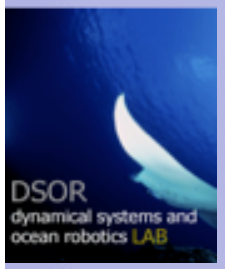

Fault Detection and Isolation of an Aircraft using Set-Valued Observers

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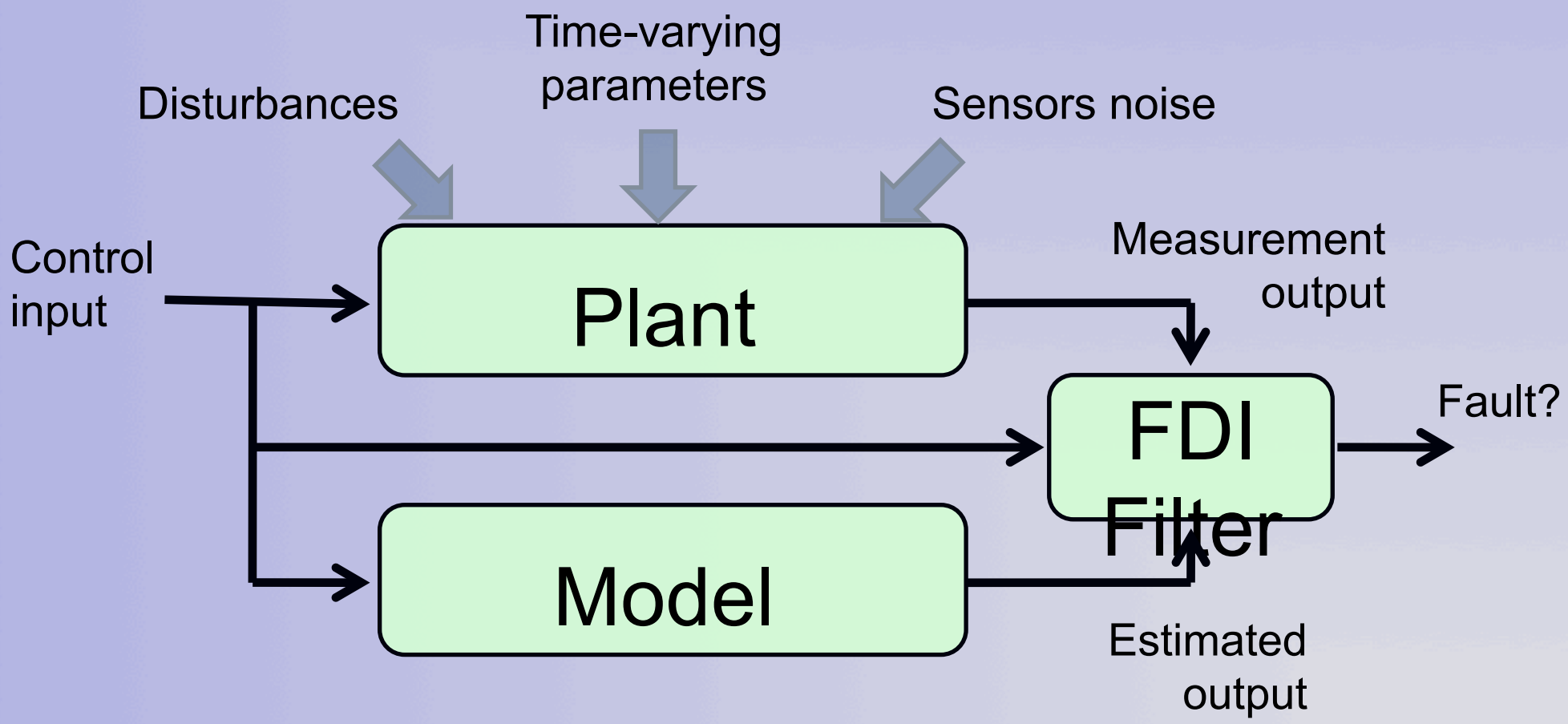
Dynamic Stochastic Filtering, Prediction, and Smoothing – July 7th – 2010

