

Model Based Fault Detection and Isolation

Robust Model Based Fault Detection and Isolation (8 Hours)

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1. INTRODUCTION

- 1.1. IMPORTANCE OF FAULT DIAGNOSIS
- 1.2. FAULT DIAGNOSIS TERMINOLOGY
 - 1.2.1. STATES AND SIGNALS
 - 1.2.2. FUNCTIONS
 - 1.2.3. SYSTEM PROPERTIES
- 1.3. RELATIVE IMPORTANCE OF FAULT DETECTION, ISOLATION AND IDENTIFICATION
- 1.4. MODEL BASED FAULT DIAGNOSIS
- 1.5. ANALYTICAL REDUNDANCY
- 1.6. A CORNERSTONE OF MBA: THE RESIDUAL SIGNAL

2. BASIC PRINCIPLES OF MODEL BASED FAULT DIAGNOSIS

- 2.1. CONCEPTUAL STRUCTURE OF MB FAULT DIAGNOSIS
 - 2.1.1. RESIDUAL GENERATION
 - 2.1.2. DECISION MAKING (DM)
- 2.2. ON-LINE FD
- 2.3. MODELING OF FAULTY SYSTEMS
- 2.4. SYSTEM DYNAMICS WITH FAULT
 - 2.4.1. COMPONENT FAULT
 - 2.4.2. MODELING OF FAULTS AFFECTING PARAMETER OF MATRIX A
 - 2.4.3. MODELING OF FAULTS AFFECTING OUTPUT SENSORS
 - 2.4.4. MODELING OF FAULTS AFFECTING ACTUATORS AND INPUT SENSORS
 - 2.4.5. MODELING OF INPUT SENSOR FAULTS
- 2.5. GENERAL DESCRIPTION OF THE FAULTY SYSTEM
- 2.6. INPUT-OUTPUT REPRESENTATION OF THE FAULTY SYSTEM
- 2.7. A REDUNDANT STRUCTURE OF RESIDUAL GENERATION
 - 2.7.1. THE SIMPLEST APPROACH: SYSTEM DUPLICATION
 - 2.7.2. OUTPUT ESTIMATOR APPROACH
 - 2.7.3. A GENERAL STRUCTURE OF RESIDUAL GENERATION
- 2.8. FAULT DETECTABILITY
 - 2.8.1. STRONG FAULT DETECTABILITY CONDITION (SFDC)
- 2.9. FAULT ISOLABILITY
- 2.10. STRUCTURED RESIDUAL SET (SRS)
 - 2.10.1. DEDICATED RESIDUAL SET
 - 2.10.2. GENERALIZED RESIDUAL SET
 - 2.10.3. FIXED DIRECTION RESIDUAL VECTOR
- 2.11. SENSOR AND ACTUATOR FAULTS ISOLATION
 - 2.11.1. SENSOR FAULTS
 - 2.11.2. ACTUATOR FAULTS

3. RESIDUAL GENERATION TECHNIQUE

- 3.1. OBSERVER (OR FILTER) BASED APPROACH
 - 3.1.1. FULL ORDER OBSERVER: THE SIMPLEST METHOD
- 3.2. PARITY VECTOR (RELATION) METHOD
 - 3.2.1. PARITY VECTOR (RESIDUAL)
 - 3.2.2. PARITY SPACE AND SIGNATURE DIRECTIONS
 - 3.2.3. PARITY VECTOR METHOD FOR CASE $rank(\mathbf{C}) = m < n$
- 3.3. FACTORIZATION METHODS (FM) FOR RESIDUAL GENERATION
- 3.4. ROBUST RESIDUAL GENERATION PROBLEMS
 - 3.4.1. ROBUSTNESS TO DISTURBANCES
 - 3.4.2. ROBUSTNESS TO MODELING ERRORS (MO)
 - 3.4.3. ACTIVE ROBUSTNESS: ROBUST RESIDUAL DESIGN
 - 3.4.4. PASSIVE ROBUSTNESS: ADAPTIVE THRESHOLDS (AD)

