SPOT5 QUANTIFIES RAPID URBAN CHANGE

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ABSTRACT:

The rapidity of urban dymanics has a significant impact on the spatial patterns associated with the growth and expansion of metropolitan areas. High resolution satellite imagery with equally rapid image update capabilities offers significant potential for helping to maintain the accuracy of associated cadastre, municipal subdivision boundaries, voting districts and enumeration areas (population census zones) in these urban areas. This paper demonstrates the value of combining new high resolution satellite image sensors such as Spot5 with enumeration areas (EA's) in a geographical information system to identify urban change as well as quantifying the type of change in a metropolitan area in South Africa.

Spot 5 images were recorded during August 2002 for the Pretoria metropolitan area in South Africa in all three modes (10m, 5m & 2.5m). All of these images were combined with enumeration areas (EA's) from the October 2001 Population and Housing Census in South Africa, as produced by Statistics South Africa. To map urban growth and model associated change, the urban EA's (consisting of appoximately 200 households per EA) were selected as a base framework around which change would be determined.

As a next step, all new areas of growth were assessed in terms of using SPOT5 for more quantitative house counts in order to demarcate new EA's boundaries. The results indicate that both the Spot5 Colour (10m) and Panchromatic (5m) are sufficient to detect and classify urban growth, while the colour enhanced Supermode and the Supermode can be used with confidence to detect individual house structures in formal residential areas and to use this to demarcate new EA's.

1. INTRODUCTION

The rapid growth in metropolitan areas in South Africa over the last decade is a direct result of legislation implemented by the previous government for 40 years. This legislation limited migration to metropolitan areas and when the new government came to power in 1994 and abolishing such regulations, the increased flow of people resulted in the creation of informal housing areas around the urban perimetre.

As a result metropolitan areas in South Africa are very dynamic, which result in rapid change of the spatial patterns and land use associated with such areas. A significant impact of this growth and expansion is that a number of jurisdictional and legislative boundaries become outdated very quickly. One of these data layers is enumerator areas (Census Zones) used for Population and Housing Census surveys, which requires updates very 10 years.

Normal census intervals are not frequent enough to incorporate this rapid change, and therefore the requirement for other methods to capture this growth. High resolution satellite imagery such as Spot5 offers the possibility to capture rapid urban change on a regular interval, and allows quantification of such change through counting individual residential structures.

This study is investigating the use of the Spot 5 high resolution sensors in the population census domain. Census survey zones (enumerator areas) are usually updated form high resolution aerial photography, but with the launch of Spot5 it provides possibilities to use a more cost efficient approach, by reducing the amount of imagery required. This study is aimed at evaluating these options available from the range of Spot5 sensors and its associated use and applications for updates of enumerator areas used in Population and Housing Census surveys.

2. SCOPE

This study has two components which relate to census cartography. Firstly, census cartography requires the identification of any change in urban patterns. This change mostly occurs on the urban perimeter, but could also occur within metropolitan areas. Secondly, once change in urban patterns have been identified, these areas have to be quantified which then allows update of the demarcation of enumerator areas (EA's)

To address the first component namely the identification of change, the first aim of this study was to assess all the sensors and derived data sets (colour enhanced merged images) for use in urban change detection. Areas of urban change were then classified into urban structural classes. The second component was to assess the value of the image data for quantification and that could allow the update and demarcation, of EA's. The images were therefore assessed for its use on the following three factors:

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1. Detect urban growth
2. Identify and classify urban growth
3. Quantify urban growth

3. METHODOLOGY

The approach that has been used in this methodology for the image processing, is straightforward without complexity to prepare the images for detecting urban growth and subsequent mapping. The images were ortho-rectified using digital ortho-photos, and then the merged layers were created, followed by the enhancement of imagery.

Once the images were prepared, the 2001 GIS layer of enumerator area of Statistics SA were overlayed on the imagery. All urban change were mapped on screen, and classified based on visual interpretation and rather than complex classification procedures (where pixel reflection values are grouped together), which requires visual checking and assessment anyway for census applications. Finally the quantification for each class was done and compared to actual structure counts.

3.1 Data Sources

Spot Image supplied the following Spot 5 images in level 1A for use during this study:

- Spot 5: Colour 10m
- Spot 5: Black & White 5m
- Spot 5: Supermode 2.5m

These images were ortho-rectified using the following two data sets as ground control points (GCP)'s and elevation layer

- GCP's: Aerial Photography: Black & White 1m
- Elevation Source: Digital Elevation Model @ 20 metre resolution

During the study two additional data sets were created by merging the following images:

- Spot 5: Colour 10m with Panchromatic 5m: rgb=321
- Spot 5: Colour 10m with Supermode 2.5m: rgb=321

This resulted in a total of five image data sets that were used and evaluated in this study.

3.2 Image Preparation

All image processing steps listed below was performed in Erdas Imagine and Orthobase modules.

