APPLICATION OF IMAGE PROCESSING AND IMAGE ANALYSIS METHODS FOR LARGE SCALE MAP REVISION

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ABSTRACT:

The aim of this study is to use different image analysis and processing methods in order to extract information content needed to update large scale maps. Recently available high resolution satellite imagery attracted mapping communities to shift their focus from aerial photographs to satellite imagery. Obviously, this new source of information requires different methods and algorithms to extract needed information for map revision. The purpose of this paper, therefore, is to examine reliability of image analysis methods to extract fine groups of classes required to update large scale maps. Data used include Ikonos and QuickBird images of the study area together with aerial photographs and digital maps of the same region.

1. INTRODUCTION

Maps are date stamped evidences of a locality preserving the state of earth’s surface in their production time. Mapping the earth’s surface, resources and ecosystems is an invaluable source of knowledge about the past and present state of our planet. Mapping is termed as “Land literacy” and a source of information for “Traditional use studies” and “Hazards management” (McCall, 2003). Maps are prepared based on the current state of the areas of interest; however, as far as we know, the surface of the earth does not remain intact and goes under changes over time. The rate of change in urban areas, which is our focus in this study, is faster than natural landscapes. In order to preserve the validity of the maps, they need to be updated in a specified time intervals and new changes should be included.

The information we need for the revision process is a vital scrap in the whole map updating procedure. Depending on the magnitude of the revision project and the extent and nature of the area covered by maps to be updated, revision process can vary extensively. In general, funding and time constraints are major concerns which make us to find more efficient and less time consuming methods to acquire essential data and accomplish revision in the least time. As a result, finding the most efficient source of information with the least cost and time involved has been always desirable for mapping communities.

Traditionally, the information required for the revision was collected through land surveying. Aerial and space imaging systems revolutionized land surface data acquisition. Aerial photography offered great help for mapping community, although became available only after the advent of airplanes. Yet it had its own difficulties; stitching many number of photographs each of which had been collected in different interior and exterior orientation of the whole imaging system were a tedious task. With parallel developments in space and imaging technologies, satellite remote sensing was evolved. Satellite systems, on the other hand, are more systematic and cover larger tracks compared to aerial photographs. Even in terms of high resolution satellite imaging systems (such as Ikonos and QuickBird), dimensions of the images are considerably larger than any high resolution aerial imaging system. Moreover, remote sensing images, by and large, cover vast areas with a standard pixel size, making further image processing tasks even more straightforward.

In view of the qualities mentioned above, this paper examines potentials of remote sensing images for map revision, putting greater emphasis on spectral methods. It is attempted to estimate the efficiency of image processing and analysis methods in the revision of large scale maps.

2. BACKGROUND

Map revision is one of critical discussions for the mapping, photogrammetry and remote sensing researchers and enjoys a rich literature. We have used a number of these researches in this study as a background and as a source of technical help and methodology. Below, a number of these works are introduced.

Patynen (1998) has described revision process of 1:5000, 1:10000 and 1:20000 scale Finish Topographic DataBase (TDB) with digital methods. He has noted that time intervals to update 1:20000 maps had been specified in 10-20 years but in populated areas where changes are more rapid, this has reduced to 5-10 years. He has outlined that some major facilities like roads, power lines and administrative structure need continuous updating (every year). He has explained the whole process of scanning, geometric registration and ortho-photo creation and object extraction methods for TDB updating process.

Di et al. (2003), Croitoru et al. (2004) and Hu et al. (2004) have extensively analyzed geometric correction and sensor modeling using rational functions. They have provided a good knowledge about rational functions and rigorous and non-rigorous sensor modeling. Origins of rational functions and their calculation formulas together with rational polynomial coefficients (known as RPCs), which has been used by satellite vendors like Ikonos to offer sensor modeling parameters, have been fully detailed.

Yi-jin and Xiao-wen (2004) have presented satellite image analysis for map revision. They have underlined utilization of knowledge derived from existing GIS database as a priori knowledge in image classification process. They have used cartographic semantics to extract objects from images based on geometry and topology rules. Finding the difference between image and vector map, new geographic features and the changed features are detected. Depending on the results, the map is updated.

Sahin et al. (2004) have analyzed automatic and manual feature extraction from KVR-1000 aerial images for the revision of 1:5000 to 1:25000 scale maps and Zhou et al. (2005) have analyzed semi-automatic map revision through human-computer interaction as a faster and more reliable method. Sahin et al. have stated that buildings, roads, water structures and forest classes can be extracted by automatic methods and the remaining object classes for the mentioned maps can be extracted by manual methods. Using GCPs[*] collected for the study area, they have analyzed geometric accuracy of the KVR-1000 ortho-images. Afterwards, they have used manual and object oriented information extraction methods to extract needed object classes from the images.

