DC 9: Adaptive compressed sensing using deep learning in non-linear microscopy.

Project Description: A key challenge in many established imaging modalities is to reduce the number of measurements needed to sense all the relevant information contained in the image: For instance, high-resolution imaging of biological samples with wide-field 2-Photon Microscopy (also known as "non-linear microscopy") relies on the spatial focusing of a femtosecond laser beam up to its diffraction limit for subsequent serial raster scanning, which usually requires the use of adaptive optics to correct for wavefront distortions and limits the temporal resolution obtainable. Traditionally, the information content of an image is associated with its Fourier representation, and spatial sensing patterns are designed to capture all frequencies up to a maximal one. The latter is often determined by the physical nature of the imaging process, e.g., images derived after propagation of light in biological tissues typically have a reduced Fourier bandwidth due to the high scattering. However, as the spatial complexity of many tissue structures is rather low, images recorded in a conventional fashion with N pixels can still often be compressed, i.e., stored compactly with $M < N$ coefficients in a suitable representation system. This means that the original image contained redundant information. It may, therefore, be possible to speed up the image acquisition without a significant loss of image quality by exploiting this redundancy and directly measure a subset of the data chosen in such a way as to maximize its non-redundancy. To retrieve the image from this compressed data, non-linear image reconstruction techniques must be used. These concepts, established as the field of compressed sensing (CS), have been applied to many imaging modalities with success. In conventional CS, a fixed sensing pattern is designed for a given class of images *a-prior, i.e.,* before any measurements of a particular image are taken. The idea of adaptive compressed sensing (aCS) is to further adapt the sensing pattern to an image during the measurement, i.e., *a-posteriori*. Conventional approaches to perform aCS such as *optimal experimental design* lead to complex numerical optimization problems that can rarely be solved fast enough to realize aCS in real-world applications.
The DC will examine the use of adaptation approaches based on deep learning (DL), in particular deep neural networks with convolutional layers (CNNs) for the image reconstruction from compressed data and deep reinforcement learning (RL) for the adaptation. We will develop mathematical formulation, numerical algorithms and implementation of adaptive compressed sensing using deep learning techniques (aCS-DL) and use the new methods to improve wide-field 2-Photon Microscopy: Within the CONcISE project, the DC is part of the "SMART-2PM" team which will develop a system that reaches higher penetration depth, sensitivity, and imaging speed.

Expected Results: Proof-of-concept of aCS-DL with a simulation study. Design and integration of dedicated aCS-DL software for SMART-2PM system. Demonstration of aCS-DL for non-linear microscopy for biological tissues.

Requirements

- Master's degree in Mathematics, Physics, Computer Science, Electrical Engineering or a related discipline, with a strong background in mathematics.
- Good programming skills.
- Proven research talent/experience is preferrable
- Good academic writing and presentation skills are preferrable
- Ability to work in multidisciplinary teams is preferrable
- English fluency* (both written and orally). English fluency can be demonstrated by providing evidence of any of the following: PTE (academic) – 62; TOEFL (iBT) – 92; IELTS (academic); C1 Advanced – C; C2 proficiency – Level C1.

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**Exceptions for native speakers and applicants having completed a prior cycle of studies in English apply. Click here to learn more about your specific requirements!*		
Host Insititution: CWI (Amsterdam, The Netherlands) **Supervisor:** Dr. Felix Lucka		
Estimated gross allowance: 51,917 €/year		
PhD awarding institution: UEF		
Secondment 1 Partner: UJI Supervisor: Dr. Jesus Lancis	**Secondment 2** Partner: DATRIX Supervisor: Dr. Matteo Bregonzio	**Secondment 3** Partner: UJI Supervisor: Dr. Jesus Lancis
Planned Starting Date: 01/09/2023 **Application Deadline:** 15/05/2023		
Contact: felix.lucka@cwi.nl		

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