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REVIEW ARTICLE

Use of Spot Panchromatic Imagery for the Revision of Forest Road Information

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Abstract. A digital 10 m - resolution level 3 SPOT (Systeme Probatoire D'Observation de la Terre) image covering parts of Menengai District in Kenya was used to update forest and rural road data in a GIS environment. Road information was first enhanced using a 3 × 3 high pass filter and then resampled to 3m × 3m pixel size. This data was then digitized off the screen. An allowable error corridor of 16 m was established around the reference roads. The digitized data was consequently compared with reference road points. The results show that about 90% of road arc points lie within the specified positional tolerance, and that no significant relationship was noted between points lying outside the 16 m zone and the values of slope gradient. It is concluded that for many forest and rural GIS road mapping tasks, on-screen digitizing of SPOT panchromatic data could be feasible and cost-effective.

Introduction

One of the bewildering problems in forest management pertains to the need for timely and up-to-date information on quality road data for the purposes of forest harvest scheduling, watershed monitoring, road access information and maintenance of local habitat data. Therefore, for forest mapping agencies with geographic information system (GIS) facilities, an annual update of road information is a necessity for efficient management of these valuable resources [1 - 3]. Conventionally, such road information used to be acquired through photogrammetry. Two techniques were followed in this respect. The first entails the use of approximate mapping instruments. Single photo prints covering the area of interest are processed under instruments such as radial line plotter, sketchmaster, or later, zoom transfer scope. Using such single prints, forest roads, paths and fire breaks can be compiled at lower costs and with little know-how of photogrammetry. This technique has long been acknowledged by forest managers and engineers as a simple and cheap method of mapping.

A major snag of the method, however, relates to the inability of these instruments to remove photo tilt and all effects of topographic relief. Further, generation of digital elevation models could only be achieved through an additional interpolatory stage using parallax bar measurements of discrete number of points in a stereomodel. Positional errors caused by various sources in the photogrammetric system are, therefore, only averaged out between control points by stretching and enlarging (or reducing) the photo. For such road information to be integrated into a GIS, the process is definitely tedious, time-consuming and slow, particularly if the area of interest is extensive e.g. spanning hundreds of aerial photos.

The other approach utilizes either conventional analog stereoplotters (with stereo aerial photos) or their analytical counterparts. The method yields very accurate results and has long been used in the compilation of large and medium scale topographic maps. Further, many other mapping processes are possible e.g. generation of digital terrain models, production of orthophotos and profiles, computation of coordinates etc. However, photogrammetric stereoplotters (analog or analytical) are very expensive (typically U.S. $50,000 – US $250,000). Moreover, to become adept in operating these instruments may need months if not years of training.

Use of Remote Sensor Data

Nowadays, high resolution remote sensor data is available at only a small fraction of the cost of photogrammetric mensuration [1;4]. A satellite such as SPOT which carries two identical high resolution visible (HRV) pushbroom scanners offers data at two resolution levels i.e. 10 m for the panchromatic mode and 20 m for the multispectral mode [1;5]. A single SPOT scene corresponds to an area of approximately 3600 square kilometers (*i.e.* equivalent to 170 vertical aerial photos at 1/20,000 scale). The SPOT data is available for all parts of the world at regular intervals; and since the data is already in digital format, geometric and radiometric corrections, image enhancement and classification could easily be performed through a multitude of digital image processing techniques.

Although some major disadvantages of SPOT data relate to the possibility of the existence of clouds (because data is not being acquired daily) and to the relatively poor spatial resolution of the sensors on board, for many forest management and engineering tasks, the panchromatic data could exhibit several merits over traditional photogrammetric methods. The present article attempts to attest this statement using an on-screen digitizing method.

Use of SPOT data in GIS environment

A number of investigators have reported on the possibility of using SPOT panchromatic data into a GIS. Early geometric tests [5 - 7] showed that SPOT panchromatic imagery is commensurate with the requirements for topographic map compilation at around 1/25000 scale. This is the first time the positional accuracy of satellite-derived imagery proves suitable for GIS applications. Also, Dowman and Peacegood [8] reported that road information (including rail roads) is 100% extractable from SPOT panchromatic imagery.

Computer-assisted extraction of road information from satellite data is accomplished using a number of techniques, the most important of which are (i) pixel or line following technique [1;9;10], (ii) knowledge-based system technique [11;12] and (iii) processing and analysis of multidate remote sensor data [2;13].

Although these techniques are powerful and efficient, providing accurate road updates, the on-screen digitizing is meritorious in that managers and engineers with good reference level in road information, soil composition, land cover, area accessibility and human impact levels present on the area under consideration, can carry out the interpretation process with relative ease and confidence.

