Urban Land Use and Land Cover Classification through an Object-Oriented Approach

Mike Lackner - Dept. of Geography University of Toronto at Mississauga

3359 Mississauga Road North
South Building Rm. 3093A
Mississauga, ON L5L 1C6
TEL: (905) 828-3868
FAX: (905) 828-5273
EMAIL: mike.lackner@utoronto.ca

Abstract

With the greater availability of high-resolution imagery and the fairly recent advances of object-oriented analysis in remote sensing, classification of urban areas can be more detailed than ever before without any need for field work. However, classifying land cover and land use in an urban area is still very difficult due to the complexity of an urban landscape and the immense numbers of parameters that need to be considered. Whereas most traditional classification techniques in remote sensing rely on spectral characteristics of the imagery pixel-by-pixel, object-oriented approaches group similar pixels together into image objects. Textural and shape characteristics of these image objects then offer ways to define land cover and land use that are not available through traditional pixel-by-pixel methods.
This project looks at one object-oriented approach of classifying an urban area, using multispectral Ikonos imagery and ancillary data. First, a detailed land cover map is produced through image segmentation of Ikonos imagery at different spatial scales. Spectral, textural, and shape characteristics are included to provide information that helps to define the image objects. Second, spatial relations of the objects are examined to create a land use classification, based on the widely used classification scheme developed by Anderson et al. (1976).
Challenges regarding the classification of certain land uses and covers that are more difficult to distinguish will be discussed in light of the accuracy assessment at a later stage in this project.

Introduction

Object-oriented vs. Pixel-based Classification

Object-oriented image classification has an advantage over traditional pixel-by-pixel classification because it does not produce the salt-and-pepper effect (figure 1) that usually results from a pixel-by-pixel classification, particularly with high-resolution imagery (Blaschke and Strobl 2004, Frauman and Wolff 2005). The major differences between the two methods are as following:

Object-oriented
- Features such as trees or buildings are treated as single objects.
- Shape, texture, and contextual information help in addition to the spectral values.
- Image objects can be extracted more easily and classified more effectively.

Pixel-based
- Features are comprised of many pixels with different spectral values.
- The method only uses spectral values for the classification.
- Extracting features is difficult and yields a salt-and-pepper effect.

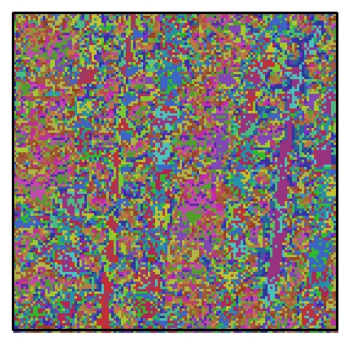
Figure 1: Unsupervised (30 clusters).

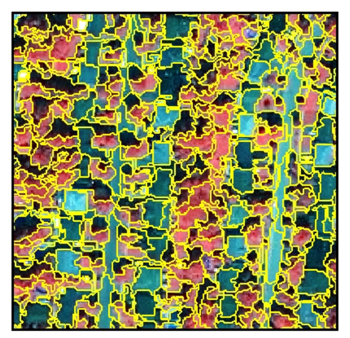
Figure 2: Segmented Image.


Figure 3: Ikonos Image (false-color infrared).

Classification Scheme

The classification scheme for urban and built-up land as described by Anderson et al. (1976) (table 1) builds the foundation for the land cover and land use classification used in this project. The land cover classes are designed hierarchically, so that they can be aggregated into more general classes. This also allows for them to be used as the building blocks for the land use classification, which is based on the contextual distribution of the land-cover classes. The land use classification is only slightly modified from Anderson et al. (1976) in order to distinguish certain classes more efficiently. The classification schemes that are used for this project are explained in more detail in the methodology section.

Table 1: Classification for urban areas, according to Anderson et al. (1976).

