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

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ABSTRACT:
Since the successful launch of IKONOS in 1999, a new source of imagery has been available to the civilian spatial-data user. In many parts of the world high resolution satellite imagery from IKONOS, QuickBird and, more recently, ORBVIEW 3, has proved to be a useful data source for the creation of orthorectified images and associated mapping products. One of the great advantages of satellite imagery is the ease of access to areas which have previously been too remote or too dangerous to reach using conventional aerial photography. However, for areas of the Earth which are not difficult to reach, and which have a tradition of high resolution mapping from aerial photography, this advantage is of rather limited importance. Ordnance Survey, Great Britain's national mapping agency, currently makes extensive use of aerial imagery in the collection of large scale geospatial data. In 2003, a project was initiated which would determine whether satellite imagery could replace, or complement, aerial photography in this data collection process; or could be used in other ways within a production environment to make the process more efficient. Interim results of this research are presented in this paper.

1. INTRODUCTION

High resolution images from satellites such as IKONOS and QuickBird have proved their usefulness over the past few years, especially in the mapping and surveillance of otherwise inaccessible areas, for example in areas of military conflict, such as Afghanistan and Iraq (see, for example, Kumar and Castro, 2001, Petrie 2003). Such images have also been used to update maps, or generate completely new mapping, in many areas of the world, including Saudi Arabia, Indonesia (Mandeville, 2001) and Alaska. In most cases up until now these applications have been in parts of the world that do not have a tradition of detailed mapping. In these areas, which often do not possess the resources required to collect and process aerial photography, high resolution satellite imagery can provide a rapid, high-quality data source for the production of image maps, thematic maps and vector-maps, to satisfy a variety of needs.

In traditionally well-mapped areas of the world, such as Western Europe, the position is different. In these areas, detailed databases of geospatial information have been built up over many years, using both field survey and photogrammetric techniques. In addition, the infrastructure required to capture and process aerial photography is already well established. In a country such as Britain, the maintenance of existing mapping, rather than the creation of new information, is the main business of the national mapping organization. High resolution satellite sensor imagery has only recently been adopted as a data source in large projects in these well-mapped areas of the world (e.g. European Space Imaging, 2003). This paper seeks to discover whether high resolution satellite imagery could be used to assist in the revision of mapping in these well-mapped countries; specifically in Great Britain.

At Ordnance Survey, Great Britain's national mapping agency, a project was initiated in 2003 to investigate the potential of QuickBird imagery as a source for updating mapping at mid scale (1:25 000 and 1:50 000) and large scale (1:10 000 and larger). The initial findings of this research were presented at the ISPRS "High Resolution Mapping From Space" Workshop in Hannover [Holland and Marshall, 2003]. During this research, the use of QuickBird imagery for topographic mapping, change detection, and quality auditing was investigated. The initial findings indicated that it was feasible to produce a topographic map at a scale of 1:6000, using QuickBird imagery. This paper follows on from the above research, and presents new findings from the second phase of the project. At the time of writing, a full production trial is due to start soon, in which a mid-scales mapping product will be updated using both high resolution satellite imagery and a traditional revision method. Two further aspects of the project have already been completed: an assessment of QuickBird imagery for topographic change detection; and an evaluation of QuickBird imagery for auditing purposes. The results of these, and a recap of the results of the original map update project, are discussed in this paper.

2. UPDATING MAPS FROM SATELLITE IMAGERY

Ever since the first commercial high-resolution satellite sensors were heralded in the mid 1990s, mapping agencies have shown a keen interest in the possible use of satellite imagery in their data collection programmes. Since as long ago as 1996 (reported in Ridley *et al*, 1997) Ordnance Survey has been investigating this potential, initially using images synthesized from aerial photography, more recently using satellite imagery from the IKONOS and QuickBird sensors. A recently-published OEEPE (now EuroSDR) report presented findings of an investigation into the potential of IKONOS data for mapping, undertaken by several European mapping agencies and institutions (Holland *et al.* 2003). The results suggested that there is potential in this field, especially in rural areas at scales between 1:10 000 and 1:50 000.

To extend the OEEPE research further, Ordnance Survey purchased QuickBird images of several areas in Great Britain and began a series of investigations into the potential of such imagery in a geospatial data production context. The study areas covered several different types of land, including urban, suburban and rural, and are listed in Table 1. The images were used for different activities within the production area, as described later in this section.

