USING HIGH-RESOLUTION SATELLITE IMAGERY IN A WELL-MAPPED COUNTRY

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ABSTRACT:

The use of imagery from high-resolution sensors on satellites such as IKONOS and QuickBird has proved that data from space-borne sensors can provide a viable alternative to aerial photography in many applications. This is especially the case in remote areas which have been poorly-mapped in the past. The benefits of satellite imagery include the rapid acquisition of data covering large areas; the frequent re-visit times of the satellites over almost any part of the globe, regardless of its remoteness; and the ability to collect data unhindered by local air traffic constraints. In areas of the world which have traditionally been well mapped, such as Western Europe, the benefits of satellite sensors may not be as clear. In this study, we look at the possibility of using high resolution satellite imagery in such a country; and assess the usefulness of such data in various applications within a national mapping agency.
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1. INTRODUCTION

High resolution imagery from satellites such as IKONOS and QuickBird has been available for several years, and has proved its usefulness in the mapping and surveillance of remote areas and developing countries (see, for example, Kumar and Castro, 2001). In countries where there is little experience in mapping and aerial photography, and an absence of the infrastructure required to collect and process such data, satellite imagery can provide a rapid, high-quality data source for the production of image maps and vector-maps of various levels of complexity. Several studies have examined the potential of satellite imagery for updating maps and spatial information in traditionally well-mapped areas such as Western Europe (Ridley *et al*, 1997). Here the economics of the data capture process are often quite different from those in the developing world. In these areas, high quality map data already exists, aerial photography is generally available, and the infrastructure to process this photography is well established. The question arises: can satellite imagery provide a viable alternative to aerial photography in these areas?

A recently-published OEEPE report (Holland *et al,* 2003) describes research into the use of IKONOS data for mapping, undertaken by several European mapping agencies and institutions. The results indicate that there is potential in this field, especially in rural areas at scales between 1:10 000 and 1:50 000. At Ordnance Survey, Great Britain's National Mapping Agency, more recent research has investigated the potential of QuickBird imagery for updating mid scale (1:25 000 and 1:50 000) and large scale (1:10 000, 1:2500 and 1:1250 in Great Britain) mapping. This paper presents some of the findings of this research.

2. CAPTURING TOPOGRAPHIC VECTOR DATA FROM THE IMAGERY - METHODOLOGY

2.1 Preparation of the imagery

QuickBird multispectral and panchromatic images were acquired for an area around the town of Christchurch in Southern England. Figure 1 shows this study area, which contained several different types of terrain, including an urban area, agricultural land, unimproved heath and woodland. The data consisted of basic QuickBird images, at a nominal Ground Sample Distance of 64cm for the panchromatic and 2.4m for the multispectral imagery. In addition to the images, the QuickBird Sensor model and associated metadata were also provided.

Ten ground control points, spread across the study area, were collected using GPS. To assess the geometric accuracy of the orthorectified images, a set of test points was also collected, using both GPS and existing topographic vector data. The digital terrain model (DTM) used in the orthorectification process was the OS Land-Form PROFILE® product, which has a 10m grid spacing and a height accuracy of 2.5m (RMSE).

Figure 1: The study area, showing the town of Christchurch to the south, the agricultural area of the Avon Valley in the centre, and the heath of the New Forest in the north-east. © DigitalGlobe 2001, distributed by Eurimage.

FEATURES	NOTES	SCALE				
		1:1250	1:2500	1:10,000	1:25,000	1:50,000
Housing & associated features	All housing easy to identify. Capture of housing satisfactory if of uniform shape. Complex shapes with juts and recesses not possible to accurately depict	N	N	M	Y	Y
Other buildings	All uniform large buildings easy to detect, particularly industrial units. Complex, multilevel and roof structures difficult to clearly identify.	N	N	Y	Y	Y
Communication networks – roads	Kerbs and traffic calming features not clearly defined. Most white lines possible to identify. General road alignments very clear	N	Y	Y	Y	Y
Dual carriageways	Barriers not clear. General alignment very clear. Slopes (and any other height data) impossible to identify in a monoscopic image.	Y	Y	Y	Y	Y
Airports	Edge of metalling clear. Major buildings okay. Small walkways and fine detail around buildings difficult to define	N	N	Y	Y	Y
Railways	Railway furniture not visible (signal posts, points etc). Single lines not visible. General alignment okay (centre of track). Major station detail clearly visible.	N	N	Y	Y	Y
Electricity transmission lines	Impossible to define actual lines. Transmission pylons possible to see in some instances. Single poles very difficult to see.	N	N	N	N	N
Major sea defences to reduce flooding	All features clear to see. Groynes and promenades very clear.	Y	Y	Y	Y	Y
Non-coastal sea defences	Weirs and dams stand out clearly. Finer detail not clear to see.	Y	Y	Y	Y	Y
Major property boundaries	Large fences easy to see. Small fences very difficult to identify.	N	N	N	N	Y
Major landscape changes	Very clear. Associated fences not so clearly defined	Y	Y	Y	Y	Y
Quarries & other surface workings	Clear to see, but quarry permanent detail (e.g. conveyor belts), difficult to fully identify.	M	M	Y	Y	Y
Field boundaries	Clear to see, but difficult to classify.	M	M	M	M	Y
Water features	Clear to see. Small streams sometimes difficult.	M	M	Y	Y	Y
All vegetation	Vegetation is clearly defined if using pan-sharpened imagery.	Y	Y	Y	Y	Y
Tracks & paths	Tracks clear to see. Unmade paths difficult to make out. Made paths in urban areas can be difficult to define.	M	M	M	M	M
Telephone boxes	Difficult to define.	N	N	N	N	N
Extensions to commercial buildings	Major shape possible to define. Small juts and recesses not so easy	M	M	Y	Y	Y
Minor property boundaries	Possible to see, but difficult to classify.	M	M	M	M	Y
Tide lines	Edge of water-line easy to see, but doubtful if imagery can be captured to coincide with high tide times.	N	N	N	N	N
Garages built after initial development	Clearly defined.	Y	Y	Y	Y	Y