Introduction

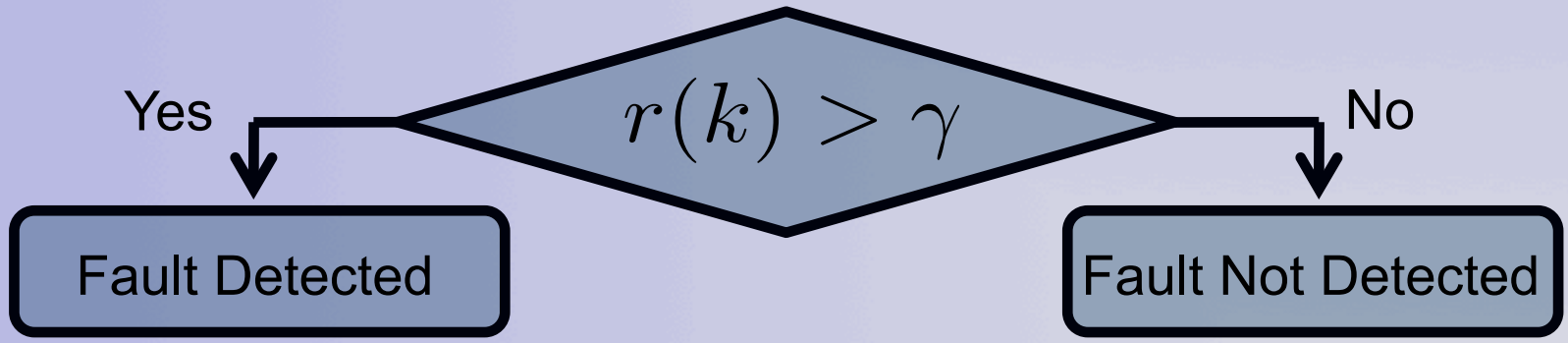


Introduction (cont.'d)

- Standard approaches for Fault Detection (FD):
  - Compute estimated output
  - Generate a residual using the actual output

$$r(k) = y_{\text{true}}(k) - y_{\text{estimated}}(k)$$

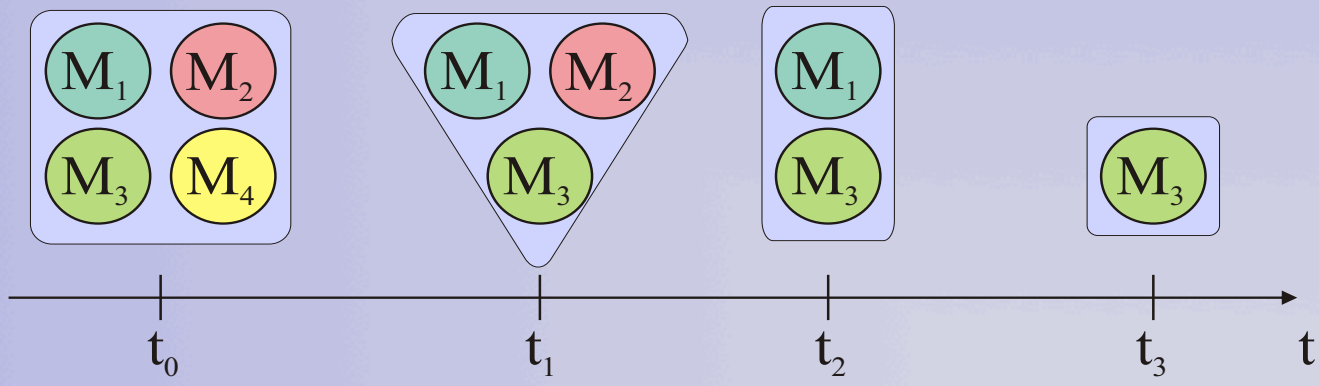
  - Compare it with a given threshold



- Main drawback: the exact value of the threshold is highly dependent on the exogenous disturbances, measurement noise, and model uncertainty!

