

DEVELOPING A NATIONAL HEIGHT DATABASE

David Holland

Ordnance Survey, Romsey Road, Southampton, SO16 4GU UK - dholland@ordsvy.gov.uk

Commission IV Working Group IV/4

KEY WORDS: Height data, spatial data infrastructure

ABSTRACT:

In November 2001 the Ordnance Survey, Britain's National Mapping Agency, launched the first release of OS MasterMap™, the definitive digital map database for Great Britain. The initial data within OS MasterMap consisted of topographic points, lines and polygons, stored as 2-dimensional features in an object-oriented database. This paper outlines the structure of OS MasterMap; the current height data and height products captured and supplied by Ordnance Survey; the research undertaken into new methods of height data capture; and describes the 3D data which Ordnance Survey may incorporate into the data in future.

1. INTRODUCTION

In November 2001, Ordnance Survey launched OS MasterMap™, as "the definitive digital map of Great Britain". The first release of OS MasterMap consists of large-scale topographic data, cleaned and processed into a topologically-structured point, line and polygon model. The OS MasterMap brand is designed to be continually updated and expanded to include many layers of spatial information, including imagery; transport networks; hydrological networks and height data. Height data, and its relationship to OS MasterMap, is the subject of this paper.

2. OS MasterMap

2.1.1 OS MasterMap data

OS MasterMap is based on the concept of a definitive core of spatial reference data, captured, maintained and supplied to a well-defined specification – forming a Digital National Framework for spatial data. The name OS MasterMap is the brand name of the product which conforms to this Digital National Framework..

OS MasterMap currently contains over 400 million spatial features, constructed from Ordnance Survey's large scale topographic data. Before the advent of OS MasterMap, the data consisted of unstructured points and lines, stored in almost 230,000 separate "tiles". During 2000-2001 Ordnance Survey undertook a major re-engineering programme, which transformed this "unintelligent" data into a single, seamless, topologically-structured point, line and polygon object database. This restructuring, and the services developed to deliver the data, has many benefits to the user, which are discussed below.

OS MasterMap contains features representing buildings, roads and paths, administrative boundaries, railways, water features, and many other topographic features. These are collected into themes (such as "buildings" and "roads, tracks and paths"), to allow users to extract data within a particular theme, or group of themes. Eventually OS MasterMap will encompass many other types of spatial information, which may include smaller scale topographic data (ideally derived from the large scale data), imagery, points of interest,

integrated transport networks, address information, pre-build data (e.g. data from building plans before construction begins) and building heights and terrain models.

Each feature in OS MasterMap is assigned a unique identifier (a Topographic Identifier, or "TOID"), allowing users to make a definitive reference to any building, road segment, land parcel or any other feature in the database. This makes it much easier for users to associate their own information to the feature; to refer unambiguously to a particular feature and therefore to share spatial information with other users.

One of the great strengths of OS MasterMap is that the different spatial data layers will conform to a common framework.. All features will be registered to the same reference system, enabling users to link information in one layer with data in another layer. This integration of data will help users to perform more complex analysis, and to build up applications which address their specific needs. For example, a mobile phone service provider may take the road network and the height data to determine which transport routes are likely to receive signals of sufficient strength from a proposed antenna site.

2.1.2 OS MasterMap Services

The OS MasterMap service allows users to make their orders and receive quotations over the Internet. The novel features of this service are that users select their own area of interest (unconstrained by arbitrary map-tile boundaries) and may choose a subset of the available themes. The data is supplied on CD or DVD, or may be downloaded via an ftp server.

One feature of the service which has been high on the requirements list of many users for a long time is "change only update". Previously, when a customer requested an update to their data, the data was supplied as whole "tiles", which included every feature in the area covered by the tile, whether or not it had been updated. The change-only-update service changes all this. After the initial supply of OS MasterMap data, users may make online queries of the database, to determine any changes within their area of interest since a given date. They can then request an update to their data, and will be supplied with only those features which have changed. Since a large proportion of OS

MasterMap customers require regular updates to their initial data holding, this will greatly reduce the amount of data which passes between the OS MasterMap database and the user.

2.1.3 Standards

When developing the Digital National Framework, it was clear from consultation with our customers and partners that the data should be made available to users in a standard format. The Geography Markup Language (GML), developed by the Open GIS Consortium (OGC), was suggested as a possible data format. There was wide support for this from our partners and software vendors, since it is an open, non-proprietary language, designed to work in an Internet environment across multiple platforms and applications. It is also a language based on XML, acknowledged as the universal format for structured data on the Web (Quin, 2001). As such, the tools to manipulate the data are widely available. Since almost all the major GIS vendors are members of the OGC, there is also strong support from within the Geographic Information industry for GML.

