

DIGITAL PHOTOGRAMMETRY, DEVELOPMENTS AT ORDNANCE SURVEY

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ABSTRACT

Ordnance Survey has always used photogrammetric methods to update large scale mapping in the role of Britain's National Mapping Agency. The photogrammetry department revises 11,000 square km of digital map data annually, facilitating the update of mapping products at scales ranging from 1:1250 to 1:10 000.

Digital photogrammetric methods have been used since 1995 in the form of monoplotters workstations, supplied with orthoimages by two orthorectification workstations. The complement of digital photogrammetric was increased in 1998 by the acquisition of two ZI Imaging Imagestations, used for automatic aerial triangulation. In order to facilitate the introduction of a new data specification into the production flowline, up to 30 digital digital stereo capture workstations will be phased in over the next 5 years. This will entail a major change in the production system and the work methods within the photogrammetric survey section. These systems will be described in this paper.

The Research Unit continues to investigate new data sources and methods of data capture, including laser scanning, image mosaicing, Applanix differential GPS and inertial camera exposure position fixing system, and satellite communication systems from HQ to the field offices.

This paper will also discuss the results from these and related research projects currently being undertaken at Ordnance Survey.

1 INTRODUCTION

1.1 History

Ordnance Survey, from its beginnings in 1791, has been Great Britain's national mapping agency. It is widely regarded as the world leader in its field, which covers the production, maintenance and marketing of a wide range of maps, computer data and other geographical information for business, leisure, educational and administrative use.

From military beginnings, Ordnance Survey has been a wholly civilian organization since 1983. It is a free-standing UK Government Department, an Executive Agency and, on 1 April 1999, became a Trading Fund, allowing it more commercial freedom than would otherwise be possible for a public-sector organization.

1.2 Now at Ordnance Survey

Photogrammetric methods of map data capture and update for map scales of 1:1 250 to 10 000, have been employed throughout the organisations history. Analogue stereoplotters were first used followed by analytical stereo capture instruments and more recently digital photogrammetric methods.

There are two broad reasons why digital photogrammetric methods are seen as the way forward:

- Developments in digital photogrammetric systems and the wider availability of digital imagery have provided Ordnance Survey with clear opportunities for increased efficiencies and wider applications of photogrammetric methods.
- During the last 3 years Ordnance Survey has been re-engineering its the large scale mapping database for 1:1 250, 1:2 500 and 1:10 000 scale mapping. Data that was originally simple digital cartographic linework has now been re-structured to form polygons based on features. This has increased pressure to change data editing facilities in the data collection department to meet this demand.

The new data specification will fundamentally change the data capture and update software that is used. During 1999 Ordnance Survey chose Laser-Scan LAMPS2 as the corporate editor and Object Store as the underlying database for

data storage. This core data set forms the National Topographic Database (NTD) (Ordnance Survey, 1999. Holland 2000)

There will be a continuing need for a continuous revision programme, with photogrammetry being used as an increasingly prominent data capture tool; since it has been found that photogrammetric methods are currently more efficient than ground based methods. Exploitation of the increasing power and automation offered by digital systems will increase the time and cost efficiency of data collection systems. Ordnance Survey will be able to meet the demands of an increasingly competitive market place, and enable business growth.

The following sections will outline the current revision and research use of digital photogrammetry in the Ordnance Survey. A vision of future practice and use of digital photogrammetry within Ordnance Survey is discussed at the end of this paper.

