Online Active Trajectory Classification for Motion-based Communication of Robots

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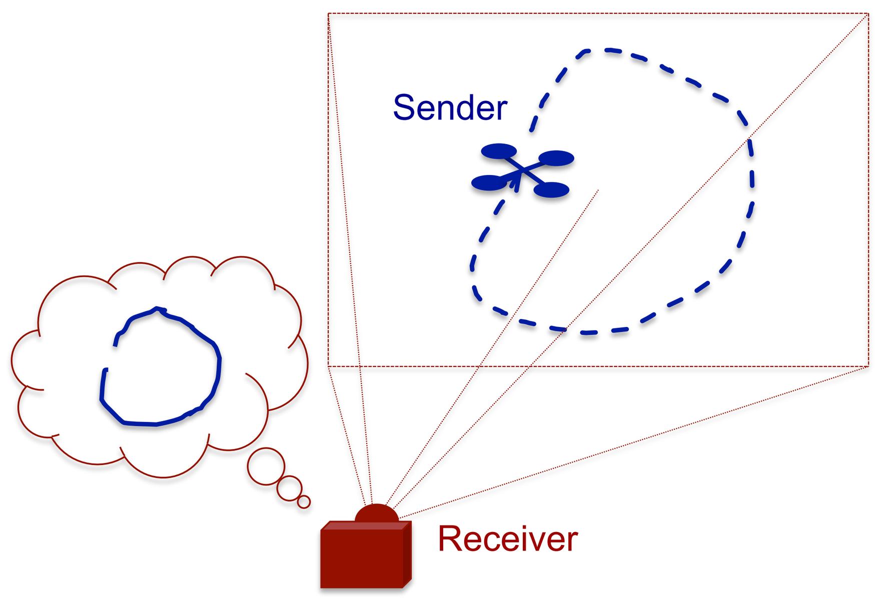
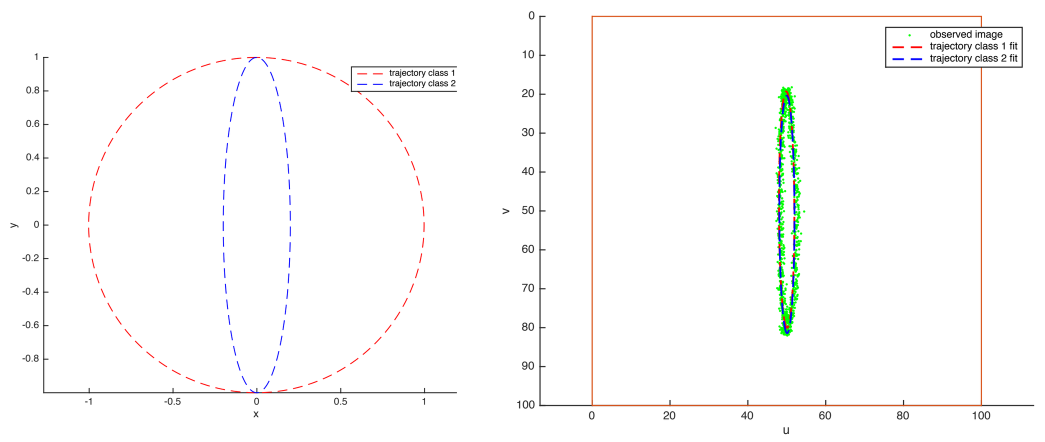
CS 229 Spring 2016 (Instructor: Prof. John Duchi)

Problem Set-up



The message sender sends a message by performing the corresponding trajectory chosen from the trajectory codebook.



Both of the two trajectory classes in the example codebook (left) fit equally well to the observed trajectory (right), yielding two different hypotheses about the message and the camera pose.

