REMOTE SENSING FOR URBAN ANALYSIS

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ABSTRACT

An image processing procedure in order to produce an updated map of built-up areas is presented. It is rooted in the classification of a Landsat TM image whose thematic accuracy is improved by its intersection with the Spot Panchro image processed through a chain of morphological transformations.
In order to analyse the urban change a comparison with a traditional map at a previous date is required. Therefore the traditional map at a scale of 1:50 000 has been processed into a grid mode, then spatially and logically overlapped to the updated map to extract the "difference map" displaying the urbanisation increase.
The procedure suggested has been applied to a case study of the Venetian Region presenting scattered settlements. It proved to be fast and accurate method to extract such a context not only the compact urbanisation but also the isolated buildings. This procedure suits very well the urban change analysis at a regional scale where the automatic methods suggested up to date based on the plain classification did not succeed at being very accurate.
The traditional method, consisting in making a new updated map and comparing the new with the old, did not prove to be a solution as it takes too long-to comply with the need of timely answer about the urban change.

Une procédure de traitement d'images satellites pour la mise à jour d'une carte de l'espace bâti est ici présentée. Elle se base sur la classification radiométrique d'une image Landsat TM et sur le résultat d'une transformation morphologique sur SPOT-Pan. L'information structurale de SPOT Pan va améliorer, à travers une opération d'intersection, la qualité de la classification du bâti obtenue dans TM.
Il est ensuite nécessaire de faire la comparaison avec une carte traditionnelle d'une date précédente. Une carte traditionnelle à l'échelle 1:50 000 est donc digitalisée au scanner afin de la rendre superposable à la carte raster obtenue par télédétection. pour construire la carte différence qui montre les changements de l'espace bâti.
La procédure ici suggérée a été appliquée dans la région de la Vénétie caractérisée par une urbanisation diffuse. Il s'agit d'une méthode très rapide et efficace dans l'extraction aussi bien de l'urbanisation compacte que des maisons isolées. Elle convient très bien à l'analyse à l'échelle régionale des changements urbains là où les méthodes automatiques jusqu'à maintenant proposées, basées sur la simple classification, n'ont pas eu de succès.
Une méthode traditionnelle qui consisterait à produire une nouvelle carte mise à jour et à la comparer à une ancienne , n'est pas une voie praticable car incompatible avec le court délai de temps dans lequel on veut une réponse dans un sujet comme les changements urbains.

1. INTRODUCTION

The occasion of this study rises from the need to set out the state of urbanisation within a research project involving the analysis of the urban development in a context of scattered urbanisation (Daest-Murst Research Project). The project started in 1992 over an area located in theVenetian Region, between Padova, Treviso and Mestre-Venice. The Remote Sensing Unit of the CICAF (the IUAV Centre of Cartography and Photogrammetry) has been asked to produce an updated map to be compared to an older one existing. The scale of 1:50 000 has been considered to be the appropriate one with regard to the large extension of the area (150.000 acres) and matching the spatial accuracy of the satellite images available (Landsat TM and SPOT). For the feature to be extracted, (i.e. isolated buildings and linear accumulation of buildings along the roads), it is required to reach the thematic accuracy for a pixel size.
The method proposed gives efficient exploration of large fragmented areas where other methods fail.

2. DATA USED

Data available at the time consisted of an August 1991 Landsat TM image (frame 192-28) and a PAN Spot one (frame 063-258) for August 1992. Besides the satellite data, graphical maps at a scale of 1:10 000 produced from aerial photographs dated 1986 were used for some sub-areas. These

maps of built space in black and white have been scanned and transferred into the same resolution as the TM sensor to be used as a test area in the supervised classification.
A traditional paper map dated about 1970 at a scale of 1:50 000 was available.

