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Models for Human Motion

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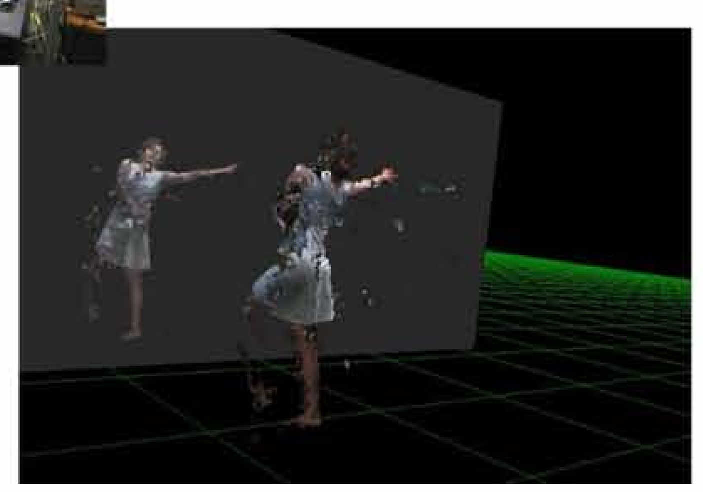
Goal

To learn from 3-D visual data, models which can describe the dynamics of human body motion. These models could then be used for recognition and simulation of human actions.

Tele-immersion setup
48 cameras in 12 clusters

3D Reconstruction



3D visual data

Body Part Segmentation

Joint angle trajectories $\theta(t)$

Equations of motion

$$M(\theta)\ddot{\theta} + C(\theta,\dot{\theta})\dot{\theta} + N(\theta,\dot{\theta}) = \tau$$

Inertia matrix — Coriolis matrix — External forces — Applied torques

From the observed joint angle trajectories, we wish to estimate the parameters of the nonlinear dynamical model and the input torques.

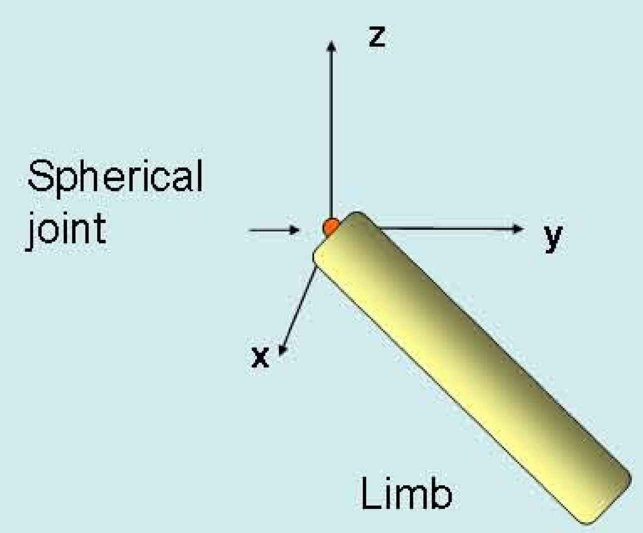
Approach

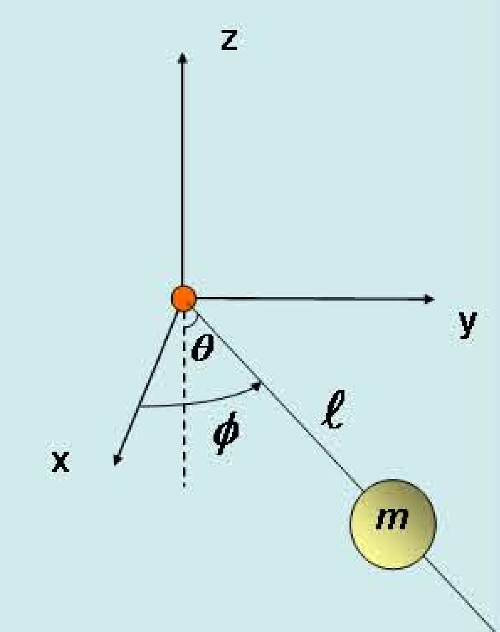
Divide and Conquer

Learn dynamical models for individual joints separately. While the human body has over 32 degrees of freedom, each joint has a maximum of 3. This approach has the advantage that the subsequent recognition can be done in a hierarchical manner.

Simplify

We assume that all the mass is concentrated at a single point on the limb. This simplifies the equations of motion and reduces the number of parameters to be learnt.





