Postdoc Annual Report

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1 Introduction

Measuring ground deformations is a key issue in geology and geophysics studies. Indeed, measuring the fault deformation after an earthquake, estimating dunes migration or calculate the velocity of glaciers is of foremost importance. In principle, this measurements can be done using correlation techniques with two (or more) remote sensed optical images. Actually, the problem has already been addressed by [6] where a phase correlation technique has been used to implement a sub-pixel algorithm named COSI-corr (Co-Registration of Optically Sensed Images and Correlation). COSI-corr is a very accurate algorithm and it is very robust to image changes. However, it needs very large image patches for correlating correctly. Moreover, the implicit deformation model is a simple translation.

During my W. M. Keck Institute for Space Studies Prize Postdoctoral Fellowship at Caltech I have addressed the same problem of measuring ground deformations by computing disparity maps from pairs of remote sensed images but the goal has been to use a different technique that allows to correlate with smaller patches and uses a more complex deformation model (affinity) while keeping the robustness to image changes.

2 Scope and aim of work

Although extracting disparity maps from pairs of images has been widely studied, ensuring high accuracy and robustness remains a challenge due to difficult situations arising in natural image sequences. Disparities to be estimated are not usually smooth, contrast variations between images are common, and large occlusions can be present.

The aim of this work is to push further the accuracy limit of image matching techniques by enhancing the well-known optical flow method, which has long been used for 3D reconstruction, and also for motion estimation and image registration problems. Many approaches have been proposed since the publication of the two milestone papers by Horn and Schunck [4] and by Lucas and Kanade [7]. Our approach is closer to the approach in [7] since our model does not consider global smoothness constraints as in [4].

In fact, optical flow methods can be separated into locally and globally parameterized methods. The global methods have risen in popularity in the last years [9] because they better solve the aperture problem [5]. Indeed, local image patches may not contain sufficient information to reliably estimate all disparities, causing many outliers in poor textured regions of the images. However, global methods with regularity terms tend to over-smooth the estimated disparity field and are quite sensitive to the parameterization used. Our decision to only focus on local methods stems from two main concerns: (1) Our desire to estimate potentially irregular and discontinuous disparity fields with high accuracy and high spatial resolution; (2) Our desire to propose an algorithm that is adequate for parallel computing with no or little communication between computing cores or nodes, e.g., GPU or distributed computing.

3 Summary of work

The classic optical flow formulation assumes radiometric consistency between images and a smooth underlying disparity field. However, these assumptions are often too restrictive and make the optical flow technique unsuitable in a general setting, in particular for remote sensing applications. Indeed, such images may have been acquired at different times, under different illuminations, and the disparity field may presents variations that are not well approximated by local translations. During my postdoc I have introduced the Contrast Invariant and Affine Optical Flow (CIAO), a generalized sub-pixel optical flow model which does not force the estimated disparity field to be smooth, and which allows for contrast and brightness changes by considering bias and gain parameters. Furthermore, CIAO is robust to drastic radiometric changes thanks to an adaptive weighting of the neighboring pixels. The algorithm is based on a multi-scale approach since the optical flow linear equation is only a first order approximation. At each scale, when the linear equation is not solvable or when the estimation is unreliable, a bilateral filter [10] extrapolates the disparity field. Finally, the proposed model considers affine displacements instead of simpler translations, which are rarely valid in real scenes with complex disparities. This more complex model produces finer measurements between corresponding points, especially when the images are transformed by a locally large tilt or shear. Indeed, image distortions arising from viewpoint changes are locally well modeled by affine planar transforms.

4 Related work

Besides the papers I have already mentioned there are other works that are highly related. For instance, [1] and [8] already suggested affine models in optical flow for registration and video tracking, respectively. In both cases, an affine deformation is estimated for a large region of the image or for the whole image instead of the local deformations we suggest here. Two relevant formulations appear in [3] and [2] where affine local models in optical flow are considered. In [3] the aim is to compute DEM's from satellite images. The local approach they present is essential for this specific application since a global modeling may not realistically represent the image changes. Their work mainly differs from ours in the parameters estimation (noise and affine parameters) which is performed with a Bayesian approach having high computational complexity. Besides that, the robustness and attainable precision of their method is undocumented. Similar to our approach, [15] also describes a hierarchical approach with an affine model. However, in addition to combining the most audacious ideas found in the literature, we achieve greater accuracy and robustness by introducing two decisive ideas in optical flow: (i) an accurate interpolation of the images and (ii) a robust method to avoid outliers. To the best of our knowledge such a robustness and accuracy have not been achieved with optical flow techniques making it one of the best methods to compute DEM's for remote sensing applications.

5 Accomplishments to date

5.1 Publications

- N. Sabater, S. Leprince and J.-P. Avouac. Contrast Invariant and Affine Sub-pixel Optical Flow. Submitted to ICIP. 2011.
- N. Sabater, S. Leprince and J.-P. Avouac. Contrast Invariant and Affine Optical Flow for Ground Deformation Measurements. In prep (to be submitted at TGARS).
- S. Beckouche, S. Leprince, N. Sabater and F. Ayoub. Robust Outlier Detection in Image Point Matching. In ICCV workshop on Remote Sensing 2011.

5.2 Talks

During my postdoc at Caltech my work was presented in several seminars, workshops and conferences. In particular:

- SIAM conference. Philadelphia (USA). May 2012.
- ASPRS conference. Sacramento (USA). March 2012.
- Caltech Remote Sensing seminar. Pasadena (USA). November 2011.
- Gipsa-Lab seminar. Grenoble (France). May 2011.
- Perception seminar, INRIA Rhne-Alpes. Grenoble (France). May 2011.
- Technicolor seminar. Rennes (France). March 2011.
- LATP Signal and Image Processing Seminar. Marseille (France). March 2011.
- MATIS- IGN Seminar. Paris (France). March 2011.
- UCLA Image Processing Seminar. Los Angeles (USA). January 2011.
- Paris Descartes Image Processing Seminar. Paris (France). January 2011.
- Caltech Remote Sensing Group Meeting. Pasadena (USA). October 2010.

5.3 Acknowledgements

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