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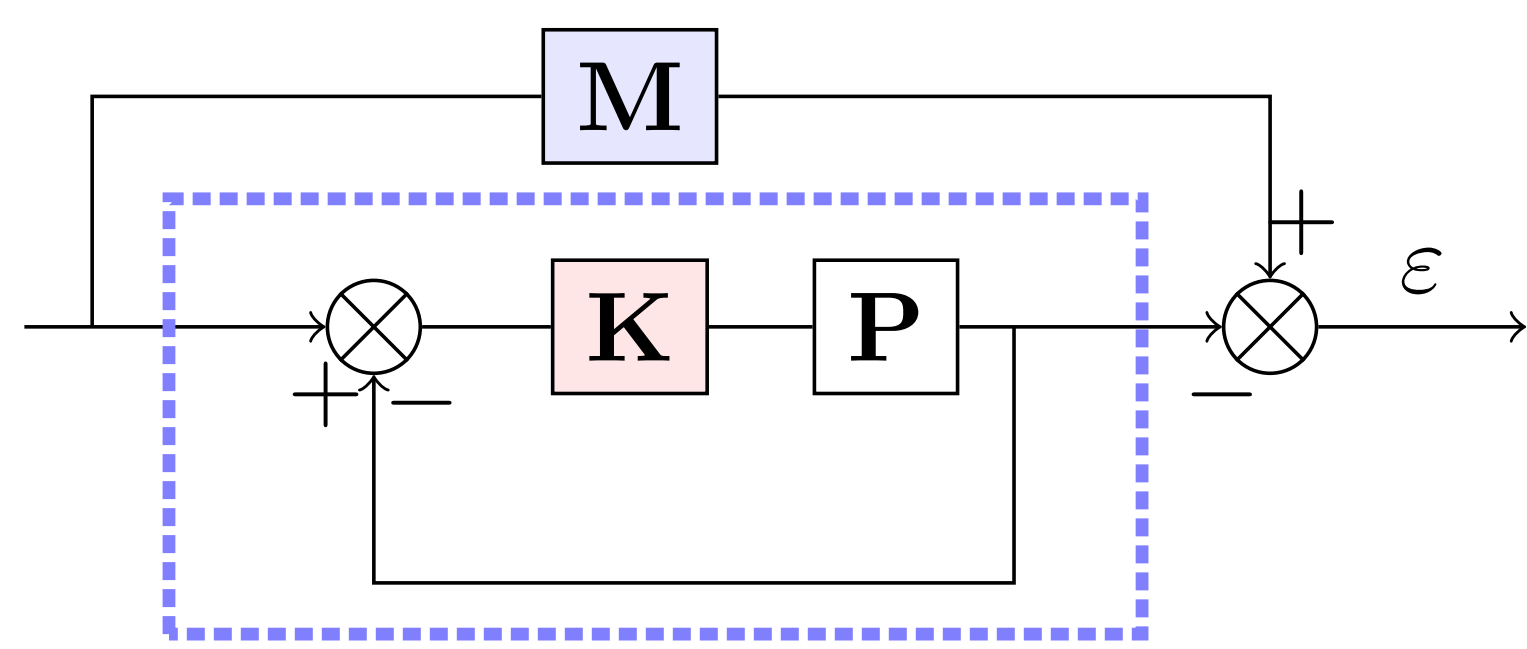
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Data-driven control in the frequency-domain: From reference model selection to controller validation

Pauline Kergus, Martine Olivi, Charles Poussot-Vassal, Fabrice Demourant

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Loewner Data-Driven Control: general formulation



Input data

- Frequency-domain data from the plant P : $\{\omega_i, \Phi_i\}$, $i = 1 \dots N$.
- Reference model M .

