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Carola-Bibiane Schönlieb
University of Cambridge

Machine Learned Regularization for Solving Inverse Problems

Prof. Zanella introduces the seminar.

Abstract
Inverse problems are about the reconstruction of an unknown physical quantity from indirect measurements. Most inverse problems of interest are ill-posed and require appropriate mathematical treatment for recovering meaningful solutions. Regularization is one of the main mechanisms to turn inverse problems into well-posed ones by adding prior information about the unknown quantity to the problem, often in the form of assumed regularity of solutions. Classically, such regularization approaches are handcrafted. Examples include Tikhonov regularization, the total variation and several sparsity-promoting regularizers such as the L1 norm of Wavelet coefficients of the solution. While such handcrafted approaches deliver mathematically and computationally robust solutions to inverse problems, providing a universal approach to their solution, they are also limited by our ability to model solution properties and to realise these regularization approaches computationally.

Recently, a new paradigm has been introduced to the regularization of inverse problems, which derives regularization approaches for inverse problems in a data driven way. Here, regularization is not mathematically modelled in the classical sense, but modelled by highly over-parametrised models, typically deep neural networks, that are adapted to the inverse problems at hand by appropriately selected (and usually plenty of) training data.

In this talk, I will review some machine learning based regularization techniques, present some work on unsupervised and deeply learned convex regularisers and their application to image reconstruction from tomographic and blurred measurements, and finish by discussing some open mathematical problems.

Biography
Carola-Bibiane Schönlieb is Professor of Applied Mathematics at the Department of Applied Mathematics and Theoretical Physics (DAMTP), University of Cambridge. There, she is head of the Cambridge Image Analysis group, Director of the Cantab Capital Institute for Mathematics of Information, Chair of the Centre for Data Driven Discovery and co-Director of the EPSRC Centre for Mathematics of Information in Healthcare. Since 2011 she is a fellow of Jesus College Cambridge and since 2016 a fellow of the Alan Turing Institute, London. She also currently holds the Chair of the SIAM Activity Group on Imaging Sciences and the Chair of the Committee for Applications and Interdisciplinary Relations (CAIR) of the EMS.

Her current research interests focus on variational methods, partial differential equations and machine learning for image analysis, image processing and inverse imaging problems. She has active interdisciplinary collaborations with clinicians, biologists and physicists on biomedical imaging topics, chemical engineers and plant scientists on image sensing, as well as collaborations with artists and art conservators on digital art restoration.

Her research has been acknowledged by scientific prizes, among them the LMS Whitehead Prize 2016, the Philip Leverhulme Prize in 2017, the Calderon Prize 2019, and a Royal Society Wolfson fellowship in 2020, and by invitations to give plenary lectures at several renowned applied mathematics conferences, among them the SIAM conference on Imaging Science in 2014, the SIAM conference on Partial Differential Equations in 2015, the SIAM annual meeting in 2017, the Applied Inverse Problems Conference in 2019, the FOCM 2020 and the GAMM 2021.

Carola graduated from the Institute for Mathematics, University of Salzburg (Austria) in 2004. From 2004 to 2005 she held a teaching position in Salzburg. She received her PhD degree from the University of Cambridge (UK) in 2009. After one year of postdoctoral activity at the University of Göttingen (Germany), she became a Lecturer at Cambridge in 2010, promoted to Reader in 2015 and promoted to Professor in 2018.