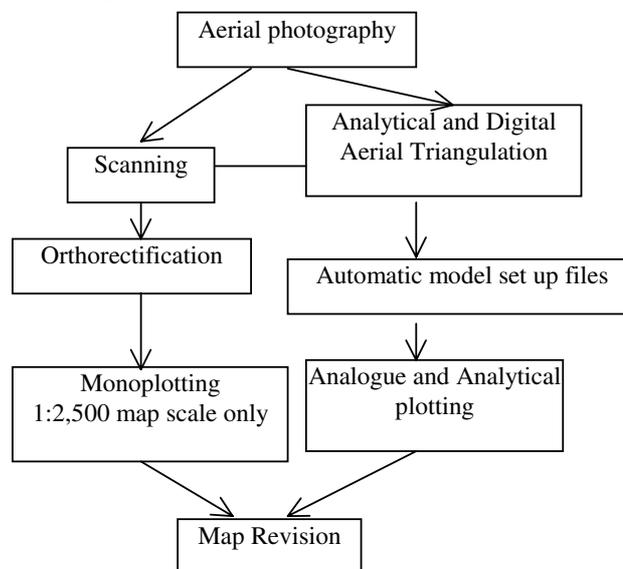
2 DATA CAPTURE AND REVISION

Map revision completed in the photogrammetric department at Ordnance Survey constitutes only one third of the total revision completed every year, the remaining two thirds is completed by contractors. At Ordnance Survey this year a total of 34,500 km² of rural 1:2,500 scale mapping and 3 500 km² of 1:10 000 mapping will be revised. The total cyclical revision process covers a total of 268 250km² and is completed every 5 years for the 1:2 500 mapping and every 10 years for the 1:10 000. The map revision workflow, outlined in Figure 1, is carried out currently using one of three methods: monoplotting (3.3), stereo analytical or stereo analogue. Table 1 outlines the photogrammetric capability of Ordnance Survey.

Table 1. Current Ordnance Survey Equipment

| Purpose | Equipment | Quantity |
|----------------------------|-----------------------|----------|
| Aerial Photography | Zeiss RMKA 30/23 | 2 |
| | Leica RC20 | 1 |
| Aerial Triangulation | Kern DRS1 | 1 |
| | Z/I ImageStation Z1 | 1 |
| | Z/I ImageStation Z4 | 1 |
| Scanning | Z/I PhotoScan TD | 2 |
| Orthorectification | Z/I ImageStation 6800 | 2 |
| Stereo Data Capture / Edit | Kern DSR15 | 2 |
| | Kern DSR11 | 1 |
| | Leica SD2000 | 3 |
| | Wild A8 | 2 |
| Monoplotting | Wild A10 | 3 |
| | Workstation | 18 |

Figure 1. Current Revision Workflow



3 DIGITAL PHOTOGRAMMETRY

Digital photogrammetric techniques will allow Ordnance Survey to exploit the increasing need for flexibility and the developments in automated processes. Virtually all future development in the photogrammetric department will be implemented in the digital environment. A number of automated processes have, or will, be introduced:

- photogrammetric scanning;
- digital aerial triangulation and automated model orientation;
- monoscopic data capture;
- digital stereo data capture
- automated DTM creation;

These developments will have a major impact in increasing the efficiency of photogrammetric methods for data provision. Estimated or realised savings will be stated where applicable. Underlying this change staff training is essential to the success in the digital evolution.

3.1 Photogrammetric scanning

At the moment two Z/I Photoscan TD scanners complete all image scanning required in the photogrammetry department. Roll fed batch scanning with automatic image pyramid and compression functions is utilised with the advantage that . No use is made of the auto-dodging or automatic inner orientation during scanning. These functions are under investigation and may be used in the future.

Scanning for aerial triangulation is at 21 μ m, while scanning for orthorectification is at 28 μ m allowing 6 – 8 scans to be completed in an hour using batch roll fed scanning.

3.2 Digital Aerial Triangulation

During the past 17years a Kern DSR1 has been used to observe aerial triangulation photograph blocks, with PATB-RS used as the computation package. The orientation and control points derived were used to automatically set up analytical plotters for update and capture. This technology has been superseded and will be phased out in the next couple of years.

An automatic aerial triangulation system, based on Z/I ImageStation Z1, was successfully introduced in 1998, followed by a Z/I ImageStation Z4 in 1999.

Automatic stereo model setup files, through a script, are released to all analytical plotters for the map update process. The advantages of the digital system include the elimination of the need for PUGed photography. This time consuming task has now been eliminated thus increasing productivity. Productivity in flat and undulating terrain doubled or trebled due to the automatic image matching process. In mountainous areas however productivity has not increased significantly due to difficulties in image matching in regions of dramatic height difference during triangulation.

