PER-FIELD CLASSIFICATION INTEGRATING VERY FINE SPATIAL RESOLUTION SATELLITE IMAGERY WITH TOPOGRAPHIC DATA.

Mauro CAPRIOLI, Eufemia TARANTINO

POLYTECHNIC UNIVERSITY OF BARI
Dept. of Highway and Transportation
Via Orabona 4, 70125 BARI – ITALY
Tel.: +39 080 5069387 – Fax: +39 080 5069209
E-mail: caprioli@dv005.poliba.it; tarantino@dv005.poliba.it

Keywords: Satellite Imagery • Topographic Data • GIS • Per-field Classification

ABSTRACT

The paper analyses an automated system for classifying land use on a locale scale, integrating Remote Sensing and GIS data, with the aim of extracting meaningful information in performing spatial analysis in urban contexts. As a first step, the basis around the central ‘urban/non urban’ dichotomy as manifest through physical form, although in practice finer segregations as well as measures of the intensity of human activities are also desirable. The informational classes of a thematic mapping are not directly registered, but must be derived indirectly by using evidence contained in the spectral data of an image. When we apply standard procedures of per-pixel multispectral classification the increase of spatial resolution leads to an increase in ambiguity in the statistical definition of image cover classes and a decrease of accuracy in automatic identification. This problem may be overcome by means of per-field classification techniques which involve analysing groups of pixels within land cover parcels. Such technique, based on the integration of remotely sensed imagery and digital vector data, has been used to generate land cover and land use information for more than a decade (Carbone, Narumalani and King, 1996; Ethers, Greenerie, Smith and Star, 1997; Hinton, 1997). Innovation and power of recent GIS platforms and analytic flexibility of Image Processing softwares make the integration of satellite data with numerical and scaled topographic data much more feasible, and this can lead to an increase in accuracy of the classification compared with the per-pixel technique, as well as improvements in interpretation of results with incorporating spatial variability and texture inherent in fine spatial resolution imagery.

This work investigates a per-field classification methodology, applied to an IKONOS multispectral image with spatial resolution of 4 m by utilising a digital large scale topographic map as a representative reference land cover, and assesses the accuracy of classification by comparing the results carried out for both the per-pixel and the per-field techniques. Finally, the nature of problems emerged with both procedures is clearly identified.

1. INTRODUCTION

The information contained in digital imagery, acquired by Remote Sensing technology, can be used for mapping, monitoring and assessing the properties of the environmental and territorial feature elements. Of all these three main application fields in Remote Sensing, making thematic cartography by means of automatic classification methods is surely among the most widespread and in many cases is an essential preliminary step for further applications.

Up to now spatial resolution of data given by earth observation satellites has proved inadequate in providing detailed topographic peculiarities, in specific application domains of analysis and monitoring of urban environment. Modality of terrestrial phenomenon representations, augmented geometric accuracy, temporal flexibility of acquiring, spatial land cover and appropriate use in spatial modelling terms suggest, instead, the diffusion and continual use of new very fine spatial resolution satellite sensors imagery, as data sources for spatial analysis in urban contexts.

The high level of investigations enabled by interacting with other disciplinary sectors, can support planners’ activities better, as Mesev, Longley and Batty (1996) have argued: ‘our concern with land use revolves around the central ‘urban/non urban’ dichotomy as manifest through physical form, although in practice finer segregations as well as measures of the intensity of human activities are also desirable’. The informational classes of a thematic mapping are not directly registered, but must be derived indirectly by using evidence contained in the spectral data of an image. When we apply standard procedures of per-pixel multispectral classification the increase of spatial resolution leads to an increase in ambiguity in the statistical definition of image cover classes and a decrease of accuracy in automatic identification. This problem may be overcome by means of per-field classification techniques which involve analysing groups of pixels within land cover parcels. Such technique, based on the integration of remotely sensed imagery and digital vector data, has been used to generate land cover and land use information for more than a decade (Carbone, Narumalani and King, 1996; Ethers, Greenerie, Smith and Star, 1997; Hinton, 1997). Innovation and power of recent GIS platforms and analytic flexibility of Image Processing softwares make the integration of satellite data with numerical and scaled topographic data much more feasible, and this can lead to an increase in accuracy of the classification compared with the per-pixel technique, as well as improvements in interpretation of results with incorporating spatial variability and texture inherent in fine spatial resolution imagery.

This work investigates a per-field classification methodology, applied to an IKONOS multispectral image with spatial resolution of 4 m by utilising a digital large scale topographic map as a representative reference land cover, and assesses the accuracy of classification by comparing the results carried out for both the per-pixel and the per-field techniques. Finally, the nature of problems emerged with both procedures is clearly identified.

2. THE EXTRACTION OF CONTEXTUAL INFORMATION FROM VERY FINE SPATIAL RESOLUTION SATELLITE IMAGERY IN AN INTEGRATED RS/GIS SYSTEM.

