Spatial Technology and Social Media

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The significant development of social media over the past decade has been complemented by the rise of spatial technologies to provide new mapping mechanisms that allow users engage with online information services and also with each other in an unprecedented way. Users of these technologies now provide a comprehensive geosocial overlay of the physical environment of the planet.

These "footprints," which can be linked to Earth observation data coming from remote sensing satellites and geographic information systems, open new possibilities for understanding how people can organize for societal impact, and lay the foundation for new crowd-powered geosocial systems. Specifically, the convergence of remote sensing technologies with social media is moving us on a fast track to a situation in which we can readily know where everybody and everything are located on the surface of the Earth, at any time, and to exploit the crowdsourcing power of social media in different contexts. This data avalanche, also called big data or exaflood, requires advanced machine learning techniques, coupled with adequate high-performance computing infrastructure.

This special issue provides a unique perspective on the combination of spatial technologies and social media, sensing and positioning, and monitoring under a big data processing framework.

Although we have made important progress in recent years in harvesting spatial and temporal data from social media, the exploitation of these data for decision making still needs further investigation, particularly in the context of its integration with remote sensing data. In this special issue, we intend to provide a snapshot of the most recent advances and breakthroughs in the aforementioned research areas, with particular focus on the combination of remote sensing data and information coming from social media, under a big data processing framework. We believe that this vision offers a unique perspective on the combination of spatial technologies and social media, sensing and positioning, monitoring, and big data that has never been explored before in the form of a monograph in the peer-reviewed literature.

I. OVERVIEW OF THE SPECIAL ISSUE

The issue begins with the introductory paper "Spatial technology and social media in remote sensing: A survey" by Li *et al.* This paper first discusses the relation between localization techniques and spatial technologies, pointing out their similarities and differences. Then, it addresses relevant

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topics such as location analysis of social media data and the fusion of multiple data sources, with specific attention to the integration of social media content with remote-sensing-based spatial technologies. The paper also includes specific examples addressing the use of social media data to perform information extraction from large data repositories.

The paper "Remote sensing image scene classification: Benchmark and state of the art" by Cheng *et al.* provides a review of the recent progress in techniques for remote sensing data classification. It also introduces a publicly available benchmark for remote sensing image scene classification that will enable the community to develop and evaluate various data-driven algorithms. The paper finally compares several representative classification methods using the newly introduced data set.

The paper "Toward seamless multiview scene analysis from satellite to street level" by Lefèvre *et al.* discusses and reviews how combined multiview imagery from satellite to street level can benefit scene analysis. The paper advocates that cross fertilization between remote sensing, computer vision, and machine learning is very valuable to make the best of geographic data available from Earth observation sensors and ground imagery.

The paper "Social media: New perspectives to improve remote sensing for emergency response" by Li *et al.* provides a detailed overview of strategies for the integration of social media and remote sensing data in time-critical applications. First, the most recent advances in the integration of social media and remote sensing data are discussed. Then, several practical case studies and examples are presented in the context of applications focused on emergency response.

The paper "Potentials of active and passive geospatial crowdsourcing in complementing Sentinel data and supporting Copernicus service portfolio" by Dell'Acqua and De Vecchi provides an overview of the concept of crowdsourcing (i.e., entrusting a pool of actors with problem solution or information collection tasks) and discusses how it relates to an important coordinated Earth observation initiative like Copernicus. It finally presents a specific example realized in the framework of a recent research project under the Copernicus framework.

The paper "A novel methodology to label urban remote sensing images based on location-based social media photos" by Chi *et al.* introduces a new methodology to classify urban remote sensing images with the support of location-based social media photos via big data analysis techniques and strategies such as active learning, crowdsourcing, shallow machine learning, and deep learning. Remote sensing images with high spatial resolution and a large amount of photos from social media sites, such as Flickr and Panoramio, are used to validate this methodology.

The paper "On combining social media and spatial technology for POI cognition and image localization" by Qian *et al.* gives a systematic review of the works that combine social media and spatial technology for place-of-interests (POI) cognition and image localization. The interactions among users, and user and POIs or services generate big social media data, which have rich information for user, location, and service cognition.

The paper "Spatial event forecasting in social media with geographically hierarchical regularization" by Zhao *et al.* discusses the topic of how to use social media as a significant surrogate for spatial societal event forecasting. Specifically, this paper proposes a novel feature learning framework that addresses the aforementioned issue by formulating prediction tasks for different locations with different spatial resolutions, allowing for heterogeneous relationships among the tasks to be characterized.

