Inventorying Environmental Resources - Paradigm Shift In Large Scale Topographic Surveys And Mapping Using high resolution Satellite Images

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Abstract

The aerial photographs have been the conventional workhorse for large scale topographic surveys and mapping. The advancement of space based imaging technology in the last decade has brought revolutionary changes in large scale surveys and mapping activities by way of facilitating high resolution images of ≤1 m from satellites such as IKONOS, CARTOSAT, QUICKBIRD, GEOEYE, WORLDVIEW etc. in Optical Infrared class. Although the airborne microwave systems like Geosar is particularly useful in perpetually cloud covered areas in tropical rain forest belts, and other virgin, inaccessible areas of the planet. This has made serious impact on the mapping community and gradually these images are making inroads as a substitute for aerial photographs in large scale map making domain. The increased need of producing more and more maps at large scale using satellite images vastly increased the number of mapping professionals. Most of these professionals are not aware of important issues in map making except for professionals in specialized national mapping organizations like for example 'Survey of India' in India. Under this background an attempt is made in this paper to discuss various issues in large scale mapping using high resolution images. The issues addressed include the geometric fidelity, the adequacy of information content, and the elevation information extraction capability of these images.

Key words: Topographic surveys, High resolution satellite images, optical infrared satellites (OIR), Global Positioning System (GPS), Aerial photographs, Ortho-photos,

1.0 Introduction

The advents of high resolution optical infrared satellites (OIR) have ushered in an era of economic and reliable topographic mapping. Topographic surveys/maps contain useful information of the physical surface of the earth including roads, railroads, settlements, drainage, water bodies, broad land use/land cover etc. This information is fundamental input in any developmental activities be it land and water resources or infrastructure. Usually the scale for such mapping for national coverage varies from 1:20,000 – 1:250,000 with contour interval from 5m – 50m. However in order to meet the planning needs of developmental projects at micro level, the demand of the user community is steadily increasing for large scale topographic maps. In present generation large scale maps may be defined as maps with scales ranging between

1:1,250 and 1:10,000 (Baltsavias, 2006). However in most of the cases the 1:5000 and 1:10,000 scales are in high demand. Some countries produce maps on these scales as their national coverage. Normally such maps are produced for specific areas undergoing development such as settlements, catchments, command areas, sites of a construction etc. In India topographic maps for national coverage are produced on scales 1:25,000, 1:50,000 and 1:250000 by the premier national mapping agency, the Survey of India. Recently, it is proposed to produce 1:10,000 scale topographic maps with contour interval of 2 m for the whole country.

The satellite images have emerged as an effective input in production of maps due to large area coverage, frequent revisit capability, fast post processing, no air traffic control, imaging inaccessible areas and the cost effectiveness. However the limitation of spatial resolution has always restricted the use of these images in large scale surveys and mapping and therefore aerial photographs dominated in these areas. The advent of high resolution satellite images of≤ 1 m in the last decade as a substitute to aerial photographs has become inevitable in large scale surveys and mapping. Notable high resolution satellites include IKONOS in 1999 (1 m resolution), QUICKBIRD in 2001 (0.6 m resolution), GEOEYE 1 in 2008 (0.4 m resolution in panchromatic mode and 1.65 m in multispectral mode) and WORLDVIEW II in 2009 (0.5 m in panchromatic and 1.8 m in multispectral mode with 8 bands). The GEOEYE 2 is proposed with 0.34 m resolution in panchromatic mode and 1.34 m in multispectral mode. These high resolution satellite images have been successfully employed in the last decade for topographic mapping on scales from 1:5,000 – 1:10,000. The increased need of producing more and more maps at large scale using satellite images vastly increased the number of mapping professionals. Most of these professionals are not aware of important issues in map making except for professionals in specialized organizations like national mapping organizations (e.g. Survey of India, in India). Therefore there is a need to bring awareness about these issues.

Under this back ground, an attempt has been made in this paper to bring out various issues involving the high resolution images for the mapping at stated scales. The issues to be addressed include the geometric accuracy requirements, the adequacy of information content and the possibility of extraction of elevation information. Also it will discuss the methods of implementing geometric fidelity of the image data and finally link the geometric resolution to the scale of mapping.

