

Deformable Object Tracking Using Optical Flow Constraints

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1. Overview

- Tracking of complex deformations, such as cloth deformation
- Application: virtual clothing, virtual mirror
- Estimation of global transformations and elastic deformation in a hierarchical framework
- Combination of deformable meshes with temporal and spatial smoothness constraints



Original scene, estimated mesh deformation, virtual logo

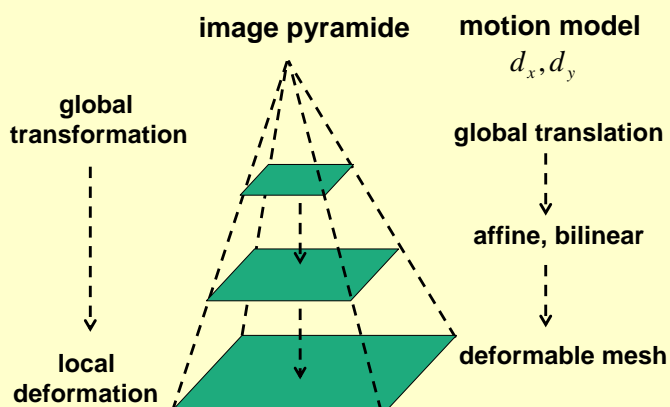
2. Global to Local Motion Estimation in a Hierarchical Framework

- Motion estimation based on the optical flow constraint with a coarse to fine motion model in a hierarchical framework
- Error minimization

$$E_{OF} = \sum \left\| \frac{\partial I}{\partial X} \cdot d_x + \frac{\partial I}{\partial Y} \cdot d_y + \frac{\partial I}{\partial t} \right\|_2$$

where $d_x(x, y), d_y(x, y)$ describe the motion model

- Hierarchical framework allows for larger transformations
- Separate estimation of global and local transformations allows smoothing constraints in local deformation estimation

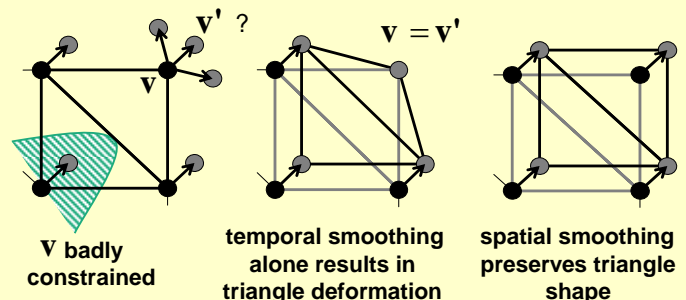


3. Mesh-Based Estimation of Local Deformation

- Motion model determined by the displacements of mesh vertices and barycentric coordinates in the mesh
- Error function is extended by temporal and spatial smoothing constraints on vertex displacements \mathbf{d}_k

$$E = E_{OF} + \underbrace{\lambda \sum_{k=1}^n \|\mathbf{d}_k\|_2}_{\text{temporal}} + \underbrace{\sum_{k=1}^n w_k \cdot E_s(\mathbf{d}_k)}_{\text{spatial}}$$

- Temporal smoothing constraint forces vertex displacements to be as small as possible between successive frames
 - Spatial smoothing constraint forces less constrained vertices to behave like their neighborhood N_k
- $$E_s(\mathbf{d}_k) = \left\| d_{kx} - \frac{1}{|N_k|} \sum_{n \in N_k} d_{nx} \right\|_2 + \left\| d_{ky} - \frac{1}{|N_k|} \sum_{n \in N_k} d_{ny} \right\|_2$$
- Weight w_k is adapted to the degree of 'constrainedness' of the vertex displacement \mathbf{d}_k by the optical flow equation



4. Experimental Results

- Method applied to a 160 frame video sequence tracking the elastic deformations of a logo on a t-shirt
- Tracking is performed estimating the transformation from the warped model to allow recovery from inaccuracies in the estimation



Example mesh deformations and outline of target logo (red) and deformed model (blue). Upper line: no spatial smoothing, lower line: with spatial smoothing