Level I	Level II
1 Urban or Built-up Land	11 Residential
	12 Commercial and Services
	13 Industrial
	14 Transportation, Communication, and Utilities
	15 Industrial and Commercial Complexes
	16 Mixed Urban or Built-up Land
	17 Other Urban or Built-up Land

Data and Study Area

Ikonos imagery
- 1 meter spatial resolution.
- 4 spectral bands (red, green, blue, NIR).
- Acquired August 2003.

Study Area (Figure 4)
- Location: Western part of Mississauga, Ontario.
- Complex urban area with a variety of different land-cover and land-use categories.


Figure 4: Ikonos imagery of the study area (A); zoomed-in part (B).

Methodology

Creating Image Objects

The first step in an object-oriented image classification is the segmentation of the imagery. The multi-resolution segmentation algorithm in eCognition, the software used for this project, combines pixel groups based on their spectral values from the Ikonos imagery into homogeneous image objects (Definiens 2003). Several parameters needed to be considered for this step:

- Number of levels to be chosen.
- Emphasis on spectral or shape criteria on each level.
- Emphasis on "smoothness" or "compactness" within shape criterion.

Table 2 shows the parameters used to create these segmentation levels. Figure 5 shows levels 3, 5, and 7. In level 3, smaller landscape features are separated as individual image objects, so this level was used to extract smaller buildings and swimming pools. On the other hand, levels 5 and 7 group pixels into larger image objects. Therefore, they were used to extract larger buildings and large parking lots, respectively.

Table 2: Parameters for image segmentation on all levels.

Level	Scale Factor	Shape	Compactness	Smoothness
1	10	0.2	0.1	0.9
2	10	0.5	0.2	0.8
3	15	0.5	0.9	0.1
4	30	0.5	0.9	0.1
5	50	0.2	0.1	0.9
6	80	0.2	0.1	0.9
7	80	0.2	0.1	0.9

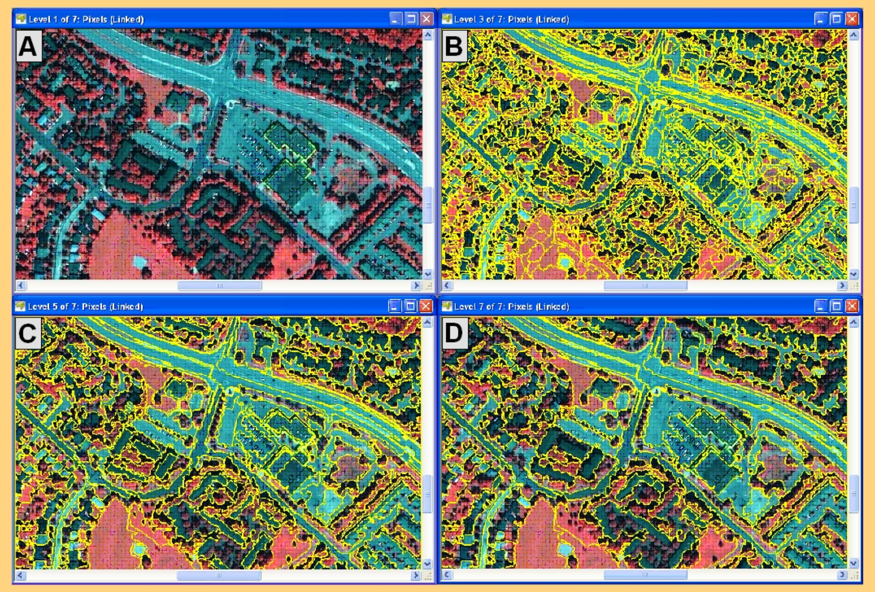
Figure 5: Original image (A) and segmentation levels 3, 5, and 7 (B, C, and D).

Land Cover Classification

The land cover classification was performed in three major steps:

1.) Level 2 was used to differentiate between vegetated and non-vegetated areas. This was accomplished by creating rules based on mean NDVI values and brightness values of the image objects in this level (figure 6). Figure 7 illustrates the result from this step.

