DEVELOPMENTS IN MULTISPECTRAL LIDAR ARE CHANGING THE WAY WE SEE POINT CLOUDS

Bringing Colour to Point Clouds

Until now, most commercially available airborne Lidar systems have operated on one single wavelength, reflecting energy from a pulse which is then used for classification or visualisation. New developments have produced the first multispectral Lidar systems, which scan using laser pulses in a number of different wavelengths. Multispectral Lidar data contains valuable information about the objects scanned. The fast-moving advancements in this field are likely to represent the next technological leap in Lidar systems.

(By Sam Fleming, Iain H. Woodhouse and Antoine Cottin)

Lidar systems have fundamentally changed the world of mapping and surveying. Airborne systems can cover large areas and remote places, while terrestrial systems can be used for local yet detailed scans both outside and inside buildings. The ICESat satellite has even shown that Lidar technology can be used for mapping from space. Since the introduction of the first Lidar system there have been many technological developments such as multiple pulses in air and full waveform recording, and the next major development will most likely be multispectral Lidar.

Images and Lidar

Multispectral imaging data has been used for decades. Apart from the visible red, green and blue values, these datasets contain reflection data for many other wavelengths in the infrared part of the electromagnetic spectrum. The technology relies on cameras that are sensitive to a large number of different wavelengths. Cameras which can pick up between four and 20 wavelengths are called 'multispectral', and the term 'hyperspectral' is applied to cameras that are capable of recording more than 20 wavelengths. Multispectral imaging data is used to classify regions or objects by their spectral response, for instance to recognise different plant species. In recent years there has been growing interest in combining such multispectral data with Lidar data. This can be done by gridding the Lidar data in a raster with a cell size similar to the multispectral data. Alternatively, a look-up method can be applied to find the corresponding value from the multispectral data for each laser point. Figure 1 shows an example of a point cloud that has been coloured by fusing the points with aerial images.

Passive or active

Current multispectral imaging systems work on the principle of passive remote sensing. They detect the sunlight that is reflected from a surface towards the camera. Hence, the data recorded is highly dependent upon the light conditions, the position of the sun and the way the sunlight is reflected in all directions by the surface material. Conversely, Lidar is an active remote sensing system which detects the reflected laser light emitted by the sensor itself. It is independent of light conditions and can even work in the dark. An active system capable of sensing multispectral data is of great interest to scientists and professionals since it can provide multispectral data that is independent of solar illumination or the reflectivity of a surface material. Active systems can also benefit from multiple returns from a single pulse, thus making it possible to see beneath higher-lying points.

Multispectral Lidar

Conventional Lidar systems operate on a single wavelength, usually in the infrared part of the spectrum. To obtain multispectral Lidar, one option is to fly multiple Lidar systems using different wavelengths simultaneously. This necessitates access to the multiple Lidar systems, and also to an aircraft which can carry multiple systems and provide the associated power supply. This set-up results essentially in a number of overlapping point clouds. A point in one of the point clouds will not be exactly coincident with points in the other, overlapping point clouds.

A more robust alternative to this is to obtain the spectral information directly from the Lidar using multiple wavelengths of light simultaneously. The concept of using two wavelengths in combination is not particularly new. In fact, the use of multi-wavelength Lidar for bathymetric applications is an old technology, with the principle first laid out in 1965. Traditionally, there are two wavelengths for these systems, one in the near-infrared portion of the electromagnetic spectrum (1,064nm) and one in the green (532nm). This is done because the infrared beam is reflected by the sea's surface and hence enables easy identification of where the water meets the air. The green beam (532nm) passes through the water's surface and is used to locate the seabed. However, since these systems were not designed to extract spectral information about the surfaces from which they are reflected, differences in the spectral signature cannot be accurately analysed and put to meaningful use. More recent developments include the use of radiometrically corrected instruments produced by Optech's CZMIL system, and the previous SHOALS systems.

Three wavelengths

In December 2014, Optech announced the first commercially available multispectral Lidar system, the Optech Titan. This system combines three separate wavelengths along a single optical path. The wavelengths are positioned in the green (532nm) and infrared (1,064nm and 1,550nm) parts of the spectrum. The system is designed to suit a range of applications such as high-density topographic surveying, shallow water bathymetry, environmental modelling, urban surface mapping and land cover classification. As the three beams do not pass along the exact same path in space, the points recorded for the Titan system do not lie in exactly the same place in 3D space. This means that a user collects three independent point clouds, each relating to a different laser wavelength. These can then be combined through a gridding process, resulting in a raster rather than a point cloud. Figure 2 shows a gridded point cloud from the Titan system, visualised in false colour to represent all wavelengths.

Further improvements

The ultimate multispectral Lidar will provide a point cloud whereby each point is recorded in each of the three wavelengths. To do so, manufacturers will have to make a system where the beams overlap precisely and the returns are measured simultaneously. Consistent calibration across the different wavelengths must be maintained, and interpreting the signal can be challenging because three waveforms have to be processed simultaneously. Once these technical challenges have been overcome, however, the benefits will be enormous. Spectral information will be available for everything that the Lidar system can measure, not just the very top surface. This is particularly important when mapping natural surfaces where there is a presence of vegetation. This technology will allow identification of differences between materials at all points where the laser has reached the surface plus it will offer all the advantages of an active system.

Applications in forest mapping

The company Carbomap, which is a spin-off from the University of Edinburgh, processes multispectral Lidar data for forestry applications. Specifically, multispectral Lidar is used in this area to identify the ground layer and the differentiation between leaves and wood. The more accurately information can be derived in this way, the more accurately biomass estimates can be made – and biomass estimations are essential in REDD+ (Reducing Emissions from Deforestation and Degradation) monitoring.

Another application is the use of multispectral Lidar for creating an understorey forest canopy map. This has been tested in practice by Carbomap. Three airborne Lidar systems from RIEGL USA with different wavelengths (532nm, 1,064nm and 1,550nm) were flown on the same platform over a forest in Virginia, USA. Carbomap's processing software was used to tie the closest Lidar points from each wavelength dataset. Subsequently, a three-channel false colour composite was created. Figure 3 shows the ratio of the energy returned from the different wavelengths. This demonstrates the amount of spectral variation within the vertical forest canopy, which in turn allows specialists to map the understorey health and species of trees. Applications for this method include fire risk management and mapping of invasive species. The future of Lidar lies in further advancements in multispectral systems. Technological leaps like these, which will pave the way for new uses and applications, make the future of multispectral Lidar very exciting indeed.

More information on the Optech CZMIL here.

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