The accuracy with which land use has been mapped up to now from satellite sensor imagery from local to national scales has been limited by the relatively coarse spatial resolution of instruments. For example, for the land cover maps generated using Landsat Thematic Mapper (TM) imagery, with a spatial resolution of 30 m, a considerable amount of detail in the scene is obscured from the image. The availability of recent multispectral imagery with very fine spatial resolution has increased our ability to map land use in geographic detail and accuracy (Koln, Atkinson and Currant, 1997) for local and national scale investigations.

However, these sources of imagery are likely to generate other problems. Even if the radiometric resolution is enhanced (11 bit for IKONOS imagery), spectral capabilities are generally limited compared to those of the previous generation sensors (seven bands for the Landsat TM). Moreover, associated with an increase in spatial resolution there is, usually, an increase in variability within land parcels (‘noise’ in the image) generating a decrease in accuracy of land use classification on a per-pixel basis (Towsendsh, 1992).

Traditional automated classification techniques classify land use on a basis of spectral distribution of the pixels within an image, whereby each pixel is associated with the most similar spectral class. This general method can produce results that are ‘noisy’ due to the high spatial frequency of the land covers. The alternative technique of per-field classification (so called because fields, as opposed to pixels, are classified as independent units) takes into account the spectral and spatial properties of the imagery, the size and shape of the fields and the land cover classes chosen.

In fact, this approach requires a priori information about the boundaries of objects in the image, for example, roads fields. If the boundaries of these fields are digitised and registered to the image, then some property of the pixel lying within boundaries of the field can be used to characterise that fields. For instance, the menes and standard deviations in the four IKONOS bands of pixel lying within roads fields could be used as features defining the spectral reflectance properties of fields. Normally, the use of map and image data would take place within a geographic information system (GIS), which provides facilities for manipulating digitised boundary lines (for example, checking the set of line to eliminate duplicated boundaries, ensuring that lines ‘snap on’ to nodes, and identifying illogical lines that end unexpectedly).
All these considerations suggest that replacing the coarser spatial resolution satellite sensor imagery with finer ones would lead to an increase in per-field classification accuracy, especially for relatively small sized fields (Harris and Ventura, 1995; Westmoreland and Slow, 1992)

However, the method used to integrate remotely sensed imagery with field boundaries is also meaningful. Such integration may be carried out in three stages (White, 1995):
- before classification (pre-classifier stratification),
- during classification (classifier modification),
- after classification (post-classifier sorting).

Many examples of these procedures employed only the latter two. Westmoreland and Slow (1992) integrated, in a single stage, cartographic data with remote sensed imagery during classification to assess land use change on per-field basis. Alternatively, other studies obtained land cover on a per-pixel basis before integrating the classified image with cartographic data for per-field classification (White, 1995)

The ways with which the two data models, raster and vector, are integrated in a RS/GIS system can be summarised in:
- a separate database, cartographic and image processing systems with facilities to transfer data between them;
- two software packages (image processing and GIS) with a shared user interface and dynamic links.
- a single software package with shared processing.

In this study the b) type of implementation is performed, because of the high level of the customisable statistical and logical tools and the possibility of modifying per-pixel classification using the spatial information derived from external data.

3. THE STUDY AREA AND THE DATA SOURCES.

This research was carried out in the Italian territory (about 4 Km per 5 Km) which includes part of the municipal district of Fasano (Brindisi) in the Apulia region (Fig. 1). It represents a critical area because of urbanisation over the last thirty years, still continuing now. Such evolution is been apparent with long period bulk-up area phenomena on a local scale (second home), with rise and spread of tourist places ("Safari" zoo, fair grounds) and, finally, with agricultural transformations (olive-groves dominating over natural areas, such as lex and Mediterranean bush).

The geomorphologic and setting features, with the town and the ancient fortified farms that are located on the plain (100 m a.s.l. quota) and the hills that are strewn around the hills (300-400 m a.s.l. quota), justify the choice of this area because it permits the testing of the validity of well-established methodologies of classification on a regional-scale, but barely investigated on new generation satellite sensors imagery. Moreover, such studies allow opening of new unexplored techniques applicable on a large scale by adding meaningful inputs to those multidisciplinary studies connected to decision-making and planning activities.

The data sources acquired for the analysis consisted in:
- the 4 bands IKONOS raster data (Acquisition Date/Time: 2000-05-12 / 09:14), processed using the remote sensing image processing system ERMAPP;
- the digital topographic map in a scale of 1: 5000 (Date 1998), stored and processed by means of the geographical information system ARC/INFO;
- the ground reference data obtained with a land use survey (January 2001).

4. METHODOLOGY.

4.1 Data processing

To facilitate the integration of the IKONOS and vector data it was necessary to register both data sets to a single map coordinate system (Mather, 1995), in this case Gauss-Bowd map projections and Rome40 datum, by identifying 30 common
Ground Control Points (GCPs). A high (3rd) order of transformation for rectification (RMS value lower than 1 pixel) and a nearest neighbour resampling method on the image were executed, in order to consider the relief of certain sub-areas as the minor distortion of radiometric values in the row data respectively (Khan, Hayes and Cracknell, 1995).

