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

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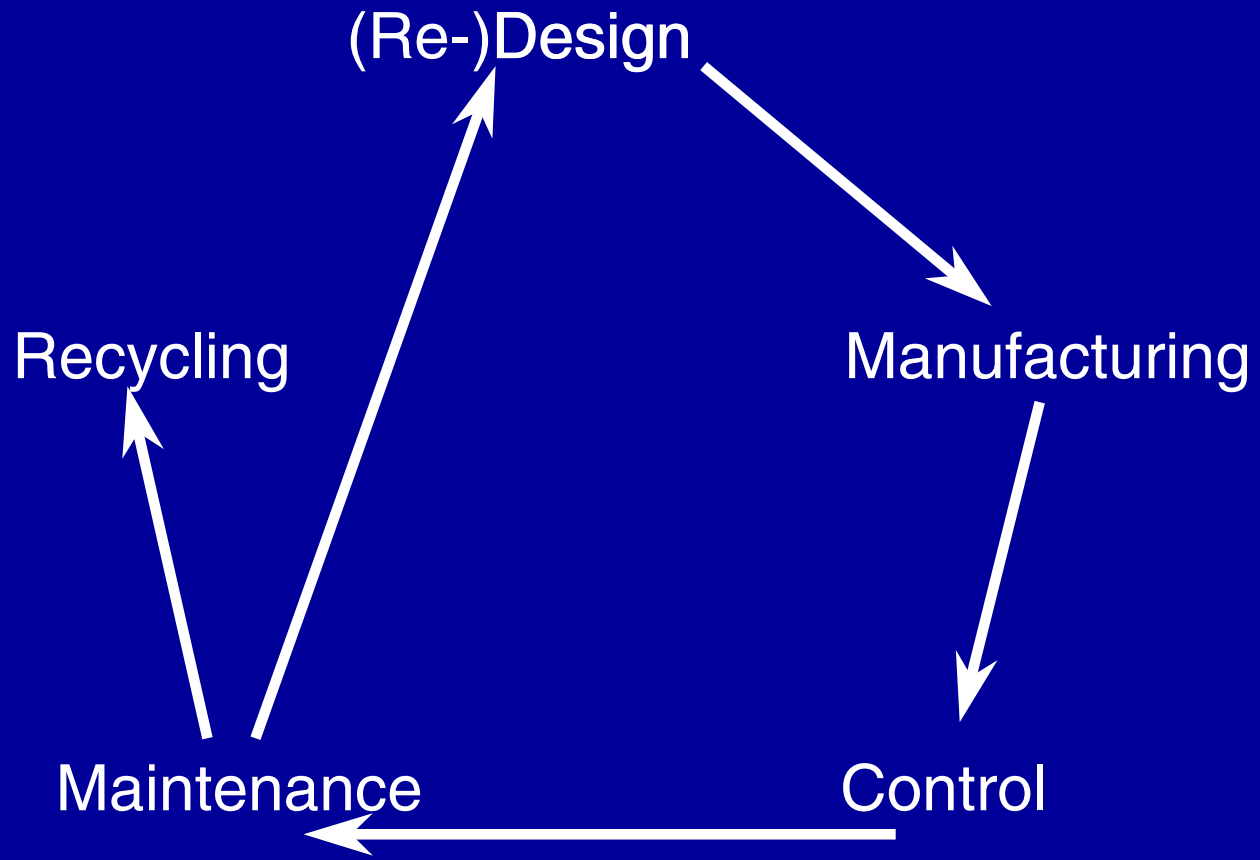
1 Tasks and Requirements
2 Model-based Solutions
3 Applications 1: On-board Diagnosis
4 Applications 2: FMEA
5 Applications 3: Workshop Diagnosis
6 Applications 4: Authoring Systems
7 Research Topics

