Foreword to the Special Issue on Optical Multiangular Data Exploitation and Outcome of the 2011 GRSS Data Fusion Contest

Up to now, the single view observing paradigm has prevailed in Earth observation systems. However, it is known that the measuring along a single line of sight provides incomplete information about the entire radiation field and the properties of the atmosphere, due to the fact that the atmospheric radiation is essentially anisotropic. Moreover, the anisotropic properties of the surface elements that reflect solar radiation depend on the relative direction of incoming and outgoing photons (which is often characterized by the bi-directional reflectance distribution function (BRDF)). Hence, ideally, the observational space of a remote sensing system should include three major dimensions: spectral, spatial, and angular [1]. Compared to the first two dimensions, the third dimension so far is somewhat underutilized, but it delivers critical information about surface and atmospheric properties that cannot be obtained from the information contents in the first two dimensions. Thus, a systematic operational multi-angular paradigm is greatly desired for Earth observation. It is noteworthy that multiangular information may be rebuilt from measurements taken in different temporal acquisitions. However, due to atmospheric and surface state variation, only information provided by simultaneous observations from different angles can be considered strictly multiangular [2]. The representatives for simultaneous angular sampling systems include: Polarization and Directionality of Earth Reflectance (POLDER) [3], [4], Multi-angle Imaging Spectroradiometer (MISR) [5], and Compact High Resolution Imaging Spectrometer (CHRIS) [6]. The success uses of their acquired data in various applications, such as atmospheric property derivation, surface structure characterization, and biophysical parameters retrieval, are widely presented in the literature (e.g., [7]–[10]).

Recently launched WorldView-2 can provide very-high-resolution (VHR) multispectral data with multiangular sampling. Specifically, the spatial resolution can reach 0.5 m (after pansharpening), which is very useful in studying very fine surface structure, such as those in urban and suburban environment. To promote the exploitation of VHR optical multiangular information, the Data Fusion Technical Committee of IEEE Geoscience and Remote Sensing Society (GRSS) held a data Fusion Contest in 2011, with WorldView-2 multiangular data being provided by DigitalGlobe [11]. The unique dataset is composed of five Ortho Ready Standard multiangular acquisitions, including both 16 bit panchromatic and 8-band multispectral images. The scene (shown in Fig. 1) was collected over Rio de Janeiro (Brazil) in January 2010 within a three minute time frame with satellite elevation angles of 44.7°, 56.0°, and 81.4° in the forward direction, and 59.8° and 44.6° in the backward direction. The multiangular sequence included the downtown area of the city, with a number of large buildings, commercial and industrial structures, the airport, and a mixture of community parks and private housing. By the end of May 2011, almost 800 researchers from 95 different countries subscribed the Contest and downloaded the dataset, with prevalence from USA, India, and Brazil. More than 30% of the participants were from Corporations or Government. This demonstrates the great interest from the Earth observation scientific research and application community. Several very interesting research topics were conducted, such as image superresolution, object tracking, vehicle velocity estimation, which are possible only when the spatial resolution is high enough.

Following the success of the Multiangular Data Fusion Contest, it is our great pleasure to introduce this special issue in order to present the most recent developments in this area in particular with sub-meter spatial resolution. 13 papers were selected after rigorous review. In the remainder of this foreword, we review key issues and topics of current interests related to the use of multiangular data that are covered by this special issue.

A. Vegetation Property Retrieval

The angular dependence of canopy reflectance contains information on the structure of vegetated surfaces. The angular variability of spectral indices has been explored, and angular-based vegetation indices can outperform traditional vegetation indices in retrieval of vegetation and forest structural attributes [12]. Vegetation-related properties, such as leaf area...
index (LAI) [13]–[15], biomes [16], [17], foliage clumping index [18], [19], can be well estimated with multiangular information. The BRDF information can be utilized to complement spectral information in vegetated area classification on local, regional, and global scales [20]–[24].

