Foreword
Special Issue on Analysis of Multitemporal Remote Sensing Images

THE development of effective methodologies for the analysis of multitemporal data is one of the most important and challenging issues that the remote sensing community should face in the next years. The importance and timeliness of this issue are directly related to the ever-increasing quantity of multitemporal data provided by the numerous remote sensing satellites that orbit around our planet. These data are captured by different kinds of sensors (e.g., multispectral or synthetic aperture radar (SAR) sensors) and have different geometrical properties. The temporal component, integrated with the spectral and the spatial dimensions, may result in a valuable information source that, if properly exploited, allows revealing complex and important patterns that are the concern of applications connected with environmental monitoring and analysis of land-cover dynamics. However, the use of the temporal domain further increases the complexity usually associated with the processing of single-date remote sensing images. In this context, the definition of automatic and semiautomatic techniques for data preprocessing and analysis is a crucial component for the development of operational tools based on multitemporal remote sensing data and, thus, for the value chain of geospatial information as a whole. An important issue that should be considered in the definition of such techniques is that the analysis of multitemporal images cannot be carried out in an efficient way by applying to multitemporal data methodologies developed for analyzing single-date images. On the contrary, the presence of the temporal dimension should be properly considered by integrating in the data processing procedures algorithms capable of exploiting the relationships between images acquired on the same geographical area at different times. The solution of this complex methodological problem can result in an increase of the accuracy provided from the data analysis process.

It is worth underlining that despite the term "analysis of multitemporal images" implicitly addressing specific methodological problems related to the temporal domain (like change detection, detection of land-cover transitions, shape change detection, analysis of changes in the temporal signature extracted from long series of images), it is also related to more classical pattern recognition problems (e.g., single-date classification), whose solution can benefit from the exploitation of multitemporal information.

The synergistic use of multitemporal remote sensing data and advanced analysis methodologies results in the possibility to solve complex problems related to the monitoring of the earth surface and atmosphere at different scales. It is worth noting that the word "monitoring" implicitly assumes the temporal domain of the observations; this clearly emphasizes the role that multitemporal remote sensing images can play in all application domains associated with the dynamics of environmental and anthropological processes. Applications range from monitoring and management of natural resources (e.g., forests, sea, etc.) to monitoring of land-cover dynamics (e.g., monitoring of ecosystems, monitoring of agricultural areas, etc.), from risk assessment (e.g., forest fires, landslides, floods, etc.) to damage mapping (e.g., burned areas, flooded areas, etc.), from assessment of urban expansion to updating of road maps on GIS systems. Many of these applications are related to important political issues and have a strategic role for decision makers and politicians.

This special issue addresses the problem of the analysis of multitemporal remote sensing data, by describing the current most advanced methodological and application-oriented developments of multitemporal data processing. It is composed of 16 papers selected according to the standard review process of the IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING. These contributions have been organized in 14 full papers (distributed in five sections) and two Communications.

The section on *Preprocessing of Multitemporal Images* contains three papers. One contribution is related to atmospheric corrections, and two articles address the development of registration procedures for multitemporal images. The paper by Viggh and Staelin focuses on the issue of estimating spectral reflectance in remote sensing imagery, and a new set of algorithms is proposed that help estimating surface spectral reflectance using prior spatial and spectral information about the surface reflectance. The paper by Coulter *et al.* presents and demonstrates the effectiveness of a new frame center matching technique for acquiring and precisely registering multitemporal airborne frame imagery. Chen *et al.* investigate the use of a new joint histogram estimation algorithm for computing mutual information to register multitemporal remote sensing images. They provide experimental results showing their registration approach significantly reduces interpolation-induced artifacts and produces better registration consistency as compared to two other popular similarity measures.

