

PhD Thesis Proposal at CVC/IMAGINE (2102)

Higher Order Graph-based 2D-to-3D Multi-modal Image Fusion/Registration

Context

Fusion is a fundamental problem of computer vision and medical image analysis. The aim is to recover a geometric mapping that establishes correspondences between two observations covering partially the same scene. The term mono-modal fusion is used when images come from the same modality while multi-modal is employed when the observations are of different nature. The problem exists in 2D as well as in 3D and often is addressed through what is so-called linear mapping [global registration] or deformable registration [non-linear deformations]. In the former case the geometric transformation consists of few global parameters acting on the physical position of observations in the image plane, while in the second case this constraint is relaxed and the aim is to recover an “independent” displacement vector. This mapping is obtained through the minimization of an objective function that quantifies the similarity/dissimilarity of the two signals given the transformation. The problem in general is ill-posed in particular when aiming to recover modular, scalable solutions since the nature of observations will impose the use of different similarity criteria. Furthermore, solving such a problem becomes even harder when considering deformable mapping due to the fact that is under-constrained in 2D as well as in 3D.

Recent progress on deformable registration [1,2] has benefited from computationally efficient solutions developed in the context of discrete optimization [3]. These methods are by far the most generic/efficient registration methods, but still are far from being near-real time. In many contexts, like for example image-based navigation in known environments or computer assisted surgery, the ability to perform continuous real-time mapping between the observed image and a pre-reconstructed scene or 3D volume of observations that are not necessarily on the same visual space would have been of great scientific and application interest. It will provide means to navigate in hostile environments, indentifying moving targets as well as navigate and reach for example tumors in elastic organs that will greatly impact surgery procedures and success rate. Such a problem though is even more challenging than the case of 2D-2D or even 3D-3D registration since it consists of indentifying a plane – the one corresponding to the observed image – and then estimating the in plane deformations towards performing the appropriate mapping.

Objective

The aim of this thesis is to introduce a 2D-3D registration paradigm that explores higher order graphical models. Higher order interactions between points [4] will be the driving force to determine the observed plane while pair-wise and singleton terms will produce the in-plane deformation. Due to the use of graphical model the proposed solution will be extremely flexible and independent on the nature of images to be fused – examples could refer to a navigation setting either in the context of military settings or computer assisted surgery, and could produce real-time performance if appropriate use of parallel programming architectures is considered. The scientific impact of the thesis could be

tremendous as well since the combination of low-rank and high-rank graphical models is an open research topic that requires research both in terms of optimization as well as in terms of dimensionality reduction. Such models could be used to cope with the most challenging problems in computer vision, like pose invariant object detection/recognition, image segmentation, 3D reconstruction, etc.

Bibliographic References

- [1] B. Glocker, N. Komodakis, G. Tziritas, N. Navab & N. Paragios. Dense Image Registration through MRFs and Efficient Linear Programming. Medical Image Analysis, Vol. 12, pages 731-741, 2008.
- [2] B. Glocker, A. Sotiras, N. Komodakis & N. Paragios. Discrete Medical Image Registration/Fusion. Annual Reviews in Biomedical Engineering (AR), 2011.
- [3] N. Komodakis, G. Tziritas & N. Paragios. Performance vs Computational Efficiency for Optimizing Single and Dynamic MRFs: Setting the State of the Art with Primal Dual Strategies. Computer Vision and Image Understanding Journal, Vol 112, pages 14-29, 2009.
- [4] N. Komodakis, N. Paragios & G. Tziritas. MRF Energy Minimization and Beyond via Dual Decomposition, IEEE Transactions on Pattern Analysis and Machine Intelligence (T-PAMI), 2011

Profile and application

Required skills:

- MSc in computer vision,
- excellent background in mathematical methods for numerical optimization
- proficiency in C++.

To apply, please email:

- your CV,
- a transcript of your MSc grades/marks (even if incomplete),
- the report you wrote for your MSc thesis or for a previous internship,
- reference letters of previous supervisors or teachers,
- a brief description of your research interests highlighting the links between your education/training/experience and the thesis topic,

to

- Pr. Nikos Paragios (nikos.paragios@enpc.fr).

The IMAGINE Group

The [IMAGINE](#) Group is a joint project of the École des Ponts ParisTech ([ENPC](#)) and the French Scientific and Technical Centre for Building ([CSTB](#)), now part of the Center for Visual Computing (CVC), in association with the École Centrale de Paris ([ECP](#)), and it is part as well of the Computer Science lab ([LIGM](#)) of University Paris Est ([UPE](#)).

The domains of research of IMAGINE are computer vision, mesh processing, machine learning, statistics, optimization and constraint programming. In particular, IMAGINE has been working for several years on dense multi-view stereovision. One of the main focuses of the group has been on high precision 3D surface reconstruction from images,

targeting large-scale data sets taken under uncontrolled conditions. Part of the group now also works on the interpretation and semantization of images and 3D models.

IMAGINE has got the best results worldwide on the Strecha et al. [reference benchmark](#), with the most complete and the most precise reconstructions. This expertise and software has been transferred in 2011 to the startup company [Acute3D](#), powering [Autodesk's 123D Catch](#) (formerly [project Photofly](#)), a web service to create 3D models from photographs. In November 2011, IMAGINE also won the [PRoVisG Mars 3D Challenge](#), consisting in image calibration and 3D model reconstruction tasks on Mars surface.