Engineering Research Center for

Reconfigurable Manufacturing Systems

Fault Diagnosis Through Automatic Model Generation for Large-Scale Manufacturing Systems

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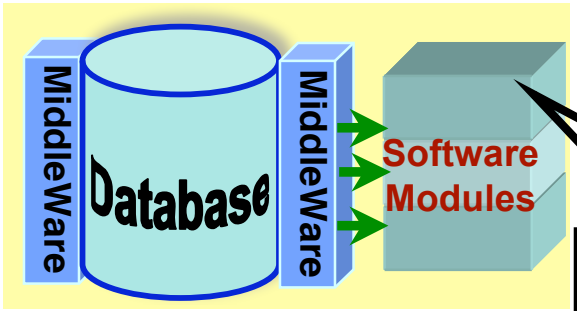
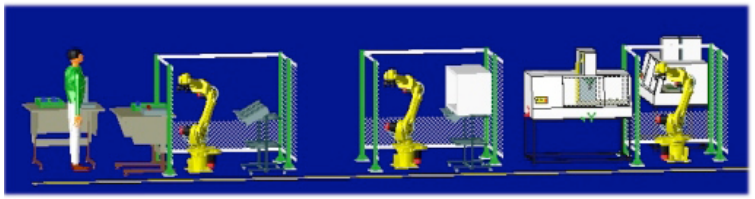
Reconfigurable Factory Testbed (RFT)

