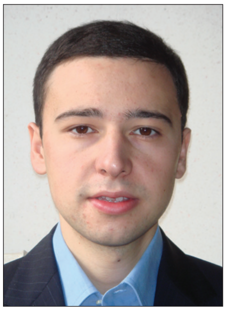
MOBILE CROWD SENSING: PART 1

Bin Guo *Francesco Calabrese* *Emiliano Miluzzo* *Mirco Musolesi*

Successful city management relies on urban dynamics and social event monitoring to provide essential information for decision making. In traditional sensing techniques such as wireless sensor networks (WSNs), distributed sensors are leveraged to acquire real-world conditions. However, static sensing suffers from several problems, such as insufficient node coverage, high installation/maintenance cost, and lack of scalability.

Mobile crowd sensing (MCS) presents a new sensing paradigm based on the power of various mobile devices (smartphones, wearable devices, smart vehicles, etc.). The sheer number of mobile device users and their inherent mobility enable a new and fast-growing sensing paradigm: the ability to acquire local knowledge through sensor-enhanced mobile devices — for example, location, personal and surrounding contexts, noise level, traffic conditions, and, in the future, more specialized information such as pollution — and the possibility to share this knowledge within the social sphere, and among practitioners, healthcare providers, and utility providers. The information collected by mobile devices on the ground combined with the support of the cloud where data fusion takes place make MCS a versatile platform that can often replace static sensing infrastructures, and enable a broad range of applications such as urban dynamics mining, social event detection, public safety, environment monitoring, and traffic planning, just to name a few.

Numerous and unique research challenges arise from the MCS paradigm, including participatory data collection, optimal sensing node selection and task allocation, proper incentive mechanisms, transient network communication, cross-space data processing, human-machine intelligence fusion, and so on. By having human participation in the loop, several other issues regarding to the privacy and security of data (e.g., sensitive information such as human voice and location may be revealed), and the quality/trust of the data contributed (e.g., there might be fake or malicious nodes involved) should also be addressed.

The articles in this issue highlight relevant current technologies and approaches pertaining to cross-community mining, including theoretical studies, practical issues, emerging technologies, and innovative applications. The responses to our Call for Papers on this Feature Topic were overwhelming, with 42 articles submitted from around the globe. A large number of reviewers assisted us in the review process. In order to ensure high reviewing standards, three to four reviewers evaluated each submission, with a rigorous two-round review process. Nine papers were selected after the review process. The selected papers fall into four main research topics of MCS: two are about MCS data aggregation, two about data collection and transmission, two about data quality/trust, and three about novel MCS applications or empirical studies. The articles are organized as Parts 1 and 2. In Part 1 (this issue), you can find six of them as listed below, and the other three will be published as Part 2 in a later issue.

The first article, "Mobile Crowd Sensing in Space Weather Monitoring: The Mahali Project" by Pankratius *et al.*, describes a revolutionary architecture that uses mobile devices to form a monitoring network for Earth's near space environment. Many observed phenomena have large signatures in the ionosphere, and affect communications, navigation, and power systems. Mahali exploits existing GPS signals traveling through the ionosphere to acquire a vast set of ionospheric total electron content projections. With the connectivity available worldwide, mobile devices are excellent candidates to establish crowdsourced global relays that feed multi-frequency GPS sensor data into a cloud processing environment to tomographically reconstruct the structure of the space environment and its dynamic changes.

The second article, "Opportunities in Mobile Crowd Sensing" by Ma *et al.*, investigates the opportunistic characteristics of human mobility from the perspectives of sensing and transmission, and discusses how to exploit the opportunities that human mobility offers to improve the sensing/transmission performance of MCS. It also outlines various open issues brought by human involvement in MCS, including the evaluation of sensing quality, efficient data collection methods, incentive mechanisms, and so on.

The third article, "Surrogate Mobile Sensing" by Wang *et al.*, proposes a new mobile sensing paradigm called surrogate sensing, which refers to the transparent use of commonly available sensors (e.g., on mobile phones) as surrogates to measure more complex logical quantities (e.g., free parking lots). The key challenge involved is to exploit appropriate aggregation techniques that leverage the availability of large numbers of smartphones to overcome the poor quality of individual surrogates. To address the challenge, they propose a rigorous analytical framework based on maximum likelihood estimation and present a case study to validate the performance of their proposed framework.

The fourth article, "4W1H in Mobile Crowd Sensing" by Zhang *et al.*, propose a four-stage process to characterize the MCS life cycle. The life cycle is represented as task creation, task assignment, individual task execution, and crowd data integration. They further use the framework of 4W1H (i.e., What, When, Where, Who, and How) to sort out the research problems in the MCS domain. Furthermore, they use the proposed process and framework to foresee new directions in future MCS research.

The fifth article, "Trust and Privacy in Mobile Experience Sharing: Future Challenges and Avenues for Research" by Krontiris *et al.*, explores the trust and privacy issues in mobile experience sharing. Today's privacy and trust tools that address web surfing and simple location-based services already struggle to be adopted in practice. To prepare for tomorrow's sensor sharing, privacy and trust must be addressed holistically, incorporating both technical approaches and actual sharing behavior. The authors summarize the results of a five-day Dagstuhl Seminar on mobile experience sharing and outline future research necessary in this domain.