3. PRINCIPLES LEADING TO THE PROCEDURE ADOPTED

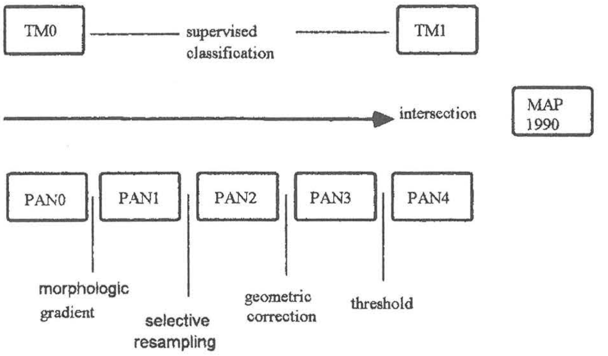
Multispectral classification is the commonest method of image processing used for territorial studies, even though it is widely criticised especially when it is applied to high-resolution images like Landsat TM and Spot (see Cushnie 1987 and Woodcock 1987) where a high spectral variability inside the thematic classes occurs. A typical case is in residential areas (Toll 1984, Shimoda 1987) or in monitoring the residential extensions in the urban-rural transition areas (Howarth 1987).
Interesting statistical approaches (in the sense of Haralik 1979) in texture analysis have been made bringing greater accuracy. Coverage indices have been introduced to provide new structural channels later used in mixed textural and spectral classifications (Marceau D.J. **et al.** 1990, Dong-Chen 1987, Baraldi A. and Parmiggiani F. 1990). In our case there are evident limits in that texture in itself implies the repetition of atomic elements, or the sequence of the grey-tone function values in a given region. Such an approach is clearly inadequate when the regions to be extracted are strips quite long and of only 2- 3 pixels wide as in the case of linear settlements along the roads , or little areas of only 1 to 2 pixels as in the case of isolated houses.
It is certainly a good idea to take advantage of the high spatial resolution of Panchromatic images to supply structural information to be added to multispectral TM classification. The issue that remains is that of merging data sets with different spatial resolutions. Methods most frequently employed refer to transformations based on global statistics or histograms (Hue-Intensity-Saturation or Principal Component Analysis) or others using high-pass filters on the high spatial resolution image and the successive linear composition with high spectral resolution, but low spatial resolution, images (Chavez 1991). The High-Pass Filter method, which is a local transformation by a convolution method, is considered to be the one that distorts least the spectral characteristics of the TM image.
Alongside these considerations, our own recent methodological inquiries and the experiments (Bianchin A. and Pesaresi M. 1992; Pesaresi M. 1992) have shown how the instruments for local transformation provided by mathematical morphology, as opposed to those given by linear treatment of the signal (Serra 1982) are particularly fitted for land studies, above all when considered in their numerical version (Serra 1988). Among other reasons, these morphological trasformation s possess a good control of the spatial domain of application as well as the preservation of values directly interpretable by the transformed grey-tone function.

To sum up the considerations above:
- Plain spectral classifications are not very accurate where high spatial resolution is combined with high spectral variability within classes,
- Accuracy of classification can be increased by using structural information but the texture indices are not the appropriate ones in our case of study,
- The PAN-Panchro image fits for extracting structural information because of its greater spatial resolution,
- The most interesting merging method of images with different resolutions apply to local transformation,
- Morphological transformation methods appear to be the best ones for territorial studies based on mapping approach.

In the light of the above, the method proposed is based on a spot PAN morphological transformation used as a basis for building an intersection image with the classification generated by the radiometric channels of the TM sensor.

4. IMAGE PROCESSING PROCEDURE

There are basically two distinct chains of treatment; one for the TM image and one for the SPOT-Pan image. The images generated from the two treatment chains are then logically intersected on the purpose of improving the thematic accuracy of the final result.



4.1 The TM image Chain

It is basically a maximum likelihood supervised classification on the 1,2 and 3 wavebands of the TM sensor .
As said above, we could make use of some mono-thematic maps of built space from where to extract some test areas. In order to have a representative sample of all kinds of settlements, three test areas have been chosen in the cities, three in the small settlements and three in the filiform settlements.
In the classification two thematic classes have been considered and extracted: built space (a)with tiled roofs and (b) with concrete roofs; the former, in general, corresponding to housing and the latter to industrial and commercial buildings. The outcome of this procedure is the image TM1.

4.2 The SPOT-Pan Chain

Starting from the monospectral image SPOT-Pan (PAN0), the PAN1 gradient image is generated using a morphological gradient. (Coster 1988).
The morphological gradient function g(x) may be defined as the difference between the dilation and the erosion divided by the diameter of the domain of application Bx. For a structuring element of size 1, the gradient will therefore be defined as:

$$g(x) = \frac{D^B f(x) - E^B f(x)}{2}$$

Where $f(x)$ is a defined grey-tone function in R^2.

The gradient image (PAN1) brings out the radiometric breaks which appear in connection with limits between different objects. In the case of built -up space extraction where the object size is next to the pixel one, these breaks take the shape of high gradient region whose diameter is 3-4 pixels at least when isolated buildings occur; or of linear structures mostly less than 3 pixels in width connected with roads, field borders, etc..
Such features will be taken into account in the resampling phase generating the PAN2 image. PAN2 is obtained by a selective re-sampling in which, for every 3x3 window of the PAN1 image only the lower grey function value is kept. The window dimension and the sampling strategy adopted enable to suppress the linear gradient structures generated by roads and by field borders; but to keep the gradient regions corresponding to the built-up areas. In the resampled PAN2 image most of the unnecessary structural information was eliminated.
PAN2 image corresponds to the result of an erosion with resampling of the gradient image and has the same geometric resolution as the TM image (pix=30x30m).

A geometrical correction procedure is then applied to the PAN2 image to allow its superimposition with the TM one. Twenty seven control points were found on both images and a cubic convolution algorithm was applied.

By using aerial photographs as truth the gradient distribution of the PAN3 for buildings, fields and bare soil has been drawn. From it the gradient threshold allowing to keep only the built space in PAN4. is determined. PAN4 is the outcome of the application of this threshold in PAN3 where the unnecessary structural information is eliminated. PAN4 is a binary image displaying the presence/absence of built space based on the structural information.

MAP1990 is the intersection image of TM1 providing the spectral information and PAN4 providing the structural one ; both related to the built-up space. MAP1990 image keeps only the pixels classified as builtt-up space in both images TM1 and PAN4.

