CS448A: Experiments in Motion Capture

Christoph Bregler, bregler@stanford.edu
Gene Alexander, gene.alexander@stanford.edu

- Project Course
- Lectures on all key-algorithms
- 3-4 Homeworks (implement key-algorithms)
- Lot’s of programming and experimenting!
- Final Group Project
- In-Class presentation of Paper from reading list
CS448A: Experiments in Motion Capture

Motion Capture - Pipeline

- Tracking
- Model Fitting/Acquisition
- Kinematics
- Dynamics
- Learning
- Applications
Visual Tracking

Visual Tracking: Unsolved for general settings

<table>
<thead>
<tr>
<th>t</th>
<th>t+1</th>
</tr>
</thead>
</table>

Standard Techniques:
- Template Matching
- Edges / Shape / Color
- Background Subtraction
- Optical Flow

New Challenges:
- Complex Variation
- Self Occlusion
- Noise (Folds, Low Contrast)
Example

Optical Flow

local ambiguities
Kinematic Model Constraints

- Optical Flow/Feature tracking: no constraints
- Layered Motion: rigid constraints
- Articulated: kinematic chain constraints
- Nonrigid: implicit / learned constraints

Tracking = Constrained Optimization
**Tracking = Constrained Optimization**

\[ E(V) \]

Marker-Tracking \[ \rightarrow \] Dense Flow

**Constraints = Subspaces**

\[ E(V) \]

Analytically derived: \textit{Affine, Twist/Exponential Map}

Learned: \textit{Linear/non-linear Sub-Spaces}
Tracking = Constrained Optimization

Constrained Function Minimization

\[ E(V) = \sum_{i=1}^{n} \left( I_i(1) - V(1)^T \right) \left( I_i(1) - V(1)^T \right)^T + \sum_{i=2}^{n} \left( I_i(2) - V(2)^T \right) \left( I_i(2) - V(2)^T \right)^T + \ldots + \left( I_i(m) - V(m)^T \right) \left( I_i(m) - V(m)^T \right)^T \]
Constrained Function Minimization

\[
\| I_t(1) - \nabla I_t^x \|_2^2 \\
\| I_t(2) - \nabla I_t^x \|_2^2 \\
\vdots \\
\| I_t(n) - \nabla I_t^x \|_2^2
\]

\[= E(V) \]

\[V = M(\theta)\]

2D Translation: Lucas-Kanade

\[
\| I_t(1) - \nabla I_{t+\theta}^x \|_2^2 \\
\| I_t(2) - \nabla I_{t+\theta}^x \|_2^2 \\
\vdots \\
\| I_t(n) - \nabla I_{t+\theta}^x \|_2^2
\]

\[= E(V) \]

\[V = [dx, dy; \ldots; dx, dy] \]
2D Affine: Bergen et al, Shi-Tomasi

\[
\begin{bmatrix}
I_i(1) - \nabla I_i(x, y) \\
I_i(2) - \nabla I_i(x, y) \\
\vdots \\
I_i(n) - \nabla I_i(x, y)
\end{bmatrix}^2 = E(V)
\]

\[
V_i = \begin{bmatrix}
a_1, a_2 \\
a_3, a_4
\end{bmatrix}
\begin{bmatrix}
x_i \\
y_i
\end{bmatrix}
\begin{bmatrix}
dx \\
dy
\end{bmatrix}
\]
**K-DOF 3D chain: Yamamoto, Bregler-Malik**

\[
\begin{align*}
\| & I_i(1) - \nabla I_i(1) \|^2 \\
& I_i(2) - \nabla I_i(2) \\
& \vdots \\
& I_i(n) - \nabla I_i(n) \\
\end{align*}
\]

= \( E(V) \)

\[ V = M(\theta) \]

---

**Twist and Product of Exp. Maps**

**Orthographic projection**

\[
\begin{pmatrix}
S & 0 & 0 & 0 \\
0 & S & 0 & 0 \\
0 & 0 & S & 0 \\
0 & 0 & 0 & S
\end{pmatrix}
\]

\[ e^{\hat{\xi}_0} e^{\hat{\xi}_1} e^{\hat{\xi}_2} q_i \]

\[ \frac{\delta}{\delta t} \]

\[ v_i = M_i \begin{pmatrix} \hat{\xi} \\ \hat{\alpha} \end{pmatrix} \]
Analytically derived Constraints

\[ \sum_{i=1}^{n} \left( I_i(1) - \nabla I(1) \xi_1 \right)^2 = E(V) \]

\[ V = M \begin{bmatrix} \xi \\ \alpha_1 \\ \vdots \\ \alpha_n \end{bmatrix} \]

---

Example Track
Multiple Views

Example Track -2-
Tracking + Acquisition of Kinematics

- Acquire Kinematic Chains.

Non-Rigid Constrained Spaces

\[ S = (p_1, \ldots, p_n) \]
Non-Rigid Constrained Spaces

Linear Subspaces:
- Small Basis Set
- Principal Components Analysis

Nonlinear Manifolds

Mixture Models

Nonrigid Examples

Constrain
Nonrigid 3D Acquisition

Human Dynamics

- Forces applied on masses
- Exploit models from Biomechanics
- Motor control / High-level processes
- Learning Statistical Models of Dynamics
- “Motion-Phonemes”: Movemes
- Laban Movement Analysis
Performance Capture based Animation
Rotoscope / Mocap: History

• Disney:

Step-mother of Cinderella

Rotoscope / Mocap: History

• Disney:

Eleanor Audley
Rotoscope / Mocap: History

- Rebecca Allen / Twyla Tharp: The Catherine Wheel
- Paul Kaiser / Merce Cunningham: “Biped”

Performance Capture based Animation

Lambsoft
Performance Capture based Animation

Lambsoft

Performance Capture based Animation

-> Popovic Files
CS448A: Homeworks

- 3 Homeworks on Tracking: Lucas-Kanade, Extensions, Kalman
- 1 Homework on Camera Calibration
- [ 1 Homework on Model Acquisition/Fitting ]

CS448A: Paper Presentation

- Presentation for 20 min (depending on class size)
- Choose from Reading List
- or – find it yourself
CS448A: Project

- Start thinking about it now
- In-class brainstorming session
- Proposal with 2 Milestones
- Group work

CS448A: Project Ideas

- Full-Body Tracker:
  - Offline / Real-time
  - Resolution: 3D Blob, Kinematic Model
- Hand Tracker:
  - 2D vs 3D / how many cameras
  - Features: Color, Silhouette, Flow, Regions, Edges
  - Explicit kinematic model vs learned PCA model
- Face Tracker:
  - Markers / no Markers
  - same issues as above
CS448A: Project Ideas

- Generic 3D Model Acquisition based on Marker tracking
- Kinematic model fine-tuning
- Pan-Tilt tracker
  - Integrate with 3D blob tracker or other
  - Angle, Zoom, Focus, …
- Gesture Recognition
  - HCI applications -> iRoom
- Application of Mocap to Animation
  - Full Body / Face
- …

CS448A: How to get in

- email to: cs448a-staff@cs
  - Your name, email, website
  - Probability of taking this class
  - Your background (Classes, childhood, etc…)
  - What you would like to do for a project

- website: graphics/courses/cs448a