Proposed methodology

1. Computation of the ideal controller K^* frequency-response: $K^*(j\omega_i) = \Phi_i^{-1}M(j\omega_i)(I - M(j\omega_i))^{-1}$.
2. Interpolation and reduction of the ideal controller K^* through the Loewner framework.

$$\left. \begin{aligned} P(s) &= \frac{0.03616(s-140.5)(s-40)^3}{(s^2+1.071s+157.9)(s^2+3.172s+1936)} \\ M(s) &= \frac{1}{0.04s^2+0.4s+1} \end{aligned} \right\}$$

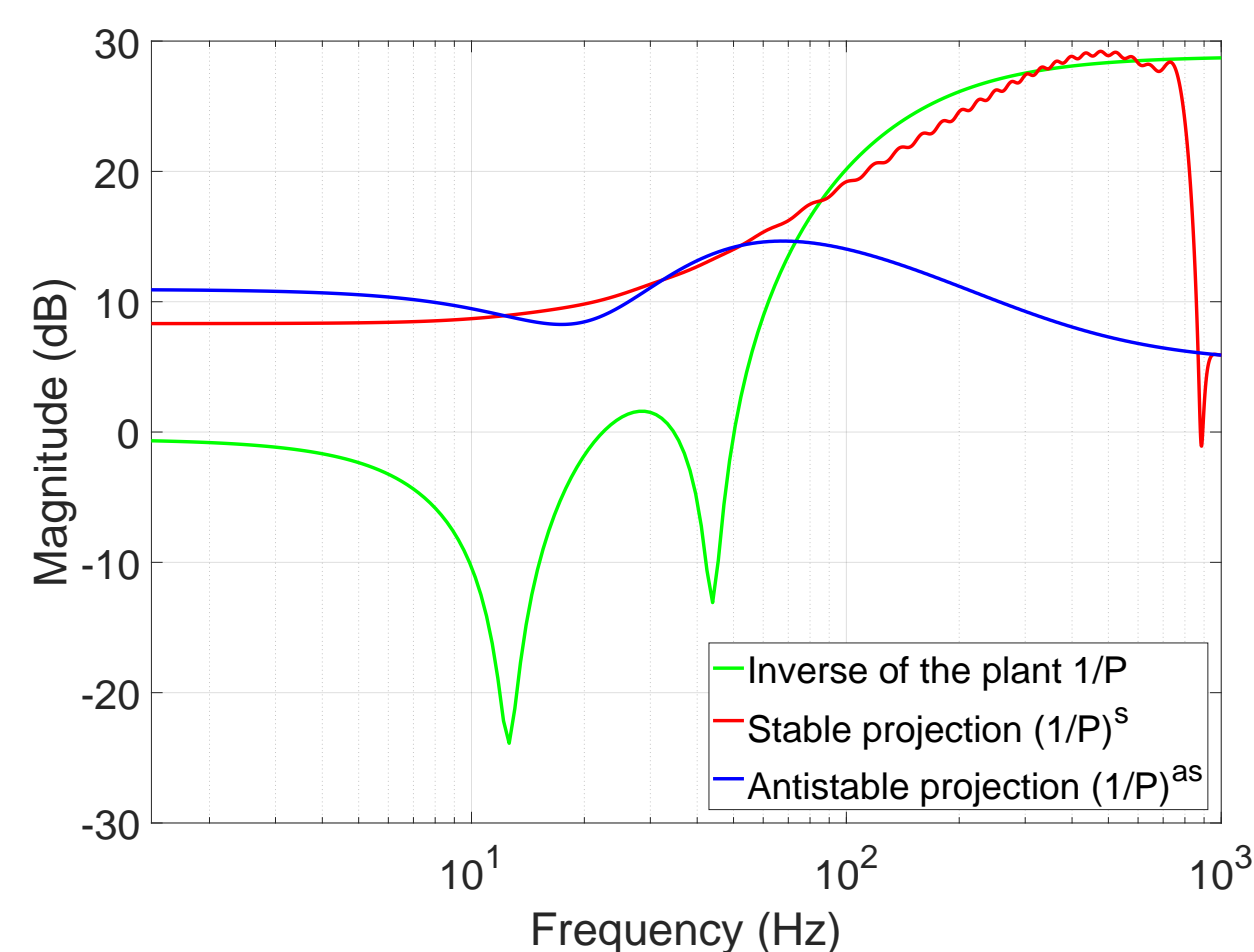
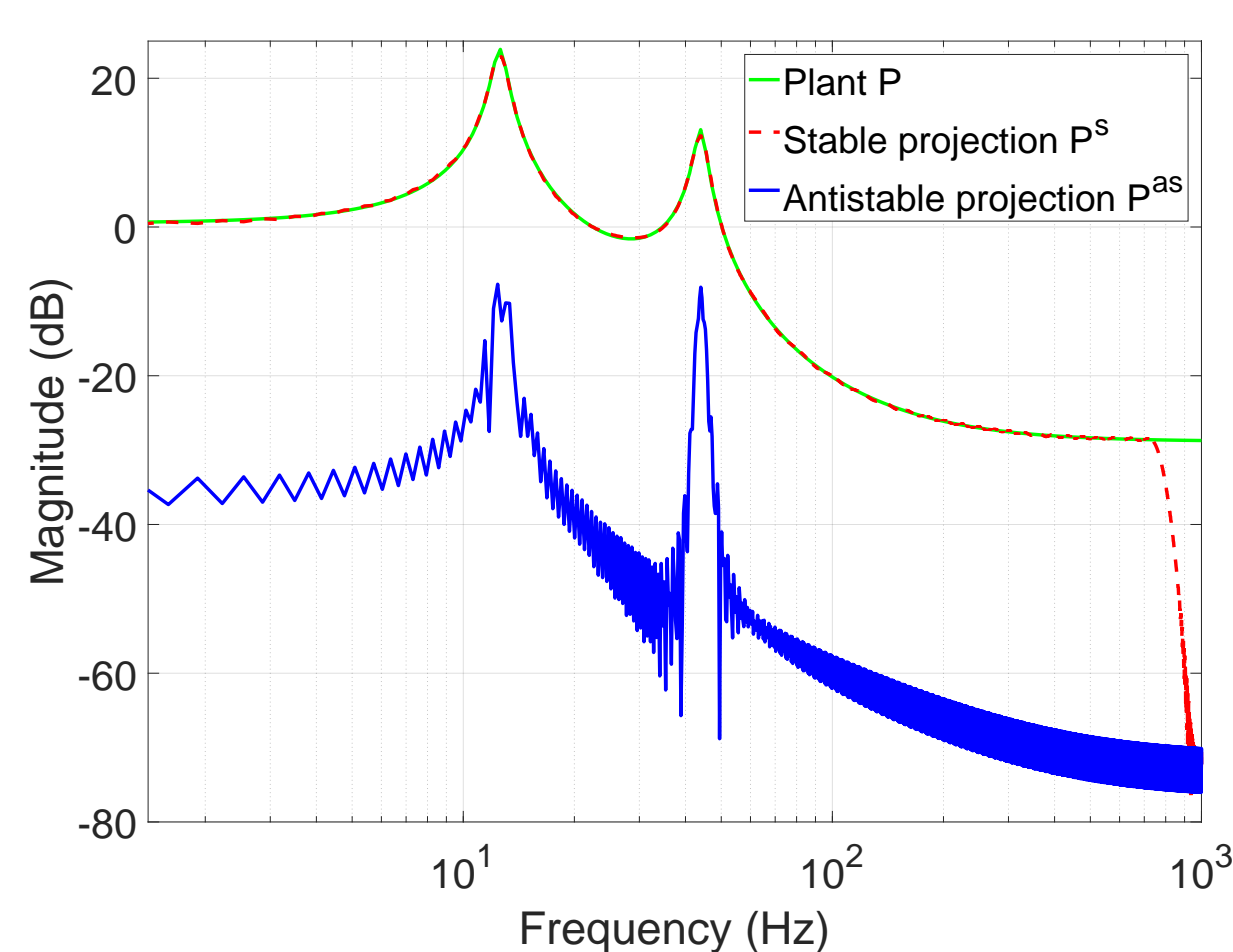
$$K^*(s) = k \frac{(s^2+1.071s+157.9)(s^2+3.172s+1936)}{s(s+10)(s-140.5)(s-40)^3}$$

- The reference model should be achievable by the plant.
- A data-driven closed-loop stability analysis is needed.

