TAMPERE UNIVERSITY OF TECHNOLOGY

TÉCNICO LISBOA

TUT-IST double PhD degree program

Call for PhD students

Area of study: Nonlocal Sparse Inverse Phase Imaging

In phase imaging applications, a physical quantity of interest is coded in an image of phase. Relevant phase imaging applications are the following:

- interferometric synthetic aperture radar/sonar – the topography of a given surface is inferred from phase differences measured by multiple radar/sonar antennas;
- magnetic resonance imaging;
- optical interferometry – the phase is used to determine shape, deformation, and vibration of objects;
- X-ray phase-contrast imaging – the differential X-rays phase shift induced by the refractive index of an object is inferred from X-ray tomographic projections;
- phase retrieval - a non-interferometric technique where the phase is determined from intensity measurements.

Duration of study 3-4 years, approximate salary 2,200-2,500 EUR per month

The research will take place at the Department of Signal Processing of Tampere University of Technology, Tampere, Finland, and at the Instituto Superior Técnico, Technical University of Lisbon, Portugal.

Requirements

- Master degree in Electrical and Computer Engineering, Computer Science, or strongly related field in Engineering (to be completed by August 2013).
- Strong mathematical background including linear algebra, optimization theory and algorithms, inverse problems, Fourier transforms.
- Programming skills: MATLAB, C++.
- Good English language skills.
- Ambition to contribute to world-class research.

Application

Applicants are requested to write a letter describing their abilities and motivation, accompanied by curriculum vitae and one or two references. Written applications should be sent by e-mail by April 15, 2013 to both addresses:

Prof. Vladimir Katkovnik
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Aim and Scope

The measurements in the phase imaging systems are usually noisy and periodic functions of the original phase, as they are extracted from or periodic signals or waves. The periodic nature of the measurement process yields very difficult inverse problems, regardless the framework adopted to formulate and solve them. For example, under the regularization framework, and even using convex regularizes for phase, the presence of a periodic data term in the objective function leads to unbearable nonconvex optimization problems.

The aim of this PhD-thesis project is to advance the research front in phase imaging inverse problems (PIIPs) by adopting nonlocal sparse phase regularization. The nonlocal paradigm exploits the similarity exiting in most real world images; i.e., in a given image, there are many similar patches in different locations and/or with different scales. This similarity allows learning dictionaries/frames, with respect to which the original images admit a sparse representation; i.e., the original image is well approximated by a linear combination of a small number of atoms of the dictionary.

The exploitation of phase regularization based on sparse representations on learned dictionaries poses a few research questions. The first is linked to the way the dictionary is learned. A possible approach is learning the dictionary from a phase image database somehow related with the image to be recovered. Another possibility is to learn the dictionary from the degraded observed phase image. The latter approach underlies a series of state-of-the-art methods in image denoising, deblurring, inpainting, super-resolution, and demosacking.

The second research question is closely related with the first one. Given that the phase measurements are noisy nonlinear versions of the original phase, does it make sense to regularize these nonlinear functions and then recover the phase from this regularized nonlinear estimates? For example, in many interferometric applications, the measurements in a given pixel are noisy pairs $(\sin\emptyset, \cos\emptyset)$, where $\emptyset$ denotes the original phase at that pixel. The above referred to approach would correspond, in this case, to learn a dictionary for image patches of pairs $(\sin\emptyset, \cos\emptyset)$. Assuming that this problem can be successfully solved, then, the original phase would be estimated from the denoised pairs $(\sin\emptyset, \cos\emptyset)$, which is the so-called phase unwrapping problem.

The third research question concerns the inference criterion. In the regularization theory framework, the optimization variable is inferred by minimizing an objective function containing a data term, measuring the misfit between the measurements and the candidate solution, and a regularizer, promoting solutions with desirable properties. As already referred to before, the data term in PIIPs is nonlinear, leading to untreatable nonconvex optimization problems. A possible line of attack to mitigate this complexity is to formulate the phase inference as a generalized Nash equilibrium problem with two competing objective functions: one associated with the data misfit term and the other associated with the regularization term. The foreseen advantage of this approach is the decomposition of a very difficult optimization problem into a sequence of simpler problems.

Research Goals

The above described research questions denote only initial points of the proposed PhD-thesis project, which has the main goal to introduce methods and algorithms for wide area of theoretical and practical phase imaging problems.