- Import imagery and check imagery for radiometric quality
  - Each satellite image was imported and checked for radiometric quality which is essential for visual interpretation

- Ortho-rectify satellite images using the following two inputs:
  - collecting ground control points from ortho-photos
  - 20m digital elevation model (DEM)

- Accuracy assessment of ortho-rectified imagery
  - imagery has been checked by overlaying and comparing to street maps and enumerator areas

- Merge of Panchromatic and Multispectral imagery
  - process of merging the 2,5m Supermode and 5m Panchromatic images enhance the image contrast and easier identification of structures.

- Enhancement filters
  - edge enhancement filters was passed over all the imagery to highlight boundaries between urban and rural areas.

3.3 Processing and Mapping

Digital mapping technologies was used to create a GIS layer that show the change in urban area between the 2001 EA layer on the August 2002 Spot 5 imagery. The change is however actually from a longer period because the 2001 EA's are prepared from imagery that is captured approximately 24 -18 months before the census. This is done to have enough time to prepare for the actual census surveys.

All mapping is based on visual interpretation and heads up digitizing of urban changes. Visual interpretation uses the human eye and brain to consider context, shape, proximity and texture to identify features on satellite imagery. The images were visually scanned using a grid pattern to identify any urban features on the imagery that is not covered by urban EA polygons. These areas were mapped out, based on the parameters below, as polygons to designate change for the different periods, using the ArcGIS software modules.

- Urban areas not covered by urban EA's (smaller than 100ha)

- Urban areas in EA's with an attribute of less 20 household structures for previous census

- Backdrop imagery showing indications of new developments (ie street patterns but no houses yet)

After the change detection polygons were mapped from the Supermode colour enhanced image, the polygons were overlaid on all the individual image sets. All the different classes were tested on the complete set of images, to determine which of the imagery contains enough detail and resolution to allow classification into different classes.

This classification can assist with the update and demarcation of the EA's. Each of the mapped polygons showing change was classified into the following classes listed below:

- townhouses/cluster housing
- security estate
- low cost housing
- informal settlement
- residential (normal suburban street layout)

The criteria were that if any of the classes could not be classified clearly from any of the five image sets it will be considered not classified.

After the classification had been completed, the next stage was to evaluate imagery for its detail to allow counts of individual structures. The ability to count individual structures allows quantification of urban change, into the number of households, on which the demarcation of EA's is based.

This was done by attempting house counts for each individual structure class listed above. Two polygons from each class were overlayed on each of the 5 different sets of Spot5 resolution imagery. House counts were generated on each resolution set by physically attempting to place a point on each visible structure. These were all compared to a base data set generated from 1:10 000 aerial photography at 1m resolution.

3.4 Results

The results have shown that Spot 5 has an advantage for census applications compared to lower resolutions, especially when attempting to classify or quantify urban change. Imagery was evaluated in three stages for its use, namely, urban change detection, urban structural classification and detail of imagery to allow counts of buildings.

During the mapping of change as described above, all the potential areas of change in the Pretoria areas could be detected by all the sensors from Spot5. It has to be kept in mind that this study has been done in a metropolitan area with clear urban structures, which is easier to identify and recognise, compared to rural settlement patterns. It is however expected not to be the case in all urban areas and patterns. Based on previous experience of similar mapping projects, this could be the case in some rural areas, where villages with low densities of small structures occur.

The classification of the change area according to the urban structural classes indicated that there is a differentiation on this factor between the Spot 5 sensors. Although some structures could be recognised and identified from all the sensors, it was not possible to classify all structures. Spot 5 Colour (10m) and Panchromatic (5m) could classify all the classes except the low cost housing and informal settlements, which are classes of dense, but very small houses. The Spot 5 merge of Colour (10m) and Panchromatic (5m), Colour (10m) merge with supermode (2.5m) and supermode (2,5m) could clearly classify all classes.

The final stage to perform building counts in order to quantify urban growth indicated that only Spot Colour (10m) merge with supermode (2.5m) and supermode (2,5m) could distinguish buildings in all structural classes, except low cost housing and informal settlements. This result has created new potential to reduce cost and time of Census Cartography as performed in preparation for Population and Housing Census surveys. It is now possible to use only one set of imagery to perform three procedures, while previously it required two or three data sets and the same amount of workflow

Spot 5 regular updates which allow an annual recording of specific metropolitan areas, adds the ability to generate historical records of spatial patterns and growth occurring around the metropolitan perimetre. Information on previous years can be useful to analyse growth patterns and serve as a base for future modelling.

4. CONCLUSION

The possibility to reduce the amount of image data sets from potentially two to only one, as well as the subsequent reduction in manpower required for processing and mapping creates the following advantages for Census Cartography:

- Only one set of imagery as input to the census cartography process
- Only one workflow procedure to perform with less cost and manpower
- Closer date of acquisition to census date
- Uniform image coverage for areas where population are concentrated
- Building counts opens potential for inter-census updates

The potential to adapt this model to other parts of the world creates the potential to apply this approach to any region with rapid urban growth patterns.

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