2. Planimetric Accuracy

The topographic maps are used for quantitative and qualitative measurements of various environmental features. The lengths and areas are most important quantitative measurements. Therefore it is desirable that the features depicted on the maps should be true to its position/location with limitation of the scale. Once such property is preserved the map becomes geometrically suitable for carrying out measurements. However, whatever the methodology may be adopted, a map will have errors. Therefore, some specification for location accuracy standards has come up and followed in surveying and mapping activities. In U.S.A it is laid down that, for maps on scales smaller than 1:20000, 90% of the location of the features depicted on it should be within 0.5 mm on the scale of publication. This statistically means that standard error in location of features on a map should be within 0.3 mm. For scales larger than 1:20,000, 90% of the features should be within 0.8 mm on the map thus implying standard error as 0.5 mm. In Europe and many other countries similar standard is adopted. In India, the apex national mapping organization, the Survey of India has also laid down similar standards. Adopting the standard error limit as 0.3 mm for large scale mapping on 1:5,000 and 1:10,000 scales, the standard error in location of features on these maps should not exceed 1.5 m and 3 m respectively. In order to achieve this, control points used for geo-referencing of the image should have higher level of accuracy and sometimes kept at one fourth of the location accuracy. Adopting this as standard, for 1:5000 and 1:10,000 scales mapping the accuracy of plan control should be 0.4 m and 0.8 m respectively. The control points for geo-referencing may be obtained by using Global Positioning System (GPS). Here it must be noted that the reference control points for GPS survey must have the accuracy better than or equal to above stipulation.

The spatial resolution of an image has its bearing on the location accuracy achievable. Notable case studies may be looked into for drawing inferences regarding this. IKONOS images were used for the Klang valley area in Malaysia where geometric accuracy of about 0.4 m has been reported (Abdul, 2006). QUICKBIRD image of 0.6 m resolution was used in Botswana yielding geometric accuracy of about 0.4 m (Das et al. 2011). One meter resolution image of IKONOS was used for Urban mapping yielding satisfactory level of geometric accuracy (Bohari *et al.*, 2011). The simulated 2 m image from 1 m IKONOS image and 5.8 m IRS 1D was used for urban mapping of part of Hyderabad city at 1:10,000 scale. From experience gained including case studies it may be safely assumed that the geometrical accuracy of at least of the order of one pixel (i.e. the resolution level) is obtainable from satellite images. The method of ortho-rectification using an existing Digital Elevation Model (DEM) having an accuracy of 1- 2 m may be adopted for infusing geometric fidelity on the image. In the absence of a DEM, stereoscopic satellite images of similar resolution may be used for generation of a compatible DEM. The latter in fact is more expensive and time consuming. However sometimes geo-referencing using polynomial transformation models may yield satisfactory results for relatively flat terrain.

Assuming one pixel level of accuracy obtainable from satellite images, linking this to accuracy of plan control and thereafter adopting a generalized view, it may be stated that for 1:5,000 and 1:10,000 scales of topographic mapping the spatial resolution of the image data should be about 0.5 m and 1 m respectively in order to meet the required location accuracy standards. It is interesting to mention that the image data of 0.5 m and 1 m spatial resolution may be ideally represented in hard copy form (as a photograph) on 1:5,000 and 1:10,000 scales where the human eye obtains a clear view of the image without blurring (Manual of Photogrammetry).

