DISCO: Double Likelihood-free Inference Stochastic Control

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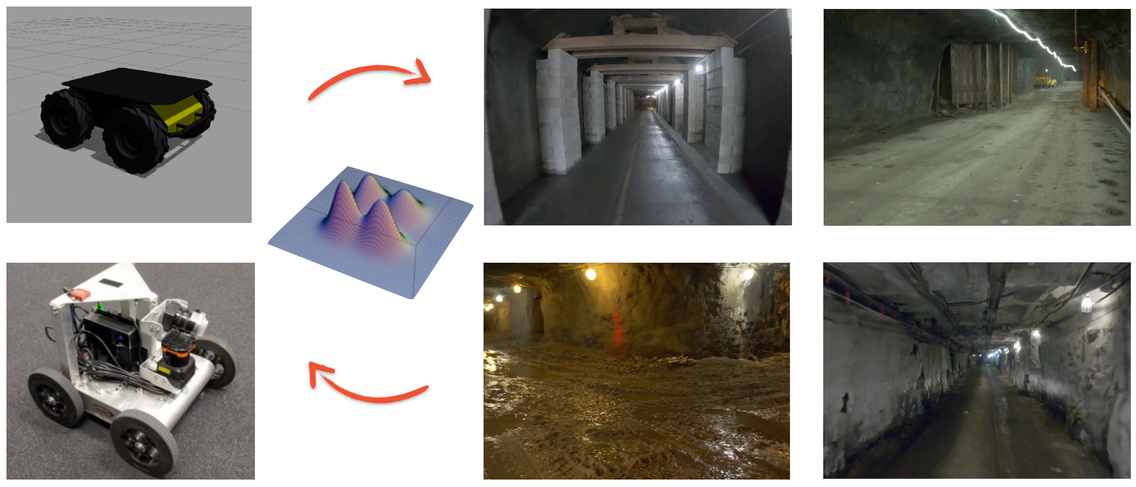
Motivation

Model based control methods are sample efficient and have been successfully deployed in many robotic problems. Because of the robustness introduced by closed-loop control, many model based frameworks use point-estimate models as their internal simulator, disregarding model uncertainty.

However model parameters may vary drastically on the wild, with changes in environment, vehicle load, and so forth. In our work we'll show how we can incorporate model uncertainty to a stochastic MPC framework in order to increase robustness and performance.

Model-Based Control: Expectation vs Reality



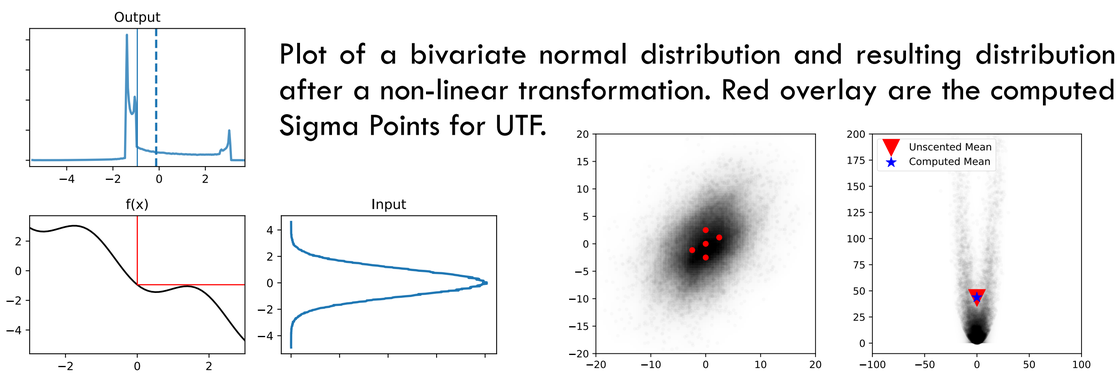
DISCO

A model-based stochastic controller leveraging advancements in Bayesian likelihood-free inference to efficiently estimate and propagate uncertain trajectories

Building blocks:

Likelihood-free Inference for Model Estimation

Unscented Transform

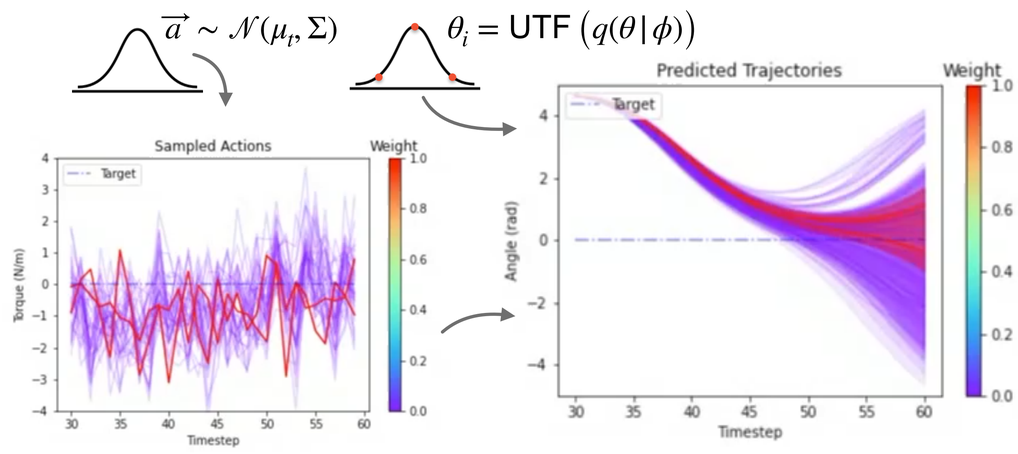


Plot of a bivariate normal distribution and resulting distribution after a non-linear transformation. Red overlay are the computed Sigma Points for UTF.

