Model-Based Diagnosis for Cyber-Physical Production Systems Based on Machine Learning and Residual-Based Diagnosis Models

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Motivation: Modern Cyber-Physical Production Systems (CPPSs) are getting more and more modular to deal with shorter product life-cycles. But the modularity increases the complexity and traditional diagnosis approaches, such as heuristic methods, are no longer suitable. For model-based approaches it is hard to create and maintain the systems' model, especially, if it is a regular changing system. Additionally, modern CPPSs are typically hybrid, so they contain discrete and continuous signals, and they might be large, so the diagnosis runtime is an important aspect.

Objectives: We propose a novel residual-based diagnosis algorithm (RDA) that tackles the challenges of hybrid, modular, and large CPPSs. A data-driven approach is used to create the system descriptions with low manual effort to allow for regular changes of the CPPSs.

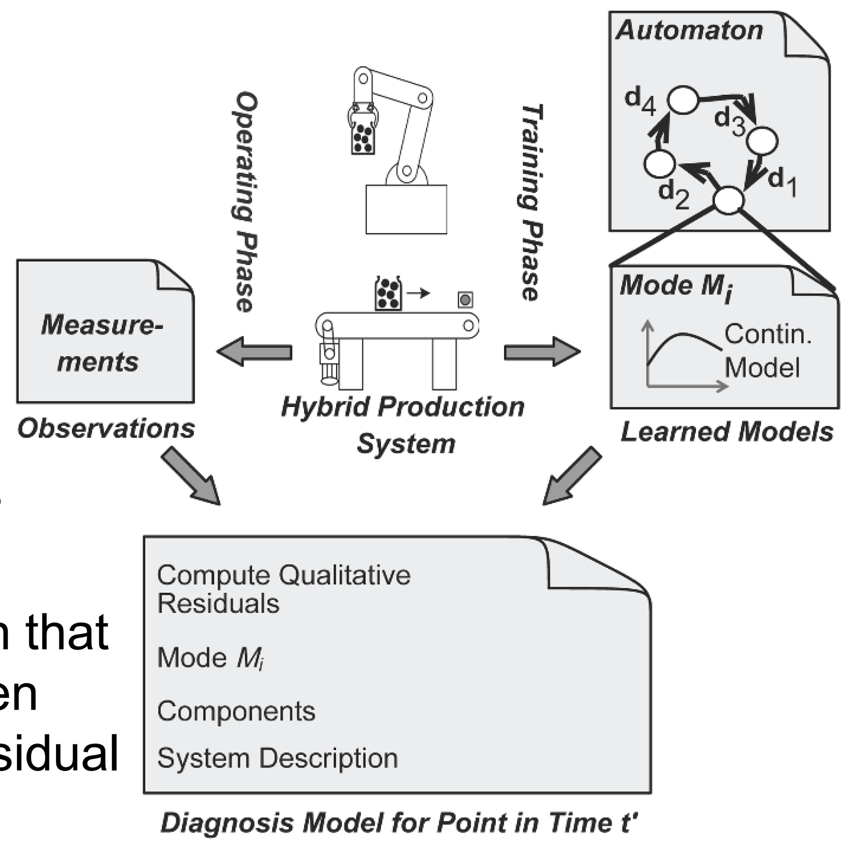
Idea

Training Phase:

- Learn automaton from discrete variables, which separates the behavior into modes
- Learn model of values from continuous variables over time in each mode
- Create system description that shows the relation between heath state, mode and residual

Operating Phase:

- Compute residuals
- Create static diagnosis model
- Compute diagnosis with traditional algorithms