3. TEST DATA AND STUDY AREA

The input data comprised a recently acquired QuickBird scene and an Ikonos image frame together with aerial photographs and digital maps, all covering the same area. The scales of digital maps were 1:2000 and 1:5000 over the whole area. The Ikonos image was the primary source of information for the analyses and the QB scene, which only partially covered the study area, was used for error checking and the interpretation of features which were not sufficiently discernible in the Ikonos image. Aerial photographs also were used as supplementary information to improve the accuracy of decisions based on image analysis processes.

4. GEOMETRIC CORRECTION AND IMAGE FUSION

Map revision involves data sources from various entities including vector layers, scanned data, aerial photographs and satellite imagery. In order to establish maximum geometric compatibility, all of the mentioned data sources should be geocoded and projected in a common coordinate system. The old maps aimed to be updated had a good geometric accuracy and the maximum compatibility between different layers of the common areas and the adjacent sheets in the edges. Accordingly, we used these maps as reference vectors to rectify other data mentioned above. With the help of different geometric correction models, specifically polynomial and rational functions, aerial photographs and satellite imagery were geocoded and projected in UTM[**] coordinate system. Later on, corrected images made ready for further processing and analysis.

In order to exploit the maximum capabilities of the images, we needed to extract pan-sharpened products. Results of multiplicative, IHS, PCA and wavelet image fusion methods were analyzed to obtain suitable pan-sharpened product according to specific needs of map revision. Quality of the results of different image fusion methods were assessed through visual interpretation. Multiplicative and wavelet methods kept spectral richness of the original multi-spectral images better than IHS and PCA methods, at the same time, the two last methods were better in keeping spatial precision of the panchromatic band. After that, smaller objects were extracted from the pan-sharpened image. From the visual point of view, pan-sharpened images acquired from PCA and IHS methods proved more useful for detection of boundaries of fine objects. Pan-sharpened images produced by multiplicative and wavelet fusion methods were exploited in automatic classification procedures.

5. OBJECT EXTRACTION

5.1 Preprocessing

There were diverse groups of surface cover types in the area, so we needed to analyze the image in smaller parts for easier processing and interpretation. For the same reason, prior to the analysis of the images, a grid with cells of 1000x1000 meter dimensions was constructed. With respect to the cell-size of Ikonos panchromatic band (which is one meter), each cell of the grid covered tracks of 1000x1000 pixels of the image. These image tracks were clipped with the overlying grid cells. In some cases, four or nine neighboring cells merged to clip the image in bigger parts. We have used Erdas Imagine, IDRISI, eCognition and ArcGIS in this project.

5.2 Visual Feature Extraction

Different image analysis methods like Principal Components Analysis (PCA), image ratios and different band combinations were employed in the visual interpretation. Color composites of principal component images offered greater help in the extraction of some object classes like buildings. These composites had better contrast in some areas which in the original image were not so easy to detect and distinguish the differences. Ratio images produced by NDVI and WI indices were useful to extract groups of classes like vegetation and wet (and shadow) areas. Each of these groups of classes was extracted separately. Color combinations of the Ikonos image were also a great help in the visual interpretation process. The QuickBird color composite with 2.5x2.5 meter pixels were a supplementary aid in judgement of some indistinct features.

5.3 Automatic Classification

Supervised and unsupervised image classification methods were applied using MS and pan-sharpened images. For the supervised method, training samples were selected through interactive visual on-screen inspection. These training sites were selected using Erdas Imagine Classifier and Viewer solutions. We should have selected training sites for each track of the image and for each of the MS and pan-sharpened images. Digital maps and aerial photographs also used for better recognition of training sites. Afterward, we produced the final classified image using training sites (Fig. 1). After running Imagine Classifier module with 10 output classes, signature files were edited using Signature Editor (Leica Geosystems, 2003). A special color was set for the signature of each of the output classes for better contrast and their plots were compared (Fig. 2). Signatures with high correlation were merged considering them as different color hues of the same major classes (such as vegetation). Once final signatures were decided and a unique color specified for each signature, setting were saved in the signature files. The edited signature files then used in the second phase of unsupervised classification. The resulting classified images then overlaid on the original MS and pan-sharpened images in

