A SIMPLE PRIOR FREE MODEL FOR NON-RIGID STRUCTURE FROM MOTION

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CVPR 2012

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About:

- This paper proposes a simple prior free method for solving non rigid structure from Motion factorization problems.
- This paper doesnot assume any extra prior knowledge except a low rank constraint hence is prior free.
- This paper is free from constraints like non rigid shape bases , coefficients , camera motion(may be smooth or rapidly changing) etc…

PRIOR WORK IN THE AREA

Tomasi – Kanade Factorization:

- P feature points over F frames in an image stream.
- Image coordinates are (u_{fp} , v_{fp}) where f = 1,2,….F and p = 1,2,……….P.

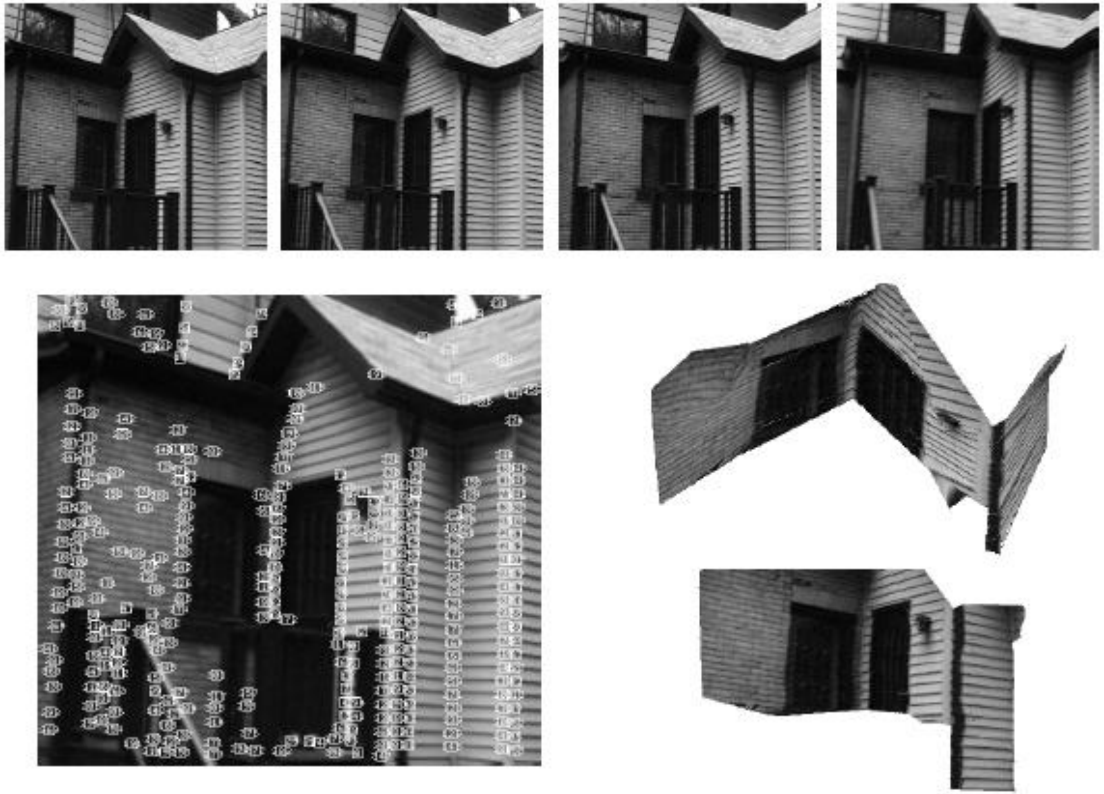
$$W = \begin{pmatrix} u_{11} \; u_{12} \cdots\cdots \; u_{1p} \\ u_{21} \; \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ v_{11} \cdots\cdots\cdots\cdots v_{1p} \\ \cdots\cdots\cdots\cdots\cdots \\ v_{f1} \cdots\cdots\cdots\cdots v_{fp} \end{pmatrix}$$

Mean is subtracted from each entity -> registered rank matrix

$$R = \begin{bmatrix} I_1 \\ I_2 \\ . \\ . \\ . \\ J_1 \\ J_2 \\ . \\ . \\ J_f \end{bmatrix}$$

