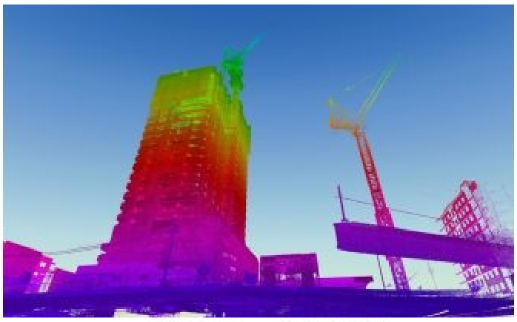
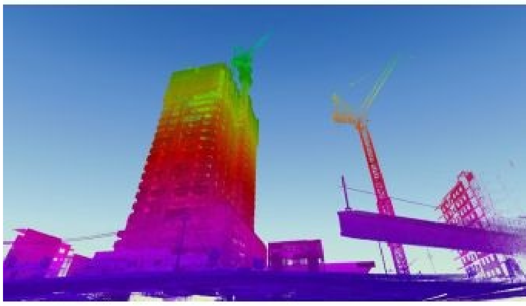
3D Modelling for Construction





When it comes to 3D modelling for construction, what are the advantages and disadvantages of photogrammetry versus Lidar in terms of accuracy, complexity and cost? Breaking away from laser measurement in construction is a taboo subject, perhaps hampering the use of photogrammetry. In construction, aerial survey has enormous time-saving benefits for measuring groundwork areas. Data can be used for asset classification and construction validation as well as health and safety. In particular, regular scans provide a time series of work in progress to detect new issues, managing risk rather than responding to it. This article looks at the state of the art.

What is Photogrammetry?

Photogrammetry is defined as the method of obtaining information about physical objects and terrain through the recording, measuring and interpretation of photographic images. Photogrammetry uses methods from optics and projective geometry to allow the creation of 2D or 3D digital models. Using camera parameters and a series of images taken from different positions and aspects 3D information can be recovered in post processing.

What is Lidar?

In Lidar (Light Detection and Ranging) a 3D target area is illuminated with a pulsed laser and the difference in reflected light return time and wavelength is measured. Lidar systems typically fire one million pulses per second with each processed return going into a 3D visualization know as a point cloud.

Uses in Construction

Several phases of construction can benefit from 3D modelling. For new build projects initial site surveys can be performed quickly using aerial data capture over traditional site walking to establish DSM/DTM information. Early ground works scrape and fill volume and position can be quickly measured. As the building stages progress to completion measurements can be taken to verify each stage is correct and in line with the BIM strategy. Read more in this article here.

3D point cloud of a building under construction, generated by a Hovermap Lidar payload.

Photogrammetry Workflow

Photogrammetry can be performed using any camera as long as sensor size, pixel count, focal length and shutter type are known. Large format cameras with global shutters are desirable but are considerably harder to use in an airborne survey. Currently the leading drone manufacturer is DJI who have a range of drone and camera options available. There is a loss in image quality using smaller drones, but this is made up for in their ease of use. Aircraft such as the DJI Phantom 4 Pro and Inspire 2 are excellent image acquisition tools given they are used in the correct way and under the correct conditions. For photogrammetry accuracy is relative to the sensor size and height. This is known as the ground sampling distance (GSD). This is typically 1-3cm depending on what is a practical height to fly 50-120m. Propeller Aero has a handy online tool to compare GSD accuracy for different DJI drones.

The computational demands of photogrammetry mean post processing requires a considerable amount of processing power. A high-end PC with maximum GPU power is required still requiring hours to complete a model. Three major distributers of photogrammetry software are Agisoft Metashape (previously known as Photoscan), Pix4D and Reality Capture. These have different strengths across different industries. They all use the same principle of using a series of captured images taken sequentially in a grid with known positions. 3D information is pulled out in processing by identifying common points. These go into making the calibrated point cloud of the scene which is often exported in the LAS/LAZ formats for use in other software.

Unless used frequently the time and cost of processing photogrammetry in house isn’t economic to most clients. We believe our own bespoke processing is a more effective proposition. Our team has exclusive expertise in construction modelling and its issues. We can turn around 3D models for construction and take care of the acquisition and processing without any of the headaches in between.

Lidar Workflow

Several aerial Lidar platforms leverage the Velodyne sensors. These use a pulsed spinning prism laser proven more accurate than smaller solid-state Lidar so far. This makes the unit considerably larger and heavier than a camera alone. A commonly used model for aerial applications is the Velodyne HDL-32E which has an accuracy of +/- 2cm at 80-100m range. Further processing equipment and sensitive IMU's and RTK sensors are required along with further signal processing to derive a filtered point cloud of the scene. Globally there remain few vendors offering this complete solution from airborne platform to point cloud available from the ground station. All the equipment requires a substantially large UAV up to 20Kg which in turn limits flight times to under 10 minutes. Routescene UK have developed such a system but look to part with around 100K for their LidarPod system. Such systems must measure drone aerial position quickly and accurately in order to position the scanned point cloud correctly.

