Foreword to the Special Issue on Big Data in Remote Sensing

BIG DATA is a very important topic in many research areas. In 2008, a Special Issue on this topic was published in *Nature*, which raised a great interest from the academic perspective.[1] On March 2012, the United States government unveiled a "Big Data Initiative" [1].

As part of the data sharing planning by American Obama government in 2009, big data for remote sensing applications is now freely available under NASA's Open Government Initiative. Furthermore, the data from other governments or organizations are becoming more widely open (or open via negotiations), such as Chinese Earth Observation (EO) data (e.g., land-cover HJ series, Oceanic HY series, and meteorological FY series) and Europe Space Agency (ESA) EO data provided via an international cooperation "Dragon project" started by ESA and the Chinese Ministry of Science and Technology (MOST). These data sets comprise different spectral bandwidths (dimensionality), spatial resolutions, and radiometric resolutions. The current estimations are that remotely sensed data are now being collected following a PetaByte level growth per day over the world. Also, other related data sets have been generated from different areas, such as social media data including pictures and tags uploaded by personal users to the Web which, for instance, can help improving the classification accuracy in land cover applications [2]. As a result, big data is becoming an "economic asset, like currency or gold" and we are in "the Age of Big Data" [3].

This Special Issue on Big Data in Remote Sensing is intended to introduce the latest techniques to manage, exploit, process, and analyze big data in remote sensing applications. It contains 11 papers that exhibit the latest advances in Big Data in Remote Sensing. To understand big data, usually three facets should be taken into account from owning data, data methods, and data applications, which contribute together to a single big data life cycle [2], including identification of applications, data collections, data processing, data analysis, data visualization, data evaluation, and so on. Here, data computing should be carried out in all the steps. In the Special Issue, a big data life cycle for remote sensing applications is presented to collect, process, and analyze massive remote sensing data for decision making in a real-time big data analytical architecture [4]. In particular, big data analysis techniques should be designed to deal with the remote sensing problems to get insight of big data in remote sensing, such as the affinity search strategy based on a graph [5]. The processing and analyzing big data are usually dealt with in a distributed or in a cloud environment through high-throughput or high-performance computing. In [6], different parallelization techniques are discussed in terms of support vector classifiers (SVCs) by turning big data to smart data. Also, SVC implemented in graphics processing units (GPUs) is presented in [7] and a distributed hyperspectral image endmember extraction algorithm is carried out by an artificial bee colony algorithm [8]. A scalable Web service for near real-time land cover mapping is provided in a cloud computing (CC) environment in terms of high-resolution remote sensing images [9]. Also, processing deformation maps and time series of differential synthetic aperture radar interferometry (DInSAR) is carried out in particular in an Amazon Web Services (AWS) CC platform [10]. Furthermore, a visualization strategy is utilized to label SAR images based on an active learning algorithm [11]. A multistratified spatial sampling approach is developed to evaluate the quality of remote sensing derived products in [12]. Finally, big data applications are described to manage Eolic parks by remote sensing data [13] and to jointly detect Web events with remote sensing data [14].

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[1] http://www.nature.com/news/specials/bigdata/index.html.

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REFERENCES

[1] "Obama administration unveils 'big data' initiative: Announces $200 million in new R&D investments," the White House, Mar. 2012.

[2] M. Chi, J. A. Benediktsson, A. Plaza, Z. Sun, J. Shen, and Y. Zhu, "Big data for remote sensing: Challenges and opportunities," *Proc. IEEE*, 2015, to be published.

[3] "Big data, big impact: New possibilities for international development," World Economic Forum, Jan. 2012.

[4] M. M. U. Rathore, A. Paul, A. Ahmad, B.-W. Chen, B. Huang, and W. Ji, "Real-time big data analytical architecture for remote sensing application," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4610–4621, Oct. 2015.

[5] A. Marinoni and G. Paolo, "An efficient approach for local affinity pattern detection in remotely sensed big data," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4622–4633, Oct. 2015.

[6] G. Cavallaro, M. Riedel, M. Richerzhagen, J. A. Benediktsson, and A. Plaza, "On understanding big data impacts in remotely sensed image classification using support vector machine methods," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4634–4646, Oct. 2015.

[7] K. Tan, J. Zhang, Q. Du, and X. Wang, "GPU parallel implementation of support vector machines for hyperspectral image classification," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4647–4656, Oct. 2015.

[8] L. Yang, X. Sun, L. Peng, X. Yao, and T. Chi, "An agent-based artificial bee colony (ABC) algorithm for hyperspectral image endmember extraction in parallel," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4657–4664, Oct. 2015.

[9] K. Karantzalos, D. Bliziotis, and A. Karmas, "A scalable geospatial web service for near real-time, high-resolution land cover mapping," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4665–4674, Oct. 2015.

[10] I. Zinno *et al.*, "A first assessment of the P-SBAS DInSAR algorithm performances within a cloud computing environment," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4675–4686, Oct. 2015.

[11] M. Babaee, S. Tsoukalas, G. Rigoll, and M. Datcu, "Visualization-based active learning for the annotation of SAR images," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4687–4698, Oct. 2015.

[12] H. Xie, X. Tong, W. Meng, D. Liang, Z. Wang, and W. Shi, "A multilevel stratified spatial sampling approach for the quality assessment of remote-sensing-derived products," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4699–4713, Oct. 2015.

[13] E. Moguel *et al.*, "Multilayer big data architecture for remote sensing in Eolic parks," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4714–4719, Oct. 2015.

[14] P. Yue, C. Zhang, M. Zhang, X. Zhai, and L. Jiang, "An SDI approach for big data analytics: The case on sensor web event detection and geoprocessing workflow," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 8, no. 10, pp. 4720–4728, Oct. 2015.

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