The paper "Geotagging text content with language models and feature mining" by Kordopatis-Zilos *et al.* presents a highly accurate geotagging approach for estimating the locations alluded by text annotations based on refined language models that are learned from massive corpora of social media annotations. The paper further explores the impact of different feature selection and weighting techniques on the performance of the approach, using a large benchmark collection from the MediaEval Placing Task over several years.

II. SUMMARY AND CONCLUSION

The increasing impact of social media has introduced the potential develop new geosocial information systems. Accomplishing this will require new methods, new algorithms, new systems, and new data processing frameworks, able to mine and analyze vast amounts of data including very high-resolution satellite imagery and social media repositories. The combination of these sources of information is poised to make major breakthroughs in the years to come, mainly due to the growing interest in spatial technology, social media, and computational/data-intensive approaches. The focus of this special issue is mainly on the exploration of potential synergies between remote sensing data and social media data, with a common processing framework based on big data analytics, information fusion, and advanced machine learning techniques. This offers a unique perspective on the combination of spatial technologies and social media, sensing and positioning, and monitoring.

Some important aspects that could be only partially covered by this special issue include the exploitation of social media for privacy issues, disease and epidemiology, and political aspects. In spite of this, the topics included in this special issue are expected to provide a relevant snapshot of current technologies for spatial technology and social media. ■

ABOUT THE GUEST EDITORS

Antonio Plaza (Fellow, IEEE) was born in Caceres, Spain, in 1975. He is an Associate Professor (with accreditation for Full Professor) with the Department of Technology of Computers and Communications, University of Extremadura, Badajoz, Spain, where he is the Head of the Hyperspectral Computing Laboratory (HyperComp), one of the most productive research groups working on remotely sensed hyperspectral data processing worldwide. His main research interests comprise hyperspectral data processing and parallel computing of remote sensing data. He has been the advisor of 14 Ph.D. dissertations and more than 30 Ms.C. dissertations. He was the Coordinator of the Hyperspectral Imaging Network, a European project with total funding of 2.8 million. He has authored more than 500 publications, including 200 journal papers (145 in IEEE journals), 22 book chapters, and over 240 peer-reviewed conference proceeding papers (94 in IEEE conferences). He has edited a book *High-Performance Computing in Remote Sensing* for CRC Press/Taylor and Francis and guest edited ten special issues on hyperspectral remote sensing for different journals. He has served as a proposal evaluator for the European Commission, the National Science Foundation, the European Space Agency, the Belgium Science Policy, the Israel Science Foundation, and the Spanish Ministry of Science and Innovation. He has reviewed more than 500 manuscripts for over 50 different journals.

Dr. Plaza is a Fellow of IEEE "for contributions to hyperspectral data processing and parallel computing of Earth observation data." He is a recipient of the recognition of Best Reviewers of the IEEE Geoscience and Remote Sensing Letters (in 2009) and a recipient of the recognition of Best Reviewers of the IEEE Transactions on Geoscience and Remote Sensing (in 2010), a journal for which he served as Associate Editor in 2007–2012. He is also an Associate Editor for IEEE Access, and was a member of the Editorial Board of the IEEE Geoscience and Remote Sensing Newsletter (2011–2012) and the IEEE Geoscience and Remote Sensing Magazine (2013). He was also a member of the steering committee of the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (JSTARS). He is a recipient of the 2015 Best Column Award of the IEEE Signal Processing Magazine, the 2013 Best Paper Award of the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, and a recipient of the most highly cited paper (2005–2010) in the *Journal of Parallel and Distributed Computing*. He received best paper awards at the IEEE International Conference on Space Technology and the IEEE Symposium on Signal Processing and Information Technology. He is a recipient of the Best Ph.D. dissertation award at University of Extremadura, a recognition also received by six of his Ph.D. students. He served as the Director of Education Activities for the IEEE Geoscience and Remote Sensing Society (GRSS) in 2011–2012, and is currently serving as President of the Spanish Chapter of IEEE GRSS (since November 2012). He is currently serving as the Editor-in-Chief of the IEEE Transactions on Geoscience and Remote Sensing. Additional information: http://www.umbc.edu/rssipl/people/aplaza

Jón Atli Benediktsson (Fellow, IEEE) received the Cand.Sci. degree in electrical engineering from the University of Iceland, Reykjavik, Iceland, in 1984 and the M.S.E.E. and Ph.D. degrees in electrical engineering from Purdue University, West Lafayette, IN, USA, in 1987 and 1990, respectively.