Model Falsification

- Main idea:
  - Set of plausible models for the plant
  - Discard models that are not compatible with the input/ output sequences



- Model falsification for FD
  - A fault is detected when the model of the non-faulty plant is invalidated

But… How can we invalidate models?

Robust Set-Valued Observers

- Problem formulation:
  - Dynamic system with no disturbances

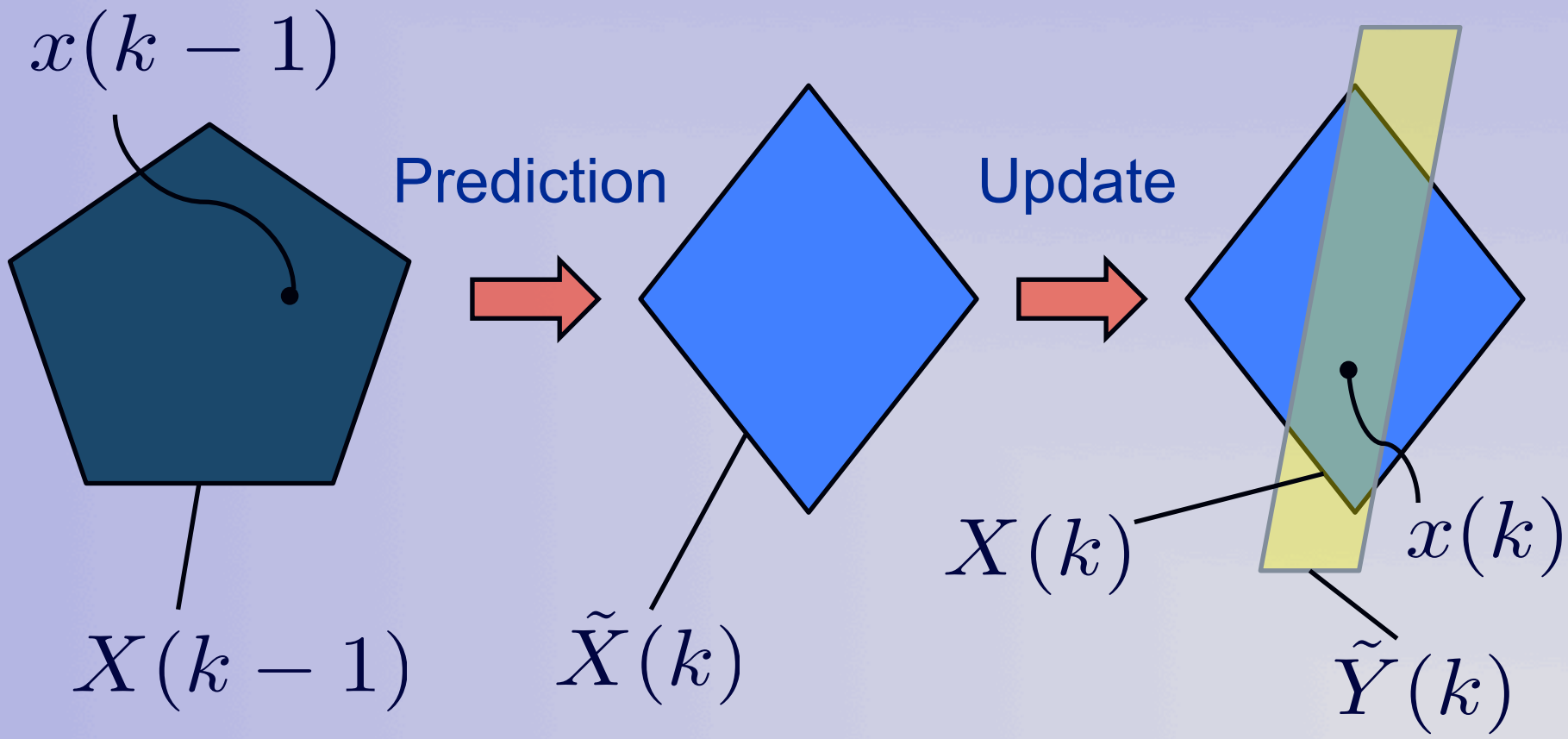
$$x(k+1) = f(x(k), u(k))$$

  - Dynamic system with disturbances, unknown initial state and uncertain model

$$x(k+1) \in F\left(x(k), u(k), d(k), \Delta(k)\right)$$

solution is a set, rather than a point!