Table 1: Analysis of the types of features which can be captured from QuickBird imagery, at various national mapping scales. Key: Y = Yes - feature can be captured; N = No - feature cannot be successfully captured; M = maybe - in some circumstances the feature can be captured, in others, not. Note that, for the 1:1250 and 1:2500 scales, even when features can clearly be identified, the geometric accuracy is not sufficient to meet the mapping specification (see section 2.2).

2.2 Orthorectification

Several different orthorectification processes were available to us, but the one chosen for this study was PCI Geomatica OrthoEngine, which uses the parametric sensor model of Thierry Toutin (see Cheng *et al.* 2003). The images, DTM and GPS points were processed in PCI Geomatica, to produce an orthorectified image with a geometric accuracy, relative to vector map detail, of 2.2m (RMSE). The national mapping accuracy statements in Great Britain indicate RMSEs of 1.1m for 1:2500 scale data and 3.4m for 1:10 000 scale data. It can be seen that the geometric accuracy of the QuickBird image in this study lies between these two values. This indicates that, purely from a geometric accuracy point of view, QuickBird imagery may be appropriate for a mapping scale of around 1: 6000. It should be noted that this study was carried out in a reasonably flat coastal region. Further tests would be needed to determine the level of geometric accuracy in hilly and mountainous areas.

2.3 Topographic data capture

The orthorectified imagery was then analysed by a small team of surveyors and cartographers, familiar with the capture of spatial information from imagery in a production environment. Both positional accuracy and feature attribute accuracy were analysed and compared with results obtained from aerial photography. Six sub-areas of the image were analysed, to ensure that the following different types of topography were investigated:

- Urban – coastal and floodplain
- Urban – inland
- Semi-urban - airport
- Rural – agricultural
- Rural – moorland

In each of these areas, the cartographers attempted to capture all the features present in the specifications of the various mapping scales used in Great Britain. These are 1:1250 (urban), 1:2500 (rural) and 1:10 000 (mountain and moorland). The features collected in this study included roads, railways, tracks and paths, buildings, vegetation limits, water features and field boundaries. In addition to the large scale specifications, the images were assessed against the specifications of the derived scales of 1:25 000 and 1:50 000. Note that the large scale data is mainly used by the professional sector (including national and local government, utility companies and emergency services) while the smaller scale data is mainly used to create paper products to serve the consumer sector (especially the outdoor leisure market). Hence the requirements of these two sets of products are quite distinct.

2.4 Results of the topographic data capture

The main findings of this study are described in Table 1, which indicates those features that can successfully be captured at each scale of mapping. Table 1 also gives a brief description of the result for each type of feature.

Table 1 shows that many of the feature types that are required for 1:10 000 – 1:50 000 scale mapping could be satisfactorily identified and captured. In some cases, features required for larger scale mapping (e.g. roads and woodland boundaries at 1:2500 scale) could also be captured. The major exceptions to this are narrow linear features (such as electricity transmission lines, walls, fences and hedges), which are generally impossible to distinguish in imagery of this resolution. A combination of panchromatic and multispectral imagery can help to differentiate between hedges and walls, but in general the imagery is unsuitable for the capture of these features.

When taken together, the results for the feature capture and the geometric accuracy indicate that QuickBird imagery shows potential as a data source for 1:10 000 scale mapping at the current specification, and could be used to derive topographic data up to scales as large as 1:6 000. The main drawback of the imagery is the inability to resolve small linear features, which, if required, would have to be captured in other ways.

3. OTHER USES OF QUICKBIRD IMAGERY

Although the main focus of this study was the study of topographic data capture, the imagery was also assessed for other uses within a mapping agency. It was reasoned that, if a single data source, such as QuickBird imagery, can be used for several different purposes, it becomes a much more cost-effective option. This section describes the potential uses of QuickBird within Ordnance Survey. It must be stressed that this was a feasibility study only, and that the processes described do not currently use satellite imagery.

3.1 Change intelligence for topographic information

One of the challenges to a mapping agency is to identify any changes to the landscape and add these changes to the topographic database as soon as possible after they occur. There are several ways in which change is detected, including local observation by field surveyors; provision of planning information by local planning authorities or commercial change detection agencies; and the supply of new development plans by architects and house building consortia. The use of imagery could complement these, by allowing surveyors to find areas of change which would not be detected using the other methods. For example, in areas of continual change, such as central London, satellite imagery could provide regular snapshots of the area, enabling surveyors to constantly monitor and capture topographic change.