2.) Rules were created for the other intermediate classes on levels 4 to 7, with the information from the vegetation classification already used. For example, the "rectangular fit" criterion, one of numerous shape criteria, was used to extract different sizes of rectangular buildings on several levels. Figure 8 shows a large building in level 6 as one single object, highlighted in blue. This building is separated into more than one image object on lower levels.

3.) All intermediate classes were combined on level 1, which contains the desired land cover classes, by creating rules based on the image objects in the other levels.

An ancillary roads data layer was used to extract smaller roads that were obscured by trees. Through refinement of the rules, the use of ancillary data will ideally be avoided in further work on this project.

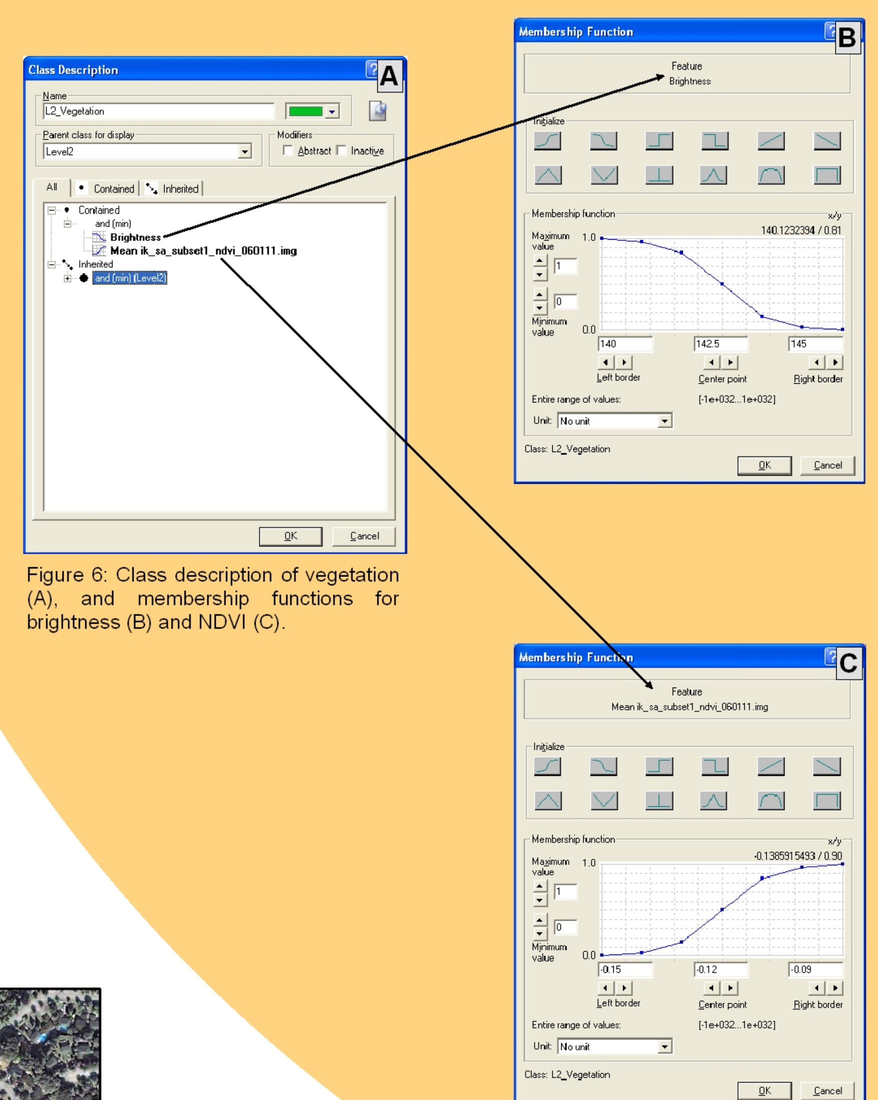
Figure 6: Class description of vegetation (A), and membership functions for brightness (B) and NDVI (C).

