MULTI-FRAME OPTICAL FLOW FOR NON-RIGID OBJECTS

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Abstract

This poster discusses a novel approach to compute multi-frame optical flow for a non-rigid object. Imposing the rank constraint to compute a 2D motion basis and expressing 2D trajectories as a linear combination of this basis has been successfully used in the literature. In this work we present a continuous extension to rank-constrained optical flow, using a variational formulation to compute highly accurate optical flow. Since the optical flow obtained satisfies the subspace constraint it is directly usable by most of state of the art non-rigid structure-from-motion algorithms to obtain dense 3D reconstructions.

Introduction

- Subspace constraints are used to solve aperture problem.
- Variational regularization is used to obtain highly accurate dense optical flow.
- Motion information is used to solve a single dense tracking problem instead of solving optical flow for every frame.

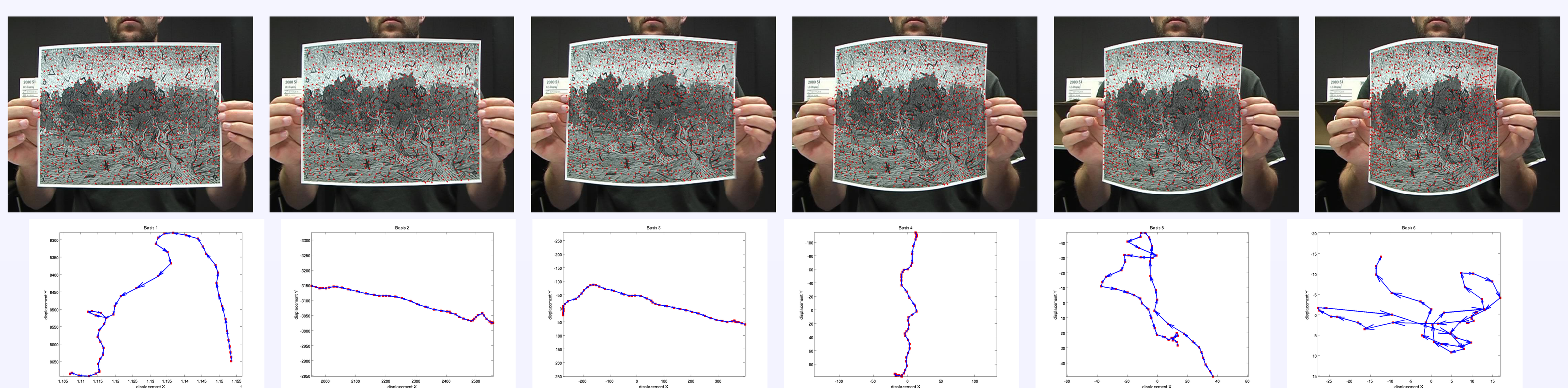
Motion Basis

- Non rigid 3D deformation can be modelled as a linear combination of K basis shapes in 3D.

$$W_{2F\times P} = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1P} \\ u_{21} & u_{22} & \cdots & u_{2P} \\ \vdots & \vdots & \vdots & \vdots \\ u_{F1} & u_{F2} & \cdots & u_{FP} \\ \hline v_{11} & v_{12} & \cdots & v_{1P} \\ v_{21} & v_{22} & \cdots & v_{2P} \\ \vdots & \vdots & \vdots & \vdots \\ v_{F1} & v_{F2} & \cdots & v_{FP} \end{bmatrix} = \begin{bmatrix} Q_u \\ \hline Q_v \end{bmatrix}_{2F\times r} * \begin{bmatrix} L^1 \\ L^2 \\ \vdots \\ L^r \end{bmatrix}_{r\times P} \quad (1)$$

- Every individual 2D track can be obtained as a linear combination of $r = 3K$ reliable tracks.

$$T_p = \begin{bmatrix} u_{1p} & v_{1p} \\ u_{2p} & v_{2p} \\ \vdots & \vdots \\ u_{Fp} & v_{Fp} \end{bmatrix} = [\ Qu * L_p \quad Qv * L_p\ ] \quad (2)$$



- This model reduces the number of unknowns to r per point from the usual $2F$ flows to solve aperture problem.