Software Infrastructure &
Control Workflow Manager



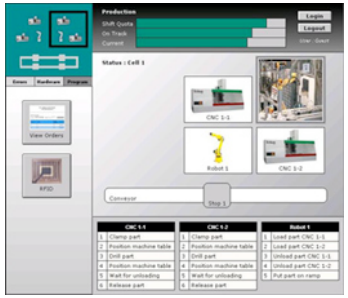
Virtual Factory



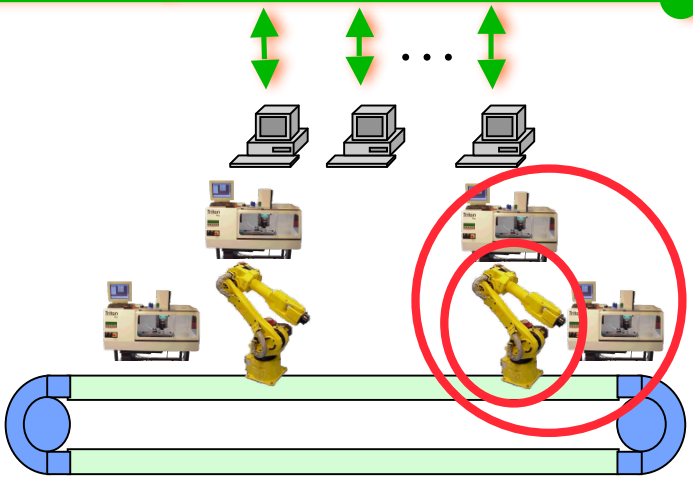
Fault diagnosis added here

Network

RFID

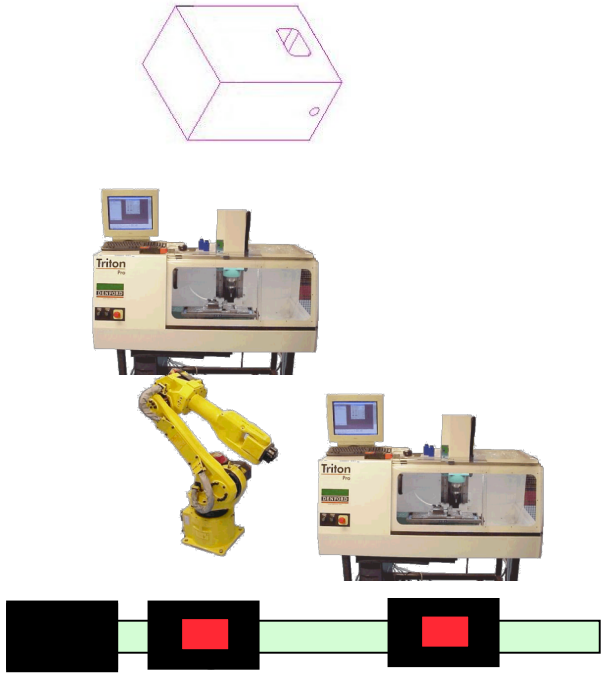


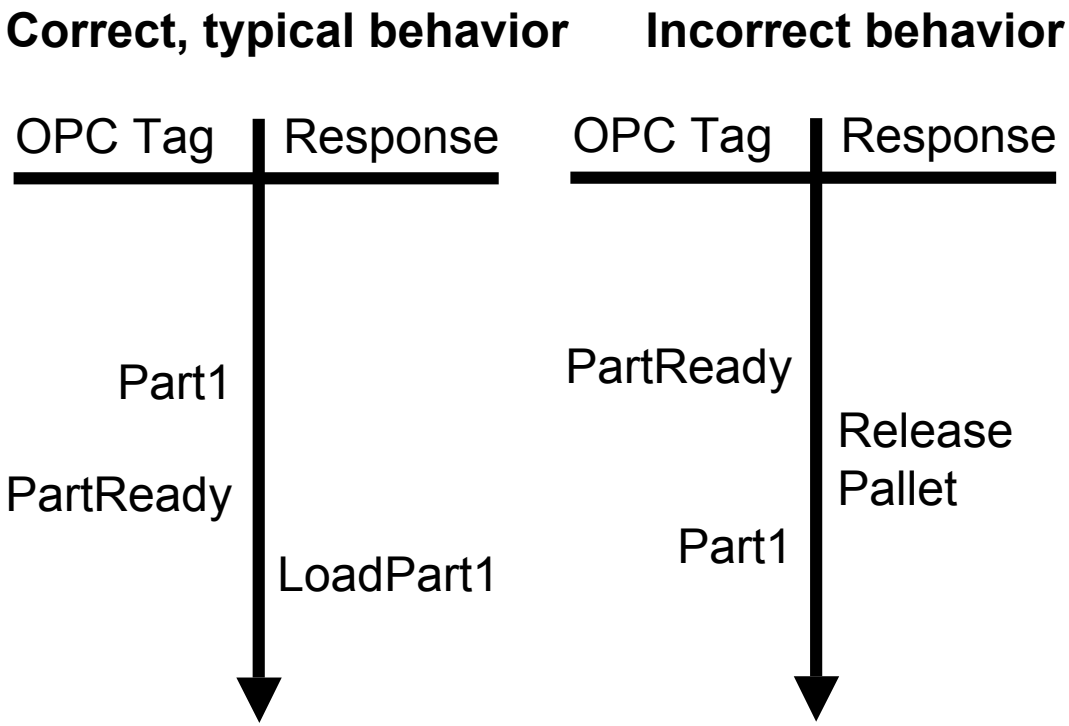
Remote HMI



Serial-Parallel Line

Motivating RFT Example





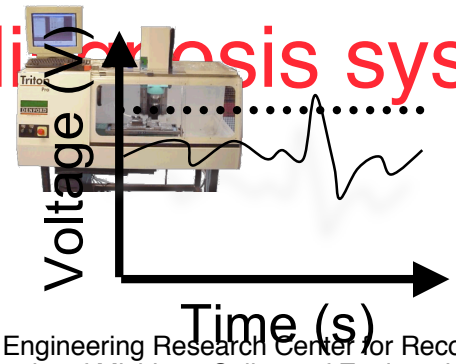
- No model of entire system's correct behavior
- Manual inspection – laborious, offline
- Fault diagnosis using estimated model(s) – automated, online

Fault Detection and Diagnosis

- Fault – deviation from correct behavior
- Detection – determining fault has occurred
- Diagnosis/classification – identify which fault occurred
- Within this work, “diagnosis” refers to detection and diagnosis/classification