3.3 Monoscopic data capture

The digital monoplottting system was the first digital photogrammetric system used at Ordnance Survey and was introduced in 1995. This workflow is used for 1:2 500 map revision only, and uses 1:6 500 scale photography. The flying scheme ensures that every second photograph is centred on the 1km by 1km map tile that it will update.

3.3.1 Orthorectification

Orthorectified images are produced using Z/I ImageStation 6800 orthorectification software. The system has been customised to use 1:2 500 map scale control for every image (XY only), with the height control being derived from Ordnance Survey's national cover DEM (Land-Form PROFILE). The stages in the orthorectification system are

- Calculation of the external orientation for each image. This is achieved by directly measuring map detail control and height from Ordnance Survey's national cover DEM (Land-Form PROFILE). Resection calculates the camera exposure position. Each image undergoes this process independently.
- Orthorectification is then performed using Ordnance Survey's national cover DEM (Land-Form PROFILE). No DEM is created automatically using automatic image matching as part of this process.

This current flowline has led to poor geometric join on neighbouring orthoimages due to the independent nature of the exterior orientation calculation. This is currently being improved with the use of automatic aerial triangulation to derive

the exterior orientation for each image. The aerial triangulation adjustment carried out will mean that a block of images will act as a homogeneous mosaic and the geometric join should be precise (4.1.1).

3.3.2 Monoplotting map revision

Digital map tiles that undergo revision and update are overlaid on the orthoimages using Laser-Scan software. Twenty workstations update around 10 000 km² of 1:2 500 mapping annually. This method of update is highly efficient and the advantages include the ease of digital images manipulation to optimise capture and interpretability. Stereoscopic training and appreciation is not required leading to a simple system although the use of a simple Leica zoom stereoscope is encouraged to aid interpretation when required.

There are however a number of disadvantages of this system. The orthorectification process does not account for building height, so overthrow remains in the orthoimage and can be restrictive to image interpretation. Photograph interpretation is more difficult with a single image compared to a stereo model.

3.4 Digital stereo data capture

In 1999 Ordnance Survey awarded a tender for 30 Leica Helava Systems digital photogrammetric workstations over the next 5 years to be implemented for stereo data capture commencing in mid - 2000. These digital photogrammetric workstations will replace existing analytical and analogue equipment (Table 1) on a rolling implementation starting with the analogue plotters. The stereo capture environment is fully integrated with Laser-Scan LAMPS2 data capture environment which will be customised to capture data under the Ordnance Survey data specification. In order to ensure success training will play a major part in the implementation plan for these systems.

4 RESEARCH

Research undertaken by the Ordnance Survey investigates new data sources and methods of data capture, building on the current data capture systems to increase efficiency and reduce costs.

Collaborative research projects are underway through academia and industry, and proposals are always welcomed from all areas of the geographic information industry.

Three projects related to data capture and imagery are discussed below, followed by a list of other research areas that are of interest to Ordnance Survey.

4.1 APPLANIX Trial – Integrated GPS and Inertial System for direct Exterior Orientation of aerial photographs

Shortcomings in the current photogrammetric control acquisition have led to the investigation of new technology and methodology. These are :-

- In 1:10 000 map scale areas of Scotland control is acquired using control points from previous aerial triangulation schemes ('Masterblock'). Due to the changing landscape it is now becoming difficult to identify the same points in current photography.
- For positional accuracy evaluation of 1:2 500 base mapping there is now a requirement for orthoimages to an accuracy of 0.65 RMSE in X,Y,Z. These need to be established from more rigorous methods than the current monoplotting orthorectification flowline (3.3.1).

All these problems can be overcome by direct exterior orientations generated at the camera. This is possible using Integrated GPS/Inertial systems where the requirement for ground control can, in theory, be reduced to zero. In practice ground control is required as a quality check. The advantages of this type of system are very attractive and could potentially dramatically reduce production costs.

