Better inversion of neural networks with regularisation theory

Supervisor: Marin Benning

Research Group: Statistics and Data Science

Project description:

Deep neural networks are computing systems that have outperformed traditional *machine learning* approaches for a wide range of applications over the previous decade. In recent years, we have seen a substantial shift in interest from traditional deep neural networks to deep neural networks that are invertible [1] or approximately invertible, fuelled by high-impact research in (variational) Autoencoders [4], Normalising Flows [3, 5] and Cycle-Consistent Generative Adversarial Networks [6].

An important aspect, which is often overlooked, is that invertible operations alone are not automatically *well-posed* or *well-conditioned*. For example, computing the solution to the heat equation with initial conditions and suitable boundary conditions is well-posed, but estimating the initial condition from the solution of the heat equation is very *ill-posed* and cannot be solved without approximation of the inverse with a family of continuous operators, also known as *regularisation*. The research field of *Inverse and Ill-posed Problems* [2] and its branch *Regularisation Theory* focus strongly on the stable approximation of ill-posed and ill-conditioned inverses via regularisations. The goal of this PhD project is to utilise and generalise regularisation theory, in order to construct superior deep neural networks with well-posed (approximate) inverses for which we have solid mathematical guarantees. Research questions include (but are not limited to) the computational realisation of such networks as well as the generalisation of regularisation theory to nonlinear forward models arising from deep neural networks.

Applicants should have, or be expected to obtain by the start date, a 1st class or 2:1 degree (or equivalent) in Mathematics or a related subject. They should have excellent programming skills, preferably in Python. A strong background in Inverse Problems and experience in programming with libraries such as PyTorch or Tensorflow are desired, but not mandatory. The successful candidate is expected to publish research outcomes in top-ranked journals, present their research results at selected conferences and workshops, and to contribute their findings in multidisciplinary research collaborations, especially between IADS, HIMR and the mini-CDT Data Analytics of Large Coupled Structures.

The applicant will be supervised by Dr Martin Benning, who is Lecturer in Optimisation and Machine Learning at the School of Mathematical Sciences; his area of expertise is the theoretical and computational handling of inverse and ill-posed problems. Queen Mary University of London is a leading research-intensive Russell Group university, ranked 5th among multi-faculty institutions in the UK for research outputs (Research Excellence

Framework 2014), and 110th in the world overall (Times Higher Education World University Rankings 2020).

Informal enquiries regarding the post may be made by email to Dr Benning (m.benning@qmul.ac.uk).

References

[1] J. Behrmann, W. Grathwohl, R. T. Chen, D. Duvenaud, and J.-H. Jacobsen. Invertible residual networks. In Interna- tional Conference on Machine Learning, pages 573–582. PMLR, 2019.
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[4] D. P. Kingma and M. Welling. Auto-encoding variational bayes. arXiv preprint arXiv:1312.6114, 2013.
[5] D. Rezende and S. Mohamed. Variational inference with normalizing flows. In International Conference on Machine Learning, pages 1530–1538. PMLR, 2015.
[6] J.-Y. Zhu, T. Park, P. Isola, and A. A. Efros. Unpaired image-to-image translation using cycle-consistent adversarial networks. In Proceedings of the IEEE international conference on computer vision, pages 2223–2232, 2017.

Further information:

How to apply

Entry requirements

Fees and funding