Lidar requires little post processing in comparison to photogrammetry. The goal is typically to clean up any noise, lock in position and visualize data. The majority of software is closely tied to the industry of use, be it construction or land survey. In construction software such as Autodesk and Solidworks are chiefly used for architecture but have a growing role in BIM and design validation during construction using interior and exterior Lidar scanning. In land survey ArcGIS, Global Mapper and QGIS now have Lidar tools available.

A Quick Word on Position Accuracy

In aerial mapping and model making geotag information is required in the form of GPS position, bearing and altitude. In photogrammetry most mapping software requires geotagged images to identify scale and position but isn't always required if there is no GIS (Global Information System) requirement for data consumption. For Surveying GPS isn't very accurate +/-2 meters. A way around this is to use GCPs or RTK/PPK techniques.

Real Time Kinetick RTK positioning uses a base station of known position with a data uplink to the drone that sends position corrections. Post Process Kinematic PPK is similar be it these corrections are done in post processing. These technologies can still be prone to error due to solar activity and other system errors.

Ground Control to Major Tom…

Ground Control Points are points that are marked on the ground in such a way as they have a visible center point in the aerial image. Existing features can be used such as manhole covers or other permanent features between surveys. Spray paint patterns around survey nails or posts are also a popular choice along with temporary survey targets that can be pegged in place. The center points of these targets can then be measured and recorded using ground survey equipment and the position information passed to the processing software. If a site allows, ground control points should still be used if only to validate RTK/PPK results.

The point cloud created from photogrammetry can then be processed to derive a 3D model, Digital Elevation Model DEM, Digital Surface Models DSM or Digital Terrain Model DTM.

Best Method for Absolute Accuracy?

Surveying places a great importance on measurement error and understanding its sources, these are typically:

Gross: operator mistakes such as manually reading or noting the wrong figure

Systematic: Equipment errors due to fault, calibration or bias

Random: measurement noise.

An accurate system has few errors after cross checking manual measurements and rigorous equipment calibration. Now only random errors remain described by standard deviation denoted sigma.

Eliminating spatial positioning differences between photogrammetry and Lidar point cloud quality is now compared. Comparing raw point clouds of the two methods in photogrammetry a point is a feature which software has identified and matched in two images. Whereas with Lidar each point is a laser return value.

An Illuminating Fact

Photogrammetry relies highly on the reflectance of ambient light. Daylight is therefore essential. Shadows can be a problem depending on the time of day as cameras need equal lighting across the image. White or reflective surfaces can also be a problem casing images to blow out. The image quality and the surface recorded play the greatest role in establishing good points for matching. Software such as Pix4D places a great emphasis on the quality of its accuracy in its processing quality report returning information on the number and quality of matching points.

Pre-construction survey point cloud via photogrammetry (Image courtesy: Pointscene)

Which Is More Effective?

Using photogrammetry smooth low contrast surfaces are problematic such as: water, snow, foliage and areas of concrete. Matching points between images can't always be found. Some solutions here are to fly higher, use GCPs or use a wider angled lens to capture more suitable points in shot. This will lower GSD. If this is an issue, then a camera with higher pixel density is required (DSLR 50MP). Removing many RTF (Ready To Fly) drones from say DJI of being used (around 20-25MP). This has its own issues as generally higher sensor density leads to poor low light performance. Price and weight again come into play. Another benefit of photogrammetry is that additional images can be mixed in from ground, pole, cable or crane cameras to compliment aerial photography.

An immediate drawback of Lidar is that true colour is not captured. From the laser light a limited colour profile of surfaces can be recovered. A fully integrated Lidar system consists of several components each with their own accuracy value. For Lidar achieving the highest accuracy means more expensive and often larger heavier components which for a UAV equates to lower flight time and productivity. Lidar as with photogrammetry has problems with black or reflective surfaces that either absorb or scatter the laser light. Over Photogrammetry one benefit Lidar has is its ability to penetrate light vegetation cover allowing both DSM and DTM to be capture simultaneously.

A method of covering the shortcoming of each method is to perform both simultaneously and fuse the data. The Lidar point cloud can be imported and used to improve the uniformity of the 3D model for smooth areas where photogrammetry fails.

Conclusion

This article has reviewed issues for aerial photogrammetry and Lidar captured using construction drones. Each has its merits depending on budget and schedule. At Construction Drone Services we believe photogrammetry is a stronger technology because of its rapid deployment capability and colour information, ideal for time series data for BIM and asset classification and tracking. Construction Drone Services can provide accurate 3D models with our partners which will meet your needs first time, on time.

The original version of this article was published by Construction Drone Services, a cooperation between three drone companies – each with their own individual set of skills and equipment.