**This Hand Is My Hand:** A Probabilistic Approach to Hand Disambiguation in Egocentric Video

Stefan Lee, Sven Bambach, David Crandall, School of Informatics and Computing, Indiana University  
John Franchak, Chen Yu, Department of Psychological and Brain Sciences, Indiana University

1. Motivation

- We use head-mounted cameras to **study how toddlers interact with parents**, including how they coordinate hands, head turns, and gaze
- To study how different hands help capture the toddler’s attention, we need to **detect, disambiguate, and track all hands** in the video
- We use a probabilistic framework to **jointly model head motion and hand position** of interacting people in egocentric video

![Diagram of head camera and hands](image)

Our probabilistic framework models paired interaction, incorporating hands’ spatial, temporal, and appearance constraints in egocentric video.

2. Challenges

- **Given** an egocentric video sequence $I = \{I_1, \ldots, I_n\}$
- **Estimate** location of parts $P = \{yr, yh, yl, mr, ml, ml\}$ in each frame as latent variables $\{L_p\}_{p \in P}$
- Also jointly estimate **global shift** $G$ between pairs of consecutive frames (caused by head motion)
- Use weak **skin, head and arm appearance models** to generate (noisy) likelihood maps within each frame
- **Model spatial constraints** on hand position with a fully-connected graph within each frame
- **Model temporal constraints** with edges between corresponding parts in adjacent frames, and the global shift variables
- **Handle out-of-view parts** with a special $\emptyset$ state, estimating its probability as an integral over the portion of spatial constraints outside the frame
- **Solve using Gibbs sampling**, modeling priors as isotropic normal distributions for efficient inference

3. Modeling Egocentric Interactions

- **Graphical depiction of our model for a two frame video.**

![Graphical model of hand disambiguation](image)

4. Experiments

- We tested our model on **5 different parent-child subject pairs** in a lab setting (31 min of video)
- We additionally captured **naturalistic videos** of two adults using **Google Glass** (4.5 min)
- To evaluate our results, we manually **annotated 2,700 frames** (about 1 frame/second) with ground-truth bounding boxes of head and hands

<table>
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<tr>
<th>Method</th>
<th>Lab Videos</th>
<th>Overall Accuracy</th>
<th>Observer L Hand</th>
<th>Observer R Hand</th>
<th>Partner L Hand</th>
<th>Partner R Hand</th>
<th>Perfect Frames</th>
<th>Disambiguation Error Rate</th>
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5. Results

- **Frames from our lab videos**, where rectangles are ground truth bounding boxes and dots are estimated positions. Key: red: your head, blue: your left hand, green: your right hand, magenta: my left hand, cyan = my right hand.

![Lab Videos](image)

- **Frames from our naturalistic videos**, with participants playing cards, tic-tac-toe, and solving a 3-D puzzle, while one wore Google Glass.

![Naturalistic Videos](image)

6. Future Work

- More complex, naturalistic video data
- Stronger appearance models
- Joint models of attention and hand/head motion

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