Foreword to the Special Issue on the 14th International Conference on Ground Penetrating Radar (GPR2012)

THE 14th International Conference on Ground Penetrating Radar (GPR2012) was held in Shanghai, China, June 4–8, 2012. It was chaired by Tongji University Professor Xiongyao Xie. The Conference had 235 attendants from 27 countries and regions, among which were many young researchers and 45 graduate students. Nearly 180 papers were presented in both the oral and the poster sessions. The review process was rigorous, thanks to the work of about 90 reviewers coordinated by three Technical Co-Chairs, Prof. Lanbo Liu, Prof. Motoyuki Sato, and Dr. Fannian Kong. The Proceedings have been available through the IEEE digital repository [1]. Two young researchers, Mr. Hai Liu of Tohoku University and Ms. A. Klotzsche of Research Center Juelich, Germany, received the Excellence of Research award by an international review committee for the quality of the work they presented.

The Conference papers with the most significant scientific findings and important technical developments have been improved and expanded to the quality of peer-reviewed journal articles and published in four special issues on ground-penetrating radar (GPR): "GPR for Geotechnical Engineering," in *Journal of Geophysics and Engineering* (JGE); "Forward and Inverse Problems in GPR Research," in *Journal of Applied Geophysics* (JAG); "Innovative GPR Systems," in IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING (IEEE/JSTARS, this issue), and "GPR for Hydrogeology and Groundwater Problems," in *Journal of Environmental and Engineering Geophysics* (JEEG).

This special issue on "Innovative GPR Systems" showcases 10 papers on latest developments in the development of GPR systems and innovative geophysical applications. We divided these papers into two groups: 1) innovations in radar system development and 2) advanced signal processing algorithms and their applications to a variety of scientific and technical fields. Naturally, some of the papers do straddle both groups, therefore we have made ever attempt to order the papers in a way with smoother transition between these two groups.

The first group of four papers focuses on the innovations in GPR system development for meeting the challenges of various environments and settings. The paper by Xia *et al.* [2] presents the development and implementation of a dual-channel, light-weight air-coupled ultra-Wideband (UWB) GPR for targeting highway pavements and bridge deck inspections. In comparison with most of the existing GPR systems with a single channel and low survey speeds, their newly developed GPR system possesses competitive features, including wide coverage of detection area, high spatial resolution and operating capability at normal highway driving speed (up to 60 mph). The second paper in this group by Fu *et al.* [3] presents a step-frequency continuous-wave (SFCW) airborne GPR system with resistively loaded planar dipole antennas. The resistively loaded antennas were based on the Altshuler discrete resistive loading approach. The distance from the loading point to the feeding point and the resistance were optimally designed. In addition, a balun at feeding point was introduced to convert the unbalance signal from coax to balance signal. The testing results showed that the antennas have a wide bandwidth with a frequency range from 55 to 275 MHz. The paper by Shao *et al.* [4] presents a shallow Vee-shape cavity shielded planar dipole UWB antenna with a center frequency of 400 MHz as the major device for a human vital sign detection radar system. The antenna consists of two half-ellipse-shape arms tuned with four semicircular slots and loaded with six resistors. A resistive and slot loading technique for improving impulse radiation and reducing late time ringing is adopted. With proper shielding, four semicircular tuned slots and the resistive loading, this antenna system has low ringing, large bandwidth, and suitable resolution for human body. The laboratory test shows that the performance of this antenna has met the design. The paper by Liu and Liu [5] investigates the problem of human vital sign detection by SFCW radar technique. The data of the experiment were acquired by an SFCW radar system consisting of a pair of bowtie antenna and a vector network analyzer controlled by a PC system. In general, the SFCW radar system achieves superior performance for human vital sign detection, at least in the lab conditions. For non-line-of-sight human vital sign detection the posture of the subject relative to radar antenna and the position of the antenna relative to human subject's chest are not critical for breathing signatures. These facts grant us advantageous gains for higher probability of vital sign detection in the field.

