Tracking and Augmenting Deformable Surfaces

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Overview

- Tracking and augmentation of complex surface deformations from monocular images under varying lighting
- Joint estimation of deformation and shading parameters using mesh-based deformation and shading priors

Joint Motion and Illumination Estimation

deformation: pixel displacement field $\mathbf{D}(\mathbf{x})$
brightness change: pixel intensity scale field $\tilde{S}(\mathbf{x})$

Parameterize fields with a 3-dim. mesh-based model

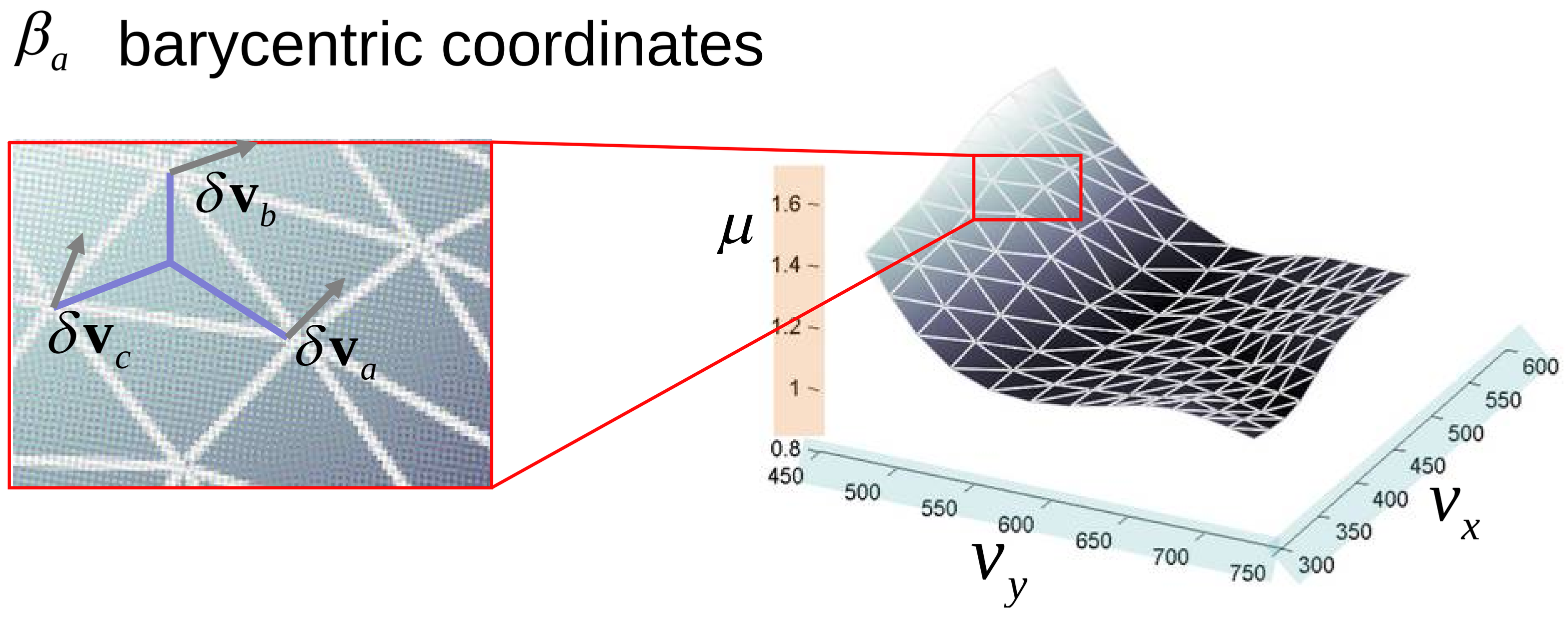
$$\mathbf{D}(\mathbf{x}_i) = \beta_a \delta\mathbf{v}_a + \beta_b \delta\mathbf{v}_b + \beta_c \delta\mathbf{v}_c$$

$$S(\mathbf{x}_i) = \beta_a \delta\mu_a + \beta_b \delta\mu_b + \beta_c \delta\mu_c$$

$\delta\mathbf{v}_i$ three surrounding vertex displacements

$\delta\mu_i$ deviations of the brightness scale parameters from identity scaling at the surrounding vertices

