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Predictive, Dynamic and Stochastic Production Scheduling: An Overview

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Outline

- Introduction
- Dynamic and Stochastic Scheduling in Ceramic Tile Industry.
- Predictive, Dynamic and Stochastic Production: an overview.
- Remarks and ongoing work. Dynamic Production Planning/Scheduling Platform.

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Introduction

A major challenge for today's manufacturing organizations is…

… how to respond agilely and cost-effectively to <u>events</u> in a dynamic and stochastic system.

- *Fast changes of customers' needs and demands*
  - Urgent Job Arrival
  - Job cancellation
  - Due date change
  - Change in Job Priority
- *Supplier's faults*
  - Delay in Arrival
- *Failures in machines*
- *Operator Absenteeism*
- *Over or under estimation of processing time*
- *Rework or Quality Problems*
- *…*

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Introduction

So a manufacturing system is dynamic and frequently unexpected events occur…

Rescheduling is necessary to update a production schedule when the planned state of manufacturing system is disrupted.

More than 300 contributions on this field have been revised, trying to summarize the main approaches to the dynamic stochastic scheduling problem.

*The interest of dynamic stochastic scheduling in **tile** industries will be justified*

A platform based in Multi-agent approach is proposed

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Dynamic and Stochastic Scheduling in Ceramic Tile Industry

- Production Management in a Ceramic Tile Industry is a process under uncertainty in the terms expressed by Galbraith (1973). This uncertainty has the source in the environment and in the own process too, according to Ho (1989).
  - Environment uncertainty in ceramic tile industry is mainly due to changes in the demand.
  - System uncertainly, related directly to the production process of ceramic tile, are changes in:
    - The Quality of the product
    - Finish job dates at every stage (due to setup and process time changes).
  - Other uncertainties like machine breakdown, resources variations, etc. are similar in other production systems.

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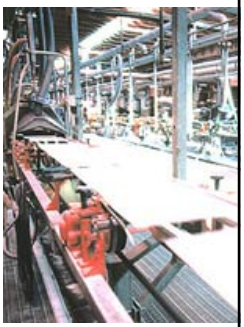
Dynamic and Stochastic Scheduling in Ceramic Tile Industry

- The tile enterprises suffer big quantities of stocks of w.i.p. and final products...
  - ... because they try to reduce the impact of the producer uncertainties in the customer by means of high quantity of available final product.
- To reduce the uncertainty...
  - ... traditional sheduling approaches
  - ... improvements in control mechanisms
  - ... improvements in product design
  - ... improvements in quality control
  - ...improvements in raw materials quality



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Dynamic and Stochastic Scheduling in Ceramic Tile Industry

Our proposal tries to...

...identify the uncertainties in order to palliate its effects.

...consider the continuous arriving of jobs during the execution of a productions program as events that convert the problem in a Dynamic Problem

...define an approach to cope these aspects using an multi agent system (MAS) based approach.

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Dynamic and Stochastic scheduling: an overview

- Certainty: when the model is known with precision.
- Uncertainty: is the difference between the amount of information needed to execute a task with precision and the information actually available in a organization (Galbraith, 73).
- This lack of precision could belong to two categories (Zimmermann, 96):
  - Stochastic uncertainty (random)
  - Fuzziness (the quality of being indistinct and without sharp outlines)

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Stochastic Uncertainty...

Causes of uncertainty (Vieira, Herrmann, and Lin, 03) show a set of references classified according to a type of event in the productions system:

- Machine failure,
- Urgent or emergent jobs
- Cancel jobs
- Supplier delays
- Quality problems

...

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Dynamic...

Aspects to be afforded in a problem related to the time:

Rescheduling environments (Vieira, Herrmann and Lin 2003) :

In a static problem, events, priorities, resources, needs and requirements are finite.

Deterministic: All information is known before start time

Stochastic: Uncertainty

Meanwhile a dynamic problem models a volatile environment that needs often changes in order to adapt to requirements (Stankovic, Spuri, Marco, and Buttazzo, 95;Suresh and Chaudhuri, 93).

Cyclic scheduling

Arrival variability

Process flow variability

Rescheduling strategies:

Predictive-reactive scheduling. (Yamamoto and Nof): Planning Phase, Control Phase, Rescheduling Phase

Pure reactive (non schedule).

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Rescheduling Policies in a Predictive-Reactive Strategy

Predictive-reactive scheduling is a common dynamic scheduling approach used in manufacturing systems.

But we must specify when system revision decisions are made.

There are three alternatives:

- periodic, reschedules the facility periodically.
- event-driven, rescheduling can happen repeatedly in dynamic environments or a single event can revise a schedule in a static system.
- Hybrid, reschedules the system periodically and also when special (or major) events take place.

Periodic and hibrid rescheduling have recived special attention under the concept of "Rolling Time Horizon" or temporal space re-periodification. (Muhlemann et al. 82;Adam et al. 80;Ovacik et al. 94;Shafaei et al. 99b;Shafaei et al. 99a;Sun and Lin, 94;Singer, 00;Qi, Burns, and Harrison, 00;Chen et al. 03a) are some of highlighted references in which the Rolling Time Horizon is applied.

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Rescheduling methods

- There is a tradeoff between nervousness and stability
- Methods:
  - Robust schedule generation: Attempt to maintain good system performance with simple schedule adjustments.
  - Schedule repair
    - The right-shift technique (Sadeh et al. 93;Leon et al. 94;Efstathiou, 96;Brandimarte Rigodanza, and Roero, 97;Abumaizar et al. 97) is a heuristic that move the full sequence towards the future until the event is overcome in the time.
    - The matchup technique (Bean, Birge, Mittenthal, and Noon, 91) needs to match the old and the new sequence in the time.
    - Affected Operation Rescheduling (AOR) (Leon et al. 94;Hasle and Smith, 94) is a heuristic that modify only the operations affected by some event.

