COMBINING SUPERVISED CLASSIFICATION AND AIRPHOTO INTERPRETATION OF HIGH SPATIAL RESOLUTION SATELLITE IMAGERY FOR LAND USE ANALYSIS

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ABSTRACT: This study combines methods of supervised classification and aerial photo interpretation for land use analysis using high spatial resolution satellite imagery. A multi-spectral IKONOS image with four-meter spatial resolution in Beijing, China was used to conduct the study. Simplified Land-Based Classification Standards (LBCS) by the American Planning Association (APA) was applied to formulate the classification scheme. The spatial distribution of the land use categories was extracted from the imagery using conventional, fuzzy logic, and single category targeted classifications in the Idrisi remote sensing system. An aerial photo interpretation method was incorporated with the supervised classifications to minimize the error identification and uncertainty classes. The results suggest that the combined approach can both help in eliminating the uncertainty classes of imagery classification and enhance the production speed of land use mapping in large areas using high spatial resolution images. The results also indicate that commercial and residential buildings of both low-rise and high-rise increase sporadically from the center to outskirts in downtown Beijing.

INTRODUCTION

Thematic information extraction of spatial objects on the Earth's surface in remote sensing can be accomplished by applying either supervised classification (Jensen, 1978; Mather, 1985; Mausel et al., 1990; Wang, 1990) or unsupervised classification (Richards, 1986; Skidmore, 1989; Jahne, 1991; Rigbot, 1994) of imagery pixels. Supervised classification identifies the spectral signature(s) of the expected land use or land cover classes first. Then, a procedure is used to evaluate the likelihood that each of the image pixels belongs to which of the identified classes. Unsupervised classification, by contrast, classifies the distinctive reflectance patterns on the imagery first. It then correlates each class with real world land use features. The supervised classification is thus a decision making process based upon available information, while, unsupervised classification is actually a process of segmentation of the image (Eastman, 1999). Uncertainty imagery classification exists in both of these two approaches because they largely rely on spectral classifications by computer systems (Congation, 1988; Wang, 1990; Sharma and Sarker, 1998). Meanwhile, aerial photograph interpretation and photogrammetry have long been applied for extracting thematic data in high spatial resolution aerial photos. Visual aerial photograph interpretation is largely based on human examination of images for the purpose of identifying spatial objects (Philipson, 1997; Jensen, 2000). This study combines methods of both supervised classification and aerial photo interpretation for land use analysis using high-spatial-resolution imagery. This approach can help to eliminate the uncertainty classes in the imagery classification on one hand. On the other hand, it can classify large areas using a large quantity of image data automatically. Vector-based GIS mapping and map layer overlay were applied in this study to combine the information extracted.

Advancement of the sensors of space remote sensing increased the interpretation capability of satellite images. The IKONOS satellite that was

launched in 1999 generates panchromatic images with one-meter spatial resolution, and multi-spectral images with four-meter spatial resolution (Space Imaging, 1999). These spatial resolutions are similar to that of aerial photographs. One multi-spectral IKONOS image in downtown Beijing, China was used to conduct detailed land use classification in this study. It is a true color image with three visible bands namely blue, green, and red. The image was collected in October 20, 1999. It covers one square kilometer on the ground (Figure 1).

METHODS AND APPROACHES

The land use classification scheme applied in this study was modified from the Land-Based Classification Standards (LBCS) developed by the American Planning Association (APA, 1999). Land-Based Classification Standards provide a consistent model for classifying land use types based on their characteristics. Various land use classification systems have been published for different kinds of applications (Hardy et al., 1971; Erie County Department of Environment and Planning, 1997; etc.). However, the common difficulty of these

schemes are: 1) lack of a comprehensive inventory of land use types, land cover types, and other common land-based information terms; 2) lack of standards for sharing land-based information and data between land use applications (Jeer, 1997). The LBCS is one of the land use classification systems that provides comprehensive schemes and flexibility of sharing information across different disciplines. The LBCS is a multi-dimensional land use classification scheme that comprises five dimensions. These are: activity, function, structure, site development characteristics, and ownership. Land use types are organized with a particular set of characteristics in each of the dimensions. For example, activity refers to the actual use of land based on its observable characteristics, such as farming, shopping, vehicular movement, etc. Structure refers to the type of structure or building on the land, such as single-family house, office building, highway, etc. The land use classification scheme of this study was simplified from the structural dimension of the LBCS system (APA, 1999) and it is shown in Table 1.