The sixth article, "Recommending Travel Packages Based on Mobile Crowdsourced Data" by Yu *et al.*, proposes a travel package recommendation system that helps users make travel plans by leveraging mobile crowdsourced data. The system extracts user preferences, discovers points of interest (POIs), and determines location correlations using the large-scale check-in records from LBSNs. It further generates personalized travel packages by considering user preferences, POI characteristics, and temporal-spatial constraints (e.g., the time budget and starting place).

In concluding this overview, we would like to address our special thanks to Dr. Sean Moore, Editor-in-Chief of *IEEE Communications Magazine*, and Charis Scoggins and Jennifer Porcello for their great support and effort throughout the whole publication process of this Feature Topic. We are also grateful to all the authors for submitting their papers, and the reviewers for their professional and timely work in making it possible to publish these articles in this important area.

BIOGRAPHY

BIN GUO [M'06, SM'14] (guob@nwpu.edu.cn) is a professor at Northwestern Polytechnical University, China. He received his Ph.D. degree in computer science from Keio University, Tokyo, Japan, in 2009. During 2009–2011, he was a postdoctoral researcher at Institute TELECOM SudParis, France. His research interests include pervasive computing, mobile social networking, and mobile crowd sensing. He has served as an Associate Editor of *IEEE Communications Magazine*, *IEEE Transactions on Human Machine Systems*, and *Personal and Ubiquitous Computing*. He is the leading Guest Editor of the *ACM Transactions on Intelligent Systems and Technology* Special Issue on Participatory Sensing and Crowd Intelligence and the *Springer Journal of Ambient Intelligence and Humanized Intelligence* Special Issue, From Digital Footprints to Social and Community Intelligence. He edited the book *Creating Personal, Social, and Urban Awareness through Pervasive Computing* (IGI Global, 2013). He has served as General Chair of ACM/IEEE SCI '11 and SCI '14, Program or Vice Program Chair of IEEE UIC '13, ANT '14, and IEEE CIT '14, Workshop Chair of iThings '13, and TPC member for a number of conferences. He has published over 70 scientific papers in referred journals, conferences, and book chapters. He won the best paper award of IEEE CPSCom '13, AMT '12, and GPC '12.

FRANCESCO CALABRESE (fcalabre@ie.ibm.com) is an advisory research staff member at the IBM Research — Ireland Center, Dublin. He manages the Smarter Urban Dynamics group, focusing on developing analytics and tools to better understand and optimize the urban dynamics. He received his Laurea (B.S. and M.S.) degree in computer engineering, cum laude, in 2004, and his Ph.D. in computer and system engineering from the University of Naples Federico II, Italy, in 2007. He was a research scientist and postdoctoral associate at the Massachusetts Institute of Technology (MIT) from 2007 to 2010, where he led research on urban networks and society. His research interests include ubiquitous computing, intelligent transportation systems, urban network analysis, and the design of distributed control systems. He has co-authored over 60 scientific publications. His work has been exhibited in leading museums worldwide, including the Venice Biennale, Science Gallery and the Museum of Modern Art, New York. He was leading Guest Editor of the Special Issue on Pervasive Urban Applications of the *Pervasive and Mobile Computing Journal*.

EMILIANO MILUZZO (miluzzo@research.att.com) is a researcher at AT&T Labs Research. His work sits at the intersection of mobile systems and applied machine learning, pioneering the field of smartphone sensing research, where a person's smartphone can be used to infer personal and surrounding context in a resource-efficient manner. Results of his research have been published in top-tier conferences such as SenSys, MobiSys, and UbiComp, and workshops (e.g., HotMobile). He serves on the program committee of leading venues and co-organizes a number of smartphone sensing, infrastructure, and data analytics workshops, and mobile app competitions (co-located with SIGCOMM '13 and SenSys '13, MobiCom '14 Mobile App Competition, and more). He holds a Ph.D. in computer science from Dartmouth College, and his M.Sc. and B.Sc. in electrical engineering from the University of Rome "La Sapienza," Italy.

MIRCO MUSOLESI (m.musolesi@cs.bham.ac.uk) is a reader in Networked Systems and Data Science at the School of Computer Science within the University of Birmingham, United Kingdom. He received a Ph.D. in computer science from University College London in 2007 and a Master's in electronic engineering from the University of Bologna in 2002. Before joining Birmingham, he was a lecturer in Computer Science at the School of Computer Science at the University of St. Andrews, United Kingdom. From October 2005 to August 2007 he was a research fellow in the Department of Computer Science, University College London. Then, from September 2007 to August 2008, he was an ISTS postdoctoral research fellow at Dartmouth College, and from September 2008 to October 2009 a postdoctoral research associate at the Computer Laboratory, University of Cambridge. His research interests are in the areas of ubiquitous computing, networked systems, and large-scale data mining. He has been involved in several ACM and IEEE events in the past years as Program Chair and Program Committee Member. He is also a reviewer for leading computer science journals, including many ACM and IEEE Transactions.