Postgraduate Level Course on
Technical Fault Diagnosis and Fault Tolerant Control

Course Instructor: Prof. Dominique Sauter, University of Lorraine, France

Duration: 26 May 2014 – 6 June 2014

Number of Credits: 5

Short Description of the course

Over the past two decades, the growing demand for reliability in industrial processes has drawn increasing attention to the problem of fault detection and isolation (FDI) and Fault-tolerant control (FTC). A fault (abrupt or incipient) is any kind of malfunction or degradation in the plant that can lead to a reduction in performance or loss of important functions, impairing safety. Therefore, FDI & FTC can be motivated by different goals depending on the application under consideration, for instance, safety in flight control or reliability or quality improvements in industrial processes.

The goal of FDI is to perform two main decision tasks: fault detection, consisting of deciding whether or not a fault has occurred, and fault isolation, consisting of deciding which element of the system has failed. Usually, the general procedure for model based FDI comprises the following three steps:

- ✓ Residual generation: the process of associating, with the pair model-observation, features that allow evaluating the difference with respect to normal operating conditions.
- ✓ Residual evaluation: the process of comparing residuals to some predefined thresholds according to a test and at a stage where symptoms are produced.
- ✓ Decision making: the process of deciding, based on the symptoms, which elements are faulty (i.e., isolation).

FDI residual generation algorithms can be shared into two categories. The first is based on state estimation and includes detection filters, parity space approaches] as well as diagnostic observer based methods. Parameter estimation techniques belongs to the second category. In practice, the two kinds of methods do not apply to the same FDI problems: parameter estimation is especially suitable for multiplicative faults (process faults) whereas state estimation should be preferred for additive faults (instrument faults). Assuring the robustness of residual generators in practical situations against inevitable unknown input disturbances is commonly recognized as the main design problem for FDI schemes. In the case of structured types of uncertainties, the current literature proposes a variety of solutions for achieving robustness. The geometrical approaches and the techniques of fault effect decoupling based on observers with unknown inputs constitute the two most relevant approaches for achieving enhanced robustness. Whenever it is not possible to totally decouple the effects of faults from the system's perturbations, one often resorts to optimization. The frequency domain based approach has produced very encouraging results in the design of robust residual generators. Finally, another alternative is to use an adaptive algorithm for residual generation or evaluation.

Once the fault has been detected and isolated, a way to prevent system deterioration is to develop a controller having some capabilities to compensate for faults. In this framework, fault tolerant control is a quite recent research topic very close to the FDI problem itself. Fault tolerant control systems are characterized by their capabilities, after the fault occurrence, to recover performances close to the nominal desired performances. The accommodation capability of a control system depends upon many factors such as the severity of the failure, the robustness of the nominal system, the actuator redundancy, etc. A classical way to achieve fault tolerant control relies on supervised control where an FDI unit provides the information about the location and time occurrence of any fault. Faults are compensated via an appropriate control law triggered according to the diagnosis of the system. This can be achieved using gain scheduling or compensation via additive input design.

The aim of the course is to give an introduction to the main concepts, methods and tools for FDI as well as the FTC. Laboratory exercises using MATLAB/SIMULINK environment demonstrate the behavior of the algorithms.

Contents of the course

1. **Introduction to fault diagnosis**

    a. Problem statement
    b. System modelling
    c. Definition of the main concepts
    d. Architecture of a FDI System

2. **Decision making – Statistical testing**

    a. The fundamental problem of statistical testing
    b. Sequential testing : Likelihood ratio
    c. Tests of SPRT, Page Hinkley, GLR.

3. **Model based Fault Diagnosis**

    a. Residual generation via observers
    b. The parity space approach
    c. Robustness enhancement

4. **Data based Fault diagnosis**

    a. Principal Component analysis
    b. Balances evaluation

5. **System modeling and identification**

    a. Structure analysis
    b. Causal graphs : introduction to transfer of entropy
    c. ARX, OE model identification

6. **Introduction to FTC**

    a. Main Concepts
    b. Passive approaches
    c. Active approaches

7. **Application Use cases :**

    a. Thermal benchmark
    b. Petro-chemical industry
    c. Paper making

Work load estimate

Lectures	40 h

Location

Computer classroom – 1,
School of Chemical Technology
Aalto University
Kemistintie -1, Espoo

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