$$S = \begin{bmatrix} S_1 \ldots\ldots S_p \end{bmatrix}$$

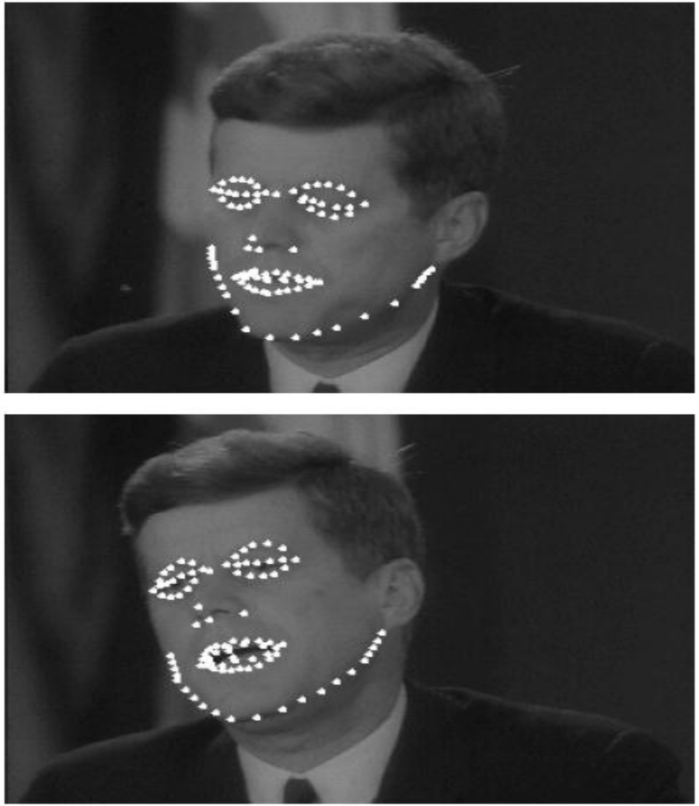
- W = RS
- Here R is rotation matrix and S is shape matrix.
- Rank of noise less W = 3!!!
- SVD :: W' = U'V'D' where R' = U'V' and S' = D'.
- But R=R'Q and S = Q^{-1} S' are also solutions.
- To find Q metric constraints $i1^{T}QQ^{t}\ i1 = 1$ and $i1^{t}QQ^{t}\ i2 = 0$.



Bregler's work

- Recover 3-D non-rigid shape models from image sequences.
- 3D shape is a linear combination of set of basis.
- This algorithm tackles the problem without use of prior model and multi-view etc…
- We describe the shape of the non-rigid object as key frame basis set s1,s2,…sk. Each key frame is 3*P dimensional.
- The required shape is linear combination of basis set.

$$W = \begin{pmatrix} I^1{}_1 R^1 \ldots\ldots\ldots\ldots\ldots\ldots I^1{}_k R^1 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ I^N{}_1 R^1 \ldots\ldots\ldots\ldots\ldots\ldots I^N{}_k R^1 \end{pmatrix} \times \begin{pmatrix} S_1 \\ S_2 \\ . \\ . \\ . \\ S_K \end{pmatrix} = \pi B$$



Track the eyes brows , upper and lower eye lids , 5 nose points , outer and inner boundary of the lips and chin contour using appearance based 2D tracking technique.

Paper's work

- According to xio et.al one cannot recover non-rigid shapes and shapes coefficients uniquely.
- But Akhter et al. proves that although ambiguity in shape basis is inherent 3D shape can be recovered uniquely without ambiguity.
- Here also S(shape matrix) is linear combination of shape basis .
- $W = \pi B = \pi G G^{-1} B$ where G is Euclidean corrective matrix.
- Orthonormal constraints are imposed to recover $Q_k = G_k G_K^T$ by

$$\pi_{2i-1} * Qk * \pi_{2i-1}^T = \pi_{2i} * Qk * \pi_{2i}^T$$

$$\pi_{2i} * Qk * \pi_{2i-1}^T = 0$$

Main Theorem

- All solutions of Qk form a linear subspace of dimension ($2k^2$ - k).
- Intersection theorem:

Avec(Qk) = 0 ∩ Qk > 0 ∩ rank(Qk) = 3. This is converted to nuclear norm rank minimisation problem – standard SDP .

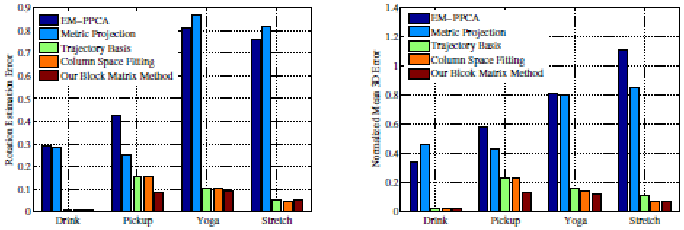
Similarly estimate S by rank minimization problem.

W = RS

Rank(S) <= 3*k

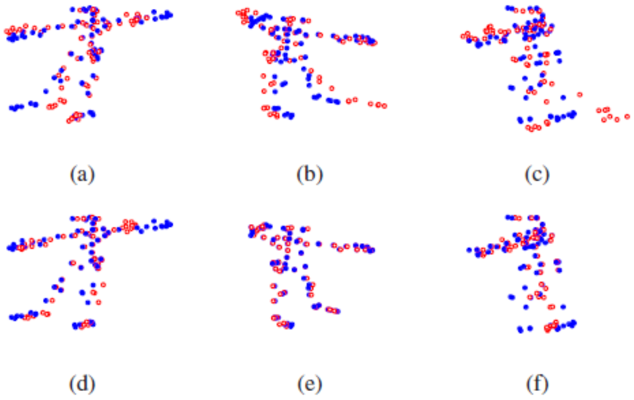
Gives $S = R^{\dagger}W$. ($R^{\dagger}$ is pseudo inverse of R)

Experimental Results



(a) (b)

Figure 3. Motion capture data experimental results. **Left**: Rotation estimation error; **Right**: 3D reconstruction error.



(a) (b) (c)

(d) (e) (f)

Figure 6. Comparison of the 3D reconstruction results on the Dance sequence. The blue dots are the ground truth 3D points, and the red circles show the reconstructed points. **Top row:** results by the trajectory basis method [3], where the 3D errors are **0.3011, 0.2827, 0.2814** for the 3 frames. **Bottom row:** our result by the block matrix method, where the 3D errors are **0.2228, 0.0355, 0.1389** for the 3 frames.

THANK YOU