Model-based Diagnosis and Fault Analysis - Applications in the Automotive Industry

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OCC'M Software GmbH
1 Tasks and Requirements
2 Model-based Solutions
3 Applications 1: On-board Diagnosis
4 Applications 2: FMEA
5 Applications 3: Workshop Diagnosis
6 Applications 4: Authoring Systems
7 Research Topics
Model-based Systems for industrial Applications

- Product Life Cycle

(Re-)Design

- Recycling
- Maintenance

Manufacturing

Control

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Model-based Systems for industrial Applications

Basis for problem solving:
- Knowledge about Technologies

(Re-)Design

Recycling

Manufacturing

Maintenance  Control

- Function
- Components
- Processes
- Materials

- Production processes
- Disturbances
- Faults
- ...

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Requirements

- Variant problem
  - versions of subsystems
- Safety critical application
  - completeness of results
- Diagnostics during design
- Representation and re-use of knowledge
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Key Ideas: **Compositional Modeling**

- **Library:** Component Models
- **Component Behavior**
- **Structure**
- **System Model**
- **CAD Data**

**domain specific**

- User: specifies structure only
- System model is generated automatically

**system specific**

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Heller AG 17.4.97 Struss Auto 1 – 7
Component Type Models
Key Ideas: Generation of Diagnosis Systems

- **domain specific**
  - Library: Component Models
  - Component Behavior
  - Structure

- **task specific**
  - Generic Diagnosis Algorithm
  - System Model

- **system specific**
  - CAD Data
  - Specific Diagnosis System

- **User:** specifies structure only
- **Diagnosis system is generated automatically**
Key Ideas: **Generic Diagnosis Algorithm**

**Diagnosis:**
- Find an assignment of a mode (Ok, Fault₁, ...) to each component $C_i$ such that
- the MODEL and the OBSERVATIONS are consistent
Key Ideas: Generic Diagnosis Algorithm

Note:
- Any kind of model will do
- if it preserves the component structure of the device
- Numerical, statistical, qualitative, ...

System \[\text{Observations} \rightarrow \text{OK}(C_1), \text{OK}(C_2) \rightarrow \text{Predictions} \rightarrow \text{Model} \]
Demonstrated

- Compositional, qualitative models
- Re-use of models
Requirements

Different Tasks - shared knowledge
- FMEA
- On-board diagnostics
- Authoring system
- Workshop diagnosis
Example: Turbo Control

- FMEA:
  “Effect of turbo control valve (2) stuck-closed?”

- Workshop diagnosis:
  “Possible causes of black smoke?”

- On-board diagnosis:
  “Signals --> Faults”
Demonstrated

- Re-use of models
- Re-use of model-based analysis
Key Ideas: Re-use of Models

- **domain specific**
  - Library: Component Models
  - Component Behavior
    - Struktur
  - CAD Daten

- **task specific**
  - Specific Test Generator
  - Specific FMEA System
  - Specific Diagnosis System
  - General Algorithm
  - Test Generation Algorithm
  - Generic Diagnosis Algorithm

- **system specific**
  - System modell
  - Diagnosis System
  - ...
Additional Power through Qualitative Models

Cover

- Classes of Systems
  - independently of specific parameters
  - and contextual conditions
- Classes of Faults
  - “valve does not open properly”
  - e.g. FMEA
- Classes of Symptoms
  - “increased carbon emissions”
  - e.g. diagnosis manuals

- Efficient analysis and diagnosis
Qualitative Modeling

Equations
Q₁ + Q₂ = 0

Domain Signs
[x] := sign (x)

Derivatives
∂x := [dx/dt]

Deviations
Δx := x_{act} - x_{ref}

Model Fragments

[Q₁] ⊕ [Q₂] = [0]
∂Q₁ ⊕ ∂Q₂ = [0]
[ΔQ₁] ⊕ [ΔQ₂] = [0]
Engine Model - Combustion (Partial)

fuel atomisation $\Delta AF$
fuel mass $\Delta MF$
air mass $\Delta MA$
air oxygen rate $\Delta AO$

Combustion

$E$ combustion energy
$EO$ exhaust oxygen rate
$NO$ nitrogen oxides
$EC$ carbon emissions

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