Model-based Systems for industrial Applications

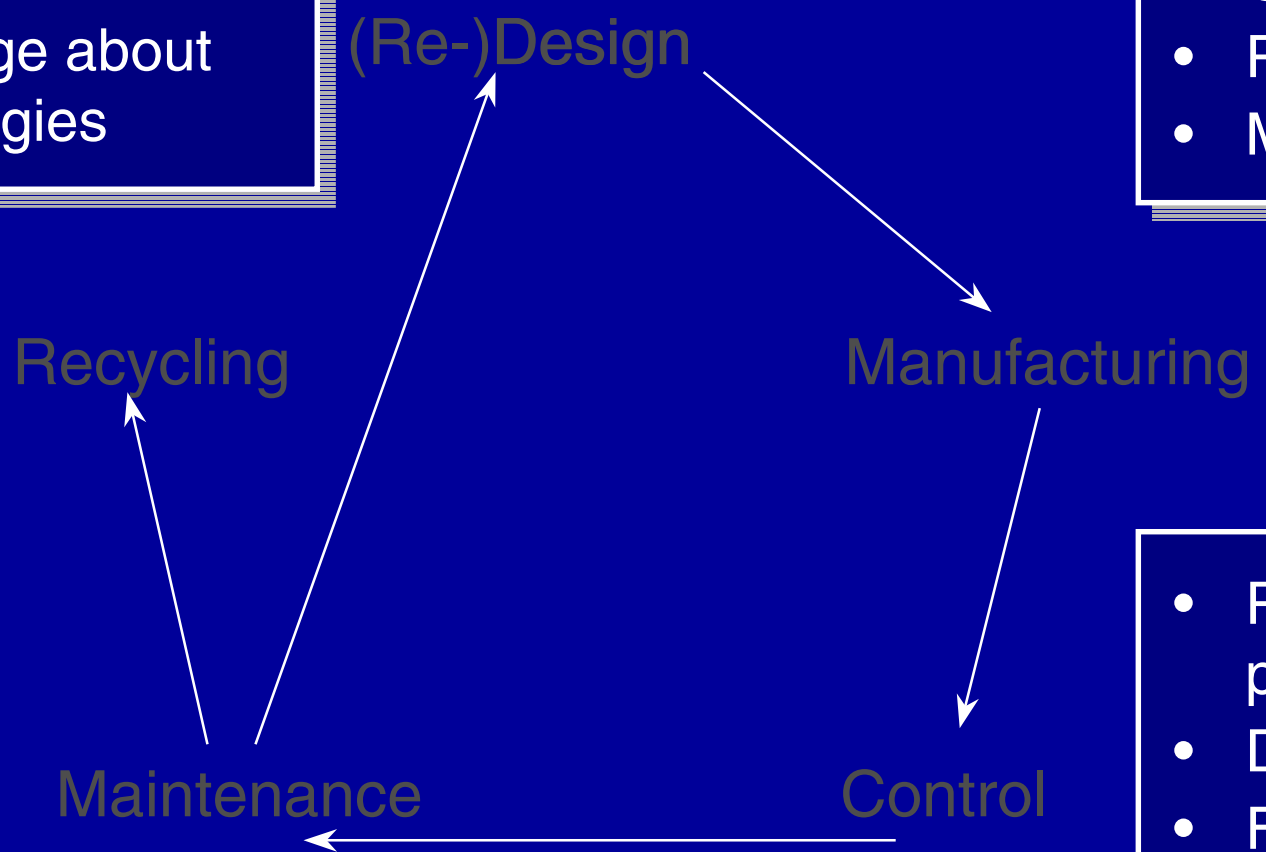
- **Product Life Cycle**



Model-based Systems for industrial Applications

Basis for problem solving:

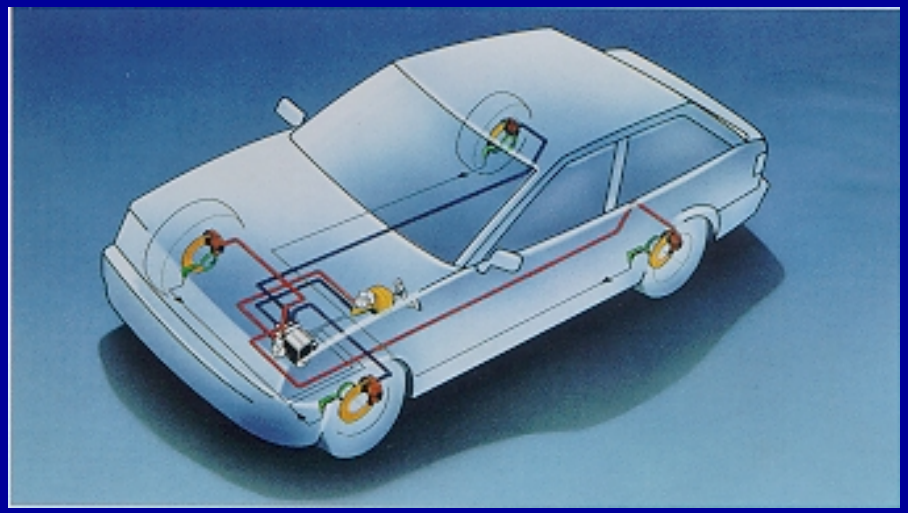
- Knowledge about Technologies



- Function
- Components
- Processes
- Materials

- Production processes
- Disturbances
- Faults
- ...

