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`

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

where

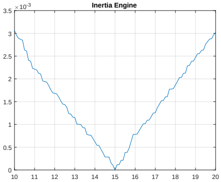
$$
\alpha_1 = \frac{1}{\|\overline{U}_{\mathrm{hst}}\|_{\mathrm{F}}^2} \qquad \|\overline{U}_{i,j}\|_{\mathrm{F}}^2 = \sum_{j=1}^{n_{\mathrm{tra}}} \sum_{i=1}^{n_{\mathrm{sim}}} |\overline{U}_{i,j}|^2
$$

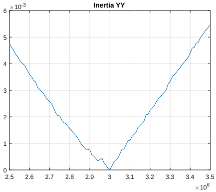
$\|\cdot\|_{\mathrm{F}}$ is the Frobenius norm

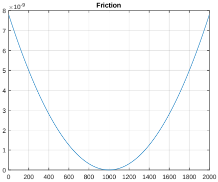
Influence of the Parameters

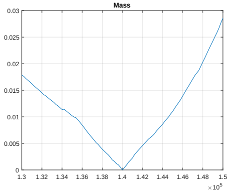
10% deviation of parameter . . . cause in the objective function:

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

	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

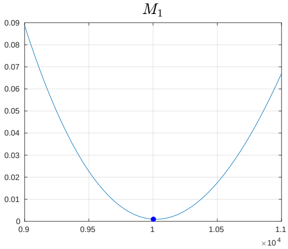
Optimization Problem

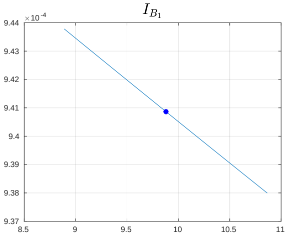
$$
\begin{aligned}
\min_{p \in \mathbb{R}^{10}} f(p) = & \quad \frac{1}{2} \| x_{\mathsf{ref}} - x(p) \|^2 \\
\text{s. t.} & \quad p_i \geq 0
\end{aligned}
$$

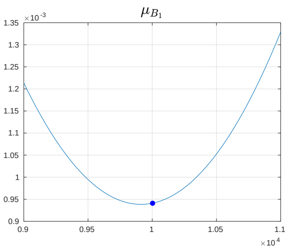
- state $x = (s, \theta, \dot{s}, \dot{\theta})^T$
- x_{ref} reference trajectory
- $x(p)$ approximation using Runge-Kutta methods of Order 1/2/3/4

Influence of the Parameters

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

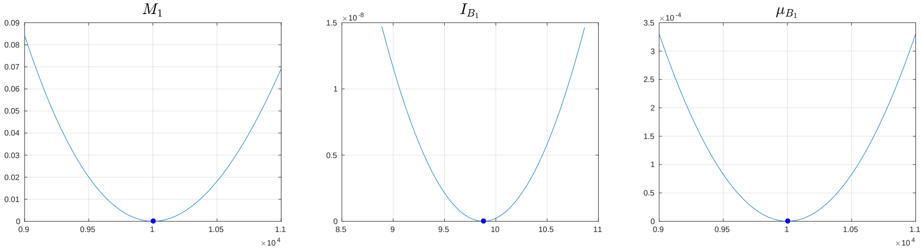






Influence of the Parameters

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_{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_{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

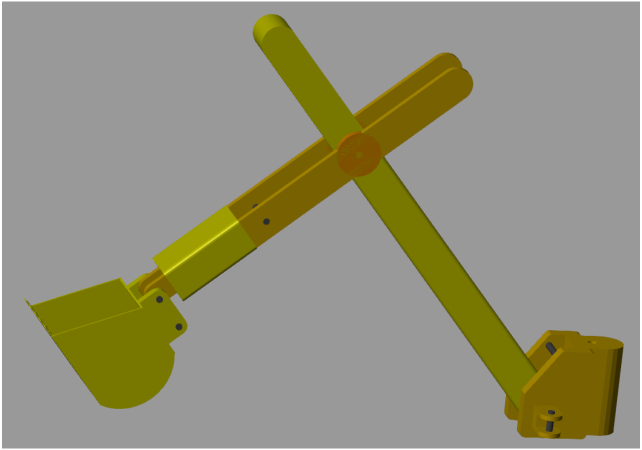


Figure: Current state