A New Approach on CPS-Based Scheduling and WIP Control in Process Industries

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Background

- Diversification of consumer’s needs
- Global competitiveness

Manufacturers have to manage
- wide variety of products
- in various quantities
- within short delivery lead time

Small amounts, wide variety of products are still produced with human interaction in shop floor
- complexity of the process flow
- huge investment in plant and equipment
Difficulties on flexible automation

- Difficult implementation of a "top down"-structured control system in huge and complicated shop floor with unreliable facilities
- Delay of processing and customer order changing happen quite often

It is difficult to realise robust WIP control at the planning phase and frequent re-scheduling is needed

Human interactions in shop floor level are always required to keep autonomous WIP control including material handling system without any estimation
Objective of the study

- Propose CPS based scheduling method for robust WIP control in dynamic environment which can
  - be applied also into operational phase
  - respond flexibly and automatically to internal dynamic situations such as delay of processing
  - follow the variation of external dynamic conditions adaptively, such as demand fluctuation or due date change
Real-Virtual Integrated Scheduling System

Simulation on virtual system to predict and reconfigure parameters

Real-time scheduling to control real system

Scheduling logic
- Real-time Scheduling
- Reactive Scheduling etc.

Modification of Method and/or Parameter

Virtual System
- Computer Simulation
  - Uncertainty Component (Virtual)

Real System
- Actual Plant
  - Uncertainty Component (Real)

Feedback fluctuation conditions
- Variation of processing time
- Increasing/decreasing of demands

External Fluctuation
- (Virtual)
- (Real)

Feed back fluctuation conditions

Cyber

Physical

Prediction Results
- Simulation Command
- Operational Command

Actual Results

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Auction based scheduling method

- Advantage of the auction-based scheduling method
  - Flexibility of being applicable to many cases by configuring the selection of items, bidders and bids
  - Simple and fast algorithm which selects the most suitable winner on the current status

- It is suitable for real-time scheduling under the frequently changing situation
Proposed control mechanism for real-time scheduling and simulation

- Integrate two systems transparently
- Execute the real-time scheduling and simulation using the same system models and processing algorithms
Experimental Environment for Scheduling System

- **Software Emulator**
  - Experiment can be done under the limited situation assumed by the researcher

- **Experimental Model Plant**
  - Scheduling system is connected to actual hardware
  - System can be examined more practically under the possible situations of the actual equipment

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Real-time scheduler

Scheduling logic

Software emulator

Experimental model plant

Actual plant

(a) Virtual experiment

(b) Real experiment

(c) Real manufacturing operation

Operational command

Operational result

Condition changing
Overview
Conclusions

- Scheduling method using combination of auction-type real-time scheduling and simulation has been proposed for automated process industry
- Control mechanism for the scheduler, auction algorithm for the real-time scheduling and the method of simulation predicting the changing situation of the shop are investigated
- The proposed system is effective to automate the scheduling and respond flexibly under dynamic environment
- Implementation is now ongoing into pilot shop floors