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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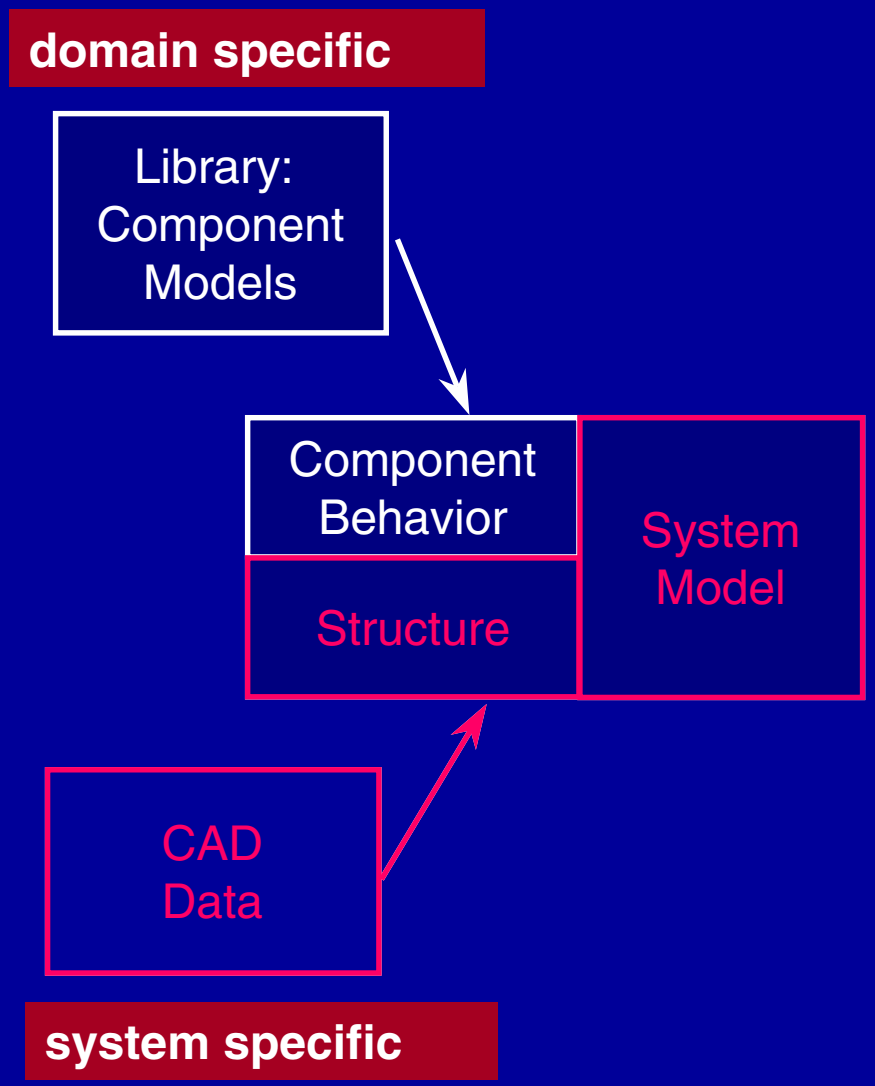
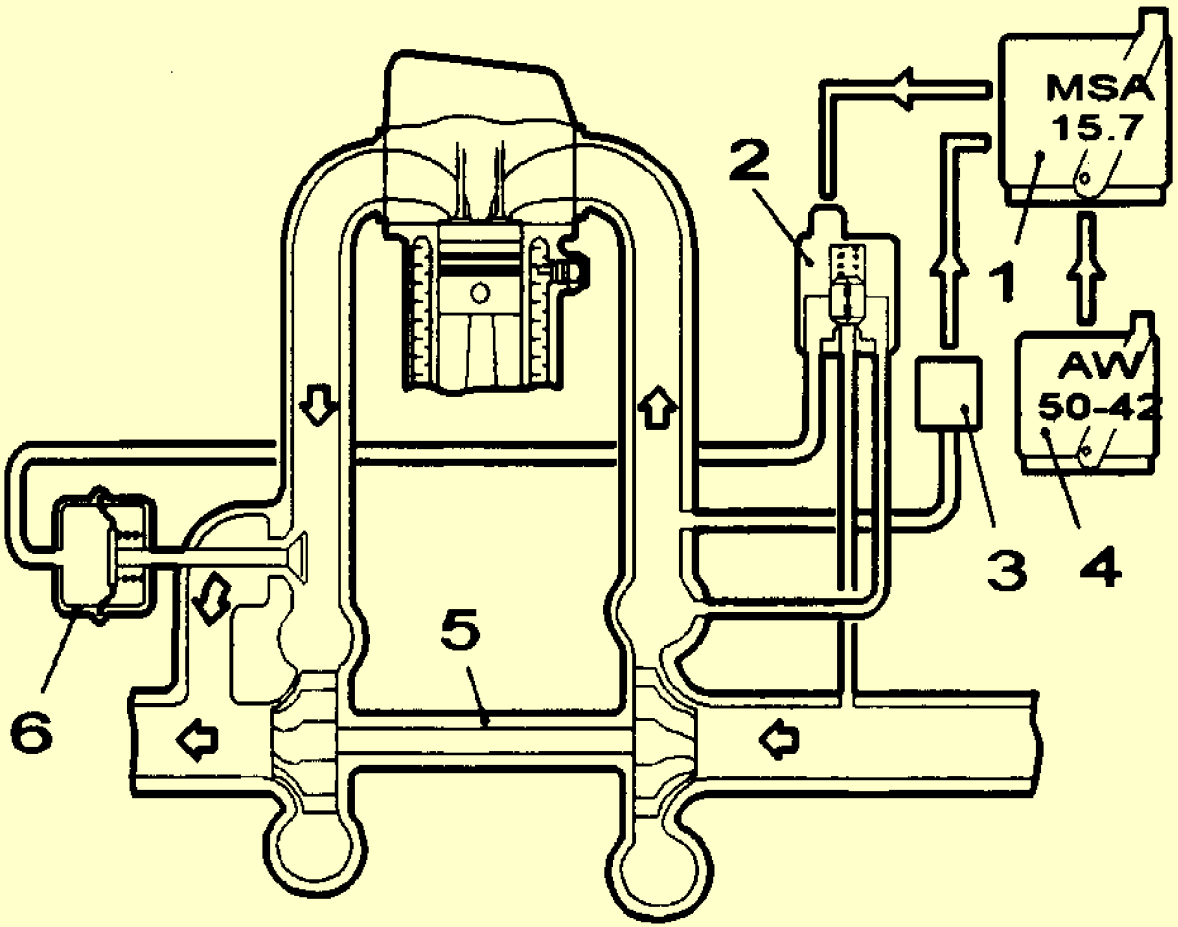
Key Ideas: Compositional Modeling