In this special issue, several contributions are related to this topic. The retrieval of LAI from CHRIS is investigated in [31] using a forest reflectance model and a look-up table approach; retrieved parameter estimates are compared to forest structure measured in two species, and the experimental results show that off-nadir looking significantly reduced the normalized error (NRMSE) of forest LAI. In [32], a simplified automated radiative transfer model (RTM) inversion scheme is applied both to the single observation angles and to various combinations of multiple view angles for retrieval of chlorophyll and cotton LAI. It is shown that significant increase in accuracy is obtained when directional information is included; however, the improvement obtained by assimilating a certain observation angle appears to be strongly related to the ability of the RTM in reconstructing canopy reflectance for this constellation; for instance, the result may be strongly deteriorated when the extreme forward looking direction is included. In [33], data collected by a digital aerial frame camera flown on a standard aerial survey is used to derive information on the bidirectional reflectance characteristics of forest. The Rahman-Pinty-Verstraete (RPV) model is fitted to sampled angular observations, which concentrates the information in a few meaningful parameters and minimizes sensor noise and other perturbing factors. Relying on the fitted model parameters, it is demonstrated that the multiangular data permits a better discrimination of five forest types as compared to the sole use of spectral information. Paper [34] addresses the retrieval of spatially contiguous canopy cover and height estimates in southwestern US forests via inversion of a geometric-optical model against surface bidirectional reflectance factor (BRF) estimates from MISR. It has demonstrated that multiangle red band surface BRF estimates from MISR can be used to invert a simple geometric-optical canopy reflectance model for mapping canopy cover and height in open forest canopies, even in areas of complex and often severe topography and with a very wide range of background conditions.

B. Digital Surface Model and 3D Building Reconstruction

The advent of VHR remote sensors leads to the development of efficient detection of complex urban details, while multiangular information further enables three-dimensional (3D) building reconstruction, which has important applications in urban planning and monitoring. One of the most practical ways is to generate Digital Surface Models (DSMs) using VHR remotely sensed images from two or more viewing directions (by using LIDAR sensors). Due to occlusions, matching and interpolation errors, these DSMs may not exhibit completely steep walls. In order to obtain real 3D urban models including buildings from DSMs, advanced methods have to be applied.

In this special issue, several contributions are related to this topic. A novel approach based on building shape detection, height estimation, and rooftop reconstruction is proposed to achieve realistic 3D building representations in [35]. In [36], multilevel morphological attribute filters, is used for the definition of the objects in an image, and geometric invariant moments is exploited for the characterization of the spatial properties of the previously detected shapes to achieve 3D reconstruction. In [37], building height determination is conducted with fast template matching on Graphics Processing Units (GPUs). In [38], a relative building height estimation method is proposed to improve building classification in conjunction with support vector machine (SVM).

C. Land-Cover/Land-Use Classification Improvement

Multiangular information may improve the classification of land-cover/land-use in addition to vegetated areas [25], [26]. The detection of oil slicks under sun glitter conditions from MISR data is investigated in [27]. An interesting directional spectral mixture analysis method is proposed and applied to multiangular airborne measurements, which can generate soft-classification maps [28]. In this special issue, Paper [39] uses MISR data to investigate the view angle effects on spectral response and discrimination of urban land cover types; a spatial and angular fusion (SAF) model is developed to blend MISR and Enhanced Thematic Mapper Plus (ETM+) images, and SVM is deployed for classification of the fused data after feature selection with principal component analysis.

D. Image Superresolution

Superresolution image reconstruction is a technique which generates a high-resolution (HR) image from several low-resolution (LR) images. For multiviewing images, they can be treated as LR input data for producing a HR image using super-resolution methods; however, they pose particular difficulties for image registration due to substantial geometric distortion [29], [30]. In this special issue, Paper [40] proposes an operational superresolution approach for multiangle WorldView-2 imagery. The method consists of two stages: registration and reconstruction; in the registration stage a hybrid patch-based registration scheme that can account for local geometric distortion and photometric disparity is proposed, while in the reconstruction stage, a superresolution reconstruction model composed of the L1 norm data fidelity control and total variation regularization is defined. Pansharpening is discussed in [41], where a recently proposed hyperspherical color sharpening method is investigated, and smoothing-filter-based intensity modulation technique is incorporated to control the trade-off between the spectral and spatial fidelity in fused images.

E. Object Tracking From VHR WorldView-2 Imagery

The VHR and more spectral bands of WorldView-2 imagery, compared to those of previous VHR satellites such as IKONOS, QuickBird and GeoEye-1, together with the new sensors’ configuration (i.e., four bands on each side of the panchromatic sensor), add an opportunity to improve both moving vehicles extraction and the velocity estimation. In this special issue, two papers are related to object tracking. In [42], a three-step processing framework is proposed for the automatic extraction of moving vehicles and determination of their velocities by taking advantage of a time lag in image collection between the panchromatic and multispectral sensors. In [43], an efficient
object tracking algorithm is developed by using multitemporal WorldView-2 image series, which includes a three-step process: moving object estimation, target modeling, and target matching.

We wish this special issue might further promote the use of VHR optical multiangular data, and corresponding findings could be factored into future mission planning and data product specifications. The Guest Editors would like to take this opportunity to sincerely thank the Editor-in-Chief, Prof. Jocelyn Chanussot, for his constant support and encouragement to this special issue. Special thanks are also due to all the contributors and peer reviewers whose valuable contributions make this special issue possible.

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