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# On Closed-loop Fault Diagnosis of Complex Mechatronic Systems

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## 1 Background

The economic value of production equipment in the high-precision industry is to a large extent determined by its productivity. It is essential to minimize downtime caused by malfunction and the associated unscheduled maintenance. To this end, digital-twin-assisted fault diagnosis systems are crucial, exploiting cheap operational data and its physics-based structure to isolate the root-cause.

## 2 Problem

Many fault diagnosis systems are based on parametric first principle models of the open-loop system. For instance, based on parametric models, nullspace-based fault detection and isolation (FDI) methods enable fault diagnosis for large-scale multi-input multi-output (MIMO) systems [1]. In sharp contrast, for precision mechatronics, first principle modeling is ineffective compared to data-driven modeling, which is fast, accurate, and inexpensive [2]. In addition, precision mechatronics operate in closed loop, which is often claimed not to affect the FDI system design. Given the importance for these high-precision mechatronic systems, the aim of this abstract is to develop a closed-loop and closed-loop dynamic modeling view of fault diagnosis.

## 3 Approach

For FDI, data-driven modeling and closed-loop interconnections are investigated. For this purpose, the consequences of interacting submodules and closed-loop operators are examined and its effect on identification and residual generator design is evaluated through a numerical analysis and experimental case study.

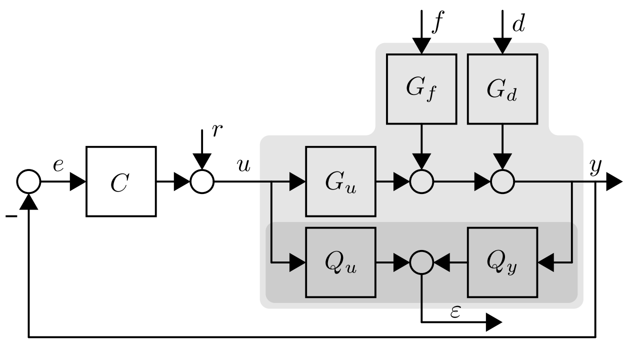


**Figure 1:** Closed-loop configuration for fault detection by means of the residual signal $\varepsilon$. The residual generator, $Q(s)$ (■), and the open-loop problem (■) are indicated.

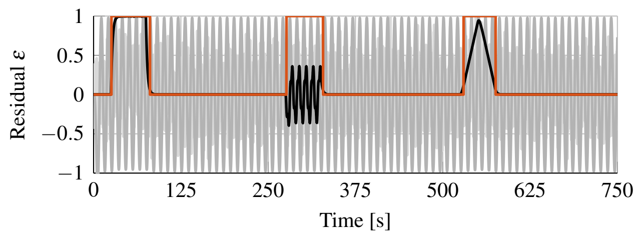


**Figure 2:** Comparison between normalized effective residual (—) with fault flag (—), and residual signals based on classical design techniques (—), (—).

## 4 Results

By means of an experimental setup, exhibiting flexible behavior similar to next-generation positioning systems, it is shown that neglecting interaction between closed-loop controlled submodules results in a severely compromised fault diagnosis system [3]. A solution is proposed in which submodules are identified and used as basis for the fault diagnosis system.

## 5 Outlook

The presented approach addresses ambiguity in fault detection for closed-loop systems since the operation of MIMO systems in closed-loop configuration has major implications for FDI and related system identification. Further details are communicated in [4]. The developed procedure shows that the framework for fault detection, in the form of a digital twin, can serve as the basis to maximize productivity through predictive maintenance for complex mechatronic systems.

## References

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