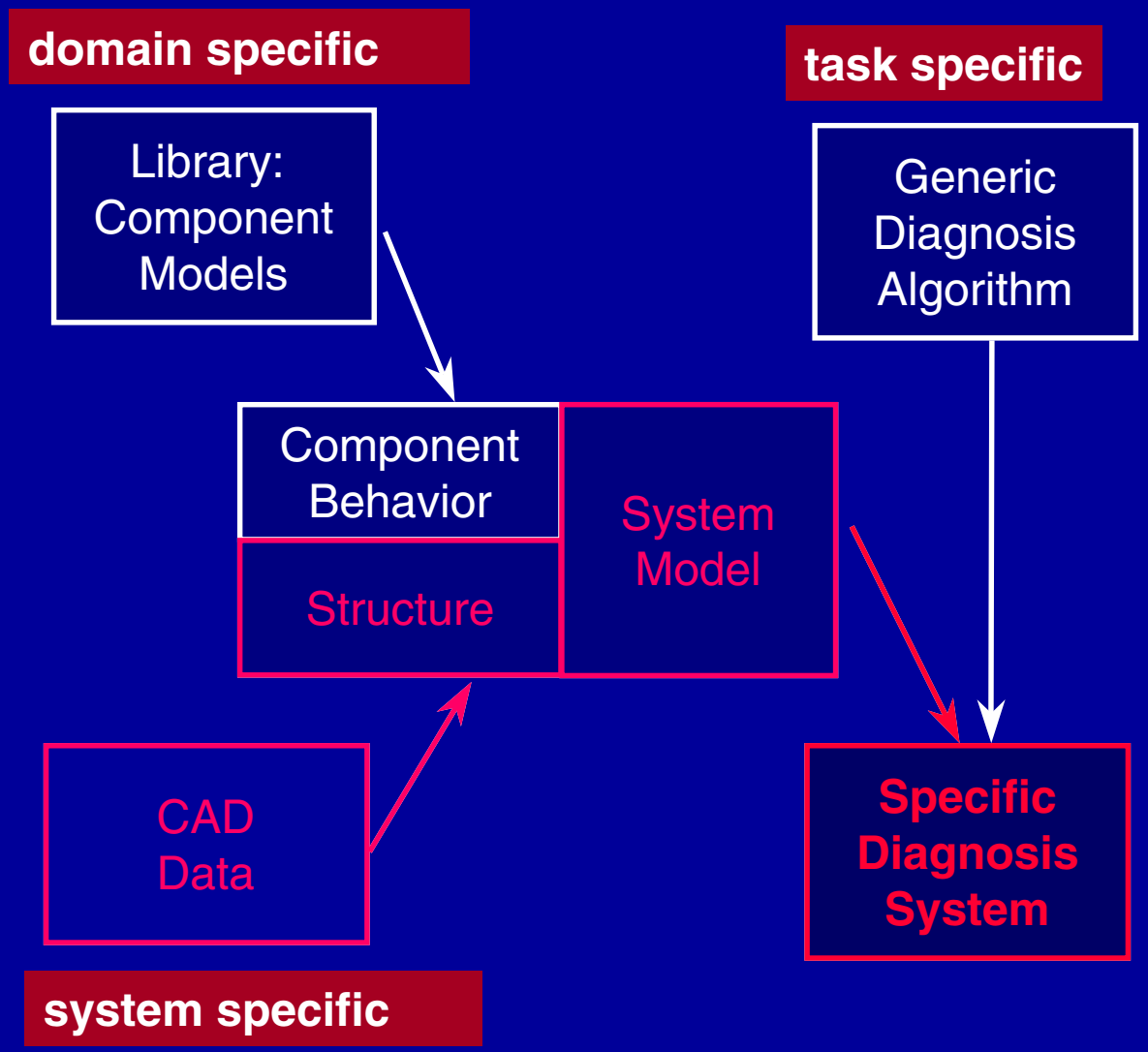


- User: specifies structure only
- System model is generated automatically

Component Type Models



Key Ideas: Generation of Diagnosis Systems

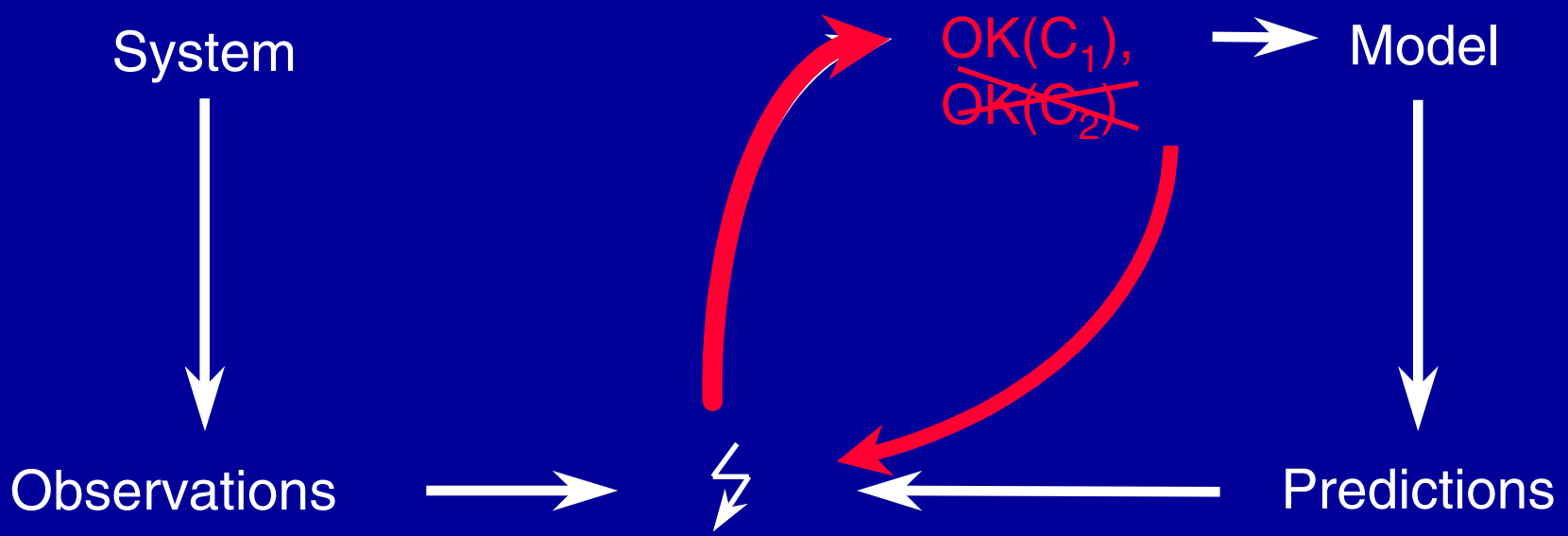


- User: specifies structure only
