MSc projects Computational Imaging

Deep learning for 3D image classification

Image classification is a common task in many applications. Deep learning has become a powerful tool for such tasks, as it can learn to recognize complex structures from given examples. Most current research is focused on classifying 2D images, and as a result efficient architectures and software are available for it. In some applications, however, it is more natural to consider 3D volumetric images. One such application is the classification of 3D CT scans of sand-core samples containing various species. The challenge with this application is that the various species have very pronounced 3D structures, so 2D intersections that look very different may belong to the same species. While 3D classification is theoretically possible, it poses serious computational challenges. In this project you will develop new deep learning architectures for 3D image classification, addressing the computational challenges to arise. You will benchmark the developed method on well-chosen generated data sets and compare the results to state-of-the-art 2D classification strategies. Finally, you will apply validate the approach on a real dataset of CT scanned core samples containing various species. The project is a collaboration between Naturalis Biodiversity Center, the Leiden Institute of Advanced Computer Science (LIACS) and the Centrum Wiskunde & Informatica (CWI). We are looking for someone with a strong background in mathematics or computer science, strong programming skills (preferably Python) and affinity with computational imaging and/or deep learning.

Supervisor : Tristan van Leeuwen (CWI), Willem Renema (Naturalis)
keywords : deep learning, image analysis, computed tomography

A discrete Ginzburg-Landau functional for regularized image reconstruction

Tomographic imaging is used in many applications, including medical imaging. Under ideal circumstances, an accurate image can be retrieved from high-quality fully sampled data. In practice, however, we can often only acquire noisy subsampled data, making the image reconstruction process more challenging. A promising avenue for increasing the accuracy of the images is to include prior information on expected image structures. One way to encode such prior information is the discrete Ginzburg-Landau (GL) functional, which has gained popularity in image processing applications. In this project, you will explore the possibilities of including the GL function in tomographic image reconstruction. You will work in the interface between Inverse Problems, Calculus of Variations, and Scientific Computing. The project is a collaboration between TU Delft and CWI. The computational imaging group at CWI develops novel algorithms for imaging in various applications and operates a micro-CT scanner. Therefore, there will be opportunities test the methods on experimental data.

Supervisor : Tristan van Leeuwen (CWI), Yves van Gennip (TU Delft) keywords : variational analysis, PDEs, inverse problems, imaging

Iterative image reconstruction with inexact adjoints

Many linear inverse problems can be formulated as convex optimization problems. These can be solved using iterative schemes that involve gradients and proximal operators of the functionals. Computation of the gradient requires the evaluation of the adjoint of the forward operator. In many large-scale applications, however, the adjoint cannot be evaluated exactly. This leads to a biased approximation of the gradient which can lead to failure of convergence of the iterative algorithm. In this project, you will develop iterative methods that are robust to such errors.

Supervisor : Tristan van Leeuwen
keywords : numerical linear algebra, inverse problems, convex analysis

Improved optical imaging with compressed sensing

Optical imaging is traditionally limited to the wavelength of the emitted light. Mathematical super-resolution techniques can go beyond this limit, but require special preparation of the sample and long acquisition times. To allows for rapid in-vivo imaging, a novel approach based on glass fibers has recently been developed at ARCNL. First result using randomized illumination and advanced mathematical image reconstruction have shown great promise. However, there is room for further improvement on both computational and theoretical aspects of this approach. In this project, you will further investigate the use of techniques from compressed sensing and experimental design to develop new practical image reconstruction approaches and theoretical reconstruction guarantees. The project is a collaboration with ARCNL.

Supervisor : Tristan van Leeuwen (CWI), Lyuba Amitonova (ARCNL)
keywords : imaging, compressed sensing, inverse problems, harmonic analysis.

Non-linear waveform inverse for biomedical ultrasound imaging

Wave-based imaging modalities such as biomedical ultrasound (US) are based on sending waves into a medium of interest through its boundary. The wave fields interact with the medium’s internal structures through different wave-matter interactions, e.g., reflection, scattering, or absorption. Measurements of the wave fields leaving the medium thus carry information about its internal properties, and waveform inversion methods try to reconstruct those using a numerical wave propagation model. Typically, wave propagation in these methods is assumed to be governed by linear PDEs. However, in many relevant applications in biomedical ultrasound, nonlinear wave propagation effects play an important role and cannot be neglected. The project aims to develop a nonlinear wave inversion approach for ultrasonic fields. The method can be used for, e.g., reconstructing material properties of interest, nonlinearities in the model, convolution kernels for nonlocal dissipation, or the boundary excitation/shape. This project is in collaboration with Radboud University.

Supervisor : Felix Lucka (CWI), Vanja Nikolic (Radboud University)

keywords : numerical methods for PDEs, inverse problems, ultrasound imaging