The spatial resolution of IKONOS image allowed indivisibility of nine land use classes (asphalt road, country road, arterial road, high density buildings, low density buildings, sown ground, uncultivated ground, Mediterranean bush, olive-grove). Generally, remotely sensed reflectance is related to land cover and not to land use, but in the present case each land use class was assumed to correspond to spectrally separable land covers. In the first step, the per-pixel classifier was trained on a representative sample of each of the land use classes by using a supervised maximum likelihood classification algorithm with equal prior probabilities for each class.

This parametric classifier was selected because, by using the shape of the distribution of membership (represented by covariance) as well as the mean of the training data to identify each class, offered a very high general level of global accuracy. Then, the classifier modification procedure was performed, in order to improve the accuracy of the results with the correction of misclassifications by providing spatial context (digital topographic map). In this case the spatial context is the geometry of a field that is an area in which only one land cover type is expected. All relevant fields boundaries was extracted from the digital cartography and processed as coverage in the GIS environment in order to perform the per-field classification in the image processing system (Fig. 2). Finally, a post-classification filtering with window width of 3x3 was executed to allow speckle reduction.

<table>
<thead>
<tr>
<th>Reference data set</th>
<th>Classified land use</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3843</td>
<td>0</td>
<td>40</td>
<td>0</td>
<td>7</td>
<td>27</td>
<td>53</td>
<td>16</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>159</td>
<td>4</td>
<td>12</td>
<td>3</td>
<td>1</td>
<td>34</td>
<td>30</td>
<td>59</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>37</td>
<td>22437</td>
<td>15</td>
<td>55</td>
<td>232</td>
<td>751</td>
<td>846</td>
<td>1538</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5416</td>
<td>0</td>
<td>0</td>
<td>301</td>
<td>282</td>
<td>424</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>30</td>
<td>27</td>
<td>9</td>
<td>1053</td>
<td>631</td>
<td>221</td>
<td>124</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>580</td>
<td>0</td>
<td>148</td>
<td>0</td>
<td>114</td>
<td>558</td>
<td>1068</td>
<td>516</td>
<td>476</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>10</td>
<td>239</td>
<td>7</td>
<td>4</td>
<td>17</td>
<td>201</td>
<td>150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>695</td>
<td>0</td>
<td>0</td>
<td>81</td>
<td>606</td>
<td>254</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>39</td>
<td>0</td>
<td>0</td>
<td>41</td>
<td>10</td>
<td>824</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Overall Accuracy: 79.294% from 53065 observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kappa statistic: 0.721</td>
</tr>
</tbody>
</table>

Tab. 1 “Confusion Matrix of the Classification Map derived from IKONOS imagery of Pisan (Italy)”

4.2 Accuracy assessment

Accuracy assessment determines the quality of the information derived from remote sensed data. To perform classification accuracy assessment correctly and to ensure objectivity and consistency, it is necessary to compare two source of information: (1) the remote sensed derived classification map and (2) the reference test information kept independent of training data. The relationship between these two sets of information is commonly summarised in a confusion matrix (Congalton, 1991).

After the reference data set was collected from the randomly located sites, it was compared on a pixel-by-pixel basis with the present information in the classified satellite imagery. This source of information was utilised to validate the results of both classifications by calculating confusion matrices (Tab. 1), k statistic and overall accuracy.

As the result of the whole procedure, inclusion of the topographic map information during the IKONOS image classification improved overall accuracy of the results (from 68% to 79%).

Flexibility of the per-pixel classification allows to update the classification maps easily if more data is available; for example, new satellite imagery becomes available, or if a different set of training data is used. The per-pixel classifier can then be updated to reflect the new information, and the classification accuracy, as measured by the confusion matrix, can be recalculated. This ensures that the classification remains current and reliable, allowing for accurate and informed decision-making.
The per-pixel method had produced misclassifications, not only as a consequence of internal variability within fields, but also due to the utilisation of land use as opposed to land cover classes. Per-field classification was able to overcome these problems in some instances, but in others, such as inexact geometric registration and errors in the original vector data, they meant in the selection of uncorrected classes.

5. CONCLUSIONS

Flexibility of the integration process in the present software packages and the high spatial resolution of the new generation satellite imagery may globally lead to an increase in geometric detail and accuracy with which land cover can be mapped over images of coarser spatial resolution in which, as many recent researches attest, the presence of mixed pixel is the dominant problem to resolve.

At present, an increasing amount of geographical data are stored in geographical information systems. This data could prove useful in the processing of remote sensing images. In addition, remote sensing images may be considerably applied to store and update data in a GIS.

The per-field classification developed in this paper should be considered as a test to validate on a local scale well established methodologies of classification applied at an over-regional scale and future researches are advisable to reduce sources of resulted misclassifications. Moreover, such types of studies allow opening of new unexplored techniques applicable on large scales by adding meaningful inputs to those multidisciplinary studies connected to decision-making and planning activities.

6. REFERENCES


KEYWORDS

ABSTRACT

Pesticides prolong and the extermination of nonpoint sources to the environment, both herbicide and transported by these components with extensive use of toxic pesticides, etc. In range of farmland properties. Applications of cypermethrin and these pesticides appearances, moves over the area activity are picked up by bodies of water more biology of aquatic animals (DEC, 1996). Smooth activity and wildlife are preserved (DEC, 1996).