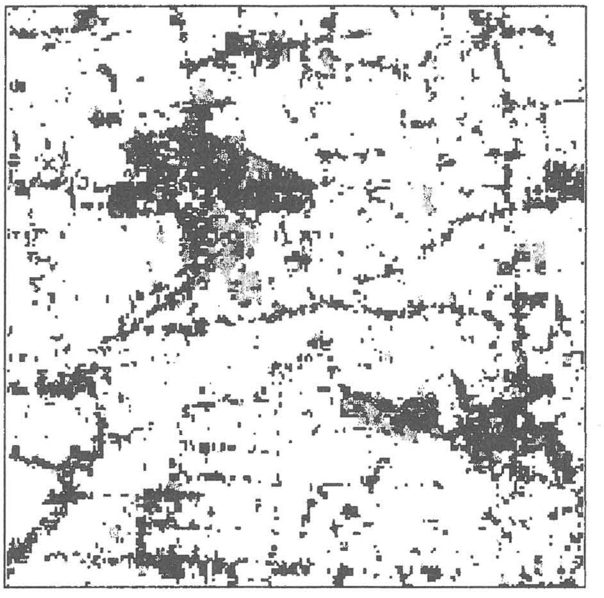


Fig. 1. MAP1990 displaying the built-up areas (two classes).

4.3 Thematic accuracy assessment

The basic idea of the method being to improve the accuracy of standard classification of TM by using the structural information from SPOT Pan; the confusion matrix for TM1 and MAP1990 have been set.

Aerial photographs have been used as truth without using a rigorous sampling method. Points have been chosen with regard to well known areas in all kinds of settlements and territorial structures.
The confusion matrix includes the two themes extracted (built areas with tile roof and concrete roof) and two other classes shown in columns, i.e., cultivated (column 3) and uncultivated fields (column 4). It is clear that the two building classes are overestimated. The widest confusion is between the tiled-roof and the uncultivated field areas, as they appear similar in colour.

Table 1. Confusion Matrix of Supervised Classification in TM1

TEST AREAS

	tile roof	concrete roof	cultivated	uncultivated	
tile roof	62.86%	00.20%	00.47%	36.47%	100%
concrete roof	13.37%	51.45%	0.00%	35.17%	100%

Table 2. Confusion Matrix of MAP1990

TEST AREAS

	tile roof	concrete roof	cultivated	uncultivated	
tile roof	99.47%	0.21%	0.11%	0.21%	100%
concrete roof	22.27%	77.73%	0.00%	0.00%	100%

5. PROCESSING THE IGM MAP INTO A GRID MODE

Now we have a raster map of the built space at 1990 and a traditional graphical map at about 1970. The pixel of the first is 30mx30m and the scale of the second is 1:50 000.
The traditional paper map has to be scanned and put in the raster format at the same resolution of 30mx30m .
Since the IGM map is colour printed and includes the typical legenda of general maps; in order to keep just "buildings" a specific procedure has been developed (Pesaresi 1993).
It is based on two steps. The first consists in analysing the grey-level distribution of the scanner (300 dpi) output and finding out a threshold differentiating black signs mainly related to the buildings from those supposed to be related to the roads drown in red.
Such previous manipulations, necessary for the second step, generate two binary maps which are going to be elaborated through some morphological geodesic transformations in order to eliminate all kinds of little details which are noise and keep just the built-up areas. A grid of 30mx30m is then overlapped to generate a binary raster map of built-up space dated 1970 whose information is consistent with MAP1990.

6. URBAN CHANGE ANALYSIS

The difference of the two raster maps is a straightforward operation and displays the urban change between the two dates.

7. CONCLUSIONS

The experience described demonstrates the interest to use raster-based representations for urban change analysis for its rapidity and simplicity. It brings forward the potential of mathematical morphological transformations in elaborating raster data set in particular when dealing with cartographic data where the information is shape dependent.
The experience states that links between the image processing tools and information produced have to be under control in each step in order to reach a sensible result.

As a practical conclusion we can state that it is possible to produce an updated map of urbanisation from the satellite image within the TM spatial accuracy.

Going to specific, the comparison between the two confusion matrixes shows that, with the method proposed here, accuracy of extraction in built-up areas is greatly enhanced and in particular the overestimation effect due to confusion of uncultivated surfaces (ploughed fields) is cut out. What does remain is a overlapping problem with the two classes of built-up area.
The method proposed proves to be very interesting when compared with alternative ones of extraction in built-up areas, because it retains an acceptable level of accuracy even in very difficult situations where extreme scattering of houses and mixed urban and rural land use render traditional classification methodologies impossible.
In general terms the approach outlined shows the interest to use the structural information in the automatic recognition of built-up areas but the strategy to be used to extract such structural information has to be adjusted to the context viewed in terms of radiometric response.
In image processing the use of morphological transformation results to be of great help for the extraction of a higher level of information related to the territorial organisation.

Note: This work started with the thesis of Martino Pesaresi (1992, Advisor: A. Bianchin) where the different image processing methods for the urban analysis studies were investigated with special regard to the mathematical morphology . It was developed within the Remote Sensing Unit of the Centre of Cartography of the IUAV between 1992- 1994.

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