[*] Ground Control Points
[**] Universal Transverse Mercator

ArcMap for interpretation and class labeling. Objects relating to each signature were identified in the second-unsupervised classified image and the classes were labeled through various image interpretation techniques. Subsequently, final signatures were used as the input signature file in a supervised classification procedure to extract a semi-supervised classified image (Fig. 3). Erdas Imagine Accuracy Assessment function used for the analysis of the results of supervised and unsupervised methods. For this matter, control points were selected with fair distribution over the image and their identity were recognized using all image data and vector maps. For each clip of the image, at least 20 control points were used; bearing in mind to choose at least one control point for each of the object classes. These control point then were used in the accuracy assessment process. We repeated accuracy assessment procedure for all the classification results of MS and pan-sharpened images. In aggregate, the accuracies of unsupervised and supervised methods in Kappa index were calculated about 0.8 and 0.9, respectively. Although the accuracy of the supervised method is better than the unsupervised one, there were larger areas in the supervised results which were assigned as unclassified due to the lack of comprehensive training signatures.

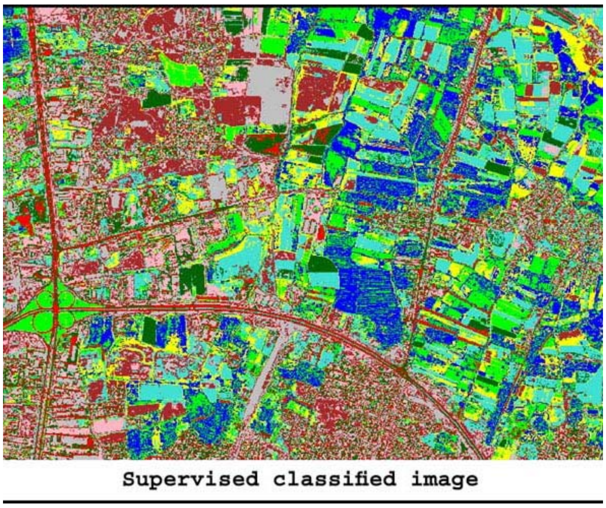

Figure 1. Supervised classified image

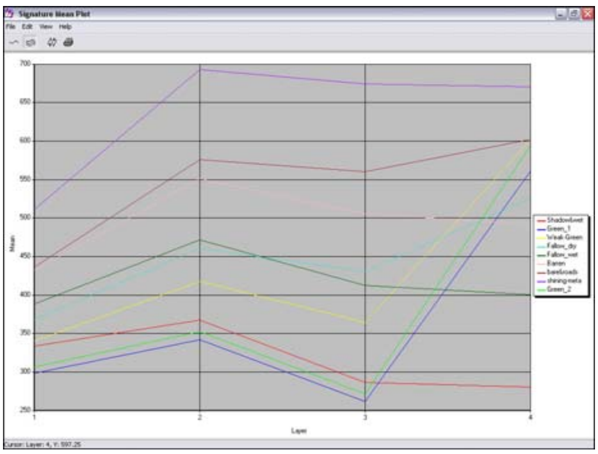

Figure 2. Signature plot of unsupervised classified image

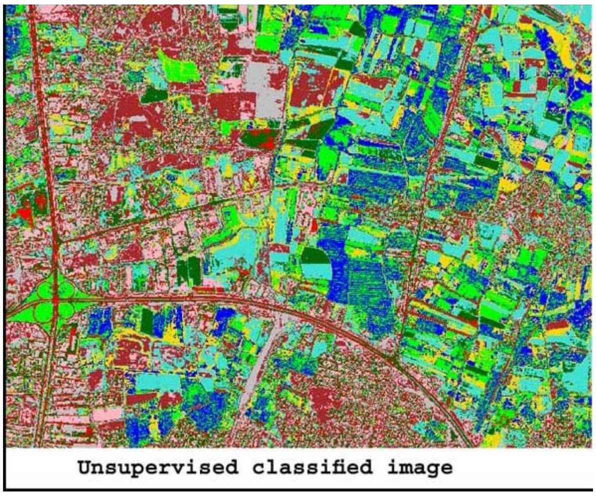

Figure 3. Unsupervised (semi-supervised) classified image

It becomes obvious that any classifier requiring high training accuracy may not achieve good generalization capability (Ng et al, 2007). That is the reason we have larger unclassified areas in the supervised method's results.