On July 1, 2015, he became the Rector of the University of Iceland. From 2009 to 2015, he was the Pro Rector of Science and Academic Affairs and Professor of Electrical and Computer Engineering at the University of Iceland. He is a cofounder of the biomedical start up company Oxymap (www.oxymap.com). His research interests are in remote sensing, biomedical analysis of signals, pattern recognition, image processing, and signal processing, and he has published extensively in those fields.

Prof. Benediktsson was the 2011–2012 President of the IEEE Geoscience and and Remote Sensing Society (GRSS) and was on the GRSS AdCom 2000–2014. He was Editor-in-Chief of the IEEE Transactions on Geoscience and Remote Sensing (TGRS) from 2003 to 2008 and has served as Associate Editor of TGRS since 1999, the IEEE Geoscience and Remote Sensing Letters since 2003, and IEEE Access since 2013. He is on the Editorial Board of the Proceedings of the IEEE, the International Editorial Board of the *International Journal of Image and Data Fusion* and was the Chairman of the Steering Committee of IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (2007–2010). He is a Fellow of the International Society for Optics and Photonics (SPIE). He was a member of the 2014 IEEE Fellow Committee. He received the Stevan J. Kristof Award from Purdue University in 1991 as outstanding graduate student in remote sensing. In 1997, he was the recipient of the Icelandic Research Council's Outstanding Young Researcher Award; in 2000, he was granted the IEEE Third Millennium Medal; in 2004, he was a corecipient of the University of Iceland's Technology Innovation Award; in 2006, he received the yearly research award from the Engineering Research Institute of the University of Iceland; and in 2007, he received the Outstanding Service Award from the IEEE Geoscience and Remote Sensing Society. He was corecipient of the 2012 IEEE Transactions on Geoscience and Remote Sensing Paper Award, and in 2013, he was corecipient of the IEEE GRSS Highest Impact Paper Award. In 2013, he received the IEEE/VFI Electrical Engineer of the Year Award. In 2014, he was a corecipient of the *International Journal of Image and Data Fusion* Best Paper Award. In 2015, he received an Outstanding Electrical and Computer Engineering (OECE) Award from the School of Electrical and Computer Engineering, Purdue University. He is a member of the Association of Chartered Engineers in Iceland (VFI), *Societas Scinetiarum Islandica*, and Tau Beta Pi.

Jun Li (Senior Member, IEEE) received the B.S. degree in geographic information systems from Hunan Normal University, Changsha, China, in 2004, the M.E. degree in remote sensing from Peking University, Beijing, China, in 2007, and the Ph.D. degree in electrical engineering from the Instituto de Telecomunicações, Instituto Superior Técnico (IST), Universidade Técnica de Lisboa, Lisbon, Portugal, in 2011.

Currently, she is a Professor with Sun Yat-sen University, Guangzhou, China, where she founded her own research group on hyperspectral image analysis and calibration in 2013. Since then, she has obtained several prestigious funding grants at the national and international level. She has published a total of 55 journal citation report (JCR) papers, 45 conference international conference papers, and one book chapter. She has received a significant number of citations to her published works, with several papers distinguished as "Highly Cited Papers" in Thomson Reuters' Web of Science Essential Science Indicators (WoS-ESI). Her main research interests comprise remotely sensed hyperspectral image analysis, signal processing, supervised/semisupervised learning and active learning.

Prof. Li is an Associate Editor for the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (since 2014). She has been a Guest Editor for several journals, including the Proceedings of the IEEE and the *ISPRS Journal of Photogrammetry and Remote Sensing*. She has also been an active reviewer for several journals, including the IEEE Transactions on Geoscience and Remote Sensing, the IEEE Geoscience and Remote Sensing Letters, the IEEE Transactions on Image Processing, *Pattern Recognition*, *Optical Engineering*, *Journal of Applied Remote Sensing*, and *Inverse Problems and Imaging*. She has received several important awards and distinctions, including the IEEE Geoscience and Remote Sensing Society (GRSS) Early Career Award in 2017, due to her outstanding contributions to remotely sensed hyperspectral and synthetic aperture radar data processing. She was also distinguished as one of the best self-funded Chinese students abroad by the Chinese Scholar Council (in 2010). She was distinguished

