## The AGI Foresight Study - The UK Geospatial Industry in 2015

# An Expert Paper

## Data Capture Tools and Techniques

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**Scope**

In this paper I will consider the data capture of geographical features in its widest sense, i.e. the 'survey' of any object with a spatial position and attributes.

**Context**

Data capture tools are the instruments we use to collect detailed survey information about objects. However, without survey control these objects cannot be georeferenced to the national co-ordinate system. So, before discussing the tools themselves I will consider briefly the current status and future of survey control.

Survey control involves fixing the position and orientation of the instrument being used for data capture. Nowadays we fix position using GPS (or rather GNSS – the term that encompasses multiple constellations) and, for instruments that are moving, we observe the orientation of the instrument using inertial systems.

New GNSS survey receivers can provide consistent high quality position-fixing at all times, but are affected by obstructions to the satellite signals. The technology is ideal for high accuracy position fixing of aircraft because there are no obstructions. On the ground however it is a different story because GNSS signals become unreliable in locations where the satellite signals are blocked by trees and buildings, or spurious signals reflect off building faces and roofs.

When the data collector is mounted on a moving vehicle, whether it's a plane, a car or a boat, we also need to know how the vehicle is tilted in order to georeference the objects that we are surveying. The technology for this comes from inertial navigation. Inertial sensors have been around since the 1980s but in the last few years have developed into more accurate, smaller and cheaper systems. These systems use gyros and accelerometers to determine attitude and velocity of the vehicle. As well as detecting tilts, they can be used for dead reckoning which makes them ideal for position fixing in those situations where GNSS does not work effectively.

Together, GNSS and inertial navigation make a powerful tool but most importantly, they have made it practical to reference all surveys accurately to the national grid – a fundamental for any SDI. The technology will be the basis for ubiquitous positioning but will also be vital for the future of data capture – particularly mobile laser scanning.

**Data capture techniques**

Data capture techniques fall into three categories – direct observation of features, remotely sensed 2D data and remotely sensed 3D point clouds.

**Direct observation**

Direct observation of features is traditional surveying, with a heritage going back centuries. The process involves getting close enough to the feature to be able to identify it and then recording its position and attributes. We choose the points we want to survey, whether they describe the outline of a bus shelter on a large scale map or whether they are the location of pubs in the Old Kent Road. We generalise positions and attributes, but according to a set of rules which ensure that users understand the meaning of the data.

At the large scale end, surveyors use GNSS for detail surveying where there is a good sky view. They use non-GNSS techniques in the more difficult areas. Recent and future developments will focus on merging of GNSS, total station and laser scanning technologies. The major manufacturers already produce a detail pole on which is mounted a GNSS receiver and a prism (for total station observations).

There are also moves to introduce a standard GML format for storage and transfer of land survey data. This will bring about much-needed standardisation and interoperability of directly observed survey data between CAD and GIS.

At the 'small scale' end of the spectrum, augmented GNSS has brought position-fixing down to the sub metre level which is about all that is necessary for backpack systems. Position can also of course be taken from existing maps. It is a simple matter to upload a map background into a field datalogger and identify features against which to store attributes.

**Remotely Sensed 2D data**

Remotely sensed 2D data including aerial photography, multispectral imagery and synthetic aperture radar (SAR) are covered in detail elsewhere. For mapmaking, the technology is being driven by the development of digital aerial cameras, ever improving positioning of the plane using GNSS and inertial navigation, increased storage and faster processors. The result is falling prices, shorter production times and larger markets. Remotely sensed data has also become a mass market commodity.

The developments have also resulted in new techniques. For example UKMap is produced by digitising in 2D from orthophoto images (available as stereo pairs) rather than from stereo models. High accuracy is not usually needed for GI applications and new techniques have altered the traditional business model. The map maker used to gear production for the most demanding applications and, as a by-product, sell the same data for lower order applications with larger markets. With the advent of new products aimed at the bulk of the market, where does this leave the high-end data?

Photogrammetry can be used to produce digital ground models but airborne laser scanning is cheaper and quality is now comparable. I therefore expect use of airborne photogrammetry to decline. However I expect orthophotography to continue to expand.