- Diagnosis system is generated automatically

Key Ideas: Generic Diagnosis Algorithm

Diagnosis:

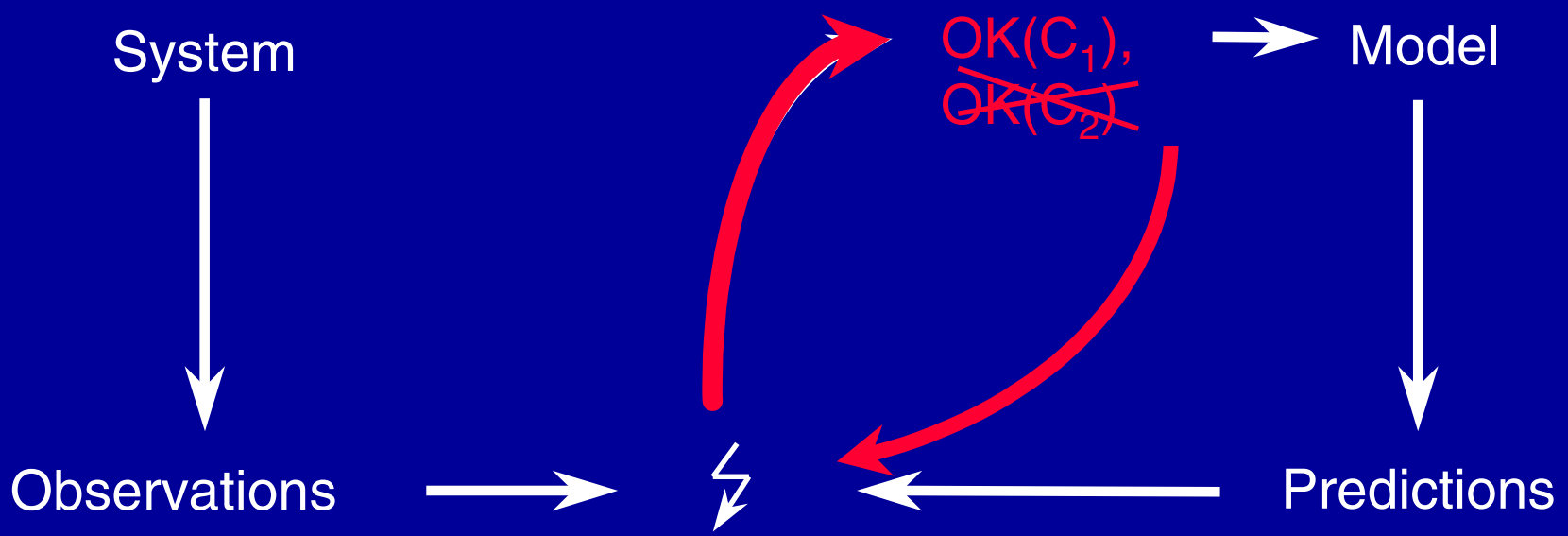
- Find an assignment of a mode (Ok, $Fault_1$, ...) to each component C_i such that
- the MODEL and the OBSERVATIONS are consistent