The IKONOS image was first imported into the Idrisi remote sensing and image processing system. It was then transposed counter-clockwise by 90-degrees to align with standard map orientation where the upper edge is the north. Three visible
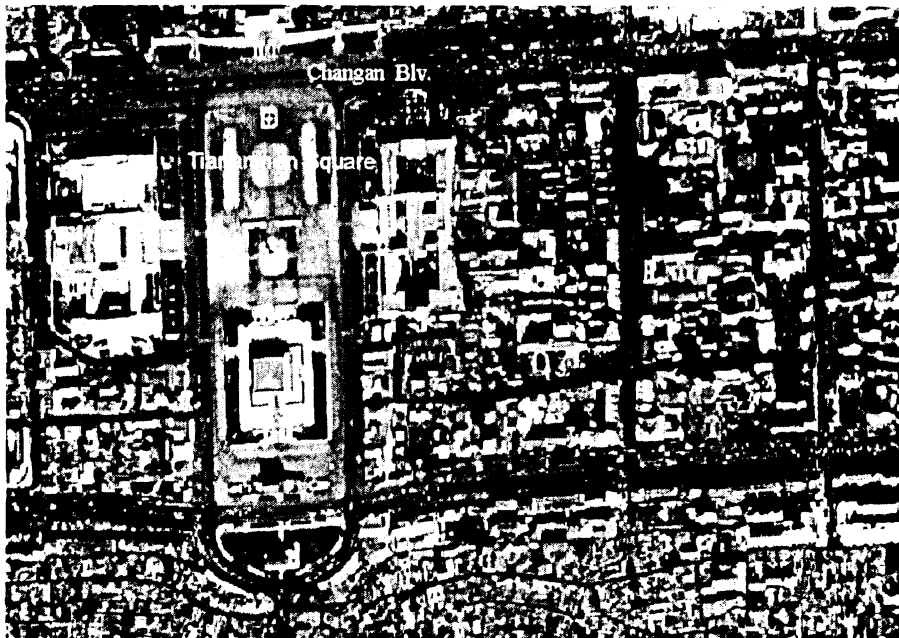

Figure 1. Sample of Ikonos satellite imagery of downtown Beijing, China

Table 1. Land Use Classification Scheme Simplified from LBCS of APA

LBCS Code	Land Use Description	Acronym
1100	Single Story Residential	SSR
1250	Multifamily Low Rise Residential	MLRR
1290	Multifamily High Rise Residential	MHRR
2150	Commercial – Office, Bank, Store, or Shop Building	OBSSB
2650	Industrial	IDST
4440	Parks and Historical	PH
5130	Highway and Street	HS
5700	Railroad Facility	RF

bands of the multi-spectral image were separated. These are: blue (0.42-0.51 μm), green (0.52-0.60 μm), and red (0.63-0.69 μm). Vector themes of training sites were developed for each of the bands according to the classification scheme established and the information from field investigation. The appropriate themes of training sites were then overlayed on each of the three bands of the multi-spectral image to develop electromagnetic reflectance signatures.

Supervised classification was conducted for the three bands of the multi-spectral image using the hard classifier of Minimum Distance to Means (MINDIST). The hard classifier in Idrisi represents the conventional classification method that yields definite classification of a pixel into a particular category. By contrast, the soft classifier only determines the degree to which a pixel belongs to a particular class (Eastman, 1999). The result of supervised classification is shown in Figure 2. The classification, in general, extracted different categories of land use across the study area. However, uncertainty classes and inaccurate identifications exist. An error assessment in Idrisi is shown in Table 2. The errors of commission in this study indicate where locations mapped as a particular category that was found to be truly something else. The values expressed in Table 2 are the proportions of sampled error occurrence on 90 percent confidential interval. Examining the results visually (Figure 2), some public and historical (PH) land uses, such as part of the Tiananmen Square were classified as Single Story Residential (SSR) in this case. Patches of pixels in the residential or commercial areas were classified as highways and streets (HS), although streets in general were very well identified. Some pixels of streets were also identified as parks and historical land use (PH).

The supervised fuzzy logic classification in Idrisi was also applied in this study attempting to reduce inaccurate identifications. Fuzzy logic is a mathematical theory that was proposed in 1965 and was developed in the 1980s and 1990s to improve the relationship between humanity and computer systems (Terano et al., 1992). The objective of developing fuzzy set theory is to combine human and computer capabilities together. Fuzzy set theory provides useful concepts and tools in dealing with imprecise information in remote sensing data. It was applied to incorporate with supervised classifications recently (Wang, 1990; Eastman, 1999). Fuzzy signature files were developed for each of the categories. This was accomplished using the "soft-classifier" of FUCLASS. The soft-classifier is different from the conventional hard-classifier in two ways: (1) each pixel is judged by a degree or probability to a particular category; (2) the classification expresses the degree of membership (between 0 and 1) of pixels to the classified sets according the selected classification method.