Area	Acquisition date	Coverage (km^2)	Use
Salisbury	03/03/2003	44	CI
Manchester	16/03/2003	36	CI & CA
Cambridgeshire	14/03/2003	25	CA
Walsall	01/10/2003	196	CI
Christchurch	02/06/2001	325	MU

Table 1: QuickBird data used in the trial

Key:

CA = map Currency Audit
CI = Change Intelligence
MU = Map Update

2.1 Orthorectification

Before any update could be undertaken, the images were orthorectified. Several different approaches were taken, using commercial off-the-shelf software. Although in a live production environment the images would have been rectified using GPS control points, for this trial the control points were simply measured from map detail taken from existing large scale mapping data (OS MasterMap®). Similarly, the digital terrain model used in the process was taken from the existing height product, OS Land-Form PROFILE®. Table 2 shows the resulting orthorectification accuracy figures for two of the study areas (one urban, one rural). These are slightly better than the results for the initial study area of Christchurch, which had an overall RMSE of 2.77m, using 27 control points. Considering the nature and number of the control points, and the ease with which the images could be orthorectified using readily-available software, these results were considered to be very good.

Manchester (map accuracy 0.4m RMSE)				
Point type	No. of points	RMSE (m)		
		(x)	(Y)	Overall
control	11	1.18	1.09	1.60
check	15	1.38	1.06	1.74
Salisbury (map accuracy 2.47m RMSE)				
Point type	No. of points	RMSE (m)		
		(x)	(Y)	Overall
control	9	1.24	1.31	1.80
check	14	2.65	2.07	3.36

Table 2: Orthorectification accuracy measures, using existing map detail as control.

2.2 Topographic Map Update

The orthorectified imagery was analysed by a small team of surveyors and cartographers, all of whom were 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 studied, 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, at the various mapping scales used in Great Britain. These scales 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 and the product specifications reflect these differences.

2.2.1 Map Update Results

For each feature type, the cartographers recorded whether or not the features could be successfully identified from the image, using the specifications of each of the different mapping scales as guidelines. Table 3 shows the results of this analysis. It was found that many of the feature types that are required for smaller scale mapping (1:10 000 – 1:50 000 scale) 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 identified. As may be expected, 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 vegetation and artificial features (e.g. between hedges and walls) but in general the imagery is unsuitable for the capture of these narrow linear features.

When taken together, the results of the feature capture and the geometric accuracy of the orthorectification 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. If QuickBird Imagery were to be used as the sole data source, some changes to the Ordnance Survey mapping specifications would be required. In a commercial climate in which customers demand more and more information, any weakening of the specification is not likely to be well received. Hence it is likely that imagery such as this should only be used as a secondary measure, to supplement the information collected by other means.

Features	Map scale				
	1:50,000	1:25,000	1:10,000	1:2500	1:1250
Dual carriageways	y	y	y	y	y
Garage blocks	y	y	y	y	y
Major sea defences	y	y	y	y	y
Non-coastal sea defences	y	y	y	y	y
All vegetation	y	y	y	y	y
Major landscape changes	y	y	y	y	y
Roads	y	y	y	y	n
Airports	y	y	y	n	n
Railways	y	y	y	n	n
Non-residential buildings	y	y	y	n	n
Extensions to commercial buildings	y	y	y	m	m
Water features	y	y	y	m	m
Quarries	y	y	y	m	m
Housing & associated features	y	y	m	n	n
Field boundaries	y	m	m	m	m
Minor property boundaries	y	m	m	m	m
Major property boundaries	y	n	n	n	n
Tracks & paths	m	m	m	m	m
Telephone boxes	n	n	n	n	n
Electricity transmission lines	n	n	n	n	n
Tide lines	n	n	n	n	n

Table 3: Analysis of the types of features which can be identified 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 features can be captured, in others, not.

3. CHANGE DETECTION AND MONITORING

3.1 Change Intelligence

Although the main duty of a mapping agency is to update geospatial data, such data cannot be updated unless it is known where topographic change has taken place. Therefore, change intelligence forms a very important part of the map revision process. There are many different ways to identify change, one of the most important being local observation by surveyors in the field. Local planning authorities may provide planning information, as do commercial change detection agencies. In Great Britain, new housing development plans are often supplied to mapping agencies by architects and house building consortia.

To supplement this direct observation and notification of change, there is a role for imagery. High resolution satellite sensor imagery may allow surveyors to find areas of change which would not be detected using the other methods. For example, in areas undergoing 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; field boundaries are changed from year to year; 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 notification bodies. In these areas, it is suggested that 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.

To test this hypothesis, extracts of QuickBird images in the Salisbury and Manchester areas were examined to detect changes. These results were then compared with change intelligence obtained by conventional means.

3.1.1 Change Intelligence Results

Previously unrecorded changes were detected in both the rural and urban images. In the urban area of Manchester, most of the changes were classed as “category A” (this category includes new housing, commercial, industrial, community and public sector buildings, roads, rail and other communications links). In the rural area, most of the changes were “category B” (this category includes small agricultural and horticultural buildings, quarries and other surface workings, field boundaries, water features, vegetation features, tracks and paths). In Manchester the analysis uncovered an average density of one site of significant change per square km; the corresponding figure for Salisbury was 0.66 sites per square km. Note that these were changes which had not been identified using traditional change intelligence techniques.

