in size and weight over that of the previous generation.

In terms of productivity enhancements, software should not be overlooked. The new Leica XPro software suite allows processing of ADS80 data at the "speed of flight", making the lead time from acquisition to exploitation significantly shorter.

2.2. RCD100 and RCD105

RCD100 represents the first system to market where all major components (i.e., positioning, orientation, camera head, data logging) are integrated into a single assembly. The RCD100 leverages the developments of the RCD105 digital frame camera system. RCD105 was introduced in 2007 as a medium-format (39 MP) frame-camera solution for precision digital imaging on the ALS50-II airborne LIDAR. Since its introduction, the RCD105 has been developed into a stand-alone medium-format frame camera system, ideal for smaller production volumes and specialized missions, as well as being a solution for existing film-camera users wanting to make a transition into a digital imaging environment at a lower cost than that of large-format systems.

RCD100 and RCD105 use common components for ease of use in multi-platform operations. Both systems offer single- or dual-head operation (e.g., for simultaneous natural-color and CIR image acquisition) and a high frame rate, as well having available a variety of lenses to accommodate different mission needs. Like the ADS80, both RCD100 and RCD105 now employ removable solid-state data storage, which circumvents any issues of vibration or altitude that might be encountered in standard HDD solutions.

3. LIDAR SOLUTIONS – ALS60 AND ALS CORRIDOR MAPPER

In July 2008, the ALS60 was introduced. This 5th-generation LIDAR continues to build on the steady productivity and accuracy gains seen in prior models. A variant of the ALS60, the ALS Corridor Mapper, has also been introduced, and is targeted to lower-volume users demanding a more affordable solution without sacrificing system accuracy and flexibility.

Both systems have benefitted from a number of advances. System measurement rates have been increased 33 percent, from 150 kHz to 200 kHz. Multiple Pulses in Air (MPiA) technology, which was new at the previous Photogrammetry Week, is now an integral option nearly every system shipped. MPiA is operable over the entire system envelope above 900 m AGL, and provides a 2:1

productivity advancement over non-MPiA systems. In fact, the gains can be even greater than 2:1, if there is significant terrain height variation in the survey area[3].

As mentioned previously, it is important that LIDAR scan rates maintain pace with advancements in measurement rates in order to avoid large differences between cross-track and along-track point spacing. With the ALS60, maximum scan rate has been increased from 90 Hz to 100 Hz. Moreover, the maximum scan rate at any given FOV is increased ~30 percent for most scan rates. This allows the scanner to maintain the small along-track post spacing required when doing engineering-level mapping or urban modeling. Alternately, it allows a given along-track spacing to be obtained at higher flight speeds.

4. PERIPHERAL SOLUTIONS – OC52, FCMS, FPES, PAV80

Peripheral components are often underestimated in terms of their benefit to overall system productivity. Leica Flight Planning and Evaluation Software (FPES) has been advanced to allow mission planning for all Leica airborne sensors, including ADS80, ALS60 and RCD100/RCD105 as well as for generic sensor types. As in prior versions, flight line layout is the most obvious product of FPES. However, FPES now features modules for optimization of ALS sensor settings, and automatic incorporation of these settings into the flight plan.

Operator fatigue is now reduced through the introduction of a larger-format touch-screen operator interface, the OC52 Operation Controller. The OC52 allows monitoring of multiple systems, including RCD100, RCD105, ALS60, ALS Corridor Mapper and IPAS20 stand-alone hardware, all through a single operator interface. OC52 represents the hardware interface that gives physical consistency to the “user experience” over the entire suite of Leica airborne sensors.

Like the OC52 in the hardware domain, the Leica Flight and sensor Control Management Software (FCMS) represents a common graphical user interface for all Leica airborne sensors. FCMS allows intuitive, language-independent operation of Leica airborne sensors, and allows upload of FPES flight plans, including sensor settings for each flight line. In addition to guiding flight navigation, FCMS also starts/stops data logging and records a variety of metrics that can be used for post-flight evaluation.

The PAV80 has now been introduced, and features both higher stabilization accuracy and greater accommodation of load variations. This latter feature is particularly important as stabilized platforms are purchased for an increasing variety of 3rd-party sensors as well as being used with ADS80. Although traditionally an instrument for aerial photography, the PAV80 also has applications in airborne LIDAR, particularly when used with auxiliary imaging sensors.

With its greater load capacity, the PAV80 can be used to stabilize the ALS60 scanner, either with or without additional RCD105 camera heads. The ALS60 is internally stabilized for variations in aircraft roll, but not pitch or yaw. Furthermore, an integrated imaging sensor, such as the RCD105 is not stabilized at all with respect to the LIDAR scanner, as it must be rigidly “tied” to the ALS IMU. Stabilization of any LIDAR carrying ancillary imaging sensors can improve image quality, particularly at lower shutter speeds or when using long focal length lenses.

Stabilization of the LIDAR scanner about the pitch axis eliminates variations in along-track spacing as the aircraft pitches up and down (i.e., stretching of the scan pattern when pitching up and compression of the scan pattern when pitching down). Stabilization of the LIDAR scanner in the yaw axis eliminates the reduction in covered swath due to aircraft “crabbing” in crosswinds. Given the reduced side overlap in a typical LIDAR flight plan (as compared to aerial photogrammetry), yaw stabilization prevents uncovered patches between flight lines when flying in heavy crosswinds.

5. CONCLUSIONS

Imaging and LIDAR sensors continue to be used in more varied applications, indicating continued improvement across a variety of system specifications. Sensor development continues to keep pace with these demands, and continued progress is envisioned over the upcoming years. These continued advancements will result in sensor solutions that offer further productivity gains. In imaging sensors, a major focus will become productivity of software while, in the airborne LIDAR arena, hardware improvements continue to lead those in processing software.

6. REFERENCES

[1] Green, K., Lopez, C., (2007): Using Object-Oriented Classification of ADS40 Data to Map the Benthic Habitats of the State of Texas. Photogrammetric Engineering and Remote Sensing, August 2007, pages 861-865.

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[3] Roth, R., Thompson, J., (2008): Practical Applications of Multiple Pulses In Air (MPIA) LIDAR In Large Area Surveys. Proceedings of XXI Congress of ISPRS, July 2008