β_a barycentric coordinates



Estimation of a parameter vector

$$\Theta = \left(\delta v_{x_1},..,\delta v_{x_K}, \delta v_{y_1},..,\delta v_{y_K}, \delta\mu_1,..,\delta\mu_K\right)^T$$

$$\Theta = \operatorname{argmin}_\Theta \left(E_D(\Theta) + \lambda E_S(\Theta)\right)$$

data term — *prior knowledge on deformation and illumination*

data term: extended optical flow equation allows for multiplicative deviations from brightness constancy

$$I\left(\mathbf{x} + \mathbf{D}(\mathbf{x}), t + \delta t\right) = \tilde{S}(\mathbf{x}) \cdot I(\mathbf{x}, t)$$

$$E_D = \left\| \nabla I(\mathbf{x}) \cdot \mathbf{D}(\mathbf{x}) + \frac{\partial I(\mathbf{x})}{\partial t} - S(\mathbf{x}) \cdot I(\mathbf{x}) \right\|^2$$

incorporating the mesh-based model leads to a system of linear equations:

$$E_D(\Theta) = \left\| \mathbf{M} \cdot \Theta - \mathbf{b} \right\|^2$$

smoothness term: penalizes the discrete second derivative of the motion and illumination parameters in the mesh

$$E_S = \left\| \tilde{\mathbf{L}} \cdot \Theta \right\|^2$$

Distance Weighted Laplacian Matrix

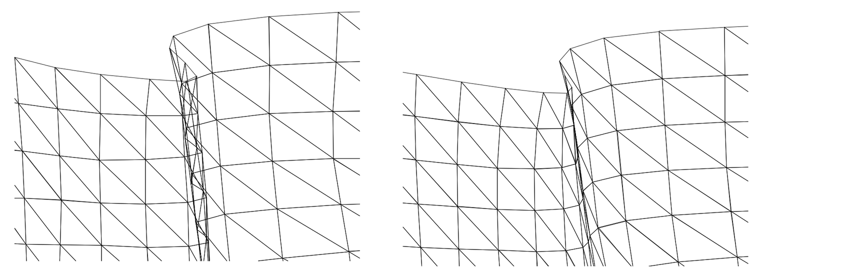
the resulting linear equation system can be efficiently solved in a Least Squares sense:

$$E(\Theta) = \left\| \begin{pmatrix} \mathbf{M} \\ \lambda\tilde{\mathbf{L}} \end{pmatrix} \Theta - \begin{pmatrix} \mathbf{b} \\ \mathbf{0} \end{pmatrix} \right\|^2$$

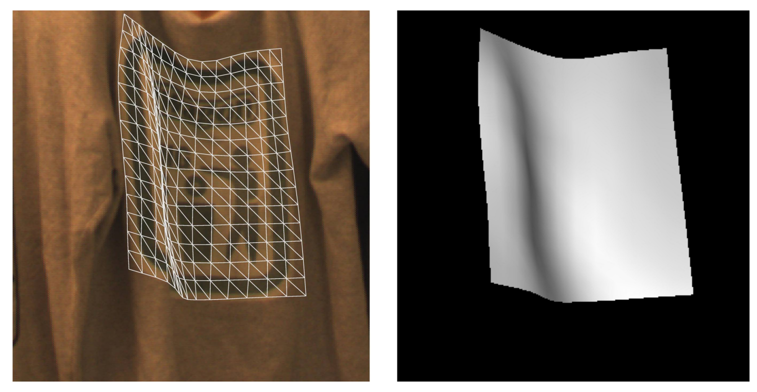
data term
prior knowledge on deformation and illumination

Self-Occlusion Handling

Foldings of the 2D mesh at self-occlusion boundaries cause inaccuracies during tracking. Self-occlusions are handled by weighting the smoothing constraints locally according to the self-occlusion of a region [1].



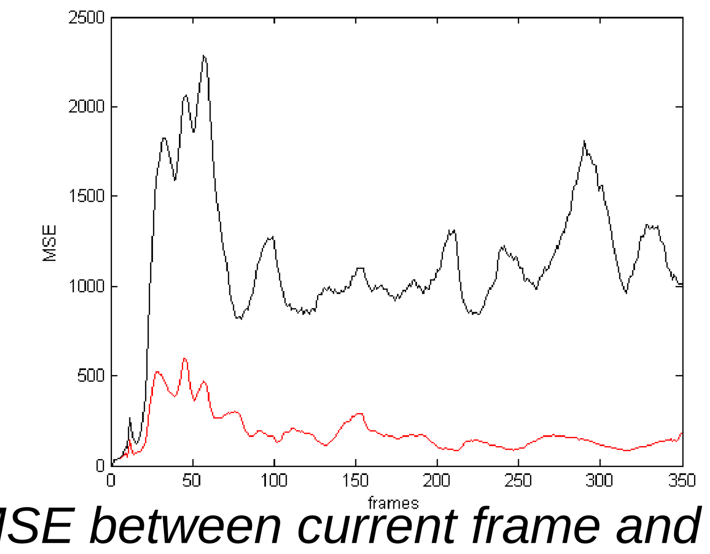
Occlusion boundary with and without self-occlusion handling