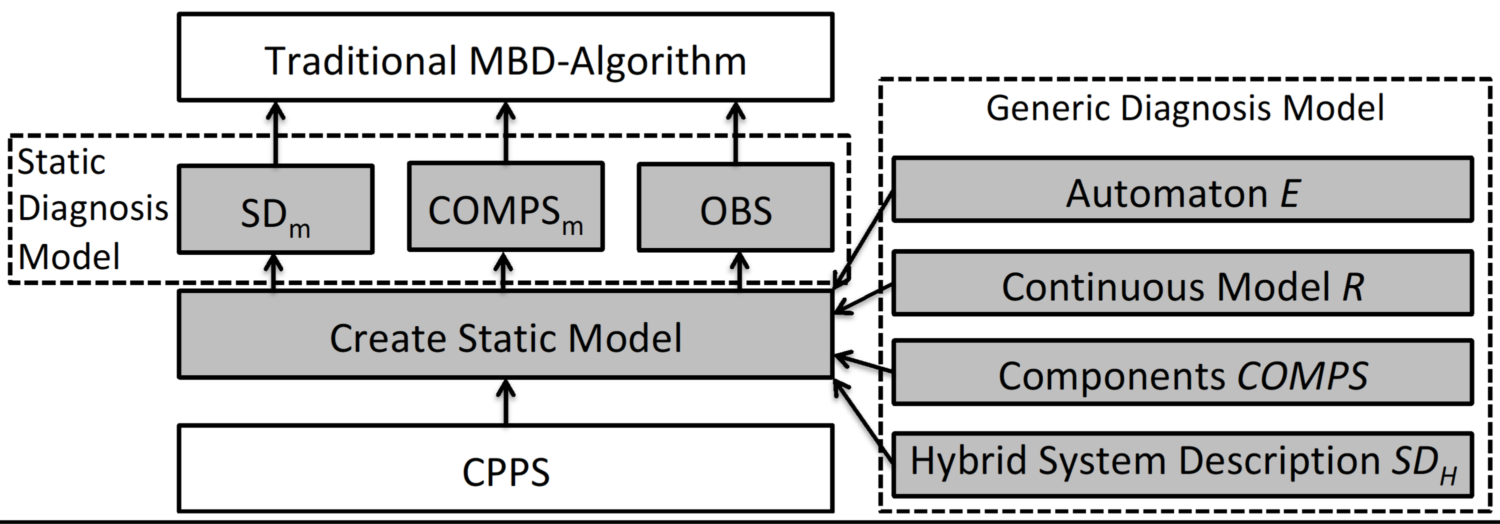


General Approach

Generic Diagnosis Model contains information that enables to diagnose the system at all points in time.

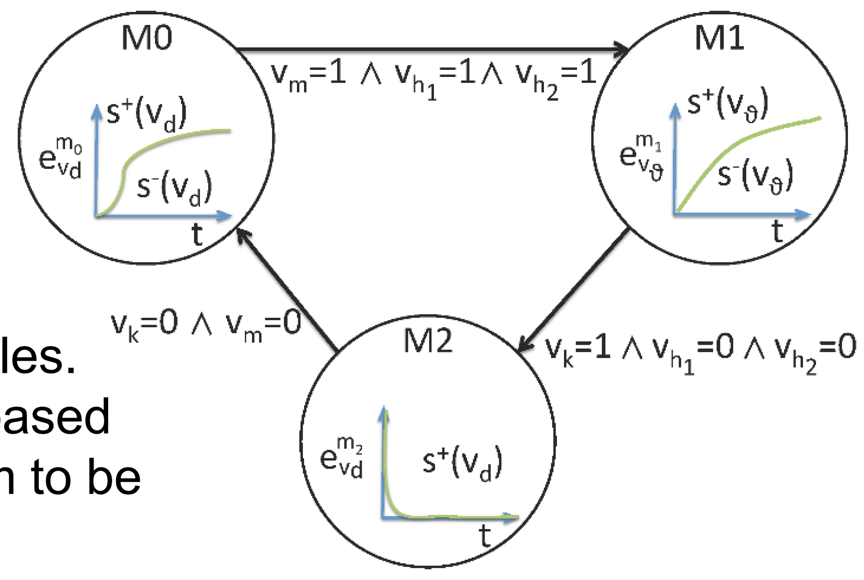
Static Diagnosis Model is a reduced model that is only valid for a single point in time. It is compatible to models from traditional model-based diagnosis, so high performance algorithms from traditional model-based diagnosis can be used. To create the static model, the following steps are performed:

- Determine the current mode
- Compute the residuals of all continuous variables
- Reduce the generic system description to a mode specific
- Reduce the components to a mode specific component set