Study area and materials

The test area selected for this study is the Menegai District in Northern Kenya. The area is centered at 36° 07.5′ E and 00° 37.5 S. The prominent feature of the area is the famous holiday resource Menegai Crater which is part of the well-known African Rift Valley. Besides its importance for holiday makers from around the world, this area was selected because it has diverse topography including grazing moorlands, a good deal of high ground, some quite hilly areas and rather extensive large scale farming with maize, coffee, silos and tea being the main crops. About 30% of the area is covered with harvested woodlands, forests and silos plantations. Also quite a number of forests and access roads exist in the area with new roads being constructed in the area in the last ten years or so. As derived from medium scale maps of the area, ground elevations range from about 1000 m above mean-sea-level to perhaps more than 1500 m.

For the purpose of the present test, three level 3 SPOT panchromatic images were acquired for three different dates, namely 14 March, 1986, 23 September, 1986 and 9 February, 1987. In order to verify the positional accuracy of road information derived from this data, reference information in the form of GIS 1/20,000 scale road inventory maps was also made available. The two sets of data were supplied to the author by the Remote Sensing Unit of the Regional Center for Services in Surveying, Mapping and Remote Sensing in Nairobi, Kenya.

The test imagery provided was believed to meet U.S.A. map accuracy standards for contour intervals of 20 m [4]. The three images were compared in order to select the most appropriate image for the task in hand. The September 1986 image suffered seriously from clouds and was consequently discarded. Although the March 1986 and the February 1987 images look much alike, the former looked somewhat silvery in appearance with some grey overcast on one side of it, and was therefore, rejected on this basis. Therefore, the February 1987 image was thought to be superior for road information delineation and was consequently used for the purpose of the test (Fig. 1).

Data processing

Processing of the test data was carried out along the following lines: enhancement of the data, resampling of the data, on-screen digitization of road information and accuracy evaluation.

For the enhancement stage, a method described by Chavez and Bauer [14] known as horizontal first difference technique was first employed in order to arrive at the optimum kernel size for this purpose. The best kernel size was found to be 3 × 3 and was therefore adopted. Suitability of this size was visually confirmed by attempting processing using 5 × 5 and 7 × 7 windows.

In order to enhance road information, three special filtering techniques described by Jensen [1] (the high pass filter, the zero sum filter and combined high pass/low pass filtering) were attempted. The result was that the high-pass filter combined with the 3 × 3 window gave better-enhanced road information.

In the process of digitizing road sectors from the screen, a mouse (or some other device) is usually employed. It is possible to increase the precision of this process by resampling of the SPOT data from 10 m × 10 m pixel size to 3 m × 3 m grid cell. This means that, after resampling, each pixel becomes nine smaller cells thus allowing digitization at subpixel level. Based on experience gained elsewhere (*e.g.* [3;15]), the

Fig. 1. Subimage of the test area.

sample values present in the new grid were estimated by interpolation of original data using the cubic convolution resampling technique. It appeared that the 3 m × 3 m resampling did not introduce significant loss in positional accuracy (root-mean-square error of around 0.1 pixel).

The on-screen digitizing process consisted of moving the cursor manually along the centre pixels of a road. A 32-bit image processing system and a 20″ VGA monitor were used to display the digitized image at 512 × 512 frame size. In this particular experiment, it was necessary to convert the digitized data from the raster format of the processing system to the vector format of the GIS. This allowed comparison to be made of the two sets of data.

There remains, however, the question of assessing the positional accuracy of digitized road data. A suitable procedure in this respect is to adopt a justified positional accuracy figure on which to base the comparison. The road inventory maps were at a scale of 1/20,000. According to North Atlantic Treaty Organization (NATO) specifications for topographic mapping, the horizontal tolerance of the road reference maps is around ± 6 m (*i.e.* ± 0.3 mm at publication scale). When this figure is combined with the resolution of the SPOT panchromatic image (*i.e.* ± 10 m), a realistic positional tolerance of ± 16 m seems appropriate for the purpose of assessing the resulting digitized road information.

A corridor of 16 m horizontal tolerance was therefore constructed using the reference roads (Fig. 2). This corridor and the digitized road information obtained from SPOT data were then compared to evaluate the positional accuracy of the latter. A technique followed by Jazouli, *et al.* [3] was adopted in this respect in order to relate derived positional accuracy of road arc information to topography. A land use/land cover digital terrain model of part of the area constructed by Farah [16] was used to classify ten ground slope-gradients. These ranged from flat (0-2%) to mountainous (> 90%). A total of 6924 road arc points were tested. The percentage of points lying outside the 16 m tolerance was also noted and related to values of slope gradient.