Commercial Fault Diagnosis

- Fault detection and classification (FDC)
  - SI Automation's Maestria, FabGuard FDC, Umetrics' Multi-variate analysis, Matlab's PLS toolbox for MVA, …
  - Multivariate analysis, stat. process control
  - Focus on tool-level rather than system-level
  - Detection in continuous rather than event data
- Gap: diagnosis system-level event data faults



Existing Academic Approaches

- Goal: diagnosis of system level event-based faults in manufacturing systems
- Achieved through academic approaches
  - Observers for finite state automata, diagnostics added to interpreted Petri nets
- Not available for most industrial systems
- Requires complete, accurate formal model of controller

Differences Between Fault Diagnosis Approaches

Our approach

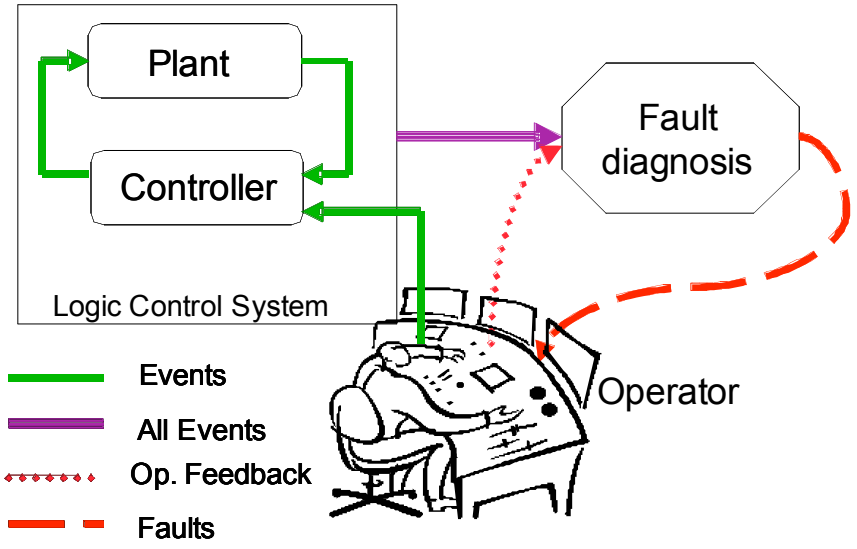
- System-level faults
- Event-based data
- No pre-existing model necessary

Existing approaches

- Machine-level faults
- Continuous data
- Requires formal model of controller, possibly plant, in specific control language

Fault Diagnosis Through Automatic Model Generation

- Goal: diagnosis of system level event-based faults in mfg systems without use of pre-existing formal model
- Approach: generate models based on training data; detect and diagnose based on certainty, performance of models