In November 1999 a trial was run from Cambridge Airport using the Applanix GPS/INS system on the Ordnance Survey's Leica Helava Systems RC20 large format aerial camera. Aerial imagery was captured for three east-west strips (9 exposures per strip) over Cambridge at a flying height of 5000' giving a photo scale of 1:5 000. Each strip had a lateral overlap of 30% and a 60% forward overlap.

The recently installed national GPS network was used as the differential GPS ground stations. During the trial these stations recorded data at a rate of 1/2 second epochs. Additionally 1 second epoch rate data was also recorded during the trial from outlying Active Network Stations (ANS) to get a check on systematic errors induced by varying baseline lengths.

The results from this project are still being analysed and the results will be available at a later date.

The Ordnance Survey is now asking for tender bids in order to purchase a system with this functionality during 2000.

4.1.1 Photogrammetric Rapid Accuracy Test

This project examined the specific needs of a system to carry out a 'Photogrammetric rapid accuracy test', i.e. to measure the spatial accuracy of Ordnance Survey large scale digital data in rural areas against an accurate orthorectified imagery backdrop.

The objectives were to:

- create an orthorectified image using GPS control, digital photogrammetric workstation aerial triangulation and a DEM created automatically using image matching on the digital photogrammetric workstation ;
- check the accuracy of the orthorectified image on the testing tool created in the Research Unit; and
- investigate significant errors identified using the testing tool, in stereo on the digital photogrammetric workstation.

The project trialed the creation of a block of 83 orthorectified images to measure from these the image position of randomly selected points of map detail.

The differences between map and image positions were analysed and used to assess the overall accuracy of the method. The results showed that the method could produce orthoimages to the required accuracy and that edge matching of adjacent images was a considerable improvement over existing orthoimages production methods (3.3.1). Since all image exterior orientation is done as part of a block adjustment, all images are in sympathy with each other. This has led to the development of an improved flowline in the photogrammetric department (5).

4.1.2 Satellite communication systems from HQ to the field offices

A trial to develop a pilot two-way satellite communication network for communication of all electronic files between Ordnance Survey land survey offices around the UK and headquarters in Southampton. Analysis of metrics gathered throughout the pilot project will be used to evaluate the business benefit of using satellite communications for the communication of data files to, and from, these land survey offices.

Currently digital map data is delivered to Ordnance Survey agents and other customers of Ordnance Survey via ISDN lines, CD or equivalent postal media. Satellite communications will also be analysed as an alternative data delivery system. This project is on-going and the final results are not available.

4.1.3 Laserscanning

Data from an airborne laser scanning (lidar) system was evaluated to determine whether this technology could be used to update existing elevation models (specifically the Ordnance Survey Land-Form PROFILE product) and/or to add height attributes to features such as buildings and vegetation. The Environment Agency for England and Wales provided lidar data for an area of Humberside, UK, as a gridded DEM with a 2m grid-spacing. The primary use for this data is for flood-defence planning in England and Wales, so the specification is geared towards this application. Based on a small sample of ground-surveyed GPS points, the lidar data was found to be accurate to 13cm RMSE, which is well within the 10-20cm published accuracy range.

Using lidar data to update our existing height model proved to be uneconomical, mainly due to the amount of manual work required to bring the datasets into sympathy with each other. The Land-Form PROFILE data is a general-purpose, somewhat generalized land-surface digital terrain model, while the lidar data is a high-resolution, ungeneralized digital surface model (which includes heights of all features present in the landscape). Smoothing the lidar data to fit the DTM is one possible solution, but to do this removes the main advantage of the lidar data (i.e. its high spatial resolution). As far as heighting buildings is concerned, the lidar proved to be reasonably effective. Building polygons, derived from large-scale Ordnance Survey data, were combined with the lidar data to derive a height attribute for each building. Further processing converted the height above sea level to an estimate of height above ground level for each building. The resulting data produced a reasonable approximation of a 3D city model, which could be greatly improved if a denser network of lidar points was available. In residential areas, the 2m grid spacing allowed only one height per building to be captured reliably. In industrial areas, further aspects of the larger buildings could be captured, such as the orientation of the roof ridge-lines or a more detailed model of the shape of the roof. As the capabilities and availability of lidar data have continued to improve since this research was undertaken, it is now possible to derive more complex 3D city models using lidar, especially when it is integrated with large-scale 2D polygon data.