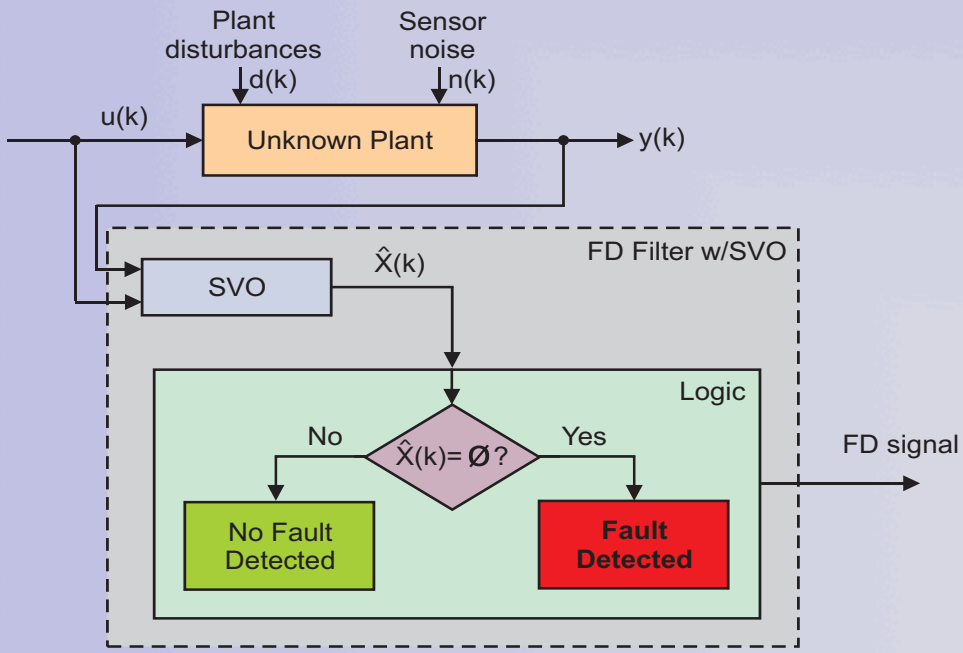
Robust Set-Valued Observers (cont.'d)