3. ORDNANCE SURVEY HEIGHT PRODUCTS

3.1 Land-Form PANORAMA

The current (2002) height products available from Ordnance Survey are sold under the "LandForm" product name. These include digital contour products derived from 1:50 000 scale and 1:10 000 scale source maps; and ground surface Digital Terrain Models (DTMs) derived from these contours augmented by spot heights captured by both photogrammetric and field survey methods. The Land-Form PANORAMA product, derived from 1:50 000 scale maps, is used extensively for such diverse applications as telecommunications network planning, visual impact assessment, and drainage network modelling. As a DTM, the data is structured as a grid, with a point-spacing of 50m and a vertical accuracy of $\pm 5\text{m}$ (RMSE). Data for Land-Form PANORAMA was captured in the 1980's and has not been updated since – the product thus provides a snapshot in time of the general terrain structure of Great Britain.

3.2 Land-Form PROFILE

LandForm PROFILE is Ordnance Survey's detailed national height dataset. This product is based on contours digitised from the reprographic material used as the basis for 1:10 000 scale topographic maps. These contours were originally captured photogrammetrically, using analogue and analytical stereoplotters. The Land-Form PROFILE DTMs derived from these contours take the form of a grid, with a point-spacing of 10m and a vertical accuracy (RMSE) of between 1m and 1.8m (depending on the original source data).

Although the Land-Form PROFILE products have been used successfully in many application areas, they still retain some artefacts of their cartographic origins. For example, the contours on the maps were broken at embankments and cuttings, so these features are not included in the contour data. In the DTM creation process (based on a Delaunay triangulation of the contour and spot height data), the software automatically fills in the gaps between contours, but this can give a false picture of the terrain. This has become

more of an issue as computer systems have improved; software capabilities have increased, leading to a demand for higher quality, more accurate height data. This trend is set to continue for several reasons. The fears over the rise in sea levels due to global warming, augmented by the increase in flooding in Britain in recent years, have ensured that accurate flood forecasting and effective flood defence mechanisms are both high on the government's agenda. Also, the telecommunications industry is looking for more accurate signal-propagation models, to allow them to optimise the siting of their antennae for the next generation of mobile communications networks. Both of these markets would benefit from detailed height data, especially when linked with other data such as property information (allowing insurance companies to determine the financial risk of flooding) or land use data (allowing telecommunications companies to differentiate between agricultural land and forest, and to adjust their predictions accordingly). A height model linked into a national spatial infrastructure, as provided by OS MasterMap, would be of great benefit to users in these, and other, markets.

Over the past few years, new techniques and new sensors have revolutionized the way in which height data is captured. During this time Ordnance Survey has been involved in several research projects which investigated the collection and management of height data. Several of these projects are outlined below.

3.3 High Resolution Satellite Imagery

In 1996, Ordnance Survey led a BNSC-supported project to investigate the potential of high-resolution satellite imagery for the creation of digital surface models. This project, detailed in Ridley *et al.* 1997, involved the analysis of simulated 1m-satellite data, derived from aerial photography. At the time, it was concluded that 1m satellite imagery would not provide an effective means of updating a national high-resolution DTM. To test this conclusion on real satellite data, Ordnance Survey planned to create DTMs from stereo IKONOS imagery, as part of a recent OEEPE project (Topographic Mapping from High Resolution Space Sensors – OEEPE report not yet published). Unfortunately it proved impossible to acquire suitable stereo imagery during the lifetime of the project, so this aspect of the research was dropped.

If possible, Ordnance Survey would still like to evaluate stereo IKONOS and/or QuickBird imagery, to determine whether they could produce elevation models of the quality required and at a price comparable with conventional data sources.

3.4 Lidar Data

An investigation into the use of lidar (airborne laser scanning) data for the capture of heights of features such as buildings, vegetation and embankments was undertaken in 1997/1998. Data for an area of NE England was kindly provided to Ordnance Survey by the Environment Agency, who have been collecting lidar data for flood-modelling purposes since 1997. The results of this research indicated that lidar could provide a very high resolution digital surface model (DSM) which could be used as a product in its own right. However, when it came to integrating lidar with existing height data (i.e. with the Land-Form PROFILE

product), this proved to be more problematic. The very detailed lidar DSM includes all the surface features (buildings, vegetation, vehicles, etc) which must be filtered out to produce a ground-surface DTM compatible with Land-Form PROFILE. Algorithms to perform such filtering were in the early stages of development at the time, and a manual process proved to be very time-consuming and not particularly effective.

Lidar has now acquired a reputation as an effective way of collecting very-high resolution height information for a variety of applications (Flood, 2001, Plaster, 2001). Lidar has proved to be particularly effective in flood-plains and coastal areas where small differences in height are important in the planning of flood defences and in the determination of flood-risk; and where conventional techniques are often unsatisfactory.