From Land Cover to Land Use

The challenge for doing a land use classification is finding meaningful objects through the image segmentation, so they can be categorized into the desired land-use classes. This was achieved through generalizing the land cover image by applying a filter to it and using this generalized image as the input for a very coarse segmentation. Figure 9 illustrates an example of a land-use polygon that was created, and figure 10 shows the corresponding values of land-cover classes within that polygon that were used to define it. However, the segmentation of the land-use polygons turned out to be problematic at times, as different land uses were grouped into one single polygon (figure 11). Improvements on how to better generate meaningful land-use polygons are presented in the Discussion and Conclusion section.

References:

Anderson, J. R., et al. 1976. "A Land Use And Land Cover Classification System For Use With Remote Sensor Data." U.S. Geological Survey. Professional Paper 964.

Blaschke, T. and Strobl, J. 2001. "What's Wrong With Pixels? Some Recent Developments Interfacing Remote Sensing and GIS." *GIS Zeitschrift Für Geoinformationssyteme.* Vol. 6, 12-17.

Definiens Imaging. 2004. eCognition User Guide 3. Munich, Germany: Definiens Imaging GmbH.

Frauman, E. and Wolff, E. 2005. "Segmentation of Very High Spatial Resolution Satellite Images in Urban Areas for Segments-Based Classification." *ISPRS WG VII/1 "Human Settlements and Impact Analysis"* (Conference Proceedings). Tempe, AZ, unpaginated.

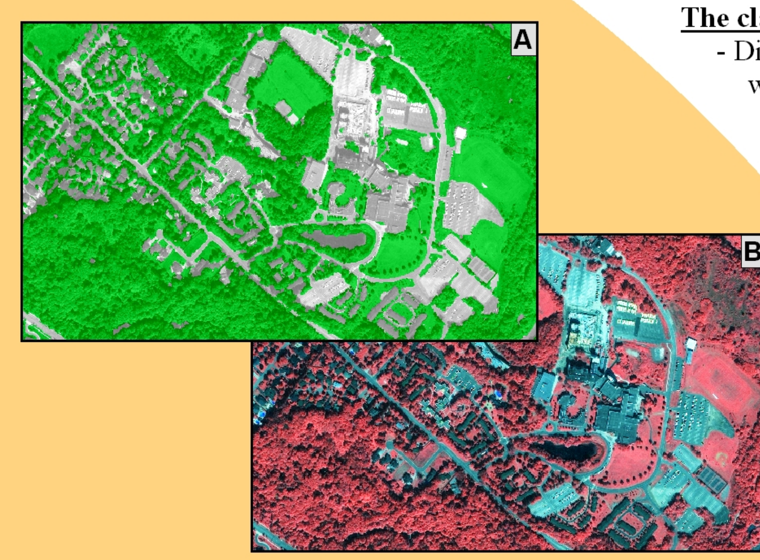
Figure 7: Vegetation is shown in green (A) as a result of the classification in level 2; the original Ikonos imagery is shown below (B).