Results, Discussion and Conclusions

Out of the 6924 points tested for the purpose of positional accuracy, about 90% were within the 16 m error corridor. This figure is viewed as satisfactory for most forest and rural road information. Mapping purposes in developing countries (see *e.g.* 17;18]). Also, it is noted that there is no significant correlation between the number of road arc points outside the 16 m tolerance zone and ground slope-gradient values. These findings reflect the higher standard to which the test image was processed. They also confirm the fact that due to the high orbital altitude of SPOT (830 km) geometrical errors induced by ground relief are minimal.

It is concluded, therefore, that on-screening digitizing of enhanced SPOT panchromatic data for the purpose of revision of forest road information could be contemplated, the main anticipated advantages being repetitive coverage of large areas, cost-effectiveness (compared to conventional photogrammetric methods) and reasonable accuracy.

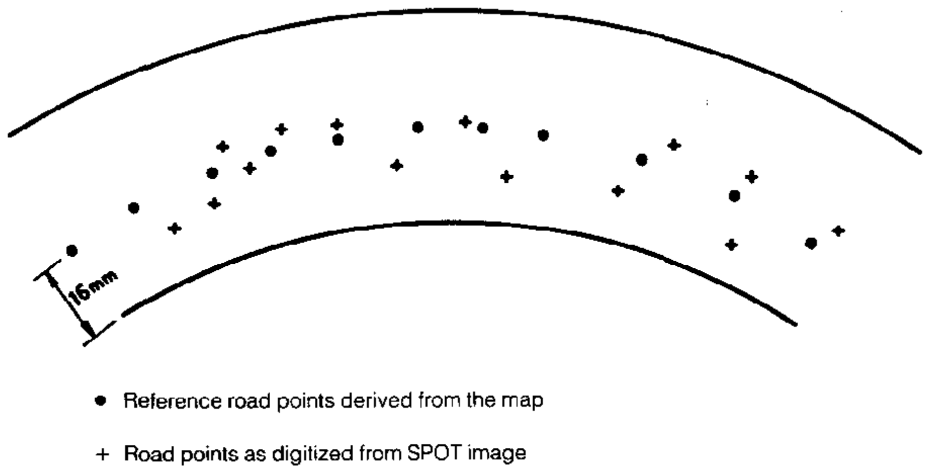

Fig. 2. Allowable error corridor used in assessing the accuracy of digitized data.

The attention of readers wishing to make use of the results of this test is, however, drawn to the fact that due to the special circumstances of the present test, these findings may pertain only to this particular area and possibly to regions with similar physical and environmental conditions. For areas with different terrain parameters (*e.g.* road type, topography, drainage network, vegetation, rainfall... etc.) different outcomes may be obtained.

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استعمال المرئيات البانكروماتية للتابع «سبوت» في تجديد معلومات طرق الغابات

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ملخص البحث. استعملت مرئية رقمية بانكروماتية ذات دقة مترية ١٠ أمتار من التابع «سبوت» تغطي جزءًا من مقاطعة مننجاي في كينيا لغرض تجديد المعلومات الخاصة بطرق الغابات والطرق الريفية في بيئة نظام معلومات جغرافي. ولهذا الغرض أجريت عملية توضيح رقمي لمعلومات الطرق باستعمال نظام تنقية رقمية سريع بحجم ٣ × ٣ أولاً، أمكن بعدها معالجة هذه المعلومات بحجم وحدات أرضية ٣ متر × ٣ متر وترقيمها مباشرة من الشاشة. بعد ذلك حدّدت قيمة ١٦ مترًا للخطأ المسموح به حول الطرق. قورنت المعلومات الرقمية بمثيلاتها المستقاة من الخرائط الطبوغرافية. وأثبتت النتائج أن حوالي ٩٠٪ من النقاط المرقمة على الطرق تقع ضمن الخطأ الموقعي المسموح به وأنه لا توجد علاقة مهمة مباشرة بين نتائج النقاط التي تقع خارج مساحة الخطأ المسموح به وقيم درجة انحدار الأرض عند هذه النقاط. وبناءً على ذلك يمكن القول: إن استعمال الترقيم المباشر من الشاشة لمرئيات التابع سبوت يمكن أن يكون مفيدا لأغراض مسح معلومات الطرق الريفية المنفذة في بيئة نظام معلومات جغرافي.