

# Trajectories

## Input

- Joystick commands: `cmd_hst_pt`, `cmd_crd_pt`

## Output

- Torques: `u_hst`, `u_crd`
- Positions: `y_hst`, `y_crd`

Currently we have:

- `n_tra` different trajectories of size `n_sim`
- `n_tra = 9`; `n_sim = 1000`
- each of them is a matrix of size `(n_sim, n_tra)`

## Objective Function

Parameters that are optimized:

`hst_inertia_engine`, `inertia_yy`, `hst_friction`, `crd_mass`

$$\begin{aligned} \min_{p \in \mathbb{R}^4} f(p) = & \quad \frac{1}{n_{\text{tra}}} \cdot \left( \alpha_1 \cdot \|\overline{U}_{\text{hst}} - U_{\text{hst}}(p)\|_{\text{F}}^2 + \dots \right) \\ \text{s. t.} \quad & \quad p_i \geq 0 \end{aligned}$$

where

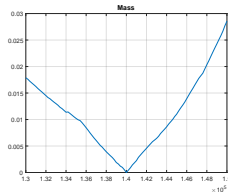
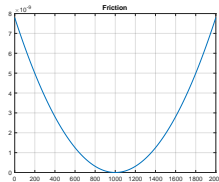
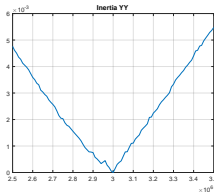
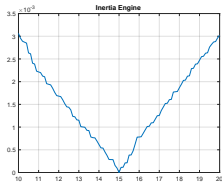
$$\alpha_1 = \frac{1}{\|\overline{U}_{\text{hst}}\|_{\text{F}}^2} \qquad \|\overline{U}_{i,j}\|_{\text{F}}^2 = \sum_{j=1}^{n_{\text{tra}}} \sum_{i=1}^{n_{\text{sim}}} |\overline{U}_{i,j}|^2$$

$\|\cdot\|_{\text{F}}$  is the Frobenius norm

# Influence of the Parameters

10% deviation of parameter ... cause in the objective function:

■ hst_inertia_engine	$1 \cdot 10^{-3}$	linear
■ inertia_yy	$3.3 \cdot 10^{-3}$	linear
■ hst_friction	$7.8 \cdot 10^{-11}$	quadratic
■ crd_mass	$52 \cdot 10^{-3}$	linear



# Solvers

## Conditions:

- Starting values:  $X \sim N(\bar{x}, \bar{x}/2)$ , where  $\bar{x}$  is the given value
- Smarm Size: 10
- Function Tolerance:  $10^{-9}$
- Time Limit: 15 min
- Max Iterations:  $\infty$

	penalty	evaluations	time
Particle Swarm	$10^{-13}$	2500	3 min
Pattern Search	$10^{-3}$	6000	8 min
Genetic Algorithm	$10^{-2}$	7500	15 min (time limit)
Simulated Annealing	$10^{-1}$	3000	4 min

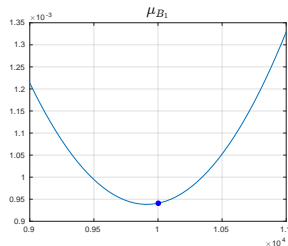
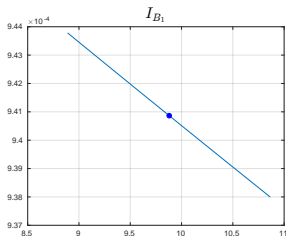
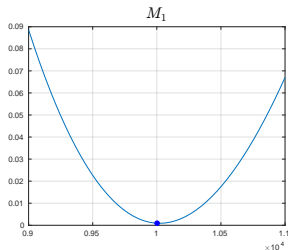
# Optimization Problem

$$\begin{aligned} \min_{p \in \mathbb{R}^{10}} f(p) &= \frac{1}{2} \|x_{\text{ref}} - x(p)\|^2 \\ \text{s. t.} \quad &p_i \geq 0 \end{aligned}$$

- state  $x = (s, \theta, \dot{s}, \dot{\theta})^T$
- $x_{\text{ref}}$  reference trajectory
- $x(p)$  approximation using Runge-Kutta methods of Order 1/2/3/4

