Based Face Characterization Using Factorized Feature Points

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Introduction

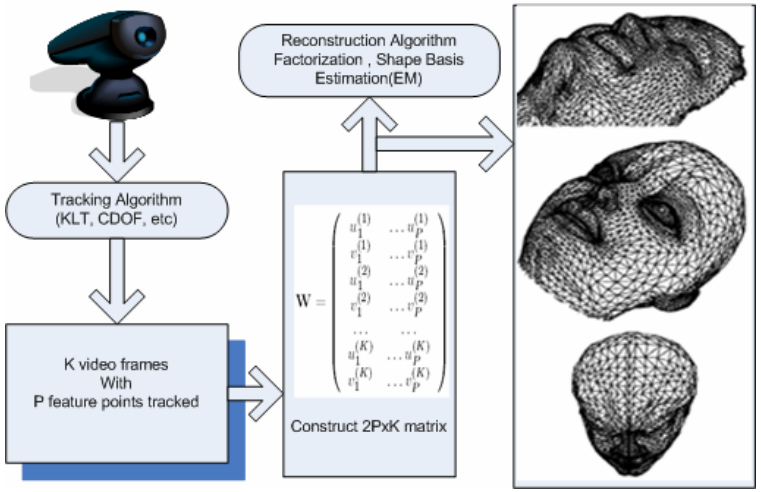
- **Efforts of our work:**

Proposed a face tracking and reconstruction scheme for human computer interaction application.

- **System Structure:**

(1)Use Color Distribution based optical flow approach to track 2D feature points.
(2)Using a factorization based algorithm to reconstruct 3D points from tracked features
(3)Combined with model based expression generation approach to generate 3D expressions

System Diagram



Facial Feature Tracking (1)

- **Image based tracking algorithms can be categorized mainly into intensity based and parameter based**
- **Intensity based algorithm use correlation match of color (KLT algo.) or use optical flow to find point matching. General purposed algo.**
- **Parameter or model based approach use active appearance model or derived parameters to track face image which is fitted on model. Database of model and parameters in arbitrary orientation of face are hard to build.**

Facial Feature Tracking (2)

- Color distribution based optical flow algorithm is used in our experiments as it integrate the advantages of color based method and optical flow based tracking
- Color distribution method is robust and effective, but has poor localization accuracy
- Optical flow has good tracking accuracy, though it is noisy sensitive and require close alignment
- How to keep the advantages of both methods

Facial Feature Tracking (3)

- Optimization criterion derived with color distribution based method:

$$\Gamma_{of} = \sum_{i=1}^{n_x} K_e\left(\frac{x_i - x_0}{h}\right)\rho\left(\left\|\frac{J_{I_2|\theta}^T \delta\theta + e_{of}(x_i, \hat{\theta})}{\sigma}\right\|\right)$$

- Criterion from optical flow based method:

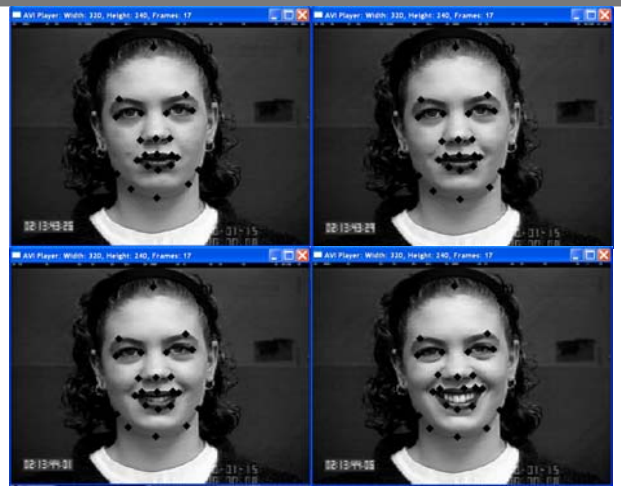
$$\Gamma_{cd} = \sum_{\beta}\sum_{u\in\beta} \rho_{cd}\left(\frac{g^T_{\sqrt{q_{u\beta}}|\hat{\theta}}\,\delta\theta + e_{cd}(u, \beta, \hat{\theta})}{\sigma \pm}\right)$$

