Temporal Integration of Multiple Silhouette-based Body-part Hypotheses

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Goals

• Estimation of human body-part locations in a video

• Temporal integration framework of an instantaneous labeling technique
Motivation

- Body-part location information can be useful in many ways
  - Tracking
  - Animation
  - Surveillance
- Should be able to do better than instantaneous
- Framework for combining discrete and continuous state information

Instantaneous Estimation: *Ghost*
State and Measurements

- Ghost outputs a measurement of the state
- $q_t$: Posture State
- $x_t$: Body-part location State
- $h_t$: Posture Measurement (Projection Histogram)
- $z_t$: Body-part location Measurement: Set of labelings $\{z_{t,q}\}$, one for each posture-based heuristic

Probabilistic State Estimation

- State Estimate
  - Expected value of $x_t$ (body-part location)
  - Most likely value of $q_t$ (posture)
- Probability density estimate
  - Filtered: $p(x_t, q_t | z_{1:t}, h_{1:t})$
  - Smoothed: $p(x_t, q_t | z_{1:T}, h_{1:T})$
    $\approx$ Filtered + Back propagation
- Non-gaussian density: mixture of continuous and discrete variables – estimate using CONDENSATION
CONSENSATION

\begin{align*}
    p(x_t \mid z_{1:t}) & \propto p(z_t \mid x_t) \cdot p(x_t \mid z_{1:t-1}) \\
    & = p(z_t \mid x_t) \cdot \int p(x_t \mid x_{t-1}) \cdot p(x_{t-1} \mid z_{1:t-1}) \, dx_{t-1}
\end{align*}

- **Prediction**
  - Posture transition probability = \( \Pr(q_t \mid q_{t-1}) \): heuristically assigned
  - Body-part dynamics = \( p(x_t \mid x_{t-1}) \): velocity predictor
- **Measurement likelihood**
  - Projection histogram likelihood = \( p(h_t \mid q_t) \): truncated gaussian
  - Body-part labelings likelihood = \( p(z_t \mid x_t, q_t) \): truncated gaussian for \( z_{t,q} \), \( q = q_t \): uniform for other labelings
**Forward Density Propagation**

- Select a sample with probability proportional to its likelihood
- Predict state of sample in next time step

![Diagram](image)

- Compute new measurement likelihood for the sample

**Smoothed State Estimation**

- Propagate samples until end of sequence
- Trace ancestors of each sample back to the desired time-step

![Diagram](image)

- Compute mean body-part locations and most likely posture from traced samples
Results

Head
Hands

Feet
Posture

Summary

• A framework for temporally integrating an instantaneous body-part labeling method is presented

• Performs density propagation for mixed discrete and continuous states

• The framework is general enough to be applied to other example domains
The End