Classification accuracy was improved for some categories using supervised fuzzy logic classification, while that of others was reduced. Inaccurate identifications and uncertainty of multifamily low rise residential (MLRR), and parks

Table 2. The Errors of Commission of Supervised Classification

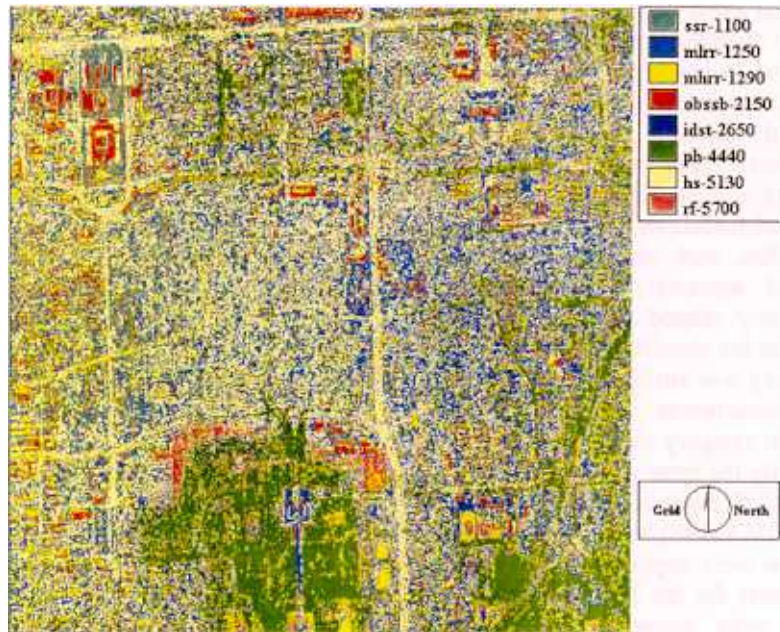| Land Use Category	Error
SSR	0.819
MLRR	0.764
MHRR	0.682
OBSSB	0.377
IDST	0.811
PH	0.561
HS	0.632
RF	0.695

Figure 2. Supervised classification of land use in downtown Beijing, China
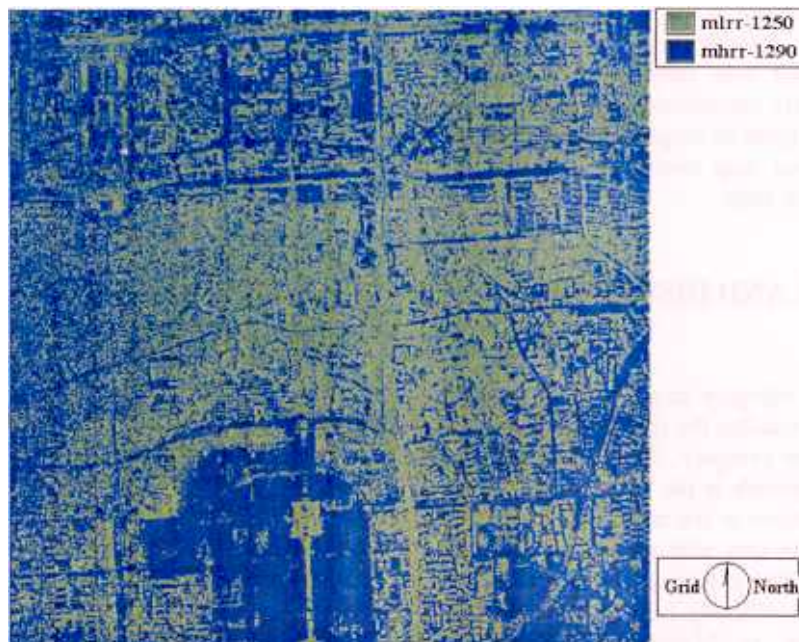

Figure 3. Example of single category targeted classification analysis

and historical land use (PH) in the study area were reduced, while, the error identification of pixels of single story residential (SSR) and streets (HS) was increased. Inaccurate classifications still exist using the fuzzy logic method, in particular when the entire classification scheme was processed.

A combined approach of aerial photo interpretation, supervised fuzzy logic classifications, and map layer overlay applying GIS was adopted to reduce the outcome of inaccurate identification and uncertainty classes. First, each category of land use types was classified separately against another category that is closely related to it in terms of reflectance signature in the classification regime. The target land use category was attributed as 60 percent in probability of occurrences and that of the uncertainty production category as 40 percent in the classification to identify the error patterns. Secondly, both the land use classification of all the categories using fussy logic (FUZCLASS) and single category targeted classifications were exported into ArcView GIS as reference themes for the land use mapping. The raster images were converted into vector database format. Thirdly, aerial photo interpretation was conducted on the original imagery to identify the land use category where error identification and uncertainty class occurred in the fuzzy logic or single category targeted classifications. Aerial photo interpretation method was only used for quality control of the land use identifications in this process. Finally, the vector layers of single land use category were combined using map overlay to produce the land use classification map.

