Fault-Tolerant Control: A Gaussian Process Model Based Approach

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Background and motivation

- **Fault-tolerant control**
  - *Controller reconfiguration to accommodate faults automatically*
  - *Economic and safety considerations*
  - *Applications include automotive, aeronautics, wind turbines, etc.*
- **Towards more flexibility...**

An Israel Air Force F-15 landed with almost half of its wing lost, 1983.

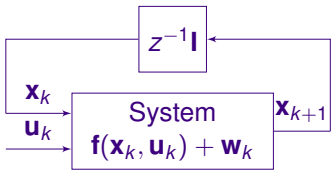
A DHL Airbus A320 landed under engine-only control after missile attack, Baghdad 2003.

Research methodology

➢ Gaussian process model based predictive control

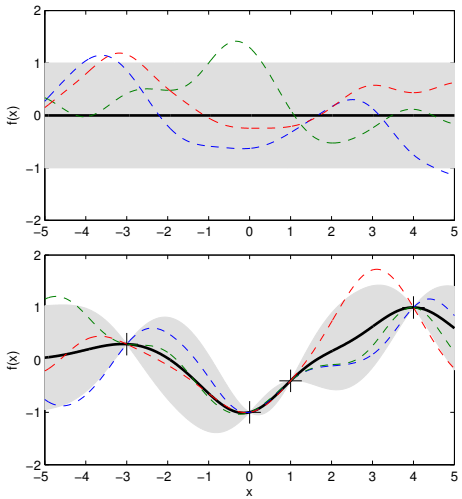
- *Model predictive control (MPC): flexibility in reconfiguring its components*
- *Gaussian process (GP) : flexibility in describing a dynamic system by a distribution over functions*
- *GP: learning capability from prior information and online data*

System

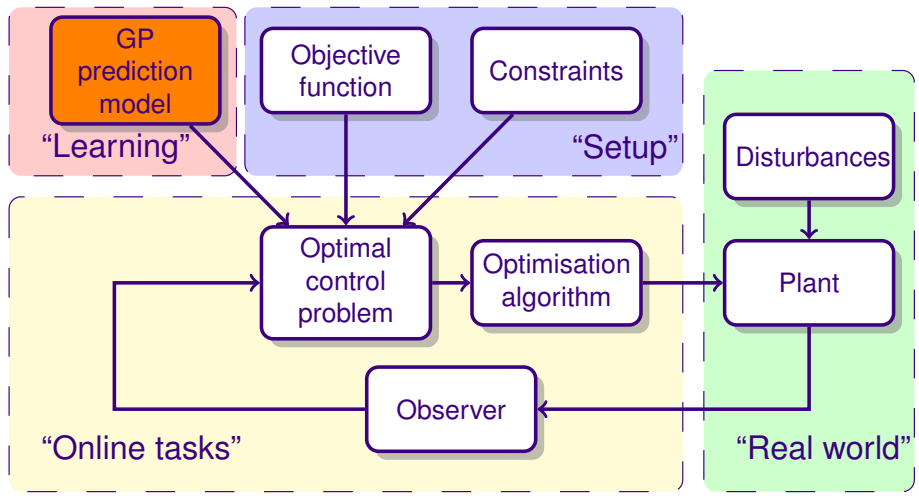


$$\mathbf{x}_{k+1} = \mathbf{f}(\mathbf{x}_k, \mathbf{u}_k) + \mathbf{w}_k$$
$$\mathbf{f} \sim \mathcal{GP}$$

