Intention Estimation using Gaussian Processes on Wearable Haptics Signals

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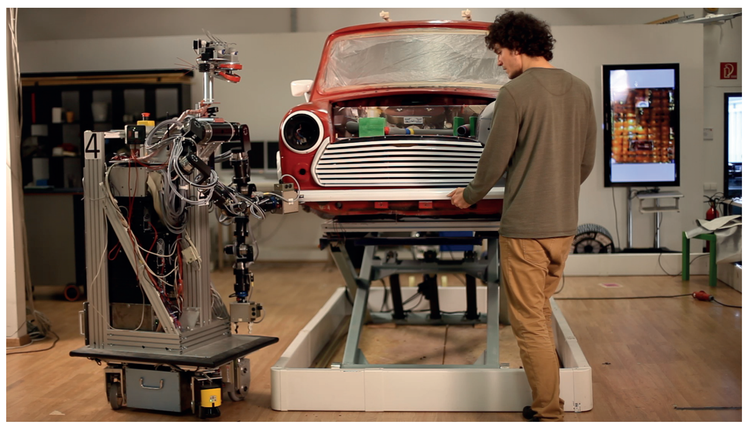
Motivation

Human haptic intention recognition and prediction for human-robot interaction

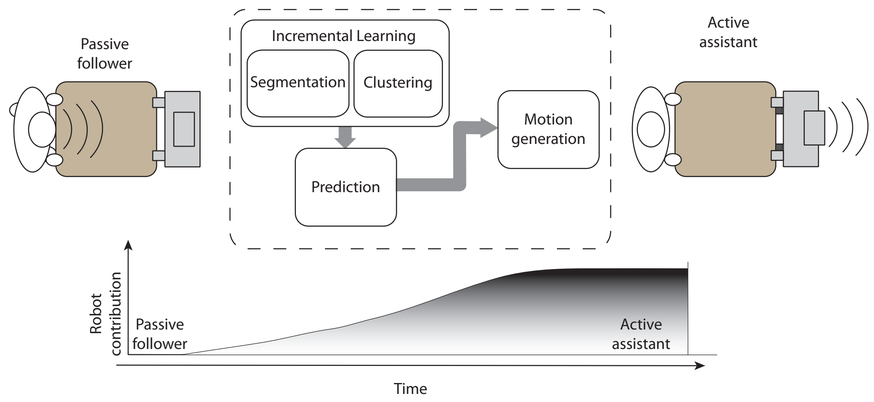


Challenge

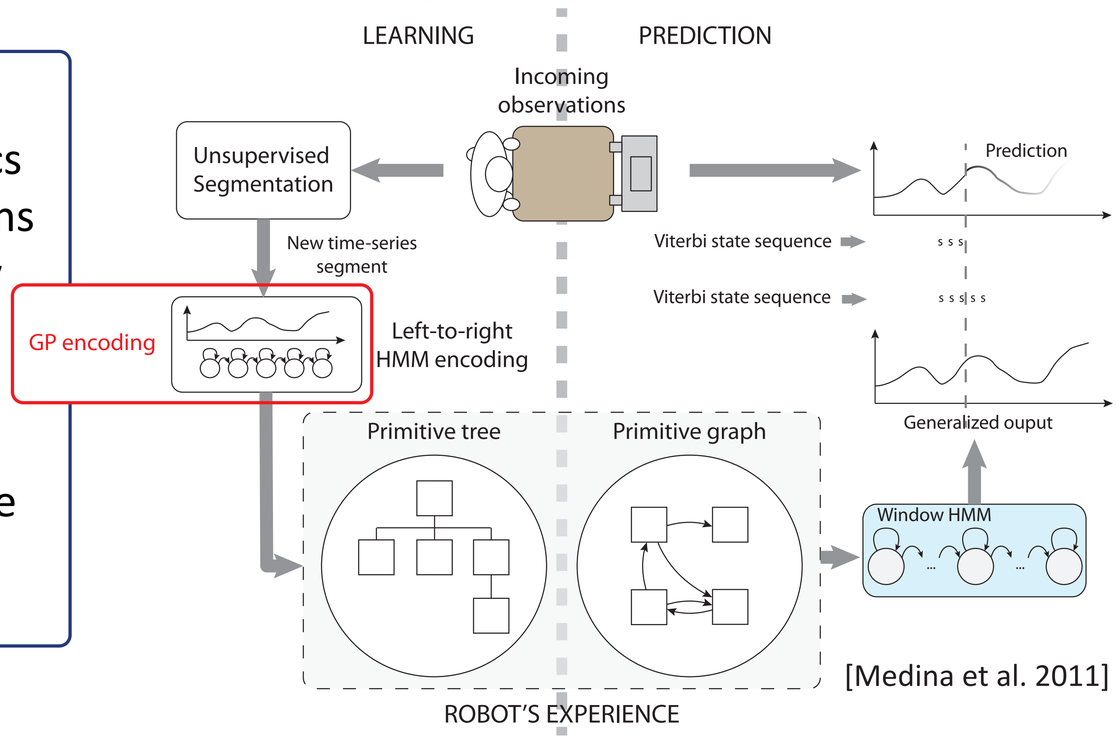
- No purely physics-based human dynamics model availabe
- Human behavior time-varying, nonlinear, input (neural signals) difficult to measure
- Task ambiguous in unstructured environments