Using Set-Valued Observers in Model Falsification

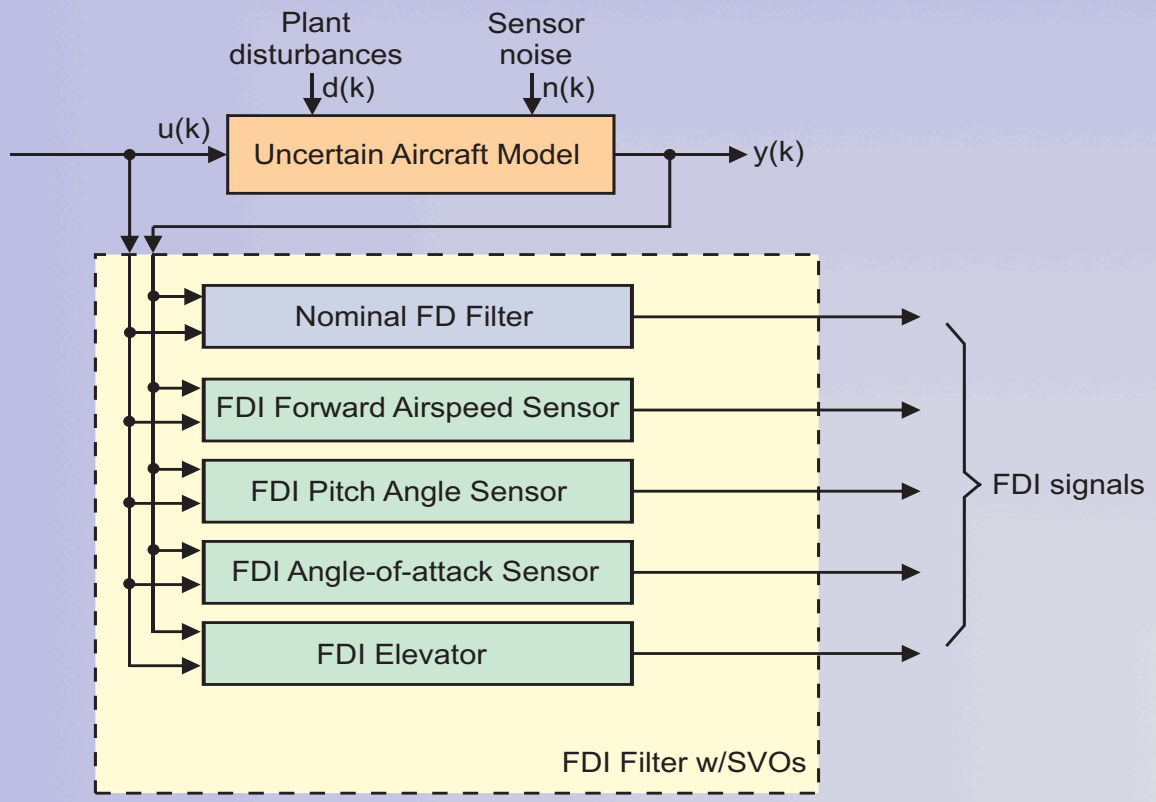
- Main idea:
  - Design a Set-Valued Observer (SVO) for each plausible model the plant
  - If the set-valued estimate of SVO #n is empty

Model #n is invalidated!



Fault Detection and Isolation using SVOs

- Architecture:
  - Example for an aircraft FDI filter



Fault Detection and Isolation using SVOs (cont.'d)

- Main properties
  - No false alarms
  - No need to compute a decision threshold
  - Model uncertainty and bounds on the disturbances and measurement noise are explicitly taken into account
  - Applicable to LTI and LPV systems

- Shortcomings
  - Computationally heavier than the classical FDI methods

Simulations

- Longitudinal dynamics of an aircraft
  - Described by a linear parameter-varying (LPV) model

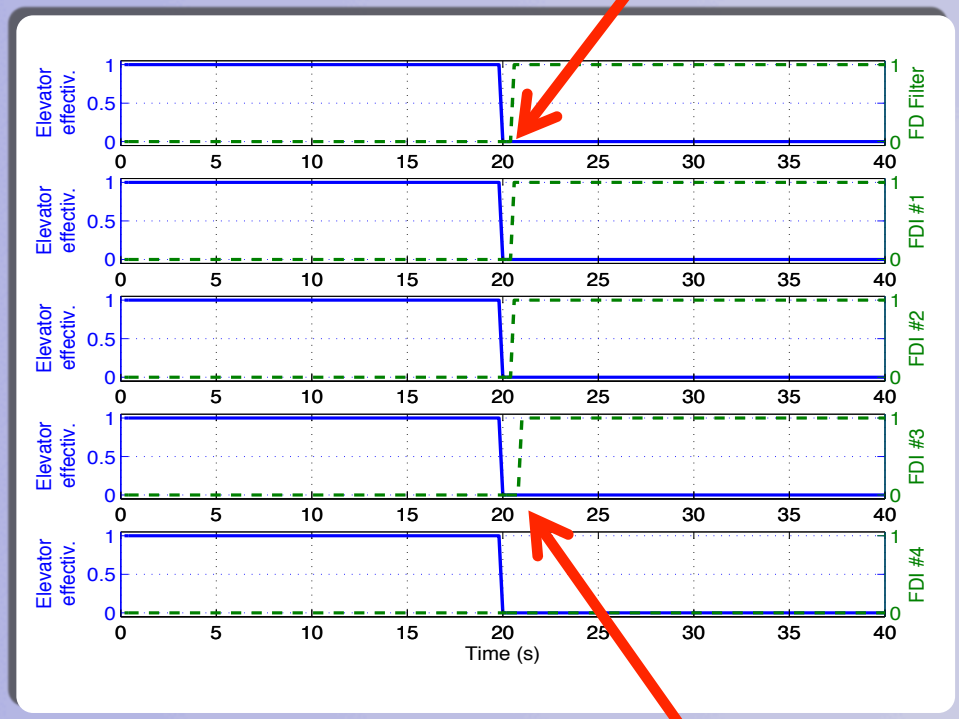
- 5 models considered:
  - Non-faulty model
  - Fault on the forward airspeed sensor
  - Fault on the pitch angle sensor
  - Fault on the angle-of-attack sensor
  - Fault on the elevator (actuation fault)