F frames Variational Optical Flow

- We solve F optical flow problems together by minimizing a global energy term optimizing over the motion basis coefficients.
- F brightness constancy equations to solve for r variables at every image point.

$$BC^f = [I_f(x + Q_u^f * L_p,\ y + Q_v^f * L_p) - I_0(x,y)]^2 \to 0 \quad (3)$$

- In addition the smoothness of the optical flow vectors is enforced by imposing spatial continuity on the coefficients for every motion basis.

$$SC^m = |\nabla_2 L^m|^2 \to 0 \quad (4)$$

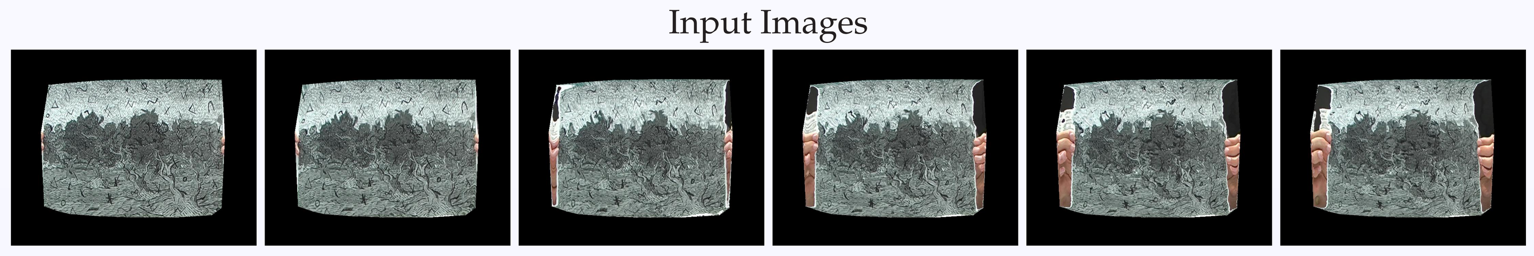
- Variational energy is built with the L1 norm nonlinearised brightness constancy as the data term and the L1 norm isotropic regularizer in image space for the r parameters.

$$E = \int_\Omega \left\{ \Psi\Big(\sum_{f=1}^{F} BC^f\Big) + \alpha\, \Psi\left(\sum_{m=1}^{r} SC^m\right) \right\} dp \to 0 \; where \; \Psi(s^2) = \sqrt{s^2+\epsilon} \quad (5)$$

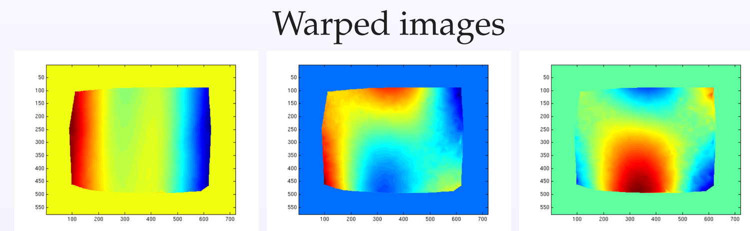
Results

Initial test without coarse to fine strategy and initial estimates of motion basis coefficients (L^m) extracted from KLT features.

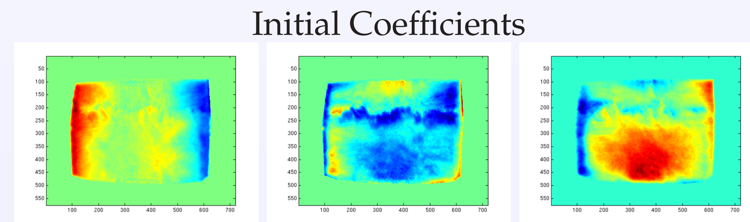
Input Images



Warped images



Initial Coefficients



Final Coefficients

References

[1] M. Irani, Multi-Frame Correspondence Estimation Using Subspace Constraints. *IJCV , Vol. 48, No.3, pp. 173 194*, July/August 2002.

[2] L. Torresani, C. Bregler Space-Time Tracking. *ECCV*, 2002.

[3] T. Brox, A. Bruhn, N. Papenberg, J. Weickert, High accuracy optical flow estimation based on a theory for warping. *ECCV* 2004.

Acknowledgements

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