Digital Object Identifier 10.1109/TGRS.2003.820004

The section on *Change Detection Techniques* includes two papers. The paper by Bruzzone and Cossu presents an unsupervised approach to change detection robust to registration noise. A strategy is proposed that allows an adaptive estimation of the distribution of the residual registration noise between multitemporal data and exploits this estimation for increasing the accuracy of the change detection process. Li and Narayanan present a procedure for efficiently retrieving and representing shapes of interesting features in remotely sensed imagery. They then demonstrate the use of a computationally efficient shape similarity metric based on the retrieved shape features in a lake shape change detection application.

The section on *Classification and Segmentation of Multitemporal Images* is composed of three contributions. Melgani and Serpico propose an MRF-based approach that aims at improving both the accuracy and the reliability of the multitemporal classification process by means of a better exploitation of the temporal information. Bachmann *et al.* develop a credit assignment approach to decision-based classifier fusion, which they apply to the problem of land-cover classification of multiseason airborne hyperspectral imagery. Lombardo *et al.* devise a new fusion technique for a sequence of multitemporal single-channel SAR images of the same area covered by a single multiband optical image. The effectiveness of this fusion technique is demonstrated on synthetic and real images.

Three manuscripts are included in the part related to the *Analysis of Multitemporal SAR Data*. The paper by Trouve *et al.* addresses filtering of multitemporal SAR images. In particular, the effectiveness of three different multitemporal despeckling techniques is assessed according to several different statistical and operational criteria. Aiazzi *et al.*present an unsupervised method for providing estimates of temporal coherence starting from a pair of multilook detected SAR images of the same scene. The paper by Onana *et al.* addresses the extraction of linear features from SAR interferometric data. The authors model the human knowledge about the phenomena of interest (mangroves/shorelines and thin internal channels) in an algorithm based on fuzzy logic, exploiting the temporal decorrelation of backscattering signals.

The section on *Application of Multitemporal Images* presents three different examples of the use of multitemporal remote sensing data for facing challenging environmental problems. Song and Woodcock present a study on the major factors that cause uncertainty in using multitemporal Landsat images for the monitoring of forest succession. Their study includes atmospheric effects, topography, phenology, and sun and view angle effects. Hall-Beyer compares single-year and multiyear normalized difference vegetation index (NDVI) time series principal components in cold temperate biomes. She shows how the time series analysis offers the possibility of refining ecoregion mapping (based on selected early components) to incorporate actual interannual variability for selected time periods as well as the long-term stable elements of biogeoclimatic regions. The paper of Gerard *et al.* is focused on the very important problem of fire scar detection. In greater details, the detection of old fire scar (up to ten years) in boreal forest is addressed by using SPOT-VEGETATION multitemporal images.

The Special Issue Communications section presents two contributions. Vincini and Frazzi analyze the effectiveness of five parametric topographic normalization methods applied to multitemporal Landsat Thematic Mapper images acquired on mixed deciduous forests. Kastens *et al.* analyze multiyear NDVI time series and describe a temporal averaging technique that can be used to determine the presence of artificial interannual value drift in any region possessing multiyear regularly sampled time series remotely sensed imagery.

To conclude, we think it is time for the remote sensing community to increase the attention devoted to the analysis of multitemporal data. If, on the one hand, an increasing awareness of the potential of multitemporal data can be observed, then on the other hand, it is important to push toward the development of more advanced methodologies for multitemporal data analysis that are specifically devised for a proper exploitation of the valuable information present in temporal series of images. This seems an unavoidable step in the direction of an intensive use of multitemporal data in operational remote-sensing-based tools.

ACKNOWLEDGMENT

The Guest Editors would like to thank the IEEE Geoscience and Remote Sensing Society for its support to publishing this special issue. Thanks are due to J. A. Benediktsson and J. A. Smith, current and past TGRS Editors, for the constant support received in the preparation of this special issue. A special acknowledgement should be devoted to the reviewers of the papers, who played the most important role in the selection of the contributions published in this special issue. Finally, thanks to Jessica Cedar and George Criscione of the IEEE staff for their valuable assistance in all the phases of preparation of the special issue.

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