4. ROBUST RESIDUAL GENERATION USING UNKNOWN INPUT OBSERVERS (UIO)

- 4.1. PRINCIPLE OF UIO
- 4.2. THEORY AND DESIGN OF UIO
 - 4.2.1. THEORY OF UIO
 - 4.2.2. DESIGN PROCEDURE FOR UIOS
- 4.3. ROBUST FDI BASED ON UIOS
 - 4.3.1. ROBUST SENSOR FAULT ISOLATION SCHEMES WITH UIOS
 - 4.3.2. ROBUST ACTUATOR FAULT ISOLATION SCHEMES WITH UIOS

5. DETERMINATION OF DISTURBANCE DISTRIBUTION MATRICES (DDM) FOR ROBUST RESIDUAL GENERATION

- 5.1. DIRECT DETERMINATION & OPTIMIZATION OF DDM
 - 5.1.1. SIMPLE INSPECTION
 - 5.1.2. NOISE AND ADDITIVE NON-LINEARITY
 - 5.1.3. MODEL REDUCTION
 - 5.1.4. PARAMETER PERTURBATIONS
 - 5.1.5. BOUNDED UNCERTAINTY
- 5.2. ESTIMATION OF DISTURBANCE AND DDM
 - 5.2.1. ESTIMATION OF DISTURBANCE VECTOR USING AUGMENTED OBSERVER

6. ROBUST RESIDUAL GENERATION USING OPTIMAL PARITY RELATION

- 6.1. DEALING WITH MODELING UNCERTAINTY
- 6.2. SOLUTION OF MULTI-OBJECTIVE OPTIMIZATION BY MINIMIZING A MIXED PERFORMANCE INDEX

7. ROBUST FAULT DETECTION VIA FACTORIZATION APPROACH

- 7.1. PERFECT FDI (PFDI) AND PERFECT DISTURBANCE DE-COUPLING (PDD)
 - 7.1.1. PERFECT FAULT DETECTION
- 7.2. PFDI FOR SYSTEM WITHOUT DISTURBANCES
- 7.3. PERFECT DISTURBANCE DECOUPLING
- 7.4. PFDI AND SIMULTANEOUS PDD VIA STRUCTURED RESIDUAL SET
- 7.5. DESIGN OF OPTIMAL RESIDUALS

Linear Polynomial Methods for FDI With Aircraft Applications

(4 Hours)

Silvio Simani, University of Ferrara

RESIDUAL GENERATION
POLYNOMIAL BASIS COMPUTATION
INPUT-OUTPUT SENSOR FAULT DETECTION
RESIDUAL OPTIMISATION
RESIDUAL GENERATOR OPTIMISATION
RESIDUAL FUNCTION POLES AND ZEROS ASSIGNMENT
INPUT-OUTPUT SENSOR FAULT ISOLATION
BANK FOR INPUT SENSOR FDI
BANK FOR OUTPUT SENSOR FDI
FAULT SIGNATURE

APPLICATION EXAMPLES

POWER PLANT OF PONT SUR SAMBRE
POLYNOMIAL METHOD RESULTS
COMPUTATION EXAMPLES
AIRCRAFT SIMULATOR FAULT DIAGNOSIS
POLYNOMIAL METHOD RESULTS
COMPUTATION EXAMPLES

Unscented and Particle Kalman Filters With Aerospace Applications

(4 Hours)

Paolo Castaldi

NONLINEAR FILTERING PROBLEM

WHY YET ANOTHER KF

UNSCENTED TRANSFORMATION

UKF AND UT

UKF ALGORITHM

TO UKF OR NOT TO UKF?

PARTICLE FILTER (OR BOOTSTRAP FILTER)

PARTICLE FILTER PROBLEM AND OVERVIEW

PARTICLE FILTER: ALGORITHM

FDI BY MEANS OF PF: A SATELLITE APPLICATION

LEO SATELLITE ORBIT DETERMINATION BY MEANS OF PF

PARTICLE KALMAN FILTERS: FEW WORDS ON

EXTENDED PARTICLE KF AND UNSCENTED PARTICLE KF

APPLICATION EXAMPLE: AIRCRAFT ACTUATOR FDI

- FEW WORDS ON NON LINEAR GEOMETRIC APPROACH TO FDI
- NONLINEAR GEOMETRIC APPROACH-BASED PARTICLE FILTERING FOR AIRCRAFT ACTUATOR FDI