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Tracking loose-limbed people

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Abstract and figures

We pose the problem of 3D human tracking as one of inference in a graphical model. Unlike traditional kinematic tree representations, our model of the body is a collection of loosely-connected limbs. Conditional probabilities relating the 3D pose of connected limbs are learned from motion-captured training data. Similarly, we learn probabilistic models for the temporal evolution of each limb (forward and backward in time). Human pose and motion estimation is then solved with non-parametric belief propagation using a variation of particle filtering that can be applied over a general loopy graph. The loose-limbed model and decentralized graph structure facilitate the use of low-level visual cues. We adopt simple limb and head detectors to provide "bottom-up" information that is incorporated into the inference process at every time-step; these detectors permit automatic initialization and aid recovery from transient tracking failures. We illustrate the method by automatically tracking a walking person in video imagery using four calibrated cameras. Our experimental apparatus includes a marker-based motion capture system aligned with the coordinate frame of the calibrated cameras with which we quantitatively evaluate the accuracy of our 3D person tracker.

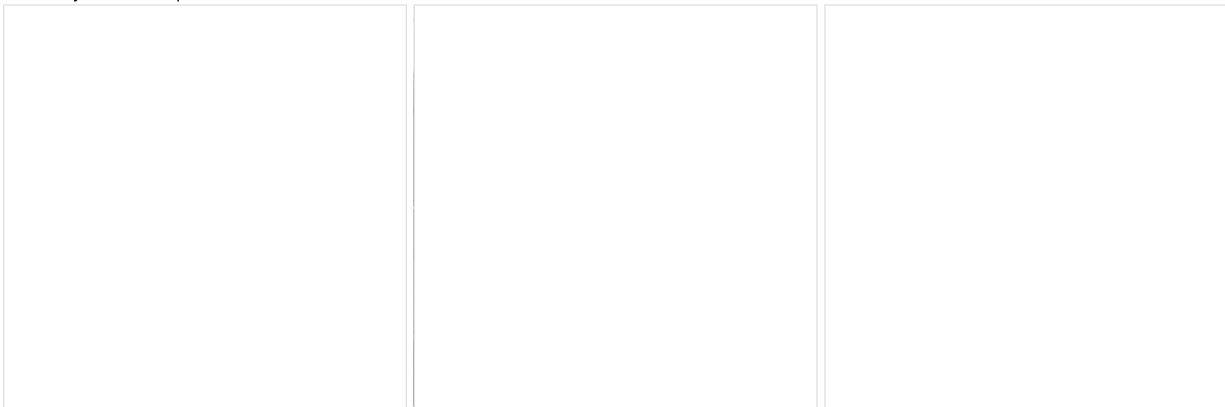


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Tracking Loose-limbed People

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Abstract

We pose the problem of 3D human tracking as one of inference in a graphical model. Unlike traditional kinematic tree representations, our model of the body is a collection of loosely-connected limbs. Conditional probabilities relating the 3D pose of connected limbs are learned from motion-captured training data. Similarly, we learn probabilistic models for the temporal evolution of each limb (forward and backward in time). Human pose and motion estimation is then solved with non-parametric belief propagation using a variation of particle filtering that can be applied over a general loopy graph. The loose-limbed model and decentralized graph structure facilitate the use of low-level visual cues. We adopt simple limb and head detectors to provide “bottom-up” information that is incorporated into the inference process at every time-step; these detectors permit automatic initialization and aid recovery from transient tracking failures. We illustrate the method by automatically tracking a walking person in video imagery using four calibrated cameras. Our experimental apparatus includes a marker-based motion capture system aligned with the coordinate frame of the calibrated cameras with which we quantitatively evaluate the accuracy of our 3D person tracker.

1 Introduction

We present a fully automatic method for tracking human bodies in 3D. Initialization and failure recovery are facilitated by the use of a loose-limbed body model [22] in which limbs are connected via learned probabilistic constraints. The tracking problem is formulated as one of inference in a graphical model and belief propagation is used to estimate the pose of the body at each time-step. Each node in the graphical model represents the 3D position and orientation of a limb (Figure 1). Directed edges between nodes represent statistical dependencies and these constraints between limbs are used to form messages that are sent to neighboring nodes in space and time. Additionally, each node has an associated likelihood defined over a rich set of image cues using a learned Gibbs model [19, 28]. The combination of

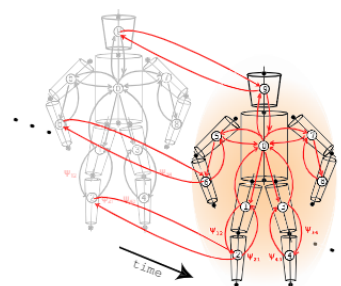


Figure 1: Graphical model for a person. Nodes represent limbs and arrows represent conditional dependencies between limbs. For clarity only a few temporal dependencies have been shown: in our model each part i at time t is connected by an edge to part i at times $t - 1$ and $t + 1$.

highly non-Gaussian likelihoods and a six-dimensional continuous parameter space (3D position and orientation) for each limb makes standard belief propagation algorithms infeasible. Consequently we exploit a form of non-parametric belief propagation that uses a variation of particle filtering and can be applied over a loopy graph [13, 25].

There are a number of significant advantages to this approach as compared to traditional methods for tracking human motion. Most current techniques model the body as a kinematic tree in 2D [14], 2.5D [17], or 3D [2, 5, 21, 23] leading to a high-dimensional parameter space (25–50 dimensions is not uncommon). Searching such a space directly is impractical and so current methods typically rely on manual initialization of the body model. Additionally, they often exploit strong priors characterizing the types of motions present. When such algorithms lose track (as they always do), the dimensionality of the state space makes it difficult to recover.

While the full body pose is hard to recover directly, the location and pose of individual limbs is much easier to compute. Many good head detectors exist and limb detectors have been used for some time (e.g. [18]). The approach we take here can use bottom up information from feature

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