Original image and occlusion map

Results

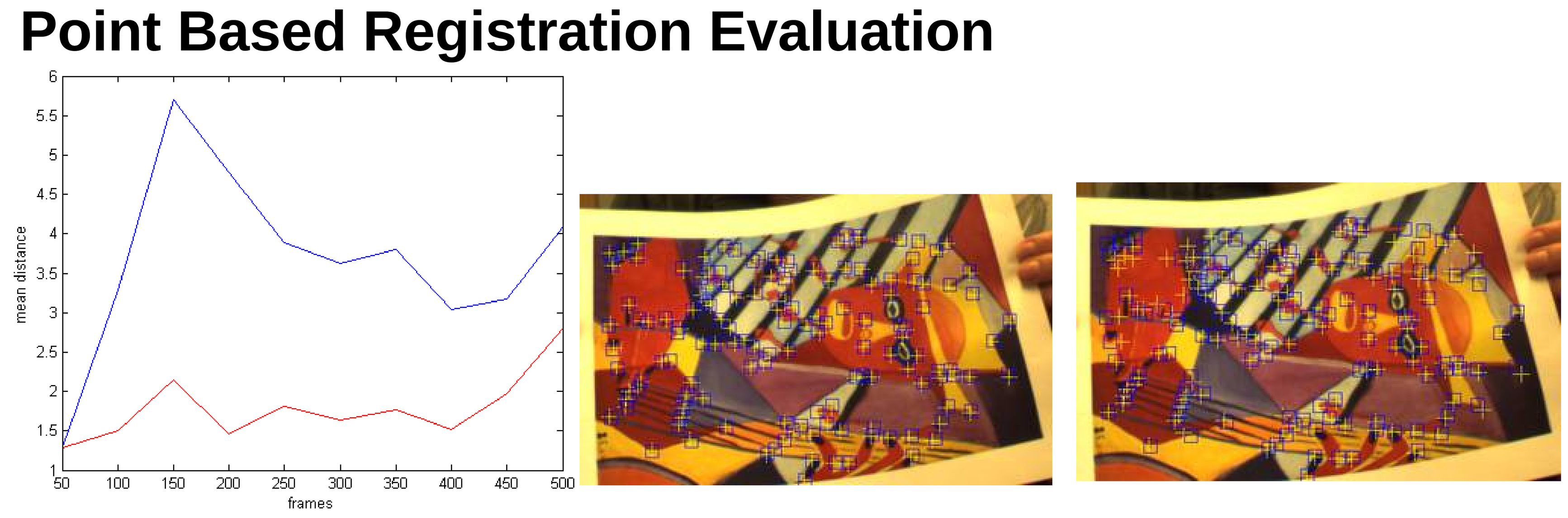
MSE Based Registration Evaluation



Sequence	MSE without ill. cons.	MSE with ill. cons.
Picasso	0.0015	0.000914
Flower1	0.0204	0.0028
Flower2	0.0174	0.0043
Art	0.0127	0.00010
Flower3	0.0137	0.0028
Shirt	2.2636e-007	2.7281e-008

MSE between current frame and warped model with illumination consideration (red) compared to classical Optical Flow (blue) (left) and mean MSE over all test sequences (right)

Point Based Registration Evaluation



Distances between manually selected groind truth points (left); estimated (yellow crosses) and true (blue squares) positions of the ground truth points with illumination consideration (middle) compared to classical Optical Flow(right)

Augmentation Results

Augmentation Results. Original image, augmented result with correct deformation and shading, shading map (left to right)

Cloth tracking and retexturing in a Virtual Mirror [3]. Original images and augmented results (left to right)

References

[1] A. Hilsmann and P. Eisert: *Tracking Deformable Surfaces with Optical Flow in the Presence of Self-Occlusions in Monocular Image Sequences*, CVPR NORDIA Workshop 2008
[2] A. Hilsmann and P. Eisert: *Optical-Flow Based Tracking and Retexturing of Garments*, ICIP 2008
[3] A. Hilsmann and P. Eisert: *Tracking and Retexturing Cloth for Real-Time Virtual Clothing Applications*, Mirage 2009