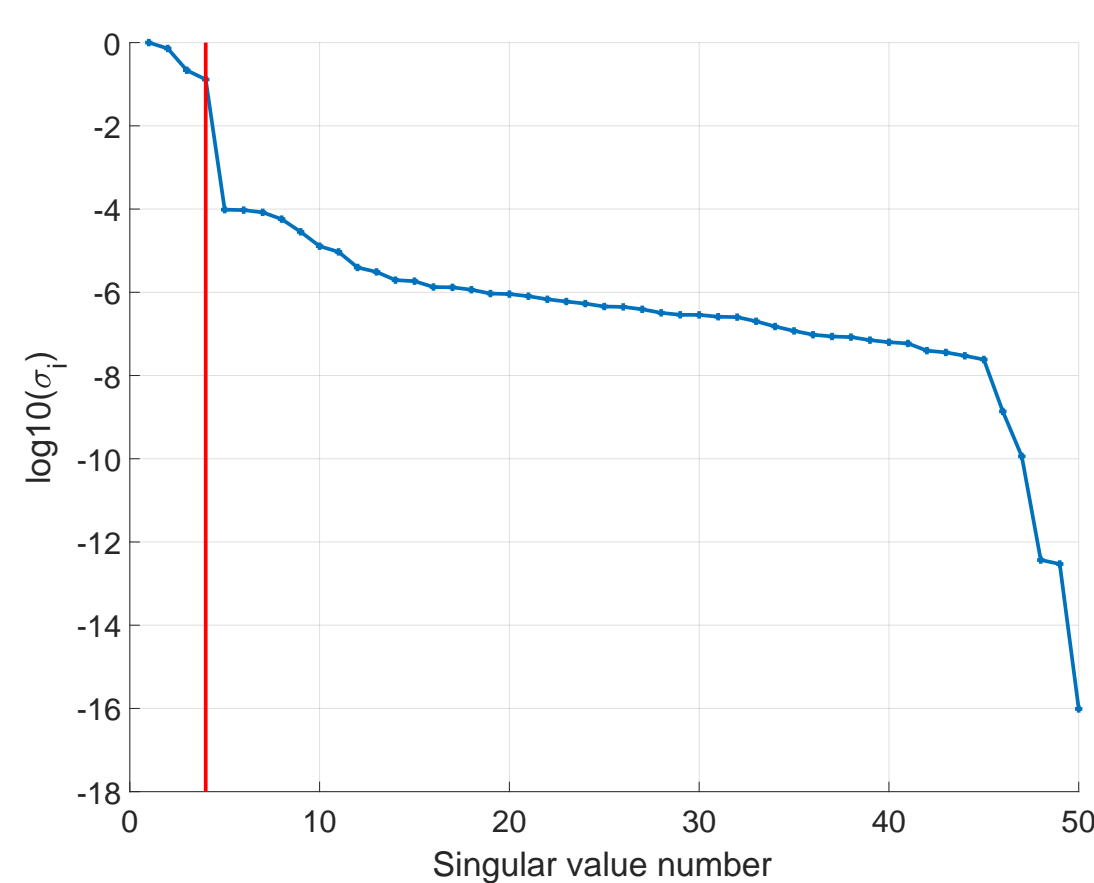
Selection of an achievable reference model

$$\begin{cases} y_{z_i}^T P(z_i) = 0 \\ y_{p_j}^T P(p_j) = \infty \end{cases} \Rightarrow \begin{cases} y_{z_i}^T M(z_i) = 0 \\ M(p_j)y_{p_j} = y_{p_j} \end{cases}$$

- 1) Projection of the available data to determine the nature of P : the system is stable but Non-Minimum Phase (NMP).



- 2) Principal Hankel Components technique to determine the number of NMP zeros and obtain an estimate of the instabilities.