Entropy-based Control Policy

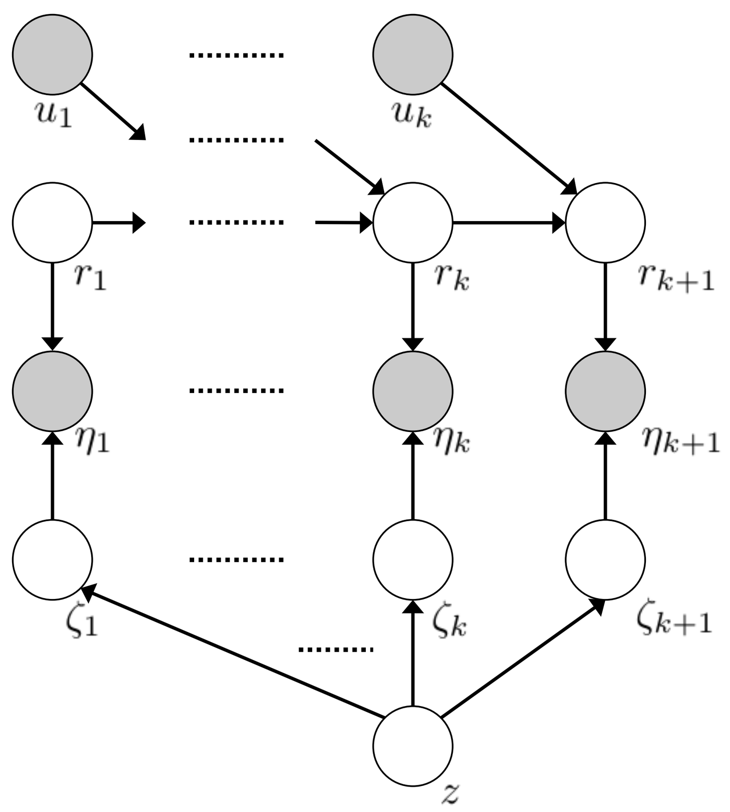
The control policy is formulated to minimize the conditional entropy over the categorical distribution z.

$$u_k = \arg\min_{u_k \in \mathcal{A}} \mathbb{E}_{\eta_{k+1}} \left[H(z \mid \eta_{1:k+1}, u_{1:k}) \mid \eta_{1:k}, u_{1:k} \right]$$

Due to the weighted Gaussian approximation to the belief state, this objective function can be evaluated analytically.

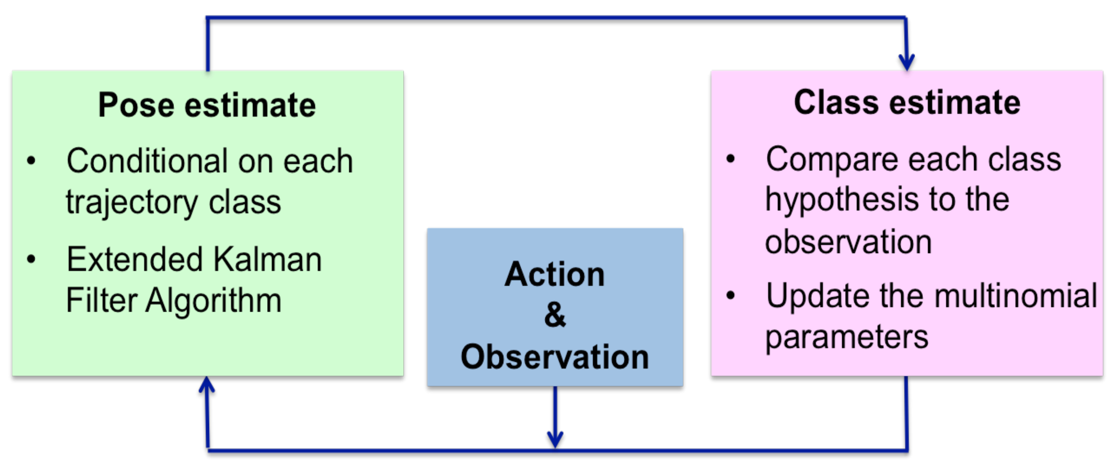
Online State Estimation

The receiver is allowed to sequentially move around the sender to estimate the trajectory class as it observes the trajectories of the same class repeated by the sender.



The message receiver makes successive moves u around the sender to estimate the trajectory class z and its own position/attitude r. The actual trajectories and observations as well as the control inputs have Gaussian noise.

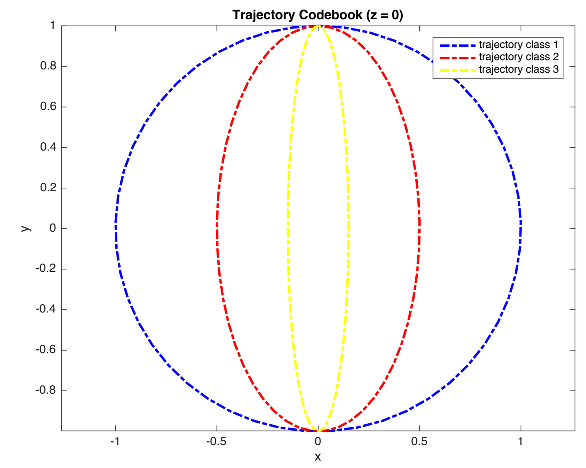
We have formulated a recursive Bayesian state estimation algorithm based on the Multi-hypothesis Extended Kalman filter with a linearized observation model.