as a Best Reviewer of the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (in 2013). One of her students received the Best Student Paper at the 2016 *SPIE Remote Sensing Europe Symposium* held in Edinburgh, U.K., for the contribution "A new tool for unsupervised classification of satellite images available on web servers: Google Maps as a case study" (in September 2016). One of her students received the 2nd prize in the Student Paper competition held at the 2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) held in Fort Worth, TX, USA, for the contribution "Hyperspectral cloud shadow removal based on linear unmixing" (in July 2017).

Tao Yang (Senior Member, IEEE) received the B.S. degree in computer science and the M.E. degree in artificial intelligence from Zhejiang University, China, in 1984 and 1987, respectively, and the M.S. and Ph.D. degrees in computer science from Rutgers University, New Brunswick, NJ, USA, in 1990 and 1993, respectively.

He joined the Department of Computer Science, University of California at Santa Barbara, CA, USA, in 1993. He served as Chief Scientist for Ask.com (formally Ask Jeeves) from 2001 to earlier 2010, and also Vice President and Senior Vice President of ASK as the head of its search engineering division in various periods. He was the founding Chief Scientist and Vice President of Research and Development from 2000 to 2001 for Teoma, an Internet search startup company acquired by Ask Jeeves in 2001. At Ask.com/Teoma, he has led teams of scientists and engineers for the design and implementation of a top-rated search engine and vertical products that power the Ask network sites with over 100 million users. He visited Microsoft Bing in 2010–2011 for search technology R&D, and advised Panguso search in 2012–2013. His research has been in the areas of parallel/distributed systems, information retrieval, and high performance computing.

Prof. Yang served for the organization and program committees of various web and high performance computing conferences and was on the editorial board of the IEEE Transactions on Parallel and Distributed Systems. He received the Research Initiation and Career awards from the National Science Foundation (NSF) in 1994 and 1997, and Noble Jeeviant Award from AskJeeves in 2002.

Bing Zhang (Senior Member, IEEE) was born in Shannxi, China, in 1969.

He is a Full Professor and the Deputy Director of the Institute of Remote Sensing and Digital Earth (RADI), Chinese Academy of Sciences (CAS), Beijing, China, where he has been leading key scientific projects in the area of hyperspectral remote sensing for more than 20 years. His research interests include the development of mathematical and physical models and image processing software for the analysis of hyperspectral remote sensing data in many different areas, such as geology, hydrology, ecology, and botany. He has been also a Professor at the University of Chinese Academy of Sciences and gave lessons of hyperspectral remote sensing for more than 15 years. He has been the advisor of 30 Ph.D. dissertations and more than 12 Ms.C. dissertations. He has authored more than 300 publications, including about 180 journal papers. He has edited six books/contributed book chapters on hyperspectral image processing and subsequent applications; those books serve as the main materials for education and research in hyperspectral remote sensing in China. His great contributions have provided the significant improved theory and techniques for the future development of intelligent hyperspectral remote sensing.

Prof. Zhang has been serving as the Associate Editor for the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (IEEE JSTARS) since 2011. He was the Guest Editor for IEEE JSTARS Special Issue on "Hyperspectral Remote Sensing: Theory, Methods, and Applications" in 2013, the IEEE JSTARS Special Issue on "Big Data in Remote Sensing" in 2015, and *Pattern Recongition Letters* (PRL) Special Issue on "Advances in Pattern Recognition in Remote Sensing" in 2015. He has been serving as Technical Committee Member of the IEEE Workshop on Hyperspectral Image and Signal Processing (IEEE WHISPERS) since 2011. He is the Student Paper Competition Committee member in IGARSS 2015 and 2016, and Scientific Committee Member of IGRASS in 2014. He also served as the Session Chair at IEEE WHISPERS in 201 and 2015, and at IGARSS in 2011, 2013, 2015, and 2016. His creative achievements were rewarded with ten important prizes from the Chinese government from 2005 to 2017, and special government allowances of the Chinese State Council in 2009. He was awarded the National Science Foundation for Distinguished Young Scholars of China in 2013. As the leader of hyperspectral remote sensing team in RADI, he won the 2016 CAS Outstanding Scientific Achievement Award.