5.4 Fuzzy Object Extraction

For the fuzzy object extraction method, we produced files of training sites for all tracks of the image. In order to minimize redundant differences in homogeneous areas of the image, a segmentation function by eCognition software applied on the image tracks. After segmentation, training sites were used to define object classes. At first, parent classes labeled, then, different classes in each parent class were defined. At last, all of image tracks were classified and converted to polygon vector layers (Fig. 4). In some cases, there were many pixel sized polygons in the extracted vector layers. To minimize the number of small polygons, classification process repeated from the segmentation step down to vectorization phase. As the last method of image information extraction, Neural Network classification implemented with the help of IDRISI. For this method, training sites defined in IDRISI and the tags of related object classes were assigned. The classification process repeated with 1000 iteration to achieve the least RMS error.

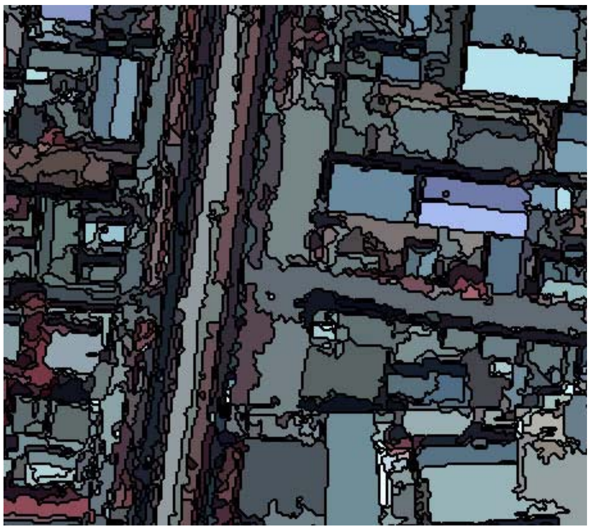

Figure 4. Fuzzy classified image using eConition

6. CHANGE DETECTION AND MAP REVISION

All of the results of the object extraction methods converted to vector layers. Images and aerial photographs together with extracted vector layers and old maps imported to a geodatabase in ArcGIS. Images saved in a raster catalog while vector layers saved in feature datasets. Both raster catalogs and feature datasets assigned the same coordinate system. All of the images and vector layers added in an ArcMap project to track changes. Two methods of change detection were used, comparison of the old and new extracted maps and comparison of the old maps with the recent images and aerial photographs. Images overlaid with aerial photographs and old digital maps. We examined those parts of the image where changes relative to the old maps had been occurred. Several kinds of changes were evident, some existing buildings had been vanished and some new ones had been constructed. In the city marginal areas, agricultural lands had been withdrawn in favor of man-made constructions. All of these changes manually digitized and saved in a dataset (named “Changes”) in the project geodatabase. In the second part of change detection process, the old maps overlaid with the new extracted maps. In this stage, different GIS methods were used to detect areas where changes had been occurred. Changed areas in the new maps were selected and exported as new layers and saved in the geodatabase (in the “Changes” dataset). At last, change layers merged together and converted to one layer. With the previous mentioned method, the change layer overlaid on the image to find those parts where editions were necessary. The final changes layer then overlaid on the old maps layer. Changed parts of the old maps and vanished features detected and newly constructed features added in an edition procedure. A new dataset called “Updated_Layers” created and each of the revised layers of the old maps imported to it. Labels and attributes of the newly added features inserted to each layer’s attribute table. All of the revised layers then added to map sessions according to the old maps indices to create new updated maps of the project.

7. CONCLUSION

In this study, we utilized different image fusion and object extraction methods to derive maximum information from high resolution satellite images and explained the process of using the extracted information for map revision. Comparison of the image fusion methods discussed in this study, multiplicative and wavelet methods were better in keeping spectral information, hence were good in terms of preserving color properties of the objects. IHS and PCA methods were better in keeping spatial details of the objects; however, IHS method was good enough in keeping spectral information as well. In sum, we concluded that IHS method is better owing to its fairly keeping both spectral and spatial information. Ikonos and QB MS images and the pan and pan-sharpened product of the Ikonos were used to extract different object classes. Multispectral images mainly employed in unsupervised and supervised classification while pan-sharpened product was a major help to extract smaller objects. Pan-sharpened image produced by PCA and IHS methods were very useful for detection of the boundaries of the objects in visual interpretation method. Pan-sharpened image produced by multiplicative and wavelet fusion methods utilized in automatic classification procedures due to their better performance in keeping spectral information. Results from automatic clustering methods and fuzzy classification needed more manual editing and visual inspection after vectorziation, even though they cost less time comparing to visual interpretation. Vectors extracted from classification methods were used for the revision procedure only after visual inspection and edition.

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