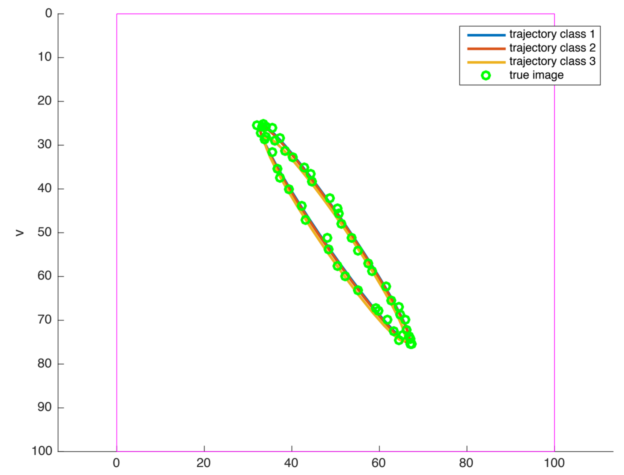
The Bayesian network structure allows us to iteratively update the current trajectory class belief and the pose belief given a new action and an observation.

Simulation Results

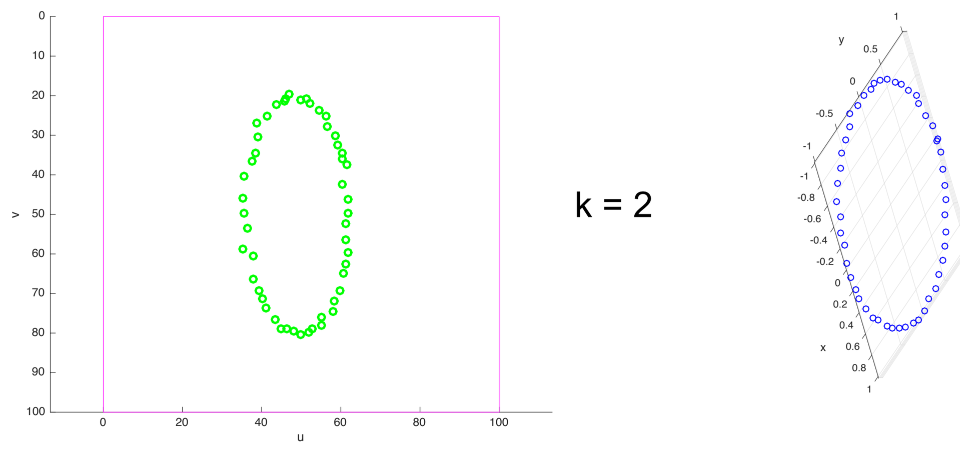
Three different trajectory classes were used in the simulation. All the trajectories were assumed to be 2D.