- By combine both criterion

$$\Gamma = \Gamma_{cd} + \Gamma_{of}$$

- The tracking become both effective and accurate

Feature Tracking Experiment



Example of tracking feature points from images of CMU face expression database

3D Reconstruction (1)

- Reconstruct 3D shape from tracking 2D features is a typical Structure from Motion (SfM) problem
- Factorization method construct a motion matrix W with 2D tracked features which are continuously tracked from image sequence

$$W = R \cdot \left(\sum_{i=1}^{N} l_i \cdot S_i\right) + T$$

- This matrix is proved can be factored to shape matrix and camera motion matrix
- Factorization is used to reconstruct 3D shape of objects with rigid motion only

3D Reconstruction(2)

- Human expression has both rigid and non-rigid motion thus factorization method need to be improved to tackle both motion
- The problem is formulized as:

$$P_t = R_t(S_t + D_t) + N$$

- Where shape S is produced by adding deformations to a shape base:

$$S_t = \overline{S} + \sum_{k=1}^{K} (V_k z_{k,t})$$

- Problem become how to simultaneously estimate the motion and shape PDF

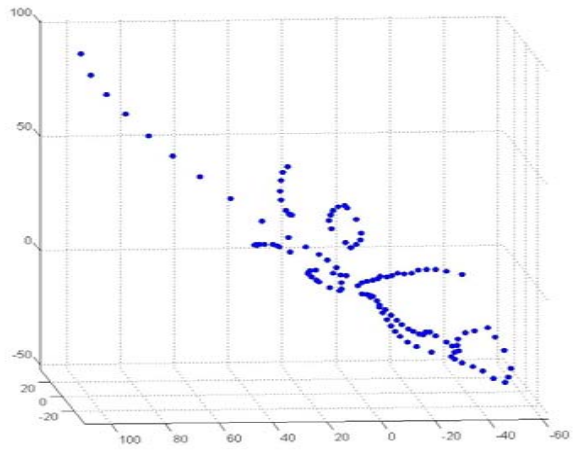
3D Reconstruction(3)

- An EM (expectation maximization) algorithm is used to estimate motion and shape PDF in same time.
- Two steps involved in EM algo., in E step for each frame t given current motion and shape estimates the distribution over shape deformations can be estimated

$$q(z_t) = (N)(z_t \mid \beta(f_t - \bar{f}_t - T_t); I - \beta M_t)$$

- M step motion parameters can be estimated by minimizing $Q(P,\psi) = E_{q(z_1),\ldots q(z_T)}[-\log p(P \mid \psi)]$

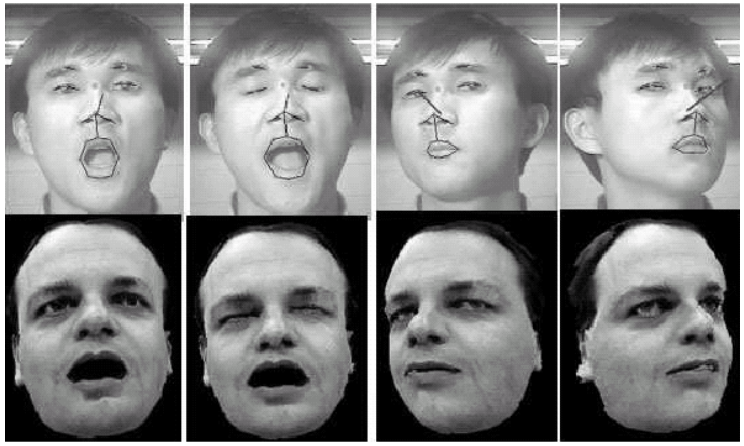
Reconstructed 3D face points



Model Instantiation

- Tracked feature points are limited due to track-ability and video quality, thus insufficient to construct 3D shape directly
- Existed face model such as morphable model could help to inference the shape
- Modification based approach and interpolation are used to reconstruct 3D shape of human expressions

Face expression mapping



Discussion and Future work

- Model instantiation is greatly affected by quality of tracking, thus tracking algorithm need to be further improved. Especially when face has large motion, current algorithm easily loses track of correct points
- A statistical analysis algorithm could be used to improve tracking by exploring 3D face features
- Reconstruction accuracy will be evaluated with comparison of result and ground truth

References (part)

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