In rural areas, the change intelligence requirements are often different. Buildings may be constructed without planning permission; fields may be split into two, or combined into one; hedges and woodlands may be removed, or newly planted. These will often be in remote areas; and therefore do not come to the attention of local surveyors or any of the change intelligence bodies mentioned above. In these areas, imagery can prove a valuable tool for change intelligence; especially if this use can be combined with a role as a source of data for the subsequent capture of the topographic change.

3.2 Quality auditing

The role of the Quality Auditing team with Ordnance Survey is to ensure that both in-house and contracted surveyors apply a consistent interpretation of the data specification to

the capture of topographic information. One of the mechanisms used by the team is a batch sampling process which monitors the currency, accuracy and completeness of the data in a sample of 600 "tiles" every 3 months. (Note each tile represents the basic unit of data capture – covering an area of 0.25 square km in urban areas, 1 square km in rural areas and 25 square km in mountain and moorland regions). These areas are visited by surveyors and any significant changes which do not appear in the topographic database are recorded. The results from these surveys are used to quantify the Agency Performance Monitor set by Government, which states that 99.6% of significant real-world features must be represented in the database within 6 months of their completion.
At present imagery does not play a role in the quality audit process. There is a potential role here for QuickBird imagery, since any significant changes will be visible in the imagery, enabling the audit to take place without a costly field visit. The drawback of such imagery in this case is the random sampling scheme used to select the tiles – to make satellite imagery cost effective, the sampling would have to be taken in larger areas, over fewer samples.

3.3 Images as images

All the previously mentioned applications of satellite imagery involve its use as a raw material for the capture of associated information. Of course, the image itself is a valuable spatial information product in its own right, which could form part of the portfolio of products offered by a mapping agency. This is especially so in the case of orthorectified imagery, which may be combined with extra topographic and cartographic information, such as place names and road classifications, to produce an image map. The demand for aerial photography is growing, and it is possible that panchromatic or "pan-sharpened" satellite imagery could be used to satisfy some of this demand, especially in areas where it is uneconomical to fly conventional aerial photography.

3.4 Further uses

Other uses to which QuickBird imagery may be put, not mentioned in any detail in this paper, include the population of land cover databases (which may in turn act as a starting point for the capture of land use information); and the capture of features not currently within the mapping specification (such as traffic lane markings on roads; individual trees and other vegetation).

3.5 QuickBird imagery vs. aerial photography

Most of the potential uses of QuickBird imagery could equally well apply to aerial photography. In order to prove a viable source of data, satellite imagery must compete aggressively against photography, especially in countries which already have an infrastructure in place to collect, process and disseminate such photography. QuickBird imagery (and, to some extent, other high resolution satellite imagery) presents the following advantages over aerial photography:

- The satellite is operational 365 days of the year,
- No extra expense is incurred in attempting more than one capture,
- The satellite orbit enables frequent re-visit times (every 4 days),
- Imagery is post-processed relatively quickly,
- No Air Traffic Control restrictions apply,
- The image has a large area footprint (16.5 x 16.5 km sq), cutting down the need for block adjustment and the creation of image mosaics,
- The satellite can easily access remote or restricted areas,
- No aircraft, cameras or other expensive equipment are required.

There are, however, some drawbacks:

- There is a strong possibility of cloud cover – in temperate regions, completely cloud-free images will be rare,
- The typical off-nadir viewing angle of up to 25˚ is not acceptable in a dense urban area – or where the DTM is not perfect,
- The production processes required for high resolution satellite imagery may be different to those of traditional photogrammetric data capture – extra equipment, different production flowlines and more training may be required,
- The reliability of capture and delivery of imagery is an unknown quantity,
- The image resolution is low when compared to large scale aerial photography.

This last disadvantage is perhaps the most difficult to overcome. Users of aerial photography are accustomed to very high resolution images (with typical ground sample distances of 15-25cm), which satellite imagery cannot match at present. Whether the advantages of satellite imagery are sufficient to outweigh this drawback in a country well-supplied with aerial photography is yet to be proven.

4. CONCLUSIONS

This study has shown that QuickBird imagery shows potential as a source of data within a national mapping agency. We have demonstrated that imagery of this type can be used for several different purposes, and it is this multiple use which makes the imagery a viable tool in this context. When judged against aerial photography, the obvious drawback of satellite imagery is its relatively low resolution (64cm, compared with typical air photo resolutions of 15-25cm). However, this weakness may be offset by the advantages of frequent re-visit opportunities, rapid post-processing, large area coverage and freedom of access to remote and restricted areas.
In order to convince a large organization to change its working practices, further studies would be needed to determine whether the benefits of satellite imagery would stand up to a fully-costed business case. The work reported in this paper paves the way for such a study and indicates that an in-depth analysis of the potential use of high resolution satellite imagery by a mapping agency, even in a well-mapped country, is a worthwhile endeavour.

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