The second group of six papers focuses on advanced signal processing algorithms and their applications to a variety of scientific and technical fields. The first paper in this group by Li *et al.* [6] proposes a processing procedure for human vital sign identification and extraction. First, curvelet transform is applied to remove source-receiver direct coupling and background clutters. Next, singular value decomposition (SVD) is used to de-noise the vital sign signals. Finally, the analysis results are presented based on FFT and Hilbert–Huang transform (HHT) to separate and extract the human vital signs frequencies of breathing and heartbeat, as well as the Doppler shift characteristics. The proposed processing approach is tested by a set of synthetic data generated by numerical simulation of UWB radar detection of two trapped victims under debris at an earthquake site of collapsed building. Then it is validated by laboratory experiments. The results demonstrate that the combination of UWB radar and an advanced signal processing algorithm has the potential for efficient vital sign detection and location in search and rescue for trapped victims in a complex environment such as the earthquake disaster sites. In order to mitigate the adverse effect of clutters the second paper in this group, by Solimene *et al.* [7], assesses the performance of an entropy based approach for clutter removal by processing experimental data collected in laboratory controlled conditions and for the challenging situation of shallower dielectric and metallic targets whose back-scattered fields overlap in time with the air–soil interface signal. This proposed entropy method is especially effective for canceling the clutters from medium interfaces. The paper by Feng *et al.* [8] proposes a fast processing method for topographic correction, which is based on the velocity model estimated by the elevated common mid-point (CMP)

Digital Object Identifier 10.1109/JSTARS.2014.2307125

GPR profile itself in order to compensate the effects of variations in GPR antenna elevation. The method substitutes the air layer between the antenna and the ground with the soil layer by shifting the propagation time. The method has been tested using experiment data acquired over a sloping ground surface under which a landmine model is buried in shallow depth. The result shows the quality of target imaging was improved, especially in the time slices in the horizontal plane. In another paper by Solimene *et al.* [9], they investigate a GPR technique for estimating the soil permittivity. The technique consists of two steps: 1) first the soil Fresnel reflection coefficient is estimated and 2) then the soil electromagnetic parameters are inferred from the retrieved reflection coefficient. In real scenarios, the transmitting antenna couples with the soil as it is in close proximity of the air–soil interface so that mutual interactions arise. To overcome such a drawback, a pre-processing stage consisting of a suitable time gating procedure is introduced. This process not only allows restore the linearity of the Fresnel coefficient estimation but also enables the mitigation of the negative effect due to miss-match of the transmitting antenna. The paper by Zhang *et al.* [10] discusses a new learning algorithm based on Gibbs sampling to learn the parameters of continuous hidden Markov models (HMM) with multivariate Gaussian mixtures for GPR target detection. The proposed sampling algorithm outperformed the standard expectation maximization algorithm and a minimum classification error algorithm when applied to a synthetic data set. It also outperforms the state-of-the-art approaches when applied to landmine detection using GPR field data. Finally, the last paper in this group deals with a more real-world geological problem. Liu *et al.* [11] propose a method to estimate the thickness of snow and ice density of frozen media (snow, firn, to ice) using common-offset GPR data. The technique is based on reflection amplitude analysis to calculate the series of reflection coefficients needed to estimate the dielectric permittivity of each layer. This field survey system is very flexible because the antenna offset range and number of channels can be easily adjusted in accordance with the expected target depth and signal-to-noise ratio of the reflected signal. This approach was tested on a brackish lagoon, i.e., Lake Saroma, Hokkaido, Japan. The last paper in this special issue by Xie *et al.* [12], though not using the GPR technique but an array of geophones for recording seismic surface waves, presents a series of technical improvement for picking up the anomalies in the profile caused by a buried tunnel. Their approach is a valuable reference for processing GPR data for tunnel detections.

We are pleased to present this special issue to the international GPR community and hope that it can serve as a snapshot of the current state-of-the-art studies in GPR research and practice. The key criteria for selecting these papers were their alignment with the focus of IEEE/JSTARS. The papers reflect a combination of advanced or new methodology for GPR system development, application novelty, or provide novel or advanced signal processing to allow more effective utilization of GPR in the applied earth science and remote sensing realm. The editor thanks the authors for their efforts in creating first quality, highly readable papers, as well as their great patience to wait for a period of time to allow the papers to be published collectively as a special issue. The editor also would like to thank the reviewers for their time and effort in helping make this special issue a reality.