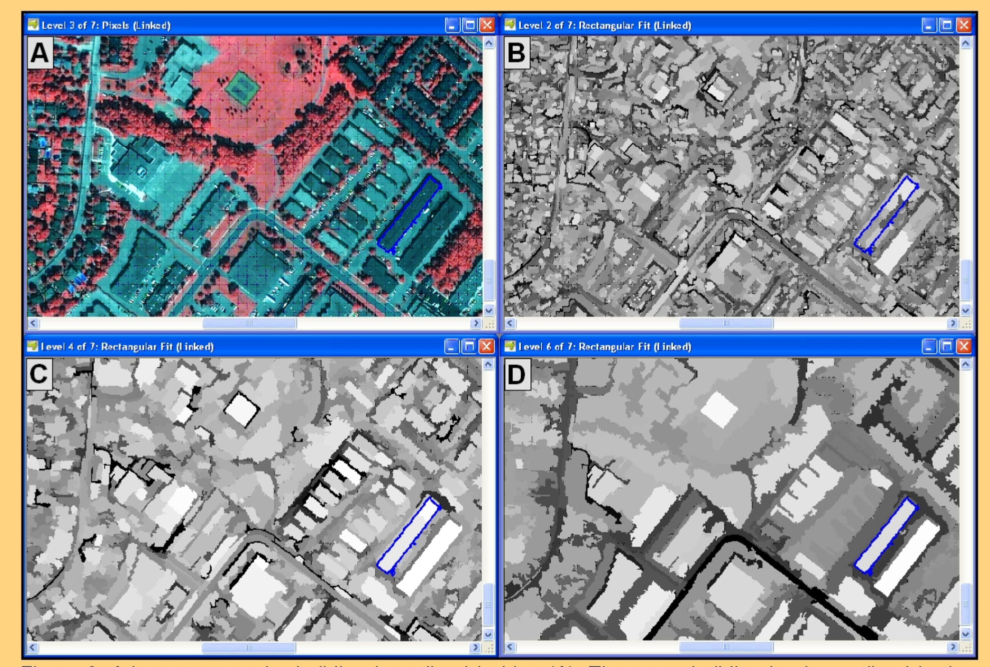
Figure 8: A large rectangular building is outlined in blue (A). The same building is also outlined in the rectangular-fit images (B, C, and D). The lighter the grey is, the more rectangular the image object. Only in level 6 (D) the building is represented by one single image object.

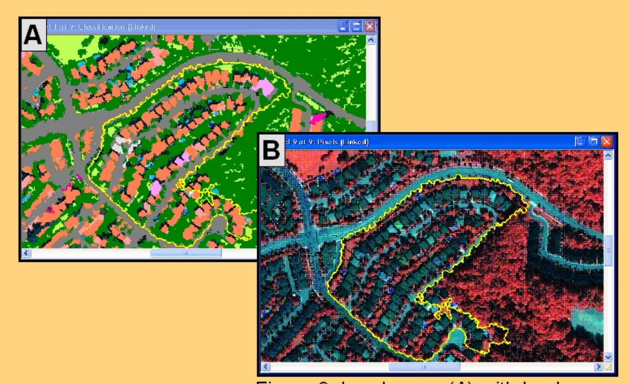
Figure 9: Land cover (A) with land-use polygon (yellow outline); original image (B). The legend for land cover is in figure 12.

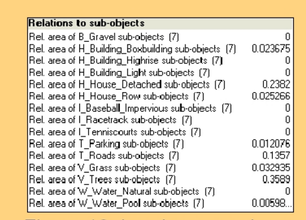
Figure 10: Land-cover values for polygon in figure 9.


Figure 11: Mixed land-use polygon.

Preliminary Results

Land Cover

The following list points out the main challenges of the land cover classification (Figure 12 A).

The object-oriented method worked well for:
- Delineation of major and minor roads even when obscured by trees.
- Classifying features such as tennis courts, baseball diamonds, and racetracks.

The classification can still be improved for:
- Distinguishing between large box-buildings and parking lots, which is where some confusion occurred (figure 12 C).
- Defining the outlines of high-rise buildings, using the spatial relation to their shadows and not confuse them with adjacent features, such as roads or parking lots.
- Distinguishing between row-buildings and detached houses.
- Distinction of building types in general. Based on the overlap in shape and size of different building types, this distinction was difficult (figures 12 B and C).
- Confusion between grass and trees appearing very bright in the imagery.

Based on visual assessment of the results, the object oriented approach seems promising for classifying land cover. A formal accuracy assessment will yield more statistically interpretable results.

