NSF Engineering Research Center for
Reconfigurable Manufacturing Systems
University of Michigan

Fault Diagnosis Through Automatic Model Generation for Large-Scale Plants

MOTIVATION AND CHALLENGE

According to ARC Online, *unscheduled downtime* is the largest source of lost revenue in process plants today. Lack of automated process and part diagnostics prevents operators from identifying the factors that can lead to predicting and avoiding downtime events. Online diagnosis of faults by human experts can be a significant source of the downtime for many plant processes. Verification of logic control can assure that the controlled process has certain properties, which can mean fewer faults. Such verification, however, usually requires formal models of the plant and control system, but some plants in use do not have complete and accurate formal models, or their models are not useful for verification or diagnosis. *We propose a solution for fault diagnosis through automatic model generation to reduce unscheduled downtime in plant systems.* Using this technique, an estimated formal model of the plant and control system is generated through passive observation of their operation. This estimated model is used in conjunction with a fault decision module that detects likely faults and learns to diagnose them. Interaction among the operator, plant, and fault diagnosis technique are illustrated in the figure below.

BENEFITS

- ✓ Reduces downtime through improving fault detection and diagnosis
- ✓ Generates formal model of system that can be used for other formal analysis
- ✓ Provides fault detection and diagnosis without requiring execution of a design of experiments
- ✓ Applicable to any discrete processing system or sub-system.

OVERVIEW OF THE WORK

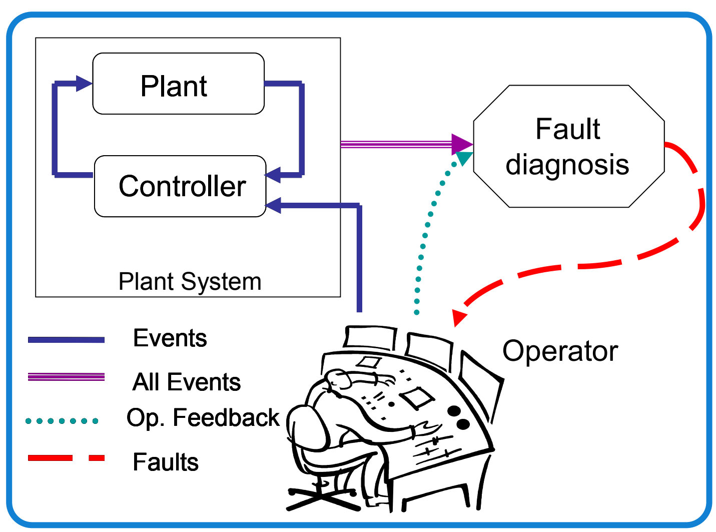
The fault diagnosis through automatic model generation technique can *reduce downtime through faster fault detection and diagnosis*. A solution utilizing this technique provides the following capabilities:

- System identification based on passive observation which supports creation of an estimated model of the complete system – plant and control – in the Petri net formalism
- Fault detection using an estimated model to detect faults
- Fault diagnosis through learning fault types from the plant operator

PROJECT DESCRIPTION

The proposed fault diagnosis solution consists of three major parts: system identification to create an estimated Petri net (model), fault detection using that estimated model and information about its uncertainty, and fault diagnosis through classification of faults utilizing feedback from the operator.

System identification can be defined as the ability to characterize a system by its operation, and will be used for automatic model generation. The ability to model the observed behavior of a plant system aids engineers in validating, optimizing, and diagnosing new and existing control logic. An additional benefit specific to the proposed system identification is that it does not interfere with normal operations of the plant system.



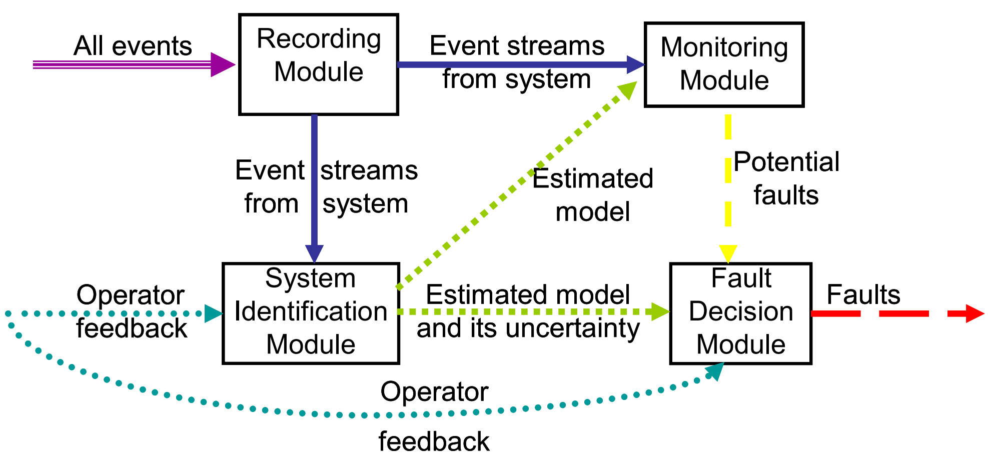
Interaction Between Plant System, Fault Diagnosis and Operator

(Continued on Page 2)

(Project Description Continued)

These parts are implemented in modules, as illustrated in the figure below. The Recording Module records all system events, the System Identification Module creates an estimated model of the system and updates it, and the Monitoring and Fault Decision-Making Modules jointly perform fault detection and diagnosis. The Factory Health Monitor (FHM) [3] is leveraged to provide a preliminary Recording Module.

The proposed fault decision-making technique, implemented in the Fault Decision module, will perform detection and diagnosis. Detection will use the estimated model produced through system identification and information about the uncertainty of this model to detect faults. During initial stages, the system operator will be notified that a fault has been detected. Diagnostic information about where the deviation occurs between the model and the execution will be given. In this way, the operator can diagnose the exact fault. In future versions of the solution, the system operator will provide feedback to the fault decision module, indicating which fault was associated with which deviation, so that the fault decision module can learn to diagnose faults on its own.



Fault Diagnosis Modules and Their Interaction

CURRENT STATUS

- Factory Health Monitor developed and tested (7/08)
- Overall concept proposed and research ideas generated (1/09)
- Incorporate industry feedback into specifics of research plan (3/09)

FUTURE MILESTONES

- Develop module for automatic estimated Petri net generation (system identification) (8/09)
- Create fault detection and diagnosis technique and algorithms that use estimated Petri net (6/10)
- Create remainder of overall fault diagnosis using automated model generation technique (11/10)

REFERENCES

[1] Schroeder et al. Factory Health Monitor: System Identification, Process Monitoring, and Control. *4th IEEE Conference on Automation Science and Engineering*, 2008.

DELIVERABLES

- Fault diagnosis algorithms that incorporate uncertainty of model and trade-off of false positives versus missed faults
- Event-based system identification technique for large-scale plants using Petri nets
- Performance metric for system identification techniques
- Measurement of uncertainty of estimated Petri net models

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