The main types of change identified in the Manchester study site were: building demolitions (industrial and housing); newly built industrial units; railway demolitions and minor road alterations. It was not possible to detect changes such as new traffic calming measures; small property boundary changes; or mobile-home movements. Of course there are other changes which are impossible to detect using any type of imagery, including name changes, conversions of buildings from agricultural to residential, or address changes.

In the Salisbury area, the main types of change were to typically rural features such as fences, tracks and vegetation boundaries. Although recorded as “Category B” and therefore regarded as slightly less important to the large scales data collector, these features are of significant interest to the leisure map user and are therefore important to the small scales map update process. As in the large-scale case, there are many changes which cannot be observed from imagery alone, including non-topographic data such as tourist information.

These results indicate that QuickBird imagery can be used to identify topographic changes for both large- and small-scale mapping. The cost of the imagery may well be the sticking point. At current costs, it would not be economically viable to use QuickBird data (or any other high resolution satellite sensor imagery) solely for the purpose of change intelligence. If, how-

however, the imagery was to be used for a number of different processes, the economies of scale may be enough to justify its use.

3.2 Map Currency Audit

Each year, the UK Government defines a set of "Agency Performance Monitors", by which to measure the performance of Ordnance Survey. These performance targets include the following:

- to ensure that a minimum of 99.6% of significant real-world features (Category A) are represented in the database within six months of their completion;
- to ensure that there is an average of no more than 0.6 standard units of un-surveyed major change over 6 months old, per standard map unit.

Note that the standard unit of change is the "house unit", which traditionally represented the amount of change observed on the building of a new house. The unit has now been formalized to encompass many other types of change. Some examples of house unit values are:

- New houses and associated features, including boundary features, name/number and associated garages = 1.25 units per house.
- New commercial, industrial, public sector and farm developments with buildings and associated features = 20 units per ha
- New single carriageway roads, railways (per pair of tracks) and canals, including associated paths, fences and boundary features = 5 units per 100 m

Also note that the standard map unit depends on the scale at which the data are captured. The unit equals 25 square km in mountain and moorland (1:10 000 scale), one square km in rural (1:2500 scale), and 0.25 square km in urban (1:1250 scale) areas.

A Quality Assurance (QA) team within Ordnance Survey is responsible for monitoring these values and ensuring that the Agency is meeting the requirements. In order to do this, a sample of 4000 map units are randomly selected every six months. The areas covered by these maps are then visited by field surveyors in the QA team and examined for any features more than 6 months old, which are not on the map.

Panchromatic and pan-sharpened QuickBird images of Cambridge (rural) and Manchester (urban) were used to test whether the quality monitoring process could be successfully augmented using satellite sensor imagery. The images were examined and compared with the current large scale mapping data. Any features identified in the image which were not on the map were recorded. The results were then compared with quality audits performed using traditional field verification techniques.

3.2.1 Results of Map Currency Audit

The QA team found that QuickBird imagery could be used to identify changes, and thus aid in the assessment of the map currency. In several cases changes were detected in the image which were not detected on the ground; and in other cases the converse was found. The general findings of the research are as follows:

Advantages of Using QuickBird:

- major shapes of all buildings can be identified;
- demolitions are easy to detect;
- small industrial buildings are easy to identify;
- QuickBird imagery is useful in areas where access is restricted;
- the imagery provides wide-area coverage and frequent repeatability ;
- the imagery provides a time-stamped snap-shot of the currency on the ground.

Disadvantages of Using QuickBird:

- QuickBird imagery can't be used to identify whether change is permanent or temporary;
- the age of changed features cannot be identified;
- the Category of the change (A or B), is difficult to determine, especially for urban areas;
- drive restriction features are difficult to identify (e.g. speed bumps and posts);
- high-rise buildings are difficult to determine in the images, and any overthrow makes it difficult to identify if any change has occurred;
- complex shapes and multilevel structures are very difficult to see clearly;
- image resolution is often not high enough to differentiate between building extensions and separate new buildings;
- all small linear features are difficult to see (e.g. fences, paths, railway lines or field boundaries).

The map currency audit must also identify any cultural or thematic changes, such as changes of use or changes in names of features. These of course cannot be obtained from imagery.

As in the change detection example, the results show that QuickBird imagery can be used in the map currency audit process, but it cannot be used alone. Additional information is required which can only be obtained by a field visit to the sites under investigation.

4. CONCLUSIONS

The results described in this paper have indicated that QuickBird Imagery can play a role in all the processes investigated.

Imagery of this resolution can be used to update mid-scale maps (1:6 000 to 1:10 000 scale) as long as small linear features are excluded from the mapping specification. This imagery can also be used in the detection of change, and in the quality checking of existing map data. However, in each case there are disadvantages, which indicate that QuickBird imagery should be used in a supplementary way, rather than as the main source of data. For example, QuickBird could be used to obtain frequent snapshots of rapidly changing urban areas, enabling change to be detected more readily than is possible by other methods.

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