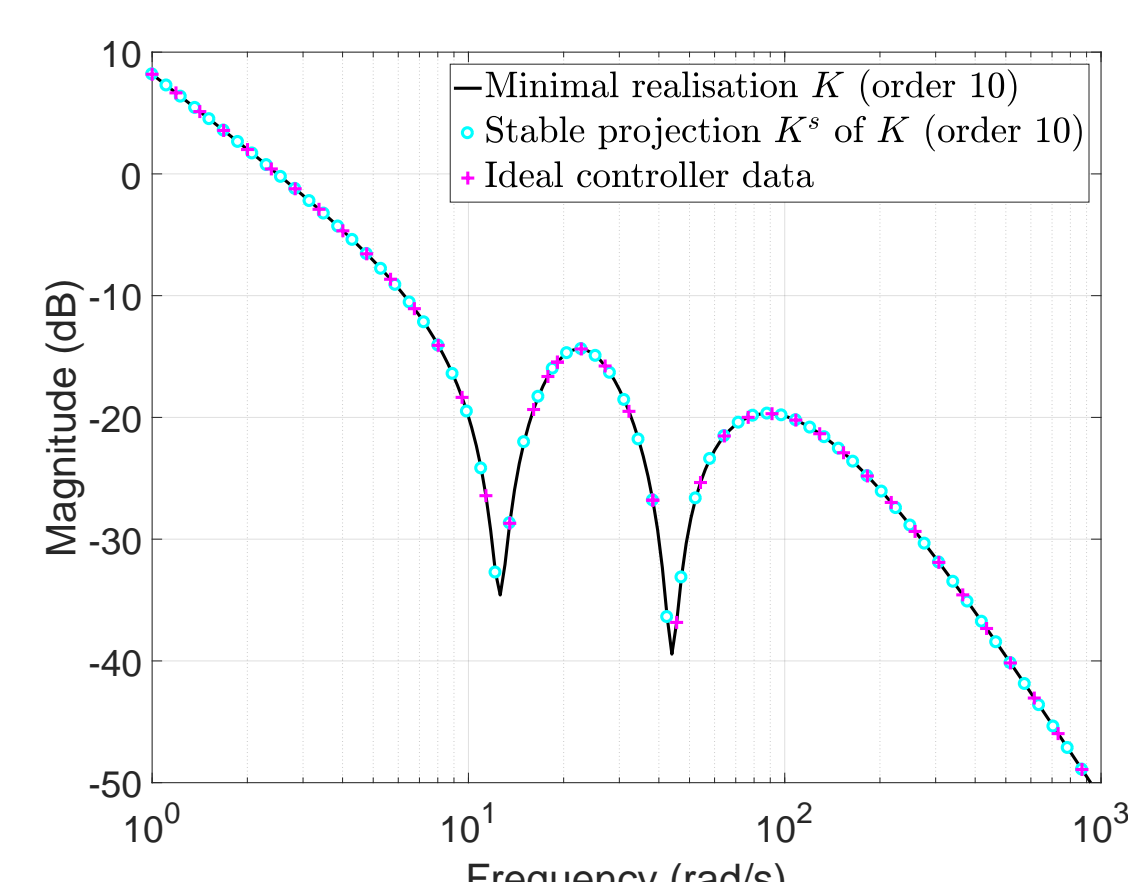
True z_i	Estimated \tilde{z}_i
140.5	140.58
40	41.3+2 <i>l</i>
40	41.3+2 <i>l</i>
40	37.4

- 3) Construction of an achievable reference model M_f .