4.1.4 Other Research

The following list outlines other projects that are currently of interest to Ordnance Survey. Additional information is available on request or the following

- Digital aerial cameras. Ordnance Survey are hoping to test the latest camera technology when released.
- High resolution satellite imagery for map update. Ordnance Survey are currently leading the OEEPE project Topographic Mapping from High Resolution Sensors.

- Change Detection in Rural Areas using Synthetic Aperture Radar (SAR)

5 THE FUTURE

Recent research, together with the dramatic changes towards object-oriented data and digital photogrammetry, have highlighted the need for change in the photogrammetry department. These changes will bring about improvements in the production systems for imagery and digital map update which will increase efficiency and reduce the costs to Ordnance Survey.

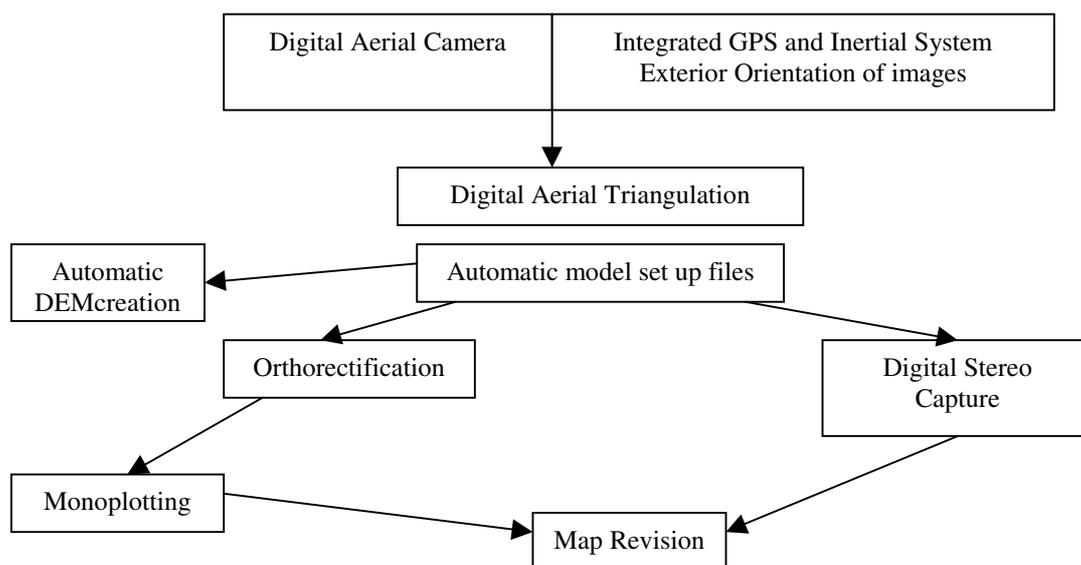
The increased efficiency and reduced cost that these developments offer will be used within Ordnance Survey. The following changes have led to the author's future vision of digital photogrammetry at Ordnance Survey

- Automatic aerial triangulation.
- Orthorectification using aerial triangulation exterior orientation parameters for each image.
- Digital stereo workstations.
- Digital Cameras.
- Integrated GPS and Inertial System Exterior Orientation of images. All imagery will be controlled this way rather than using map control.

Automatic feature extraction and change detection processes are still restricted to the research community and will only be taken up in production work when the technology is mature.

The volume and detail of mapping that Ordnance Survey hold and update is complete, current and detailed. The Research Unit will continue to investigate new technology to enhance the geospatial data that will form the Digital National Framework for Great Britain. In terms of data capture and update digital photogrammetry is the future of photogrammetry at Ordnance Survey.

Figure 2 Future Ordnance Survey Photogrammetric Workflow



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