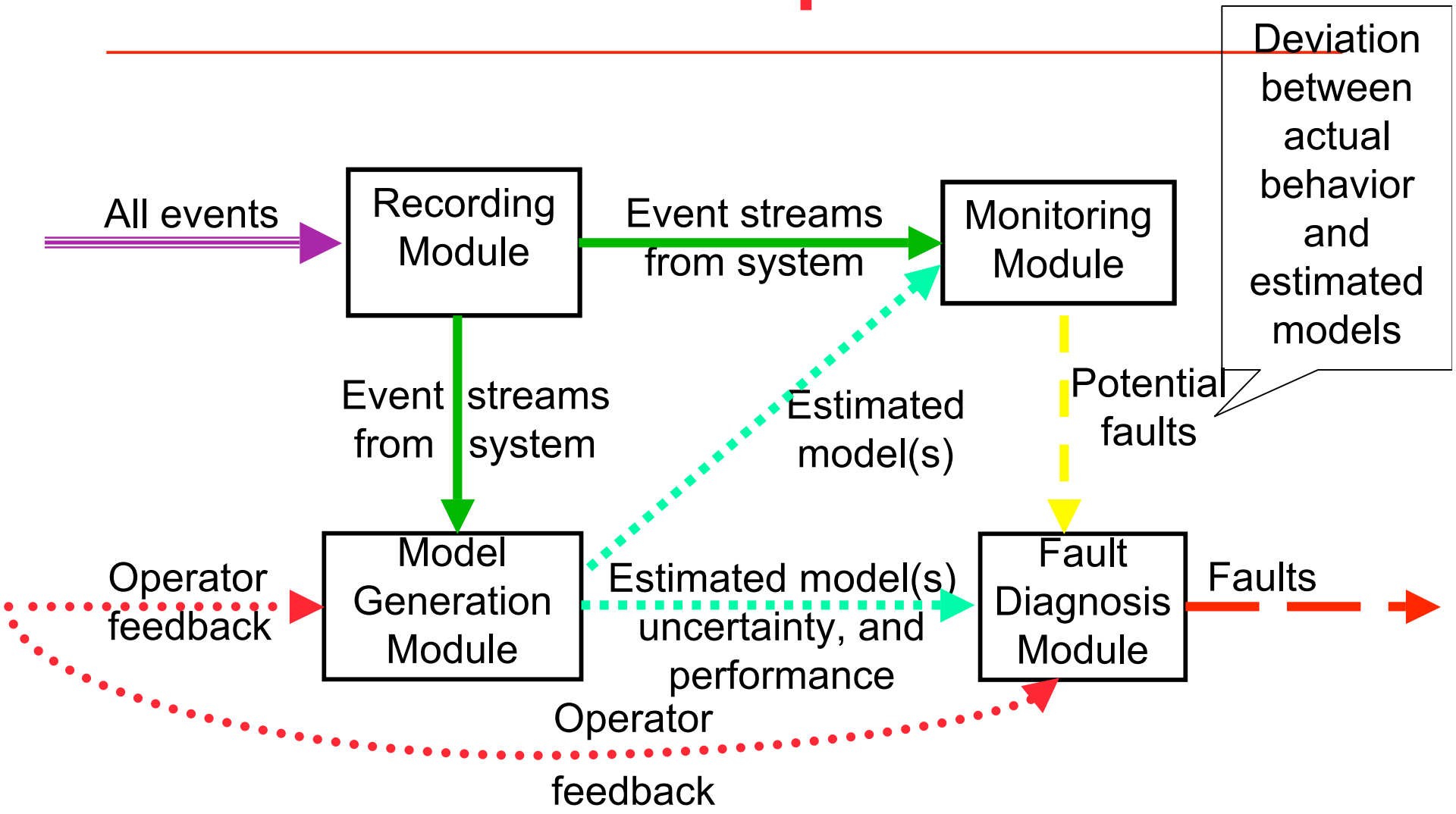
- Industry benefits
  - Reduced downtime through quicker fault diagnosis
  - Does not interfere with system operation

Solution Concept: Fault Diagnosis Using Model Generation

- Domain of applicability
  - Faults: evident in stream of the process' events
  - Processes: modular sub-processes that interact through shared resources which can be created and/or used
- Input: streams of process' events, labeling of some streams (fault or no fault)
- Output: detection of anomalous streams -- faults

Part1	Part1	PartReady
PartReady	PartReady	ReleasePallet
LoadPart1	LoadPart2	Part1
…	…	…

Solution Concept: Modules



Deliverables

- Method to detect anomalies (possible faults) in event data without a pre-existing formal model
- Demo #1: Apply fault diagnosis approach to industry data off-line
- Demo #2: Apply fault diagnosis approach to industry plant on-line