Approach

Stochastic behavior modeling:
Robotic partner acquiring knowledge through learning from observation



Framework for learning, recognition and prediction



[Medina et al. 2011]

GP pros and cons

+ Nonlinear motion dynamics
+ Minimal model assumptions
+ Accounting for uncertainty in the model
- Restricted to Euclidean space
- Commonly used Euler angle representation erroneous

Framework pros and cons

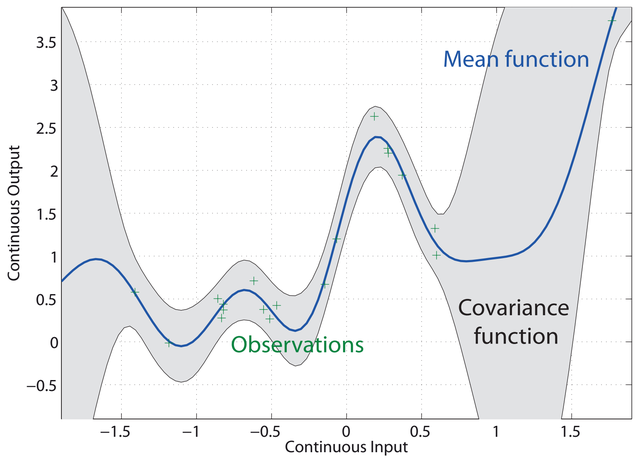
+ Time-based hierarchically clustered Hidden Markov Models (tHMMs)
- Discretized state space, leads to limitations during synthesis of continuous trajectories

Replace lower level HMMs by Gaussian Processes (GPs)

State of the art GP models insufficiently capture 6D motions enabled by WEARHAP device

GP Definition

Collection of random variables $\{X_i\}$, with $i \in \mathbb{N}$, of which any finite subset is jointly Gaussian distributed.



GP over Dual Quaternions

Enhancement of the GP to non-Euclidean space:

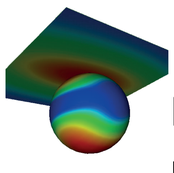
- Mathematically correct inclusion of rotation
- High prediction quality for trajectories including significant rotation

Lang et al. 2014

6D Pose Representation by Dual Quaternions

Unit quaternion for rotation
$\mathbf{q}_r := a + bi + cj + dk$,
with $|\mathbf{q}_r| = 1$

Imaginary quaternion for translation
$\mathbf{q}_t := xi + yj + zk$

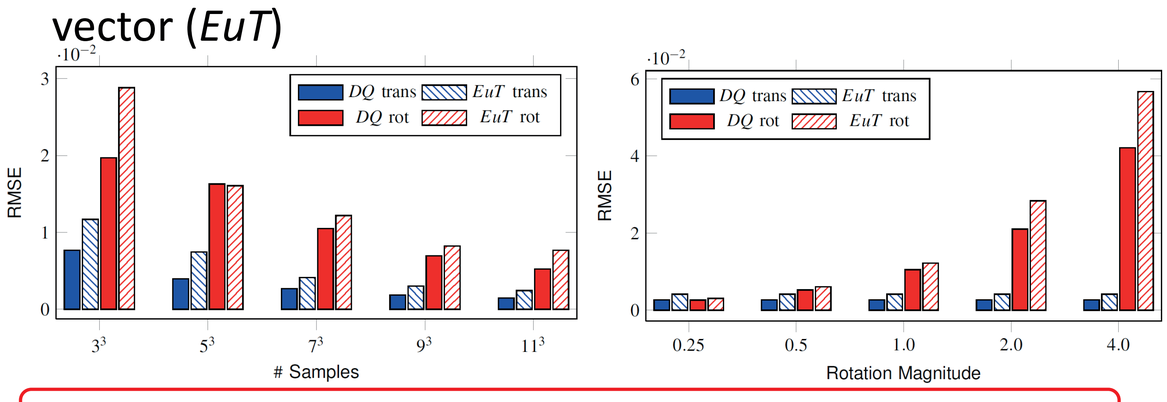


Dual quaternion encoding 6D rigid motion with $\epsilon^2 = 0$:

$$\mathbf{dq} := \mathbf{q}_r + \frac{\epsilon}{2}\mathbf{q}_t\,\mathbf{q}_r$$

Numerical Evaluation

Prediction quality evaluation of GPs over dual quaternions (*DQ*) and over Euler angles concatenated with translation vector (*EuT*)



The GP over dual quaternions outperforms the state of the art GP over Euler angles and translation vector.

Lang et al. 2014

Ongoing Work

Hierarchical models for recognition and short-term prediction of human grasping and displacement actions:

- HMM for grasp type estimation
- GP over dual quaternions for subsequent displacement action

WEARHAP FIRST REVIEW MEETING
University Pierre et Marie Curie, Paris Institut des Systemes Intelligents et de Robotique (ISIR), April 11th, 2014