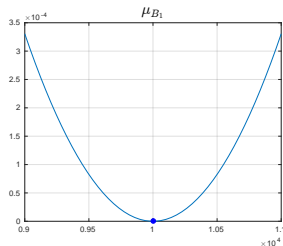
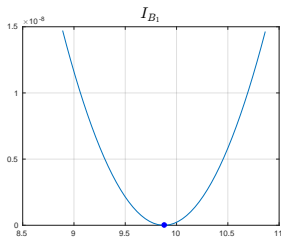
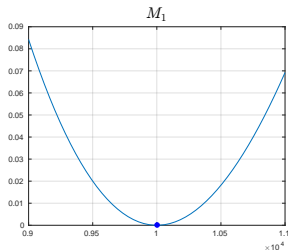
# Influence of the Parameters

Using  $x_{\text{ref}} = x_{\text{real}}$ , the real trajectory:



# Influence of the Parameters

Using  $x_{\text{ref}} = x(p_{\text{real}})$ , the approximation from the real parameters:



# Solvers

## Conditions:

- Supporting Points: 100
- Runge-Kutta Order: 1
- Reference Trajectory:  $x_{\text{real}}$
- $\frac{1}{2} \|x_{\text{real}} - x(p_{\text{real}})\|^2 = 9.4 \cdot 10^{-4}$
- Optimality Tolerance:  $10^{-10}$

	iterations	feval	$\frac{1}{2} \ x_{\text{real}} - x(p)\ $	$\frac{1}{2} \ x(p_{\text{real}}) - x(p)\ $
SQP	219	241	$1.8 \cdot 10^{-4}$	$7.6 \cdot 10^{-4}$
Interior Point	218	228	$1.8 \cdot 10^{-4}$	$7.6 \cdot 10^{-4}$
Trust Region	25 (112 cg)	26	$1.8 \cdot 10^{-4}$	$7.6 \cdot 10^{-4}$
Active Set	244	501	$2.0 \cdot 10^{-4}$	$8.3 \cdot 10^{-4}$



# Solvers

## Conditions:

- Supporting Points: 100
- Runge-Kutta Order: 4
- Reference Trajectory:  $x_{\text{real}}$
- $\frac{1}{2} \|x_{\text{real}} - x(p_{\text{real}})\|^2 = 9.4 \cdot 10^{-5}$
- Optimality Tolerance:  $10^{-10}$

	iterations	feval	$\frac{1}{2} \ x_{\text{real}} - x(p)\ $	$\frac{1}{2} \ x(p_{\text{real}}) - x(p)\ $
SQP	225	248	$8.9 \cdot 10^{-5}$	$5.4 \cdot 10^{-6}$
Interior Point	262 (37 cg)	280	$8.9 \cdot 10^{-5}$	$5.4 \cdot 10^{-6}$
Trust Region	27 (123 cg)	28	$8.9 \cdot 10^{-5}$	$5.4 \cdot 10^{-6}$
Active Set	231	469	$1.2 \cdot 10^{-4}$	$5.0 \cdot 10^{-5}$

## Visualization with Simulink

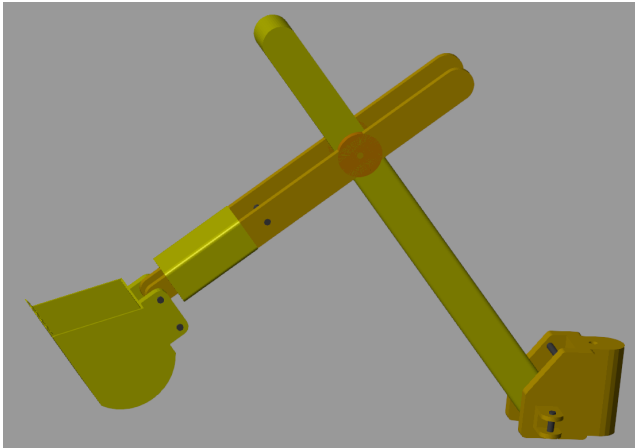


Figure: Current state