Urban land cover classification potential of high and very-high resolution SAR imagery

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ABSTRACT - Remote sensing in the optical band is a well established tool for producing and updating maps of urban land use and monitoring changes, but it can suffer from atmospheric limitations, especially where clouds systematically occur or when unpredictable abnormally long periods of cloud cover affect usually clear-sky regions. Hence, when a systematic, timely and reliable survey of an urban area is required, the use of SAR imagery might become suitable or even necessary. The aim of this poster is to bound the potential of the ERS data in identifying land cover in large urban areas. In fact, the C-band SAR data provided in the past years by ERS-1 and ERS-2, and currently by ENVISAT, are systematically available at relatively low price. Together with LANDSAT, they provide a decadal history of the urban areas, hence their value should not be neglected, rather it deserves particular attention. Moreover, the ERS image long time series provide a unique reliable means of systematically tracking, retrieving and understanding the frequently dramatic changes undergone by the land cover of large cities in all parts of the world in the past 15 years. Because of the decametric size of the resolution cells at ground, the shapes of the structures are altered and mixed pixels are expected, especially in a sub-urban landscape, where heterogeneous land covers are present over short distances.

FEATURES SELECTION - To attain a sufficient classification accuracy, careful selection and suitable processing are required to exploit the various properties of information embedded in both the amplitude and phase of the radar return and its time-space behaviour.

Features affected by different scattering mechanisms and sensitivity to the geometry of the scatterers have the potential of maximizing the quantity of information available to the algorithm. To this end, we used two features related to the backscattering mechanisms, two textural features and two features related to the phase information, contained in the ERS ELC images.

The information contained in the backscattering has been exploited by considering the time-average and the standard deviation values computed over the 5 dates for each year. The textural features consist in the Contrast and Energy, chosen among the variety of textural parameters. On the basis of several tests aimed at increasing the separability among classes, the features were computed over moving square boxes of 7x7 pixels, and considering a 16 grey levels quantization. Finally, the phase information has been included into two degree of interferometric coherence values, one calculated over two winter tandem acquisitions, the other one over two late spring tandem acquisitions.

CONCLUSIONS - The information contained in multi-temporal decametric SAR images can be exploited in a relatively straightforward manner in identifying large urban areas, such as the city of Rome.

The very-high resolution sub-metric SAR images, on the whole, is strongly affected by the complexity and the variety of scattering mechanisms, even for single structures. For the enhanced visibility, a variety of textural and geometric effects, which tend to be smeared by a coarse resolution, must be taken into account for a successful optical classification. Alternative classification approaches can be devised to better cope with the complex behaviour of very-high resolution SAR images of man-made objects. As discussed above, the radar signature of a single building is the complex combination of basic scattering mechanisms, all these contributions can be re-assembled and related using an object oriented method, to improve the classification of very-high resolution SAR data. This approach is going to be investigated in the near future.

DATA SET - The data set was composed by the ERS SAR images acquired over the city of Rome, Italy, as reported in the following table.

REGION OF INTEREST SELECTION - Given the peculiarities of the SAR image generation, we decided to include two radar specific targets types into the set of traditional land use classes. The two classes are treated because of the acquisition geometry and do not correspond to real surface types, analogously to shadowed areas in optical images. In particular we intended to single out the very dense urban area which is characterized by different vegetation and forest areas around the city. The classes forest (FD) and low vegetation (FV) have been added to the already used land cover class: high (HD), water (OW), high-density residential (HR), low-density residential (LR), undeveloped buildings (UB), agricultural (F0), high-density urban area (FU). In general, the backscattering feature dominates over the urban areas, the coherence feature characterizes the vegetated areas and the texture features are particularly apparent in the zone of the Tiber river bed. In fact, the map points out that the multitemporal backscattering images can be related to both the level of coherence and the one between low vegetation and low-density residential, by the texture Contrast.

URBAN ELECTROMAGNETIC ENVIRONMENT - The complexity of the electromagnetic environment that affects in urban areas point scatterers is in general very high and pixel SAR images, since the urban area is typically composed of natural and man-made elements characterized by different scattering mechanisms, the polarization of the incident waves is highly dependent on the polarimetric signature of the building. The first reflection is usually separated by the corner reflection, and it can be classified in several basic contributions from the various parts and structure of the building. The second-order contributions come from the radar return of different reflection paths in the urban areas, high and low contrast walls, and to the buildings.

The classification exercise has been carried out for the ERS data set acquired in 1994 and 1999, thus obtaining two different land cover maps, where the urban area is represented by four classes: the main large built area, the compact old section of the city and the Ciampino areas. A visual inspection suggests that the main large built area has been identified with good accuracy, as well as some misclassifications are manifest in the Tiber river, the compact old section of the city and the Campi office. The reader can compare the classification maps of the basic SAR features and the combined features. Different seasonal acquisitions, several features, even of relatively small dimensions, like the trees along the river and the squares with lights and plants, have been correctly classified.

NEURAL NETWORK DESIGN - Among various topologies, MultiLayer Perceptrons have been found to have the best suited topology for classification and inversion problems. As far as the numbers of hidden layers and of their units are concerned, the topology providing the optimal performance should be selected on the basis of a suitable compromise. We see that, as expected, increasing the number of hidden neurons is effective up to a given number, after that the SSE value does not change significantly. The results show a good stability (low standard deviation values) with respect to different initializations of the network. At the end, a configuration with two hidden layers with 40 neurons each was chosen.

Urbano SAR classification results over the city of Rome in 1994.