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Electromagnetic modelling, inversion and data-processing techniques for GPR: ongoing activities in Working Group 3 of COST Action TU1208

Lara Pajewski (1), Antonis Giannopoulos (2), and Jan van der Kruk (3)

(1) Roma Tre University, Department of Engineering, Roma, Italy (lara.pajewski@uniroma3.it), (2) The University of Edinburgh, School of Engineering, Edinburgh, United Kingdom (a.giannopoulos@ed.ac.uk), (3) Forschungszentrum Jülich GmbH, Institute of Bio- and Geosciences, Jülich, Germany (j.van.der.kruk@fz-juelich.de)

This work aims at presenting the ongoing research activities carried out in Working Group 3 (WG3) "EM methods for near-field scattering problems by buried structures; data processing techniques" of the COST (European COoperation in Science and Technology) Action TU1208 "Civil Engineering Applications of Ground Penetrating Radar" (www.GPRadar.eu).
The principal goal of the COST Action TU1208 is to exchange and increase scientific-technical knowledge and experience of GPR techniques in civil engineering, simultaneously promoting throughout Europe the effective use of this safe and non-destructive technique in the monitoring of infrastructures and structures.
WG3 is structured in four Projects. Project 3.1 deals with "Electromagnetic modelling for GPR applications." Project 3.2 is concerned with "Inversion and imaging techniques for GPR applications." The topic of Project 3.3 is the "Development of intrinsic models for describing near-field antenna effects, including antenna-medium coupling, for improved radar data processing using full-wave inversion." Project 3.4 focuses on "Advanced GPR data-processing algorithms."
Electromagnetic modeling tools that are being developed and improved include the Finite-Difference Time-Domain (FDTD) technique and the spectral domain Cylindrical-Wave Approach (CWA). One of the well-known freeware and versatile FDTD simulators is GprMax that enables an improved realistic representation of the soil/material hosting the sought structures and of the GPR antennas. Here, input/output tools are being developed to ease the definition of scenarios and the visualisation of numerical results. The CWA expresses the field scattered by subsurface two-dimensional targets with arbitrary cross-section as a sum of cylindrical waves. In this way, the interaction is taken into account of multiple scattered fields within the medium hosting the sought targets. Recently, the method has been extended to deal with through-the-wall scenarios.
One of the inversion techniques currently being improved is Full-Waveform Inversion (FWI) for on-ground, off-ground, and crosshole GPR configurations. In contrast to conventional inversion tools which are often based on approximations and use only part of the available data, FWI uses the complete measured data and detailed modeling tools to obtain an improved estimation of medium properties.
During the first year of the Action, information was collected and shared about state-of-the-art of the available modelling, imaging, inversion, and data-processing methods. Advancements achieved by WG3 Members were presented during the TU1208 Second General Meeting (April 30 – May 2, 2014, Vienna, Austria) and the 15th International Conference on Ground Penetrating Radar (June 30 – July 4, 2014, Brussels, Belgium).
Currently, a database of numerical and experimental GPR responses from natural and manmade structures is being designed. A geometrical and physical description of the scenarios, together with the available synthetic and experimental data, will be at the disposal of the scientific community. Researchers will thus have a further opportunity of testing and validating, against reliable data, their electromagnetic forward- and inverse-scattering techniques, imaging methods and data-processing algorithms. The motivation to start this database came out during TU1208 meetings and takes inspiration by successful past initiatives carried out in different areas, as the Ipswich and Fresnel databases in the field of free-space electromagnetic scattering, and the Marmousi database in seismic science.

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