Equations of motion

$$\ddot{\theta} = \frac{\tau_\theta}{ml^2} + \sin\theta\cos\theta\,\dot{\phi}^2 - \frac{g}{l}\sin\theta$$

$$\ddot{\phi} = \frac{\tau_\phi}{ml^2\sin^2\theta} - 2\cot\theta\,\dot{\theta}\,\dot{\phi}$$

State-space model

$$\dot{x} = f(x(t),\lambda)$$

$$x(t) = [\theta(t),\phi(t),\dot{\theta}(t),\dot{\phi}(t)]$$

$$\lambda = (m,l,\tau_\theta,\tau_\phi)$$

Learn model from data

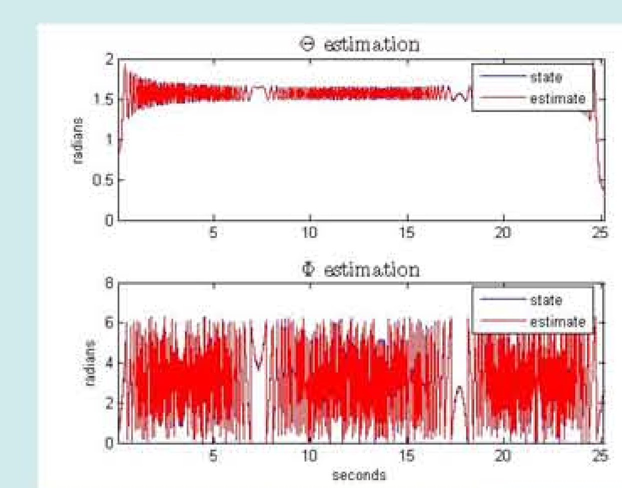
$$x_{t+\Delta t} = x_t + \int_t^{t+\Delta t} f(x(T),\lambda)\,dT = F(x_t,\lambda)$$

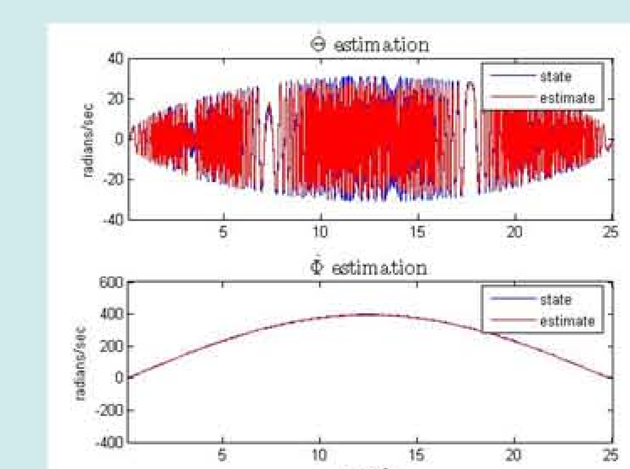
Nonlinear dynamical function

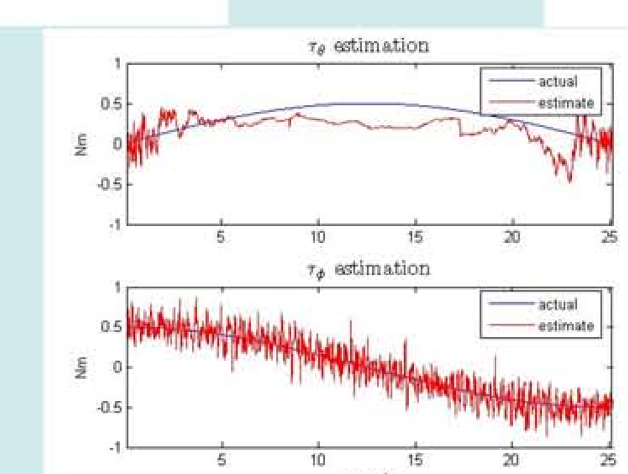
$$y_{t+\Delta t} = G(x_{t+\Delta t},\lambda) + \eta_{t+\Delta t}$$

Observation — Observation function — Gaussian noise

From noisy observations (function of θ,ϕ) estimate the parameters, here mass, length and the input torques. Joint state and parameter estimation is done by augmenting the state with the parameters and using the Unscented Kalman filter.







Future Work

- **Composition of the dynamical systems for individual joints.**
- **Classification of actions using the estimated normalized torques and initial conditions**