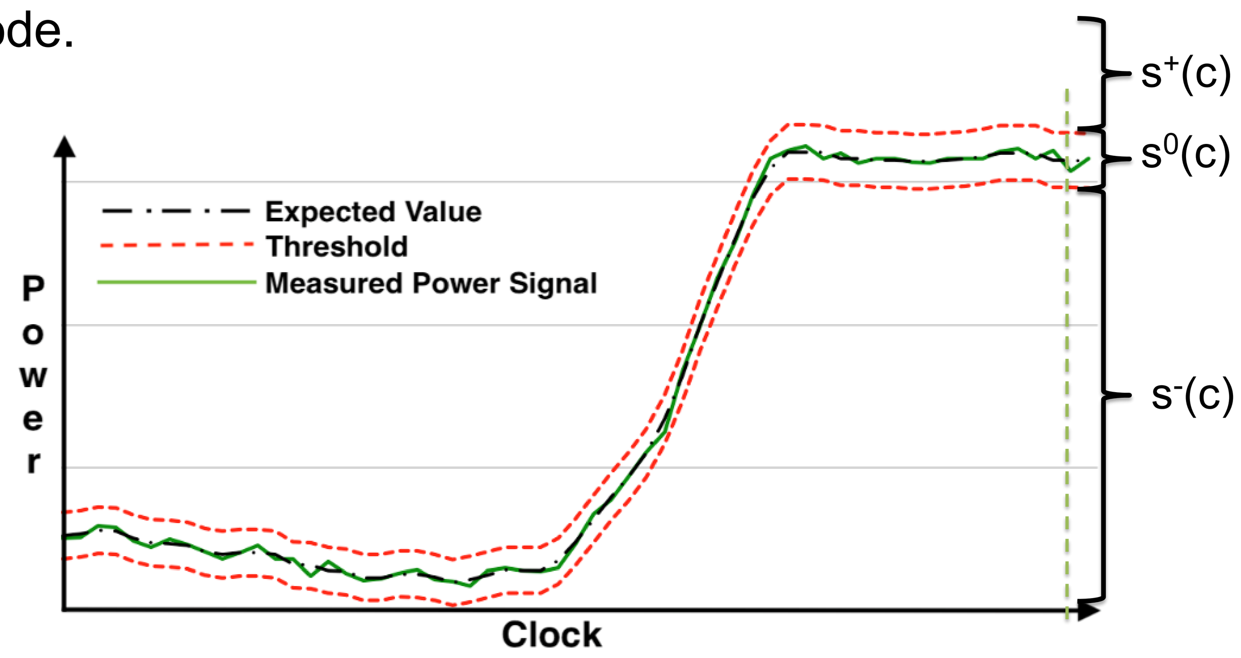


Model Learning

Learn automaton:
The automaton separates the systems' behavior into different modes. Every mode is a unique representation of discrete variables. This enables to deal with state-based systems, but requires the system to be synchronized.



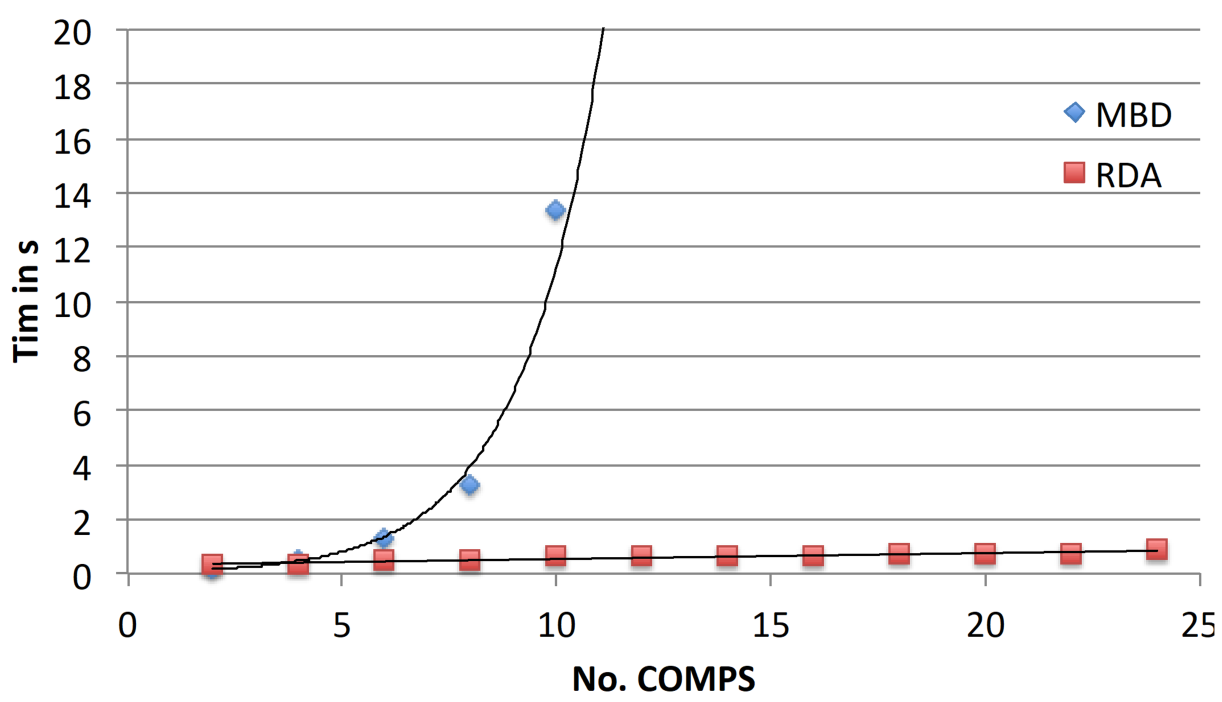
Learn continuous model:
The model represents the value of continuous variables over time. We use a machine learning approach based on neural networks that predicts the expected values given the time since the beginning of each mode.



Evaluation

85 % of continuous faults have been diagnosed correctly. If they have not been diagnosed correctly, the residuals were incorrect, which means that there was a bad continuous model or a suboptimal threshold.

Diagnosis runtime has been improved significantly. Our RDA performs linear to the number of components, traditional algorithms exponential.



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