$$M_f = MB_z$$

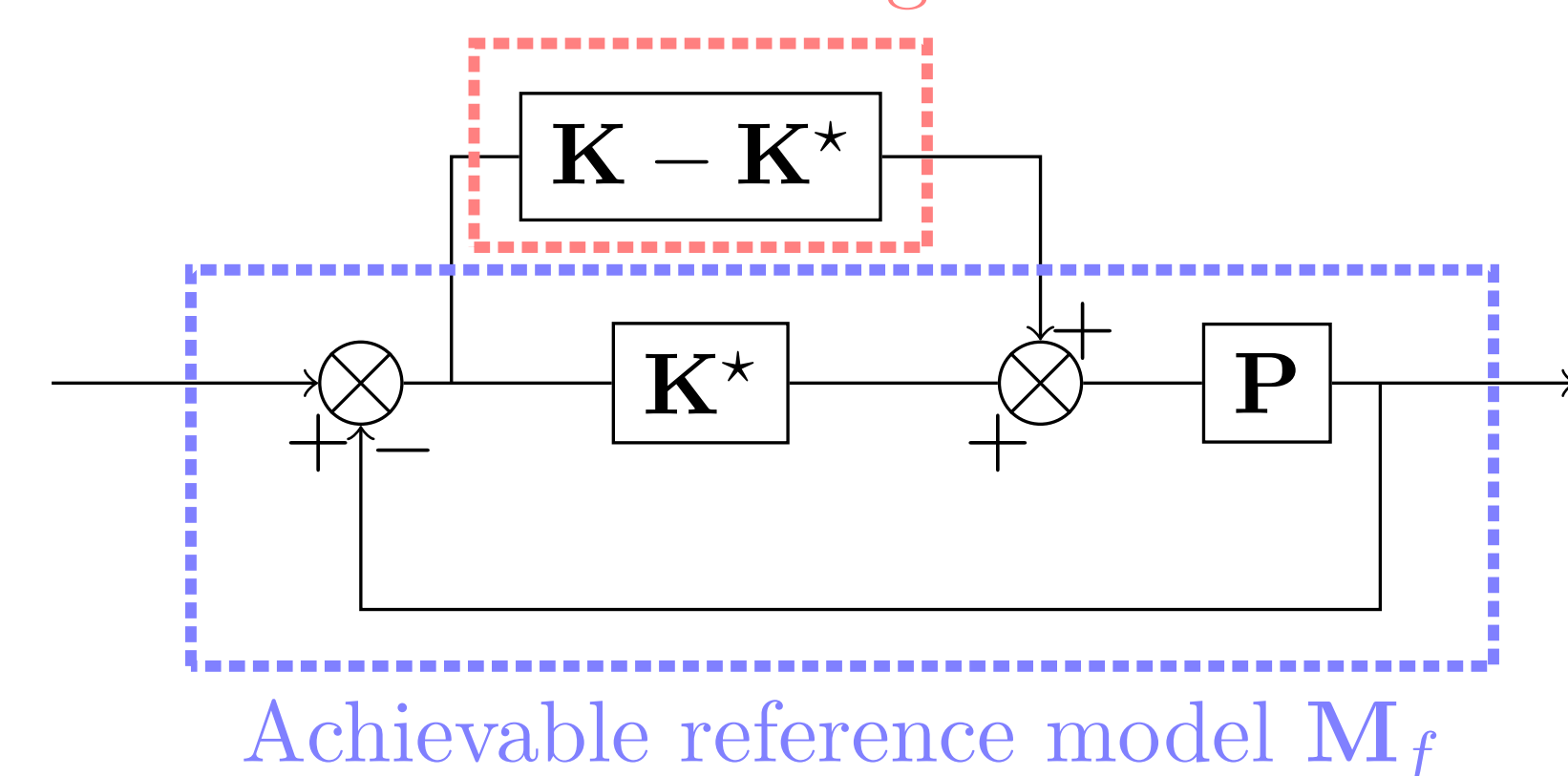
$$B_z(s) = \prod_{i=1}^{n_z} \frac{s - \tilde{z}_i}{s + \tilde{z}_i}$$

→ No more compensation of instabilities in the open-loop!



