PhD in Civil and Environmental Engineering

Research Title: Joint inversion of geophysical data for comprehensive multi-physics subsurface 3D models.

Funded by	Politecnico di Torino (Joint Research Projects with Top Universities)

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Context of the research activity	Geophysical methods are non-invasive surveying techniques that provide the distribution of physical parameters (elastic moduli, density, electrical resistivity) in the subsurface through measurements performed on the ground surface, which are interpreted through model parameter optimization techniques (inversion). Their application is widespread in many fields ranging from natural resource exploration, to environment assessment and monitoring, natural hazards, infrastructure design and cultural heritage. Different geophysical techniques (seismic, electromagnetics, potential fields) provide indirect information regarding different physical parameters and model estimation algorithms suffer from intrinsic limitations, which are peculiar of each method. Several researches have proved that the joint inversion of data from different techniques can offer a way to overcome intrinsic limitations of individual methods and provide a more reliable and comprehensive model of the subsurface. Polito research team has developed significant expertise in seismic surface wave analysis and implemented inversion codes used in the framework of simplified joint inversion of seismic and resistivity data of local 1D models. TUDelft has significant expertise in modelling and inversion of EM data. The JRP will combine the complementary expertise in the two groups to develop an inversion platform able to perform joint 3D inversion of seismic and EM data also incorporating a priori and geo-models. The joint inversion will be implemented imposing structural compliance to the subsurface models and including petrophysical laws to link the different geophysical data to mechanical and hydraulic parameters. The inversion code will represent a novel software infrastructure for the interpretation of geophysical data. The foreseeable applications are in the

	framework of underground resources, environmental and engineering problems. The inversion code will be made publicly available as open software.

Objectives	The joint research project will be organized according to five work packages (WPs) and will have a duration of 36 months. The work will be performed in close cooperation with a PhD students from TUDelft. The schedule of the student exchange is reported after WP description. **WP1 – design of a 3D inversion platform able to handle multi-parametric models and multi-physics data (Polito+TUDelft)** Task To answer two questions: 1) Which multi-parametric models best describe the earth response present in the available multi-physics data? 2) Which cost function optimally combines the different data for subsurface model parameter estimation? To design the corresponding inversion platform. Activities Investigate the possible models to represent the information in the available seismic and electromagnetic data; compute the Jacobian matrices and evaluate sensitivities; evaluate the effect of introducing multi-parametric models in the cost function taking into account offset dependent signal-to-noise ratios in the data; Define spatial regularization and constraint scheme to handle multi-parametric data and a priori Deliverables Design of the inversion platform; Code to compute Jacobian matrix for the joint inversion cost function. Journal paper on strategy for joint inversion. **WP2 – customization of seismic inversion algorithms in the framework of 3D inversion (Polito)** Task To develop and write the code for the 3D seismic part of the joint inversion scheme Activities Update the existing surface-wave data routines in the framework of the inversion scheme developed at WP1; Improve the spatial regularization to link local 1D model to reference 3D model; Include in the inversion scheme the wavelength/depth relation method and assess the sensitivities to model parameters; Compute model uncertainty from sensitivities of Jacobian matrix. Deliverables Code for the seismic part of the joint inversion; Journal paper on pseudo 3D inversion of surface wave data **WP3 – develop and implement the 3D EM inversion code (TUDelft)** Task To develop and write the computer code for the 3D EM part of the joint inversion scheme Activities Take the Jacobian matrix and sensitivity results from WP1 to further develop a stand-alone 3D EM inversion; compute the step-length and regularization parameter in each iteration; include tilted-transverse isotropy in the resistivity model; compute signal-to-noise ratios after the data amplitudes have been corrected for offset for inclusion in the data uncertainty covariance matrix; compute model uncertainty from the sensitivities for inclusion in the model uncertainty covariance matrix.

Deliverables Code for the EM part of the joint inversion;
Journal paper on 3D Gauss-Newton inversion of EM data.

WP4 – merging of the code implemented in WP2 and WP3 in the infrastructure implemented in WP1 (Polito+TUDelft)

Task Create an operational joint inversion platform

Activities Merge the seismic (WP2) and EM (WP3) inversion codes in the code developed at WP1; add possible cross-gradient conditions on model parameters;
make potentially necessary adjustments based on the results from the numerical tests to be carried out in WP5.

Deliverables Operational open software joint seismic and EM inversion platform;
Journal paper on open software joint inversion algorithm and code.

WP5 – testing of the joint inversion infrastructures on synthetic and real data (Polito+TUDelft)

Task Validate joint inversion software; provide feedback to WP4 for possible improvements.

Activities Carry out tests with numerical data computed for models with increasing complexity; analyze results and provide feedback to WP4 for possibly necessary adjustments in the inversion code;
test on data measured in the field.

Deliverables Journal papers on two field tests, one on a controlled field tests and one on a test in an unknown field.
Two PhD thesis reports.

PhD student mobility plan

PhD		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
Polito	TO												
	Delft												
TUD	TO												
	Delft												

Skills and competencies for the development of the activity	The ideal candidate has knowledge in geophysical methods with preferable focus on seismic surface wave methods. Good background in numerical modelling and inversion algorithms will be also evaluated. Matlab programming will be the core activity of the research work but the candidate should be also ready to carry out field data acquisition and processing. The project is organized such that the involved researchers will work in close cooperation as a single research team. Hence, team work attitude in an international environment is required.