

Editorial

## Editorial for Special Issue “Recent Advances in GPR Imaging”

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The Special Issue (SI) “Recent Advances in GPR Imaging” offers an up-to-date overview of the state of the art of research activities dealing with the development of Ground-Penetrating Radar (GPR) technology and its recent advances on imaging in different fields of application. In fact, the advances experimented during the last decades with regard to the appearance of new GPR systems and of the need to manage large amounts of data have implied an increasing interest in the development of new signal processing algorithms and modeling, as well as in the use of three-dimensional (3D) imaging techniques.

Most of the works present in this SI can be categorized according to their relevant application fields.

The understanding of the GPR data has been a long-term challenge among both the scientific and the non-geophysical community. In this frame, the development of new data processing algorithms and electromagnetic modeling has benefited the interpretation process of field GPR data. The paper from Salinas et al. [1] presents a processing technique to determine the Mean Amplitude of Incoherent Energy (MAEI) for each A-scan, which was applied to the study of the shallow geology in Barcelona and allows zone differentiation (underground streams and paleochannels) depending on the amplitude of the clutter caused by backscattering. Additionally, complementary numerical modeling and passive seismic measurements were applied in order to validate the proposed processing methodology. Prokopovich et al.’s study [2] deals with the development of a time-domain version of the coupled-wave Wentzel–Kramers–Brillouin approximation for the solution of the backscattering problem arising when a pulsed electromagnetic signal impinges on a non-uniform dielectric half-space. The results obtained were compared with those from Finite-Difference Time-Domain (FDTD) modeling, showing very good agreement, which demonstrates the capabilities of the new method to correctly predict the protracted return signals originated by smooth transition layers of the subsurface dielectric medium. Another example of a novel GPR data processing is shown in Fontul et al.’s paper [3], which presents a new approach for the automatic detection of signal variations based mainly on expedite frequency-domain analysis of the GPR signal. Case studies are included with the application of the new approach to railway assessment, with the identification of track events, ballast interventions, and potential locations of malfunctions.

In addition to new algorithms for signal processing and automatic detection, improvements on imaging and interpretation approaches are still needed. In Zhang et al. [4], a new method for GPR imaging based on the Variational Mode Decomposition (VMD) and the Intrinsic Mode Functions (IMFs) is proposed. In this method, the IMFs are generated trace by trace by the VMD, and then these IMFs are sorted and displayed into different profiles (IMF-slices) according to different frequency bands or ranges. Using IMF-slices, some subsurface events could be more clearly identified.

In Dérobert and Pajewski's study [5], a wide dataset of GPR data collected on a full-size geophysical test site in Nantes (France) is presented. The geophysical test site was built to reproduce an urban site (including pipes, cables, stones of various size, and masonry) in a completely controlled environment. A total of 67 profiles were recorded using three different pulsed radar systems equipped with various antenna frequencies from 200 MHz to 900 MHz. An archive containing all the profiles (in raw data) is enclosed to this paper as supplementary material. This dataset is part of the Open Database of Radargrams initiative of COST Action TU1208 "Civil Engineering Applications of Ground-Penetrating Radar" with the aim of providing unified material for the evaluation of processing methodologies and allowing intercomparisons.

Provided the complexity of the interpretation of the measured data (2D-GPR images), the use of 3D imaging techniques advances in the generation of more realistic images of the underground structures. 3D imaging is particularly relevant for archaeological investigations, allowing not only the discovery, but also the 3D reconstruction of buried structures for a more comprehensive archaeological interpretation. Puente et al.'s study [6] deals with the 3D reconstruction of the Roman fort "Aquis Querquennis", in Spain, through the combination of three different non-destructive techniques: GPR, Terrestrial Light Detection and Ranging (T-LiDAR), and Infrared Thermography (IRT). Moreover, a novel processing and 3D imaging software "toGPRi" is presented for the creation of the 3D model and the subsequent time-slices at different depths and overlaid imaging. This 3D GPR imaging is georeferenced and then merged with the orthoimages produced by the T-LiDAR, which allowed for a complete interpretation of the Roman site, including its surface geometry.

New approaches focused on the combined application of GPR with complementary non-destructive testing techniques are also recommended for high-resolution prospection. An example of integrated geophysical techniques is shown in Martínez et al. [7], in which GPR and Electrical Resistivity Imaging (ERI) methods were successfully combined for assessing the quality of ornamental rock (marble) in Macael, Spain. In Čeru et al. [8], the GPR was used to select dolines appropriate for further morphometrical and distributive analyses on LiDAR images applied to the study of geomorphological dating of Pleistocene conglomerates in Central Slovenia. The paper by Čeru et al. [9] demonstrates the capability of the GPR method to locate areas of cave sediments at the surface and to determine their spatial extent, which allowed delineating the geometry of unroofed cave systems in Lanski vrh (W Solovenia). Complementary X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses were performed to analyze the mineral and geochemical compositions of the cave sediments and soils in order to determine which factors might significantly influence the GPR signal propagation.

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