3.4.1 Synthetic Aperture Radar (SAR)

Interferometric Synthetic Aperture Radar (inSAR) has been proposed as a tool for topographic mapping since the mid 1980's (Zebker & Goldstein, 1986). Both satellite and airborne SAR systems have been used for the rapid capture of DSMs over large areas. Recently, improvements in technology (such as the incorporation of integrated GPS and Inertial Measurement Units to determine the exact position and orientation of the sensor) have led to an increase in commercial airborne inSAR systems.

At the Ordnance Survey, height data produced using SAR Interferometry has been investigated as a possible replacement for the DTMs created from contours. University College London (UCL) carried out an evaluation of "Tandem" SAR data (from the European ERS-1 and ERS-2 satellites) as part of the aforementioned BNSC project (Ridley *et al* 1997). This research showed that the ERS tandem data could be used to produce DEMs with a height accuracy of between 5.7m and 20m RMSE. Elevation models of this accuracy are valuable, but they do not meet the required specification for a national height dataset in countries, such as Great Britain, which are relatively rich in geospatial information.

The potential of airborne SAR systems has also been investigated. In a joint project with QinetiQ, Ordnance Survey recently used SAR data for an area around Portsmouth in Hampshire. The SAR DEM was merged with Land-Form PROFILE data in an attempt to fill in the gaps between embankments and cuttings and within a disused quarry. Preliminary results from this research suggest that DEMs from airborne inSAR may be sufficient to update Land-Form PROFILE in rural areas, but they are not suitable for producing height models in urban areas. This technical research project did not investigate the cost-effectiveness of inSAR data, but this would obviously be a major factor in determining the potential of inSAR as a viable replacement for traditional photogrammetric height data capture.

3.5 Digital Photogrammetry

The conversion of Ordnance Survey's photogrammetric operations, from hybrid "analytical" systems to fully-digital workstations, took place in 2000. Stereo photography is now routinely scanned, passed through a digital aerial triangulation process, and analysed on digital

photogrammetric workstations. The main purpose of these workstations is to update the topographic data for OS MasterMap, but they are also used to update the data used to produce Land-Form PROFILE. At the present time, the maintenance of Land-Form PROFILE occurs mainly in areas of major road development, and sites where old quarries and gravel pits have been re-landscaped. Methods of automatic DTM creation have been investigated and are beginning to be used within the production environment. As the software steadily improves, the process of updating Land-Form PROFILE data should become easier and more effective.

4. HEIGHT DATA WITHIN OS MASTERMAP

The initial development phase of OS MasterMap has concentrated on upgrading the 2D topographic data. However, it has always been envisaged that height will play a significant part of future development, and subsequent product releases. Work is underway to determine how best to capture height data in future, and how to integrate the height information with the other layers in OS MasterMap. Several of the technologies described above may be utilised in the development of the height layer, and it is quite possible that different technologies may be used for different areas of the country. For example, lidar is an excellent data capture tool in low-lying coastal areas, but there is little demand for lidar's level of accuracy in mountains or moorland, so it is not cost effective in such areas.

5. CONCLUSIONS

This paper has shown how Ordnance Survey has developed a new national spatial data framework and its associated products and services. OS MasterMap is designed to underpin the spatial data infrastructure of Great Britain. It will be continuously updated and improved, as new types of data and new services are introduced. Height data will play a role in this development, forming a layer within the OS MasterMap structure. Various different techniques for the capture of this data have been investigated, and it is expected that a hybrid solution will be adopted, to collect data which may be used in many varied applications and is fit-for-purpose in all the different terrain-types within Great Britain.

6. REFERENCES

- Flood, M, 2001, Laser Altimetry: From Science to Commercial Lidar Mapping, *Photogrammetric Engineering & Remote Sensing*, **67**, no. 11, 1209-1217.
- Plaster, R.L., 2001, Lidar: Transitioning Technologies from Lab to Applications Around the Globe, *Photogrammetric Engineering & Remote Sensing*, **67**, no. 11, 1219-1223
- Quin, L. World Wide Web Consortium, 2001. The eXtensible Markup Language, <http://www.w3.org/XML> (accessed April 2002)
- Ridley, H.M., Atkinson, P.M., Aplin, P., Muller, J-P. and Dowman, I., 1997, Evaluating the potential of the forthcoming commercial U.S. high-resolution satellite sensor imagery at the Ordnance Survey, *Photogrammetric Engineering and Remote Sensing*, **63**, 997-1005.
- Zebker, H., and R. Goldstein, 1986, Topographic mapping from interferometric synthetic aperture radar observations, *J. Geophys. Res.*, **91**, 4993-5001.