**3D Point Clouds**

The final group of data capture tools is laser scanners. These collect 3D point cloud data and may be mounted on a fixed tripod, a moving ground vehicle, boat or aircraft. Scanners send a rapid stream of pulses out in a narrow beam and receive back the reflected signals off the objects that each pulse hits. They may record only the first return, the first and last return or intermediate returns as well. So, if the pulse hits a tree, the first return will come from the first leaf, intermediate returns may come from leaves and branches on the tree and the last return might (or might not) come from the ground. It is possible to make deductions about the reflective object from the intensity of the return. Most scanners also incorporate a camera from which it is possible to assign colour to each scanned point and thereby build up a photo-realistic 3D picture.

The intelligence of an individual point is limited to its 3D position, the intensity and composition of whatever radiation has been detected by the sensor and the colour assigned to it by simultaneous photography. As a cloud, it is possible to derive intelligence by analysing the relationship between neighbouring points to identify surfaces and edges.

The most accurate results come from ground based tripod-mounted systems that normally have a range of less than 100m and a beam width and distance accuracy of a few millimetres. Scanners with longer ranges have lower accuracy. Some suppliers now offer waveform processing which is used to analyse intermediate returns. To obtain a complete model you need to combine scans from as many locations as necessary to survey all the faces of the object being surveyed. Scanning rate can be 500,000 points per second and some instruments permit the user to trade off faster scanning against lower accuracy. Recent years have seen a massive improvement in scanner resolution and I expect this to continue in line with increased storage capacity and faster processing.

**LIDAR**

Laser scanning from aircraft (LIDAR) has been around for several years. Longer range scanners are used and the accuracy to unobstructed objects is a few centimetres. The results are usually generalised and presented as grid Digital Terrain Models (DTM) but the point clouds can also be used to generate roof scapes for 3D city models. The products are surface models from the first return and bare earth ground models made from the last return combined with filtering of the data. The filtering process is enhanced by classifying objects in the scene using large scale map or other data. In the next few years I expect lidar to be used in rainforest areas where the intermediate returns can be used to estimate biomass for carbon offset calculations.

More recently, vehicle mounted scanning has become popular. With one or more scanners mounted on the roof together with GNSS and inertial sensors, the suppliers claim an accuracy of 5cm under good conditions for GPS. These systems would pick up most building wall detail that may be hidden from aerial lidar and are a cheap and effective way to collect a mass of data.

Presentation of point cloud data is the challenge. It can be viewed as a point cloud in 3D, but the view contains everything – even moveable objects like cars. Conversely, it cannot record hidden objects, like manhole covers under parked cars. Aerial lidar uses filtering techniques to recognise and remove unwanted detail. Ground based scanning has been using software to recognise and vectorise detail, together with human intervention to select required points from the scene to draw vectors.

The other problem for the CAD world is that most users (particularly engineers and architects) are used to dealing with vector models. 3D point clouds are new to them. They need edges and surfaces to be modelled as geometric objects and identified. Point clouds are however useful as supporting information and scanner software suppliers now supply simple viewing software with a powerful 'wow factor' free of charge to help sell the added value that comes with point clouds. Point cloud to 3D vector modelling software exists but has a way to go before the problem can be considered solved.

Point clouds and their derived products represent a market that is under development. The hardware is developing rapidly, software less fast, while attitudes and belief in the data lag behind. I can see combined air and ground laser scanning data taking off as a visualisation tool. It could effectively be the 3D equivalent of 2D raster images and become the visual backdrop of choice for other 3D data.

Scanning is a technology that can detect 90% of the objects in a scene, but what about the other 10%? These remaining objects cost a disproportionate amount to survey by other means. Within a few years I can envisage a market for 3D point cloud data from lidar combined with mobile scanning by ground vehicles. This data could be developed into products – like 3D city models – by the same company, and subsets of the data sold to other, smaller companies to model and complete using other techniques for particular projects.

**Summary**

To sum up in five points:

- Improved accuracy of GNSS and Inertial navigation systems (INS) will help make laser scanning the leading data capture tool.

- GNSS and INS will also be used for collection of geographic features as a by-product of ubiquitous positioning.

- Processing of point cloud data is still a challenge but there will be greater automation of surface and edge recognition software.

- Lidar will supersede aerial photography for production of digital terrain models but will be used to colour point clouds and for 2D geo-corrected imagery.

- 3D point cloud data from lidar and mobile scanning will be gathered for entire urban areas and sold on to survey companies for data completion by other methods on a project by project basis.