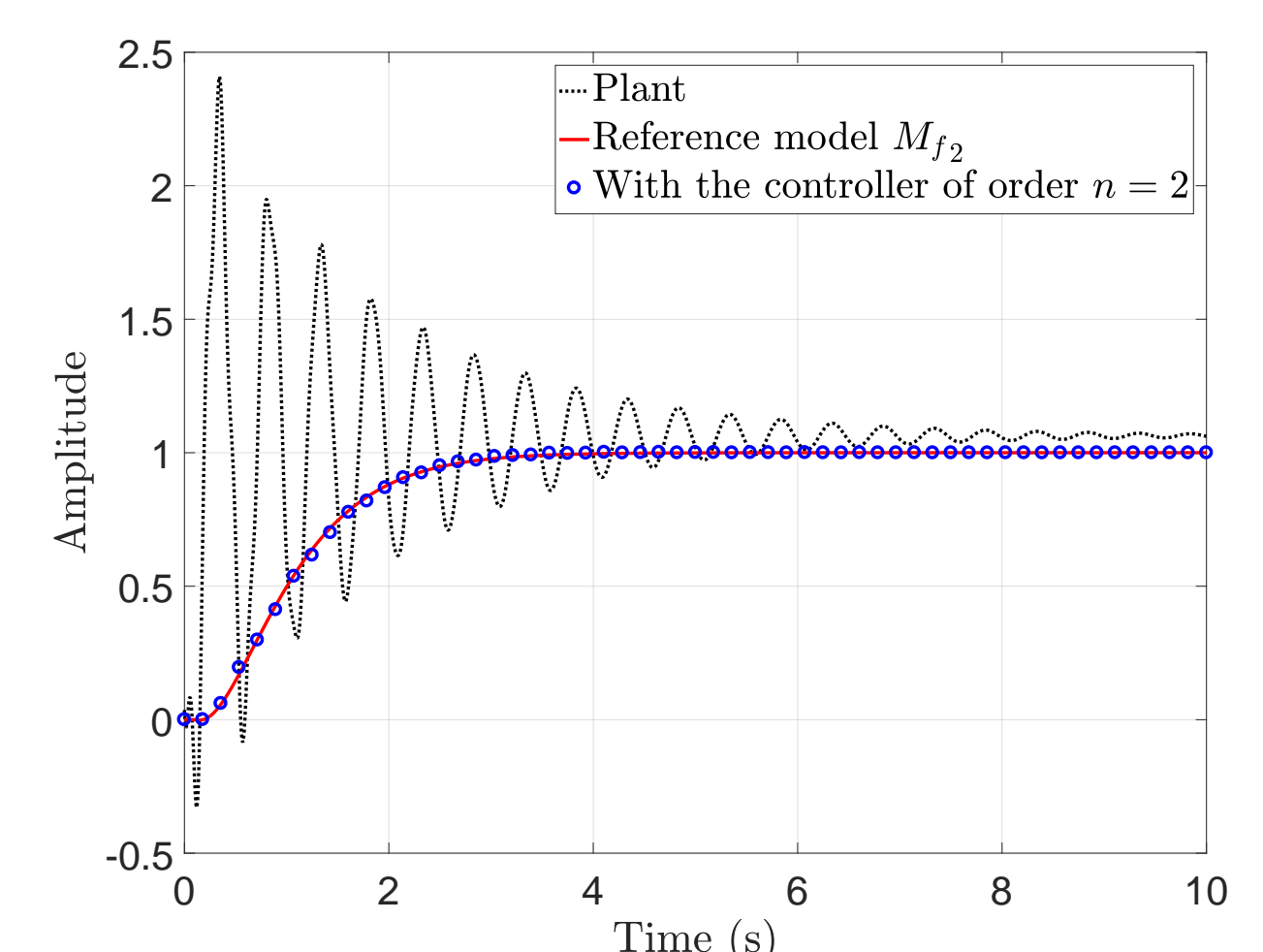
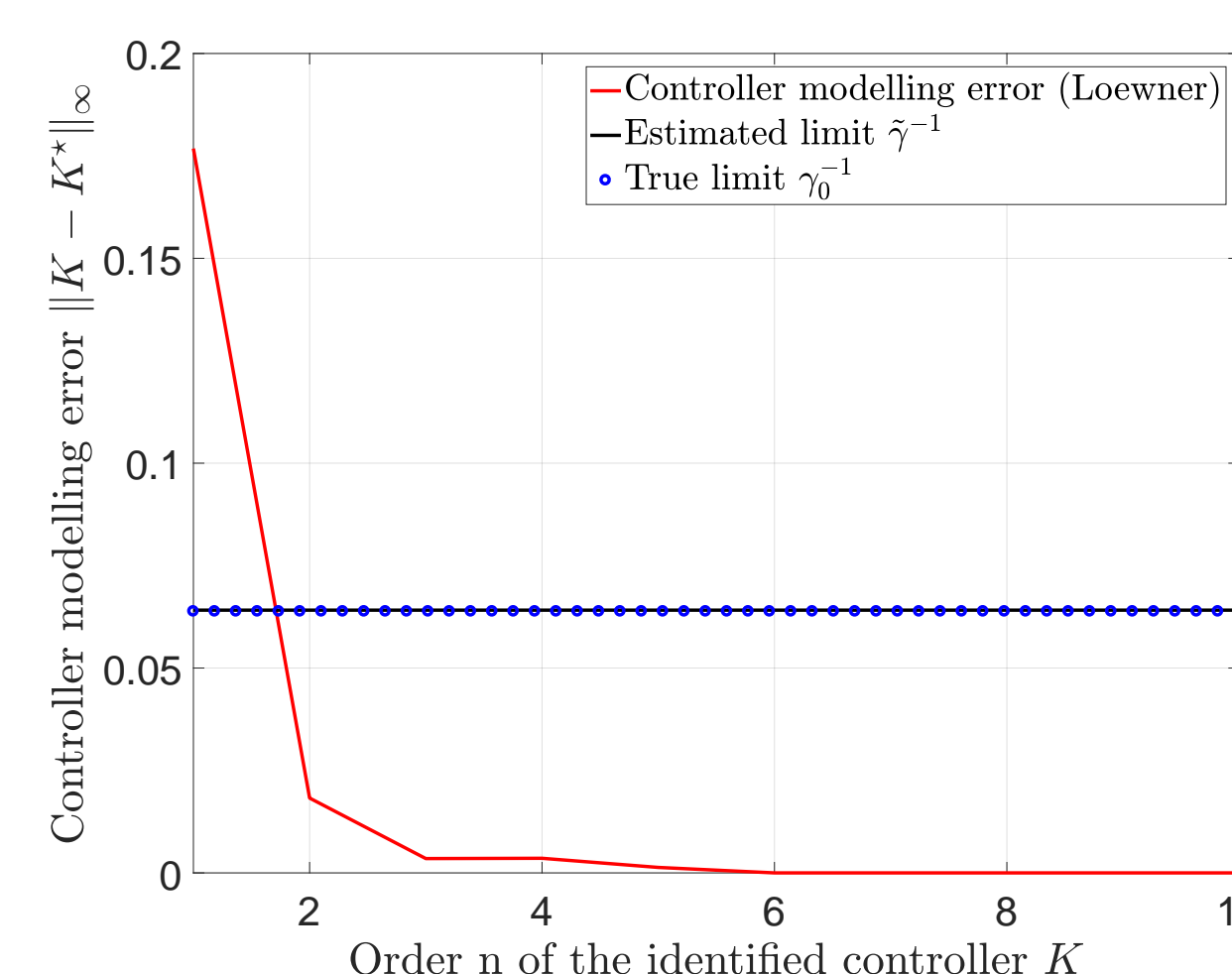
Data-driven closed-loop stability analysis

Controller modelling error Δ



The interconnection is stable for all stable Δ such that $\|\Delta\|_\infty < \gamma$ iff $\|(1 - M_f)P\|_\infty \leq \gamma^{-1}$.

→ Maximal controller modelling error $\tilde{\gamma}^{-1} = \max_{i=1 \dots N} |(1 - M_f(j\omega_i))\Phi_i|$



Conclusions and outlooks

- Data-driven technique taking into account the inherent performance limitations of the plant.
- The reduction of the controller is performed under a stability constraint.
- Need for a better data-driven estimation of the \mathcal{H}_∞ -norm.
- Too conservative stability test: possibility to use other stability indicators.

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