Lanbo Liu, Guest Editor
Department of Civil and Environmental Engineering
University of Connecticut Storrs, CT 06269 USA

References

[1] IEEE Xplore, in *Proc. 14th Int. Conf. Ground Penetrating Radar* (GPR), 2012, doi: 10.1109/ICGPR.2012.6254822.

[2] T. Xia, A. S. Venkatachalam, X. Xu, and D. Huston, "Development of a new high speed dual-channel impulse ground penetrating radar," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 753–760, Mar. 2014.

[3] L. Fu, S. Liu, L. Liu, and L. Lei, "Development of an airborne ground penetrating radar system: antenna design, laboratory experiment, and numerical simulation," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 761–766, Mar. 2014.

[4] J. Shao, Y. Ji, G. Fang, and H. Yin, "Semicircular slot tuned planar half-ellipse antenna with a shallow Vee cavity in vital sign detection," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 767–774, Mar. 2014.

[5] L. Liu and S. Liu, "Remote detection of human vital sign with stepped-frequency continuous wave radar," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 775–782, Mar. 2014.

[6] J. Li, L. Liu, Z. Zeng, and F. Liu, "Advanced signal processing for vital sign extraction with applications in UWB radar detection of trapped victims in complex environments," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 783–791, Mar. 2014.

[7] R. Solimene, A. Cuccaro, A. Dell'Aversano, I. Catapano, and F. Soldovieri, "Ground clutter removal in GPR surveys," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 792–798, Mar. 2014.

[8] X. Feng, M. Sato, C. Liu, K. Takahashi, and Y. Zhang, "Topographic correction of elevated GPR," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 799–804, Mar. 2014 (2012-00586).

[9] R. Solimene, A. D'Alterio, G. Gennarelli, and F. Soldovieri, "Estimation of soil permittivity in presence of antenna-soil interactions," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 805–812, Mar. 2014.

[10] X. Zhang, J. Bolton, and P. Gader, "A new learning method for continuous hidden Markov models for subsurface landmine detection in ground penetrating radar," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 813–819, Mar. 2014.

[11] H. Liu, K. Takahashi, and M. Sato, "Measurement of dielectric permittivity and thickness of snow and ice on a brackish lagoon using GPR," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 820–827, Mar. 2014.

[12] P. Xie, S.L. Grant, N.H. Putnam, N.L. Anderson, and A. Nasseri-Moghaddam, "An improved post-processing technique for array-based detection of underground tunnels," *IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens.*, vol. 7, no. 3, pp. 828–837, Mar. 2014.

Lanbo Liu received the B.S. and M.S. degrees in geophysics from Peking University, Beijing, China, the M.S. degree in civil and environmental engineering, and the Ph.D. degree in geophysics from Stanford University, Stanford, CA, USA. He was the Carnegie Fellow at Carnegie Institution of Washington before joining the faculty in the University of Connecticut.

He is a Professor in the Department of Civil and Environmental Engineering at the University of Connecticut, Storrs, CT, USA. He was the Summer Faculty Fellow at Schlumberger-Doll Research, and at NASA's Goddard Space Flight Center. He was a Fulbright Scholar to Norway in 2009–2010. He is also serving as an Expert for US Army Corps of Engineers. He has more than 100 publications in peer-referred journals, conference proceedings, and technical reports. He served as an Associate Editor for *Geophysics* and is serving as the Associate Editor for *Journal of Environmental and Engineering Geophysics*. His current research focuses on numerical modeling and imaging with electromagnetic, acoustic, and seismic waves for natural resource exploration, military, geotechnical, environmental, and biomedical engineering applications.

Dr. Liu received the US Army R&D Achievement Award for his work on radio wave propagation in complex terrains. In association with GPR studies, he has been a member of the scientific committees and technical review panels for the series of International Conference on Ground Penetrating Radar in 1998, 2004, 2012, and 2014. He was the Chair of the Scientific Review Committee for the 14th International Conference on Ground Penetrating Radar held in Shanghai, China. He is a Guest Editor for Special Issues in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (March 2014), *Journal of Applied Geophysics* (December 2013), and *Journal of Geophysics and Engineering* (2007, 2013) on topics concerned with GPR.