GP prior and posterior



Model predictive controller

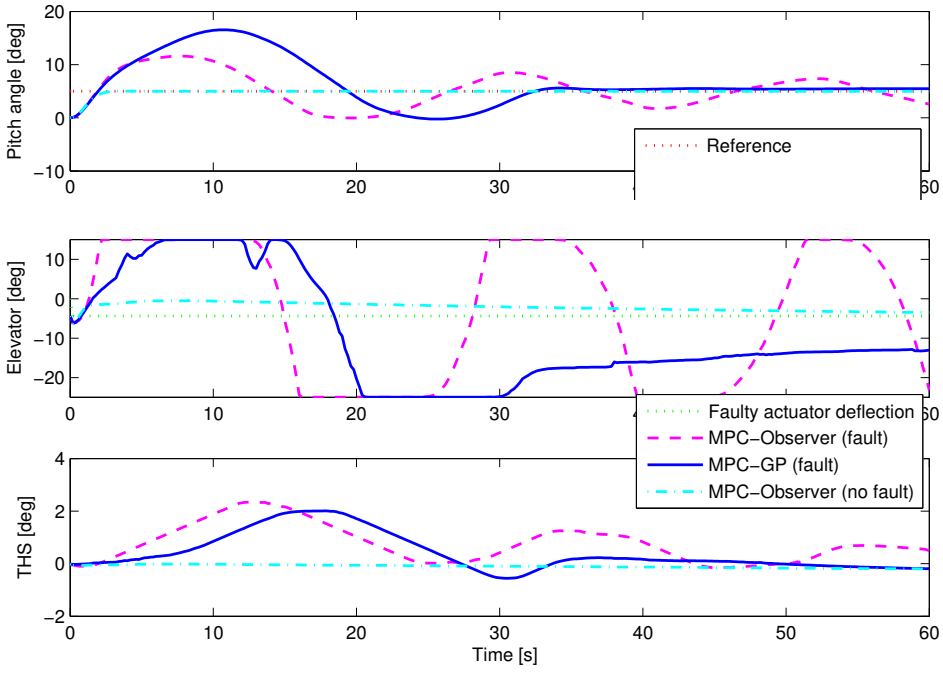


Case study: aircraft longitudinal attitude control

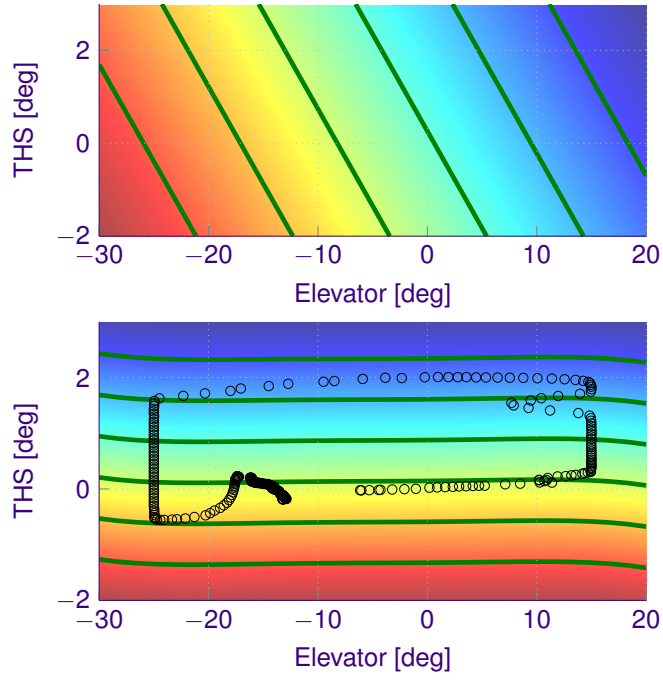
➢ System description and scenario

- *Four states, two inputs: elevator and horizontal stabiliser (THS)*
- *Pitch attitude control under stuck elevator fault*

Pitch angle response and control commands



Input-to-state mapping at 0 s and 60 s



Conclusions and future work

- **The combination of model predictive control and Gaussian process models is promising for fault-tolerant control**
  - *flexibility in the MPC framework itself*
  - *flexibility of the Gaussian process model and its learning capability*
- **Gaps still exist before industrial applications**
  - *Computational bottlenecks of the GP model and the nonlinear optimisation in the MPC*
  - *How much data is needed for a good-enough-for-control model*
  - *Validation and verification of the resulting controller*