Key Ideas: Generic Diagnosis Algorithm

Note:

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

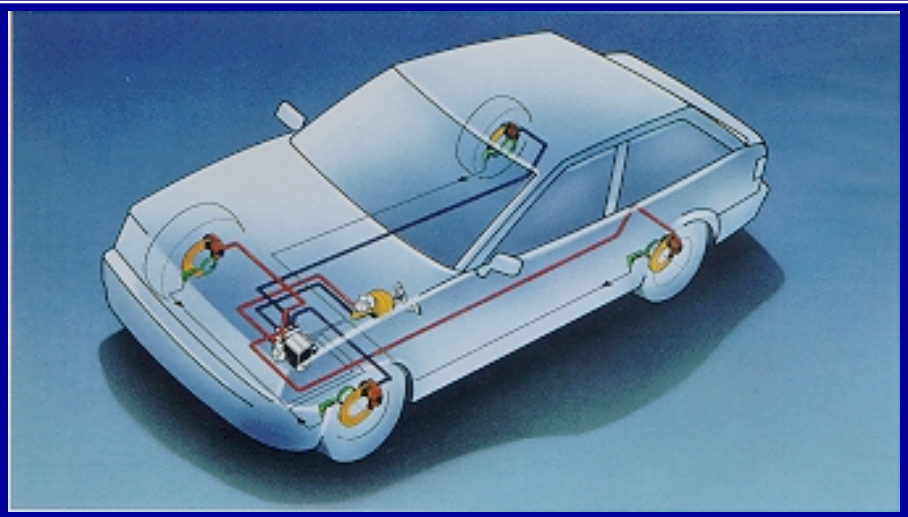


Demonstration

Demonstrated

- Compositional, qualitative models
- Re-use of models

Requirements



Different Tasks -

shared knowledge

- FMEA
- On-board diagnostics
- Authoring system
- Workshop diagnosis

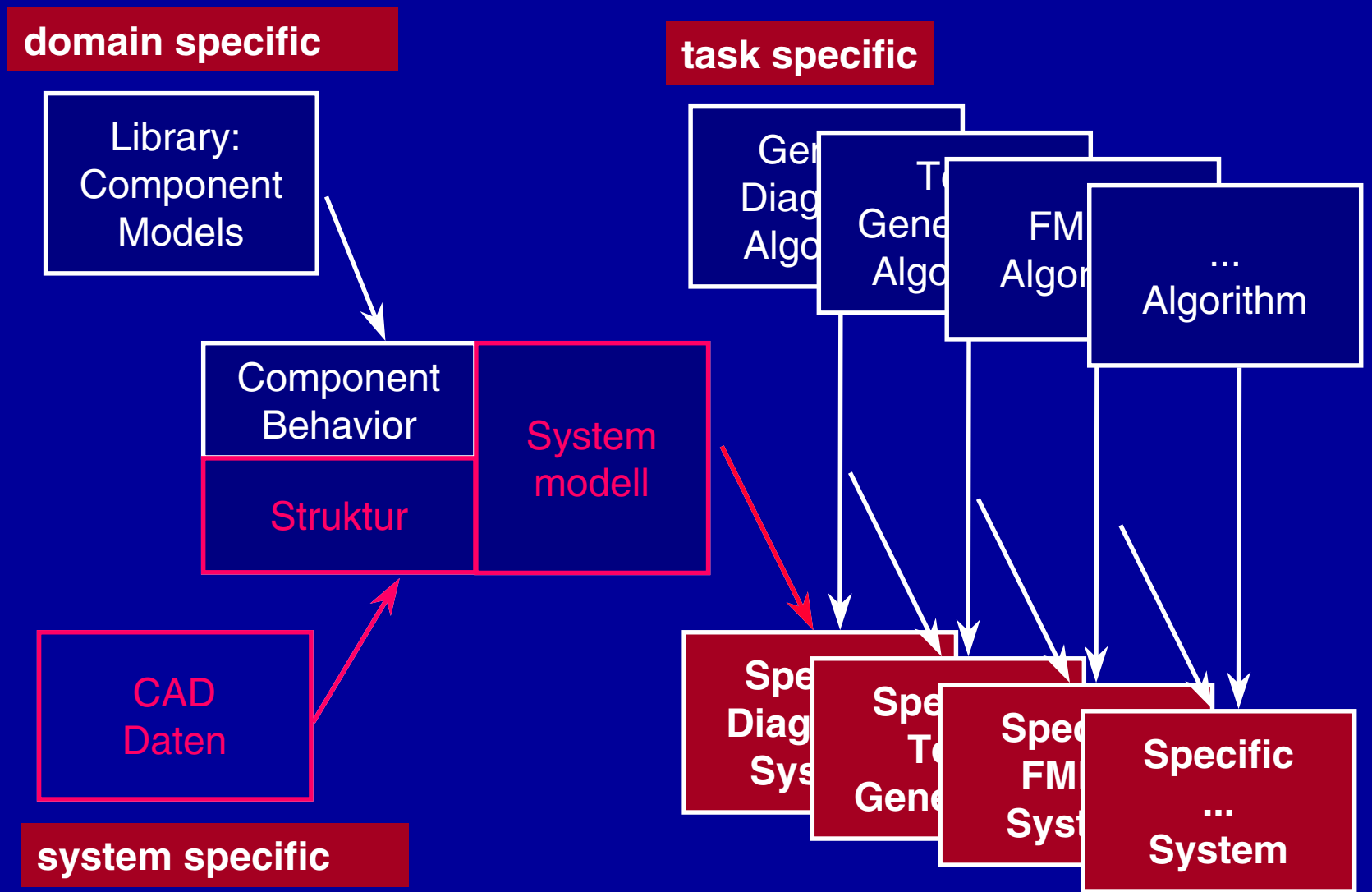
Example: Turbo Control

- 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



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

$Q_1 + Q_2 = 0$

