PERFORMANCE EVALUATION OF OPTICAL FLOW TECHINQUES: TESTING FRAMEWORK, NUMERICAL DIFFERENTIATION METHODS AND ERROR ANALYSIS

Alex Agranovich

Under the supervision of

Prof. Leonid Yaroslavsky

Summary

This work presents results of evaluations of performance, in terms of the accuracy of estimating motion field in sequences of images, of three differential optical flow methods, Lucas/Kanade's, Horn/Schunck's methods (in their multiscale versions) and Brox et al.'s one. The evaluation was conducted by computer simulation within a novel frame work that assumes

- Using, as test images, computer generated pseudo-random images with uniform DCT domain spectrum within a circular sector of a certain radius; the radius, in units of fraction of the image base band, serves as the image bandwidth parameter. To preserve the compatibility of the evaluation results with other publications, a commonly used "Yosemite" test image was used in the experiments as well.
- Introducing to test images artificial global and local shifts controlled by computer generated test motion fields. For global shifts, motion fields were constant for the entire image frame. For local shifts, motion fields were generated as 2D arrays of pseudo-random X-Y pixel-wise shifts with zero mean and specified standard deviation and DCT domain bandwidth using the same algorithm as that for generating pseudo-random test images.

Evaluated algorithms were tested with different numerical differentiation methods in order to verify how much numerical differentiation errors affect the method performance.

A comprehensive differential optical flow computation error analysis demonstrates that the errors are large for signals with substantial high frequency contain (error magnitude of the order of the shift) and that, in the areas with "close-to-zero" signal derivative, the errors become unreasonable. It was found also that the approximation errors are reasonably lower if signal shifts do not exceed 0.4-0.6 of inter pixel distance for images with bandwidth lower than 0.5 – 0.6 of the baseband. This strongly motivates using multiscale versions of the algorithms, the solution commonly accepted in all latest differential optical flow algorithms. This analysis shows also that DFT/DCT-based differentiators provide the best accuracy performance in the optical flow evaluation. For

the case of the sinusoidal signal it was shown, that its performance is identical to that of the analytical derivative.

In all experiments it was found out that the exact numerical differentiation improves performance of optical flow algorithms, especially for images rich of high frequencies, and this is in spite of the fact that in all algorithms image low-pass pre-filtering is performed. The need of such pre-filtering that kills high frequency image components, which, theoretically, can potentially improve the accuracy of motion field, has to be re-evaluated.

It was also found that for images rich of high frequency content all methods show quite poor motion field estimation accuracy: for motion field bandwidth 0.25 and test source images of bandwidth 0.75 the evaluation errors are comparable with the estimated motion field magnitude. The experiments also revealed that all optical flow algorithms tend to very substantially suppress motion field high frequencies.