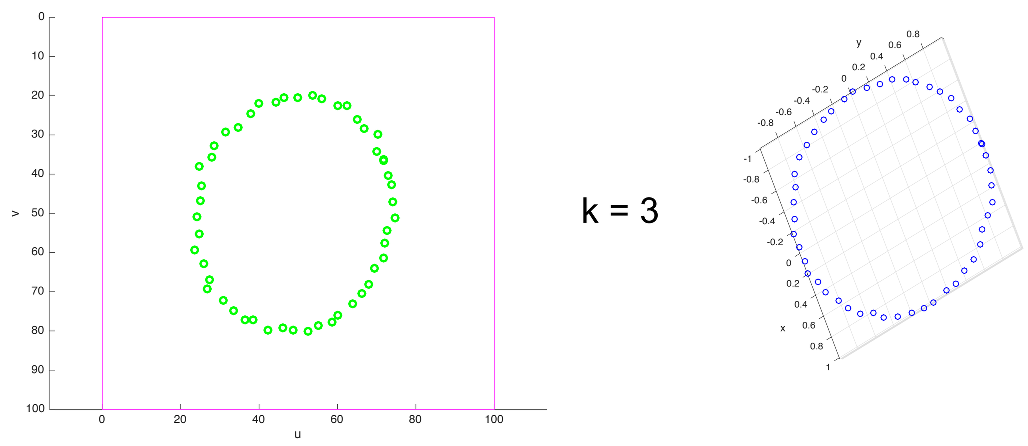


Prior (k = 1)
Class 1: 0.3414
Class 2: 0.3404
Class 3: 0.3183

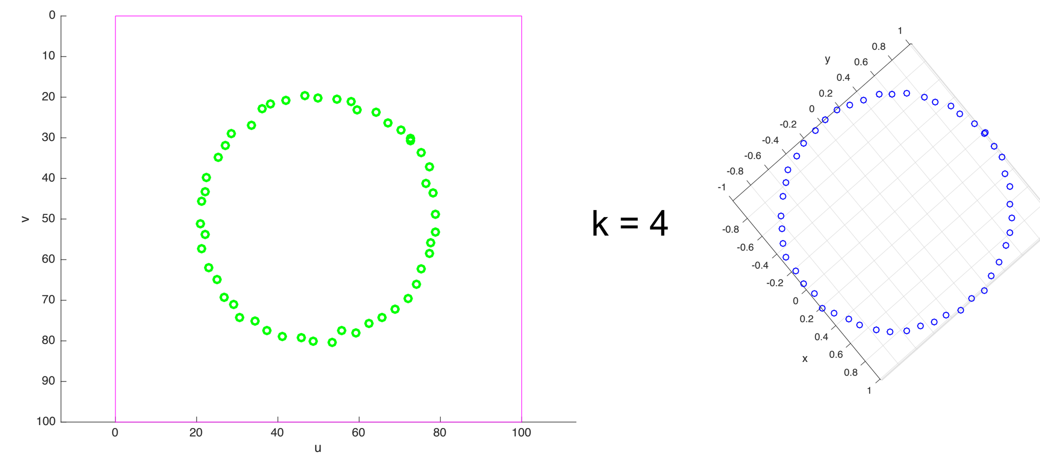


The prior estimate is based on the first observation. The Direct Linear Transformation algorithm and the Levenberg-Marquardt algorithm are employed for the parameter fitting.



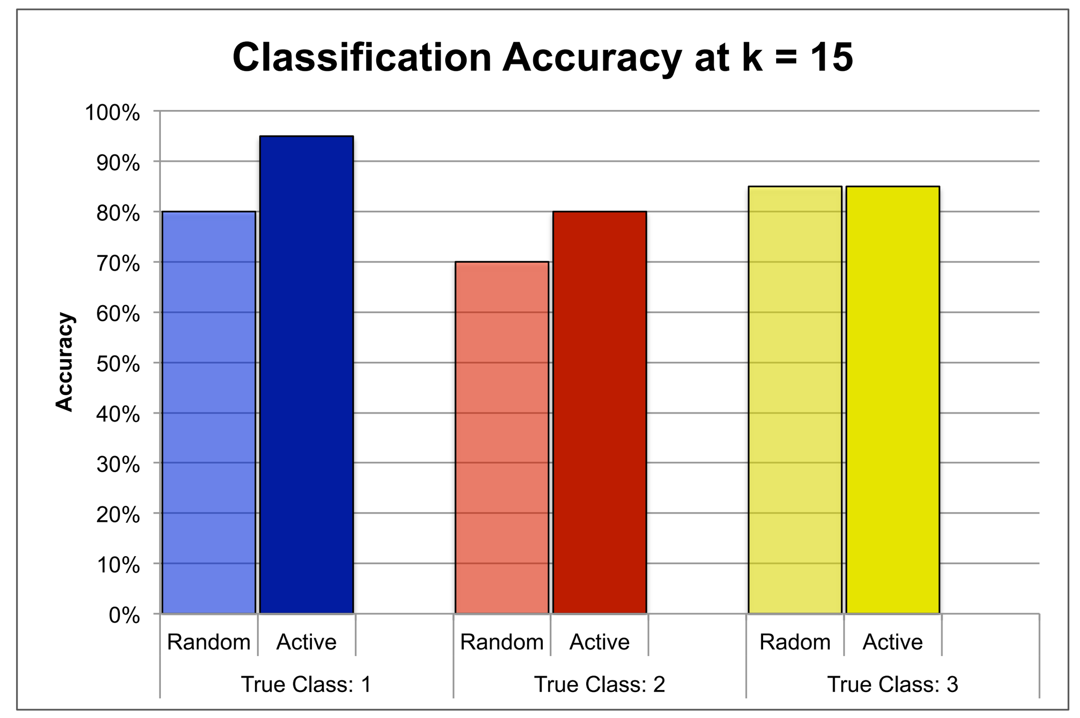


Simulation Results



Posterior (k = 5)
Class 1: 1.0
Class 2: 0.0
Class 3: 0.0

The algorithm converged to the configuration perpendicular to the trajectory plane. The resulting classification was correct (Class 1).



We also estimated the accuracy of this algorithm evaluated at k = 15 based on 20 simulations for each true trajectory class. In each simulation, the initial camera pose was randomly initialized. The performance was compared to the random policy under the same conditions.

Acknowledgements

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Contact details

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