



UNIVERSITÀ DI PISA
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE
Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

“Regularization methods for ill-posed/ill-conditioned problems”

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Short Abstract: ill-posed or ill-conditioned problems are characterized by non-unique solution and/or deleterious noise propagation from the input data to the retrieved solution. This kind of problem arises in a multitude of technical and scientific topics, such as biomedical diagnostic, computational imaging, machine learning, and numerical simulations of physical systems. In particular, ill-posedness and ill-conditioning often arise in the so-called inverse problems, wherein the cause-effect relationship is investigated in the reversed way; an example is given by the CT scan, which aims to reconstruct the structure of a body (the cause) taking as input data the measurements of the scattered X-rays (the effect). Regularization methods pursue the mitigation of the ill-posedness and ill-conditioning, and so they enable the retrieval of solutions of practical interest from problems that would be otherwise untreatable.

The course aims to provide an introduction on regularization methods that can help to deal with, or better understand, problems often met in engineering. The presented regularization methods will be supported by MATLAB trainings.

Course Contents in brief:

- Introduction to ill-posedness
- Concept of inverse problem
- Ill-posedness in inverse linear problems: image deconvolution
- Discretization of an ill-posed inverse linear problem
- Ill-conditioning: the condition number
- MATLAB training: practical issues of inverse filtering of images affected by blurring and noise
- Solution of inverse linear problem in the sense of minimum least squares and related ill-posedness
- MATLAB training: practical issues of image deblurring and denoising by means of sparse algebraic linear systems
- Regularization methods for linear problems: Truncated Singular Value Decomposition (TSVD), Landweber and conjugate gradient methods
- MATLAB training: application of TSVD, Landweber and conjugate gradient methods for image deblurring and denoising

- Ill-posedness in inverse linear problems: Electrical Impedance Tomography (EIT) for biomedical applications
- Finite Elements Methods to discretize the EIT problem
- MATLAB training: EIT for breath monitoring with the open-source EIDORS toolbox
- Ill-posedness in machine learning
- Tikhonov regularization in Support Vector Machine (SVM)
- Stochastic regularization methods
- MATLAB training: regularization methods at work to train SVM and neural networks

Total # of hours of lecture: 16 hours

References:

- [1] M. Bertero, P. Boccacci, and C. De Mol, *Introduction to inverse problems in imaging*, Second edition. Boca Raton London New York: CRC Press, 2022.
- [2] M. Pastorino and A. Randazzo, *Microwave Imaging Methods and Applications*. Boston, MA: Artech House, 2018.
- [3] D. Holder, *Electrical Impedance Tomography Methods, History, and Applications*. Bristol: IOP Publishing, 2005.

CV of the Teachers

Dr. Emanuele Tavanti

Emanuele Tavanti received the Laurea degree in Electronic Engineering and the Ph.D. degree in Science and Technology for Electronic and Telecommunications engineering from the University of Genoa in 2015 and 2019, respectively. During the Ph.D. and the PostDoc (three years) at the University of Genoa, his research activities were mainly focused on numerical methods for direct and inverse electromagnetic problems, with applications in biomedical monitoring, security, and atmospheric propagation (the latter continued during a PostDoc at the Polytechnic University of Turin). He is currently an Assistant Professor with the Department of Information Engineering (University of Pisa), where his main research topics are the localization by means of Radio Frequency Identification (RFID) and the signal processing for chipless RFID technologies.

Final Exam: written test.

Room and Schedule

Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa - Ground Floor

Monday, May 12, h. 9:00-13:00

Tuesday, May 13, h. 14:00-17:00

Wednesday, May 14, h. 14:00-17:00

Thursday, May 15, h. 14:00-17:00

Friday, May 16, h. 14:00-17:00