

# Inverse Problems (Ill-Posedness and Regularization)

## Theory, Techniques, and Engineering Applications

Inverse problems (IPs) have been traditionally considered as mathematically challenging because they are intrinsically ill-posed. There are many practical IPs in a variety of engineering disciplines requiring suitable mathematical tools for their robust/stable solution, by recovering the well-posedness typical of forward/direct problems through suitable regularization and information-acquisition/exploitation techniques. Since industry requires fast and simple algorithms for the solution of a wide variety of IPs arising in several engineering fields, this implies a growing need for users that do not have a very high degree of mathematical education.

**The course will review fundamentals and main issues of IPs, then focusing on classical/ state-of-the-art and recently introduced inverse solution procedures and algorithms. Applicative examples including exercises will corroborate the theoretical concepts.**

### Course Topics

- Introduction and basics: motivations (methodological, applicative), synthesis and design problems in engineering as IPs;
- Formulation of IPs and numerical techniques for dealing with their resolution;
- Ill-posedness and non-linearity: on the role of information in IPs;
- Ill-posedness and the need for regularization;
- Non-linearity: physical meaning, degree of non linearity, the role of a-priori/available information;
- Solution of IPs as minimization/maximization of a cost-function/functional;
- Multi-resolution and information-acquisition strategies as an effective recipe to counteract ill-posedness and non-linearity;
- Applicative examples including exercises regarding specific engineering applications.

### Lecturers

- Dr. ANSELMINI Nicola (<https://www.eledia.org/eledia-unin/peOPLE/anselmi-nicola>)
- Prof. MASSA Andrea (<https://www.eledia.org/eledia-unin/peOPLE/massa-andrea>)
- Prof. ROCCA Paolo (<https://www.eledia.org/eledia-unin/peOPLE/rocca-paolo>)
- Dr. SALUCCI Marco (<https://www.eledia.org/eledia-unin/peOPLE/salucci-marco>)

### References

- [1] F. D. Moura Neto, A. J. da Silva Neto, "An Introduction to Inverse Problems with Applications". Springer, 2013.
- [2] A. Tarantola, "Inverse Problem Theory and Methods for Model Parameter Estimation". SIAM, 2005.
- [3] R. C. Aster, B. Borchers, and C. H. Thurber, "Parameter Estimation and Inverse Problems". Elsevier, 2013.
- [4] "Microwave Imaging and Diagnostics: Theory, Techniques, and Applications", European School of Antennas (ESoA) and European Cooperation in Science and Technology (COST Actions TD1301/TU1208), Madonna di Campiglio, Italy, 24-28 March 2014.
- [5] "Microwave Imaging and Diagnostics: Theory, Techniques, and Applications", European School of Antennas (ESoA), Madonna di Campiglio, Italy, 19-23 March 2018.
- [6] "Microwave Imaging and Diagnostics: Theory, Techniques, and Applications," European School of Antennas (ESoA), Napoli, Italy, 1-5 February 2021.

**Dates:** Aug 28 – Sep 01, 2023

### Location

- *In presence:* Polo di Mesiano, Via Mesiano 77, 38123 Trento, Italy
- *Online:* Zoom Platform (video registrations will be available for 2 weeks after the event)

### Lessons

- 32 h total (including exam – not mandatory)
- 12 h hands-on (in Matlab)

**Prerequisites:** Basics of Maths

**ECTS:** 4

### Registration Fees (\*)

- Free for UniTN Students
- 200 Euro - online attendance
- 400 Euro - in presence attendance

Registration is mandatory

### Course Coordination

- Prof. MASSA Andrea
- Prof. ROCCA Paolo

### Further Information

- [summer-schools@eledia.org](mailto:summer-schools@eledia.org)

(\*) The fees include the course teaching and the slides/material

Register at: <https://edu.eledia.org/courses/phd-school-2023-inverse-problems>