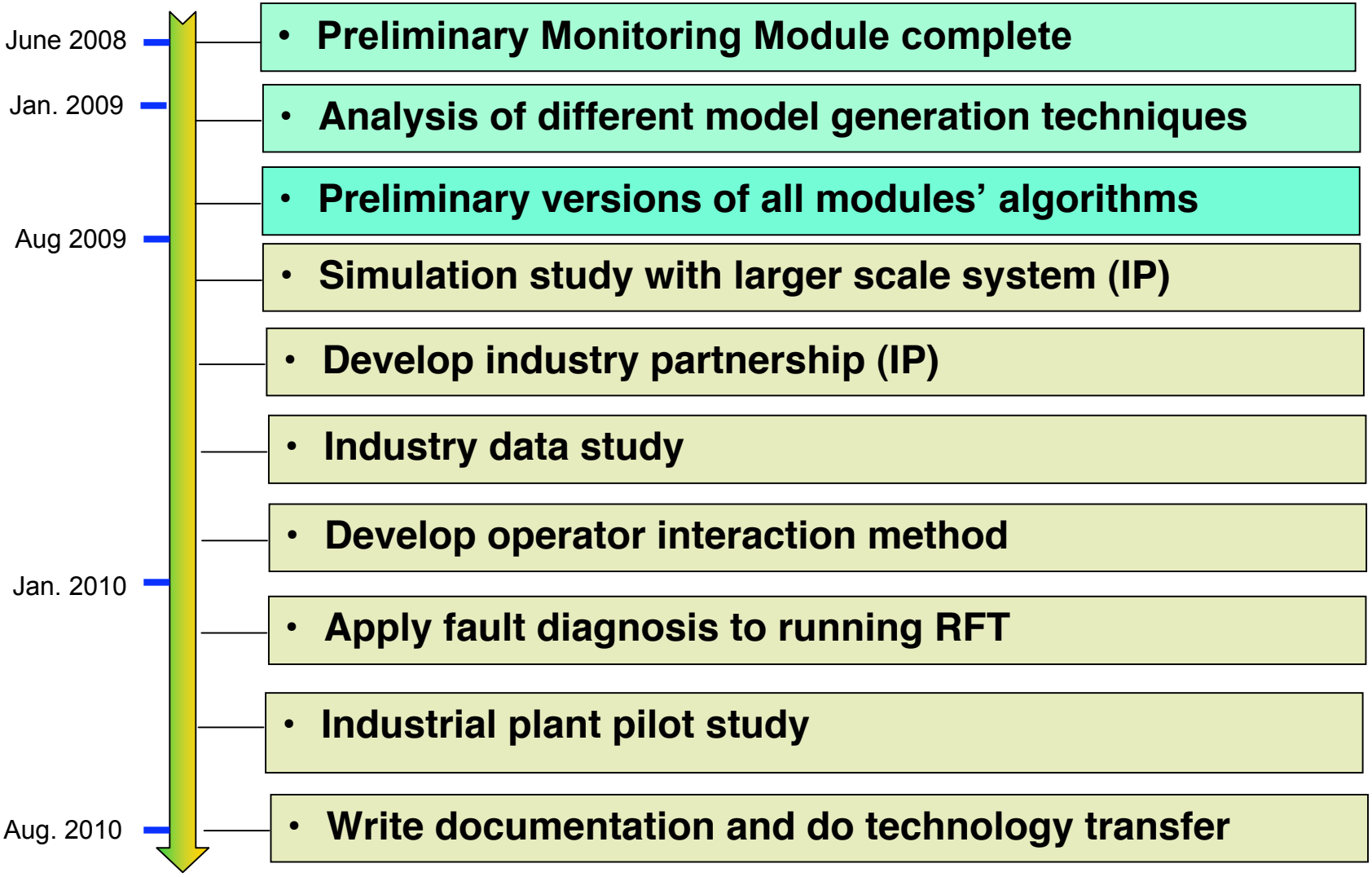
Event Data Used in Fault Diagnosis

- Events: passed among controllers, commands from controllers, responses from machines
- Event stream: continuous sequence
- Examples
  - OPC tags
  - ActivPlant
  - CIMplicity

Industry Involvement

- What we need from industry
  - Event data from industry plant
  - Feedback from operator on anomaly identification interaction
  - Partnership with industry for on-line pilot study
- Benefits to industry
  - Influence on fault diagnosis project develops
  - Event-based fault diagnosis is possible for mfg systems without using pre-existing model
  - Reduced downtime through quicker fault diagnosis
  - Does not interfere with system operation

Milestones and Future Plans



New Issues

- Decide which events to include in model
  - Most important
  - Low-level, high-level
- Multiple-bit-change (MBC) events
  - Example: Wait Aux high, Starved high, same scan
  - Make unique event or split into sequential events
  - Local decision based on local relationships