3. Adequacy of Information Content

Information content plays a vital role for an image since it is the aspect which governs the extraction of features from the image with regard to the object space. The information content is determined by the spatial, spectral and radiometric resolution out of which the spatial resolution is the major one and discussed here. A general principle connecting the spatial resolution and the mapping scale with regard to adequacy of contents is that, a smallest feature depicted on a map should have a dimension of at least 0.25 mm on the scale of publication and in order for an object to be photographically identifiable it must be imaged by about five resolution elements. According to this for 1:5,000 and 1:10,000 scale of mapping the image should have spatial resolution of at least 0.25 m and 0.5 m respectively. This general principle needs to be examined with citation from various case studies. The images from IKONOS and QUICKBIRD have been used in Turkey and it has been observed that the geometric accuracy achievable from these images meets the accuracy standards of mapping at 1:5000 scales or smaller but lacks in extraction of small features (Sahin, 2004; Veysel, 2005; Kansu, 2006 and Alkan, 2009). It is necessary to use other sources of information like aerial pictures which provided higher completeness of information, but was considerably more expensive (Alexandrov, 2004). Information extraction from QUICKBIRD image reveals that individual buildings, fenced boundaries, roads, tracks etc are clearly extractable from this image. Even small cars on the road are seen on this image. A comparison of colour aerial photographs of about 0.25 m resolution with panchromatic QUICKBIRD image shows that though the image quality of the aerial photo is sharper and clearer than the QUICKBIRD image, the information required at 1:5,000 scale more or less appears from the latter (plate I). Therefore the image broadly meets the required information content (Das *et al.*, 2011)

4. Altimetric Accuracy

The standard adopted in a number of national mapping organizations including U.S.A. European Countries and India states that ninety percent of the points tested for elevation information from a contour map should be within half the contour interval (C.I). Statistically this means C.I. = 3.32 of standard error of heights evaluated from the map. For 1:5000 scale and 1:10,000 scale maps normally contour interval of 2 m and 5 m is adopted. In terms of above statistics the standard error in heights should be 0.6 m and 1.5 m respectively. The vertical control points should have better accuracy than this. In high resolution category images, many have stereoscopic coverage. Assuming the B/H ratio as 1 and to achieve vertical resolution of at least 0.6 m compatible to similar level height accuracy so that elevation information fits to 2 m C.I., the corresponding horizontal (spatial) resolution of the image should be about 0.4 m. Similarly to fit to 5 m interval the spatial resolution should be about 1 m. When a high resolution satellite image is considered for extracting elevation information these points must be taken into consideration.

Fig 1. Aerial orthophoto (Upper) & QUICKBIRD IMAGE (Lower)

5. Discussion and Conclusion

From the above investigation it is observed that the high resolution satellite images of 0.5 m and 1 m spatial resolution can be used as a cost effective substitute for aerial photographs for topographic surveying and mapping compatible to scales of 1:5000 and 1:10,000 without sacrificing the location accuracy standards. This also can be successfully employed for elevation information extraction provided the corresponding data has stereo coverage with optimum B/H ratio. For information content, the ideal image data for 1:5000 and 1:10,000 scale of mapping should have spatial resolution of 0.25 m and 0. 50mrespectively. However considering the fact that most of the high resolution satellites provide pan-sharpened images facilitating better interpretation of features, the spatial resolution requirement may be diluted to0.50 m and 1 m respectively so that a uniform resolution can be adopted for obtaining the accuracy as well as information content. The future satellites such as GEOEYE 2 are expected to provide spatial resolution of 25 cm – 35 cm which will facilitate further enhanced quality of image.

Regarding the cost, it is worth mentioning that the high resolution images of better than 1 m costs around US $ 20.00 (INR 1200.00) per sq. km. This cost of image data dissuades many users to consider these images. Therefore the resolution of 2.5 m has come to forefront particularly in Indian context for 1:10,000 scale mapping where the CARTOSAT (IRS) provides this resolution data and the cost of which is significantly low. This data no doubt, does not meet either the accuracy requirements or the information content for the cited scale. However as a tradeoff, this data may be used as a very cost effective input for 1:10,000 scale mapping. The user community must note the limitation of this data.

Papua New Guinea, being a tropical country is handicapped with perpetual cloud cover in the bulk of its terrestrial entity; which limits usefulness of OIR satellite data. Airborne Geosar microwave data (X and P band) have been successfully used to generate 10 m contour information for the country. In order to tide over the cloud menace, OIR data RapidEye (2010) in combination with ALOS / PALSAR microwave data have been successfully used for inventorying the forest resources baseline information of the country (Ishi, 2014; Laa and Haraguchi, 2014) .

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