Domain Signs

[x] := sign (x)

Derivatives

$\partial x := [dx/dt]$

Deviations

$\Delta x := x_{act} - x_{ref}$

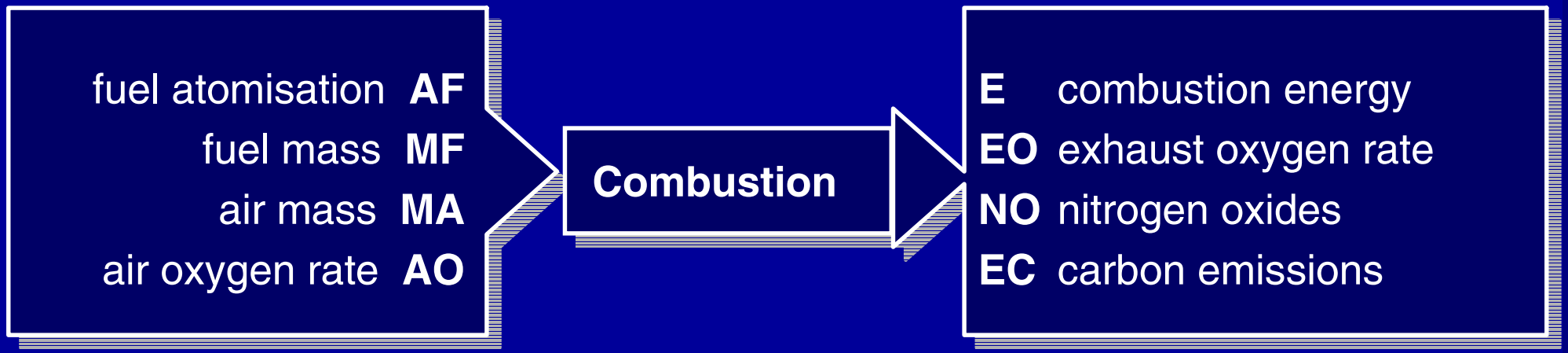
Model Fragments

$[Q_1] \oplus [Q_2] = [0]$

$\partial Q_1 \oplus \partial Q_2 = [0]$

$[\Delta Q_1] \oplus [\Delta Q_2] = [0]$

Engine Model - Combustion (Partial)



ΔAF	ΔMF	ΔMA	ΔAO	ΔE	ΔEO	ΔNO	ΔEC
[0]	[0]	[0]	[-]	[-]	[-]	[-]	[+]
[0]	[0]	[0]	[+]	[0]	[+]	[+]	[0]
[0]	[0]	[-]	[0]	[-]	[-]	[0]	[+]
[-]	[0]	[0]	[0]	[-]	[+]	[0]	[+]
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