Simplified Algorithm

$p(\theta|\mathcal{D}) \leftarrow$ UpdateModel$(\mathcal{D})$
For *episode* do:
  $\vec{a}_k \sim \mathcal{N}(\vec{a}_{t-1}, \Sigma), k \in N_{samples}$
  If *using UTF* do:
    $\theta_{sp} \leftarrow$ ComputeSigmaPoints $(p(\theta|\mathcal{D}))$
  Else do *Monte Carlo Sampling*:
    $\theta_k \sim p(\theta|\mathcal{D}), k \in N_{samples}$
  $\tau_k \leftarrow$ GetTrajectories $(\vec{a}_k, \{\theta_k \vee \theta_{sp}\})$
  $\vec{a}_t \leftarrow$ UpdateActions $(\tau_k, cost\_func(\cdot))$
  SendToActuators$(a_t[0])$

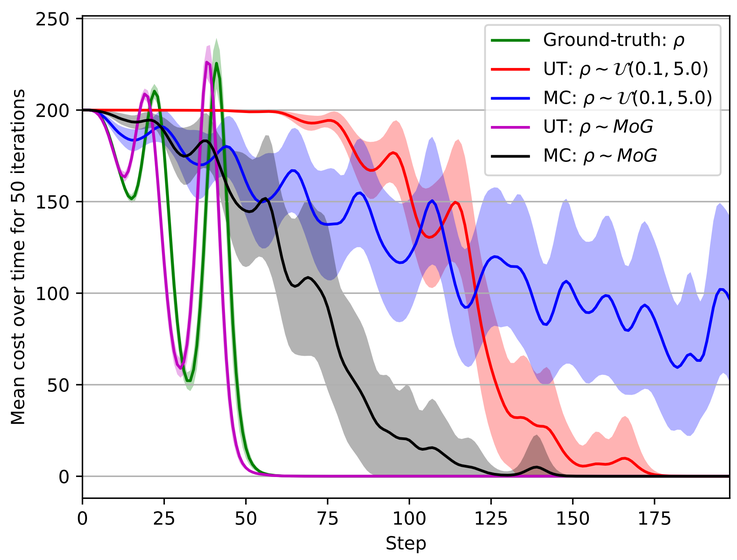
Visualising DISCO



Experimental Results

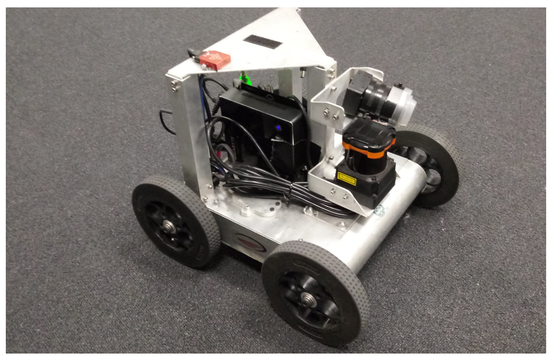
Inverted Pendulum

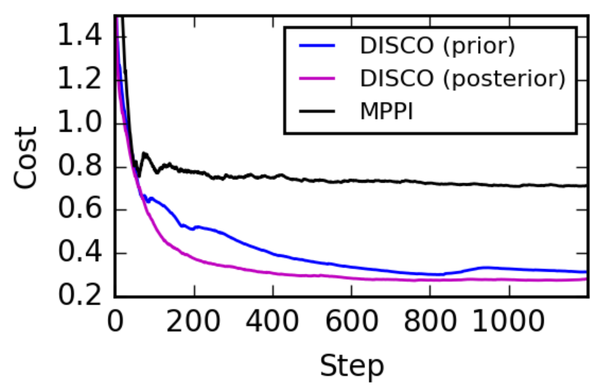
- Task was to balance an inverted pendulum
- Baseline case is MPPI with access to true dynamics
- Simulation compared the MC and UT approaches in two stages:
  - Prior distribution
  - Posterior distribution



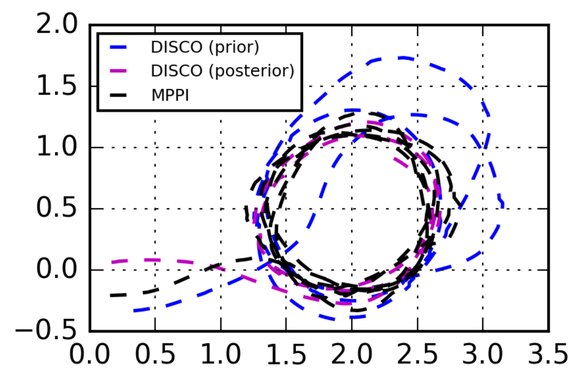
Robotic Experiment

- The robot task was to follow a circular path at constant speed.
- The cross-track error and linear velocity were used as cost function.
- Estimated parameters are wheel radius, axial distance and robot's instant centre of rotation (ICR).





Mean cost over time



Trajectories