ICCV2005
Tenth IEEE International Conference on Computer Vision
BeiJing, China October 15-21, 2005

EFFICIENT MODEL-BASED 3D TRACKING OF DEFORMABLE OBJECTS

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THE MODEL

3D Shape Basis

Face Configuration
Linear combination of shape basis

$\mathbf{S}_0 + \mathbf{B}^s$

Rigid Motion
Rotation and translation of 3D configuration

$\mathtt{R}(\alpha,\beta,\gamma) \in \Re^{3\times3}$
$\mathtt{t}(t_x,t_y,t_z) \in \Re^{3\times1}$

$\mathbf{R}(\ ) + \mathbf{t}$

$\mathbf{S} = f(\mathbf{S}_0, \boldsymbol{\mu})$

$\mathbf{I}[p(\mathbf{S},\mathbf{q})]$

Projective camera with parameters $\mathbf{q}$

TRACKING

Illumination Normalization:
$\mathbf{N}(\mathbf{I}[p(\mathbf{S},\mathbf{q})],\mathbf{c}^t) = \mathbf{I}[p(\mathbf{S},\mathbf{q})] - \mathtt{B}^t\mathbf{c}^t$

$\cdot\ \mathtt{B}^t$

Face Illumination
Linear Combination of 3D illumination basis.

Video imput sequence

TRACKING

Tracking amounts to minimize:

$$\min_{\delta\boldsymbol{\mu},\delta\mathbf{c}^t} ||\mathbf{N}(\mathbf{I}[p(f(\mathbf{S}_0,\boldsymbol{\mu}_t),\mathbf{q}),t+\delta t],\mathbf{c}_t^t) - \mathbf{N}(\mathbf{I}_r[p(f(\mathbf{S}_0,\delta\boldsymbol{\mu}),\mathbf{q}_r)],\mathbf{c}_r^t + \delta\mathbf{c}^t)||^2$$

Error term:
$\mathcal{E} = \mathbf{I}[p(f(\mathbf{S}_0,\boldsymbol{\mu}_t),\mathbf{q}),t+\delta t] - \mathtt{i}_r - \mathtt{B}^t(\mathbf{c}_t^t - \mathbf{c}_r^t)$

This equation is linearly solved :

$$\begin{bmatrix}\delta\boldsymbol{\mu}\\ \delta\mathbf{c}^t\end{bmatrix} = (\mathtt{M}_0^\top\mathtt{M}_0)^{-1}\mathtt{M}_0^\top\mathcal{E}(t+\delta t)$$

$\mathtt{M}_0$ is constant for the whole sequence

$\mathtt{M}_0 =$ [Motion | Deformation | Illumination]

ALGORITHM

- **Off-line:**
  1. Compute $\mathtt{M}_0$.
  2. Compute and store $\mathtt{M}^+ = (\mathtt{M}_0^\top\mathtt{M}_0)^{-1}\mathtt{M}_0^\top$.
  3. Compute and store $\mathtt{i}_r = \mathbf{I}_r[p(\mathbf{S}_0,\mathbf{q}_r)]$
- **Online:**
  1. $\mathcal{E} = \mathbf{I}[p(f(\mathbf{S}_0,\boldsymbol{\mu}_t),\mathbf{q}),t+\delta t] - \mathtt{i}_r - \mathtt{B}^t(\mathbf{c}_t^t - \mathbf{c}_r^t)$.
  2. Compute $[\delta\boldsymbol{\mu},\delta\mathbf{c}]^\top = \mathtt{M}^+\mathcal{E}$.
  3. Update $\mathbf{c}_{t+\delta t}^t = \mathbf{c}_t^t - \delta\mathbf{c}^t$.
  4. Update $\mathtt{R}_{t+\delta t} = \mathtt{R}_t\delta\mathtt{R}^\top$, $\mathtt{t}_{t+\delta t} = \mathtt{t}_t - \mathtt{R}_t\delta\mathtt{R}^\top\delta\mathtt{t}$.
  5. Update $\mathbf{c}_{t+\delta t}^s = \mathbf{c}_t^s - \delta\mathbf{c}^s$.

RESULTS

CONCLUSIONS

We have introduced an efficient and simple model-based 3D tracking algorithm applicable to the full projective camera case.

ACKNOWLEDGEMENTS

Work funded by the Spanish Ministry of Science and Technology under contract number TIC2002-00591 and FPU Grant AP2001-0259.