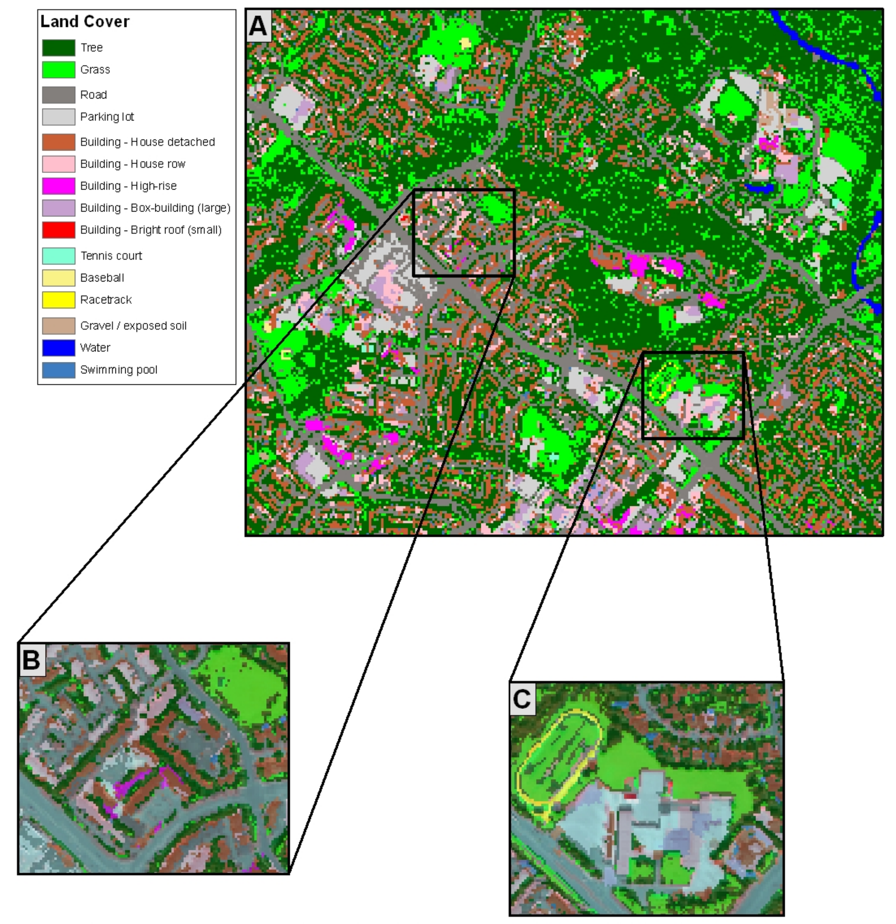

Figure 12: Land-cover classification (A) with two zoomed-in areas (B, C). The zoomed portions are semi-transparent with the original imagery underneath.

Land Use

The general methodology of classifying the land use (figure 13) seems to work, but several improvements still need to be made:

- Finding more meaningful polygons to which rules for a successful classification could be applied to avoid groupings of different land uses into one polygon, as seen with some of the transportation areas in figure 13.

- Grouping large grassy areas together with buildings that belong to schools and defining them as "Commercial and Services."

- Defining "Residential" and "Open vegetation / Undeveloped" worked better, but sometimes small areas at the edges of these categories were misclassified.

Figure 13: Land-use classification.

Discussion and Conclusion

Land Cover

Although the land cover classification generally worked well, several things can still be improved:

- Performing the classification without the roads data, using just the satellite imagery.

- Better defining high-rise buildings with regards to their shadows. Incorporating the direction of the shadows would possibly help.

- Using shadows to better distinguish parking lots and large box-buildings, such as shopping malls, large school buildings, or industrial buildings.

- Applying the methodology to a different area to determine how transferable the developed procedure is. Using a larger area for this will also show if the processing time for some of the segmentation and classification methods are within reasonable limits.

Land Use

Classifying the land use was definitely more challenging than the land cover. Several approaches could be explored to correct the current deficiencies:

- Extract features from the land cover, such as major roads, rivers, and edges of large vegetated areas and use them as land-use boundaries.

- Generalize either the land-cover classification or the original imagery in order to create homogenous land-use areas.

- Include spatial relations of the land-cover classes as well as their shape characteristics instead of just relying on their percentages within a land-use polygon.

Probably a combination of the above points will yield the best results for the land-use classification.