RESULTS AND DISCUSSION

The single category targeted classifications were performed to visualize the spatial distribution of a particular land use category. The paired-category selected for this approach is the one that makes the most error identifications to the target category. Or in other words, it is the one with closest signature of reflectance to the target category. For example, the target category of Multifamily Low Rise Residential (MLRR) contrasting to Multifamily High Rise Residential (MHRR) is shown in Figure 3. The result shows the distributions of the MLRR and MHRR

Table 3. The Errors of Commission of Single Category Targeted Classification

Land Use Category	Error
SSR	0.241
MLRR	0.058
MHRR	0.511
OBSSB	0.537
IDST	0.267
PH	0.244
HS	0.269
RF	0.441

across the study area. The MLRRs are mainly distributed in the central areas south of the Tiananmen Square and the Changan Boulevard, while the MHRR tends to occupy the outskirts of the study area. The identification accuracy was drastically increased using supervised fuzzy logic classification to identify each of individual categories (Table 3).

Aerial photo interpretation of uncertainty classes and translation of land use polygons from raster format to vector format in Idrisi and ArcView GIS were conducted for each of the categories. The eight layers of different land use identified were then combined into one theme using map overlay in ArcView GIS. Error identification and uncertainty classes were thus minimized from the original outcomes of supervised classifications. The result of combined approach is shown in Figure 4. The results of land use classification indicated that the commercial land use of office buildings, banks, and shopping centers either cluster along the major streets and avenues or concentrated in the north part of the study area, particularly along the Changan Boulevard. Residential, commercial, and industrial land uses are well mixed in downtown Beijing. Single story traditional houses (SSR) and low-rise multifamily buildings (MLRR) mainly occupy the center of the study area south of the Tiananmen Square. High rise residential buildings (MHRR) gradually increase from the center outward in the study area in Beijing.

The objective of the single category targeted classification is to identify spatial distribution of inaccurate classification and uncertainty of one category by supervised image classifications. The
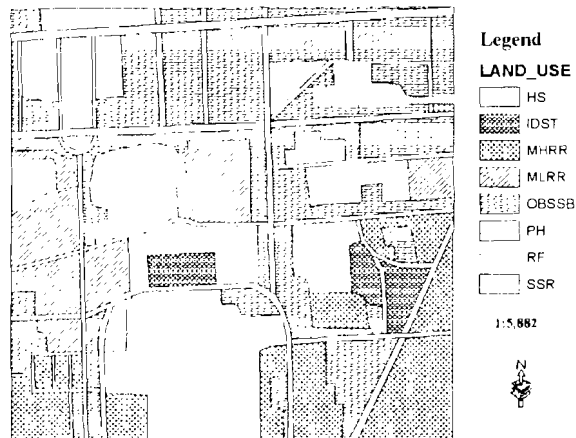
Figure 4. Land use classification by combined approaches in down town Beijing, China

mean error of commission in conventional supervised classification of this study is 0.668, and that of the fuzzy logic classification is 0.678. By contrast, the mean error of commission in single category targeted classifications is 0.321. The results indicate that the accuracy of feature identification increased drastically from multi-category classifications to the single category targeted classifications. The results of this study also suggest that the combined approach of computer intelligence based and human intelligence based classifications can enhance both accuracy and production speed of land use mapping in large areas using high spatial resolution satellite images.

Studies of land use and urban sprawl in Beijing (Gaubatz, 1995; Chen et al., 2000) indicated that the built-up area was increased by about 39 percent during the period from 1987 through 1994. The green space or recreation areas in Beijing were also increased by 8.6 percent from 1987 to 1994 (Chen et al., 2000). Previous research (Huus, 1994; Gaubatz, 1995; USGS EROS Data Center, 1999) identified distinctive spatial patterns of land use between Beijing and typical U.S. cities. Most U.S. cities, such as New York City, are often shaped like a circus tent, with a sharp peak of skyscrapers in the center, sloping off to mid-rise buildings and then low suburbs of single-family houses. By contrast, Beijing is bowl-shaped, with low-rise historical buildings in the center that are surrounded by commercial skyscrapers and residential towers. The results of this study indicate that commercial and residential buildings of both low-rise and high-rise increases sporadically from downtown out, while the bowl-shaped pattern does exist.

ACKNOWLEDGEMENTS

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