Simulations (cont.'d)

Fault: Elevator stuck (loss-of-effectiveness)

Hard fault

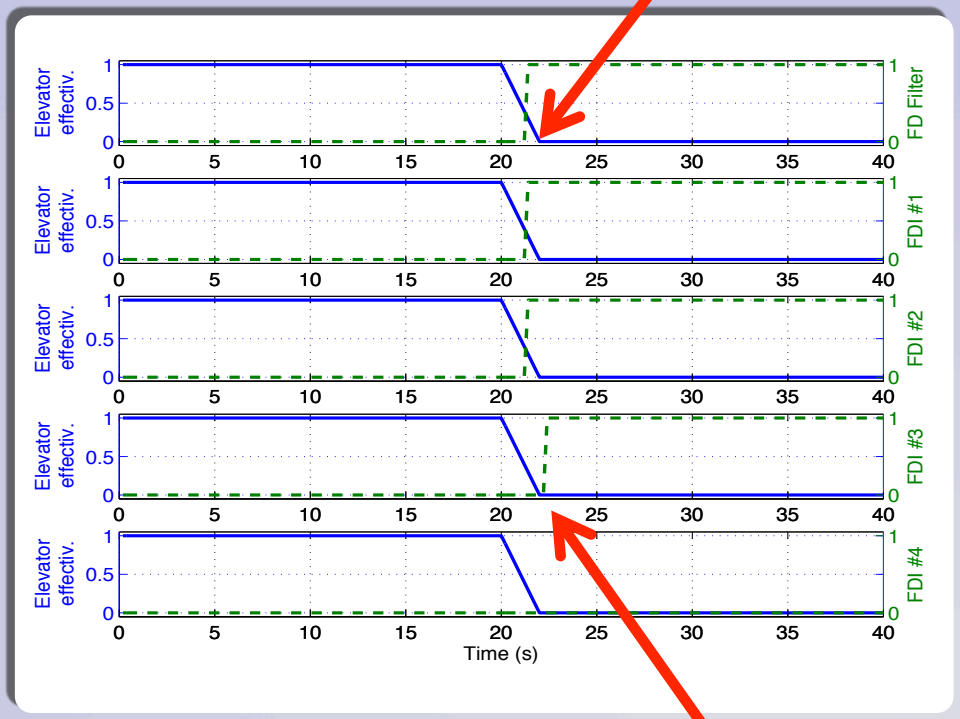
Fault detected



Fault isolated

Soft fault

Fault detected



Fault isolated

Conclusions

- A fault detection and isolation (FDI) technique using set-valued observers (SVOs) was introduced

- The method handles model uncertainty and exogenous disturbances

- It is guaranteed that there are no false alarms

- The detection and isolation of faults usually requires only a few iterations

- Unlike the classical approach in the literature, the computation of residuals and thresholds is avoided

- Main drawback: computationally heavier than the classical solution

Thank You

Questions/Comments?