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Some results

- (Cowling and Johansson, 02a;Vieira et al. 03) : repaired and full rescheduling proceeding
- (Wu et al. 91;Wu et al. 93;Daniels et al. 95;Abumaizar et al. 97;Jensen, 01) carried out several studies using robustness, efficency and stability parameters simultaneously in order to decide about the best rescheduling technique.
- In (Abumaizar et al. 97) was concluded that reparation of a production program was the most extended technique in practice and the full rescheduling was used in a few times.
- (Sabuncuoglu et al. 00) showed the powerful of reparation technique in terms of stability of a production program.
- (Yamamoto et al. 85) carried out a study by means of full rescheduling in a floor-shop with stochastic events in machines.
- ...
- (Vieira et Al 2003): Rescheduling policy needs to be considered in system design. However existing models provide little support for rescheduling.

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Methods and Algorithms in a Predictive-Reactive Strategy

Heuristics (right-shift, matchup, affected operation rescheduling (AOR),...).

Systems based on knowledge and Artificial intelligence (programming based on cases reasoning, programming based on restrictions, programming based on fuzzy logic, neuronal networks,...)

Multi-agent systems ...

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Dynamic Production Planning/Scheduling Platform

In the ceramic tile industry the master plan is normally used as the major input data to generate the production scheduling. Nowadays, this generation process is characterized by:

(i) *Weak automatization*, where a large number of schedules are static and each of them is a simple manual conversion from the master plan;

(ii) *Not reactive*, where scheduling systems do not face the set of several events happening in a period (break down, supplier fault, environmental impacts such as humidity, temperature, etc.);

(iii) *Not Distributed*, as schedules are executed on a single, centralized computer;

(iv) *Myopic*, as models are based on one simple objective function.

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Dynamic Production Planning/Scheduling Platform

Our way to modularize a complex system is in terms of multiple autonomous components that act and interact in flexible ways to achieve their objectives (AGENTS).

We have chosen the multi agent oriented approach because provides rapid responsive and dynamic reconfigurable structures to facilitate flexible and efficient use of manufacturing resources in a rapidly changing environment (Maturana and Norrie,1996)

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Dynamic Production Planning/Scheduling Platform

Such agents will not have all data or all methods available to achieve an objective (this can be referred to as "limited viewpoint") and thus will have to collaborate with other agents. There may be little or no global control.

Regarding the ceramic tile manufacturing system, a multi-agent system (MAS) can be used to achieve dynamically integrated production programs.

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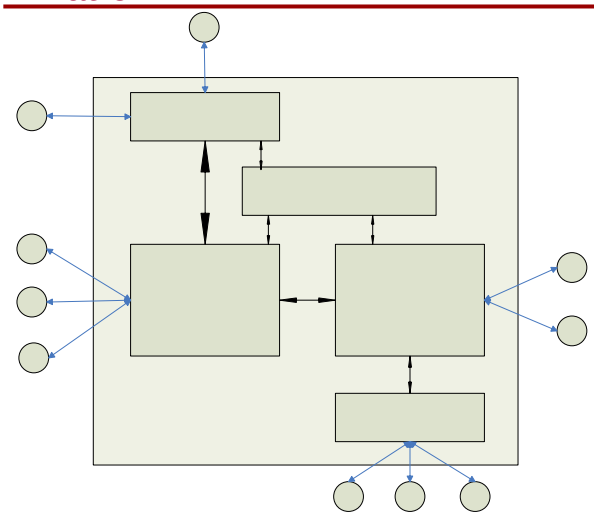
Dynamic Production Planning/Scheduling Platform



Each module represents specific functionalities which all together implement the entire manufacturing system.

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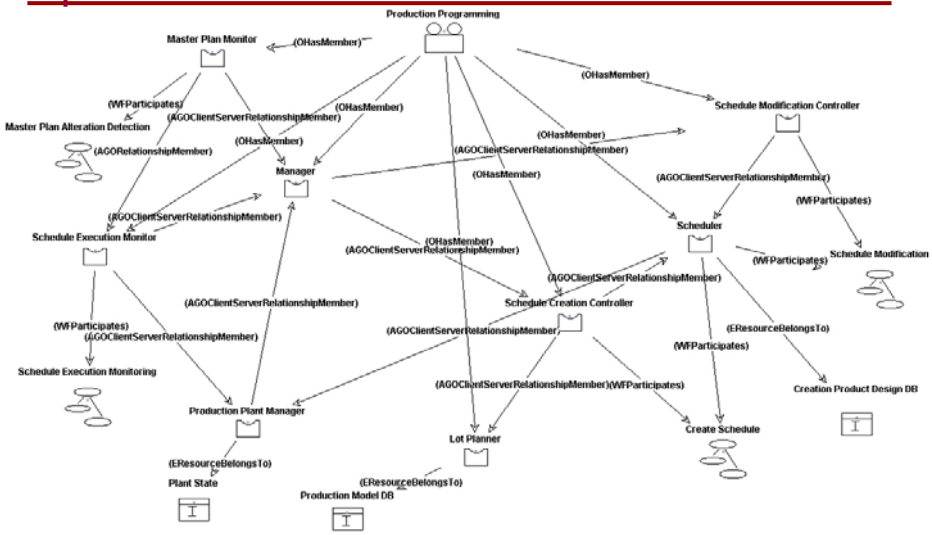
Organization model for the scheduling process



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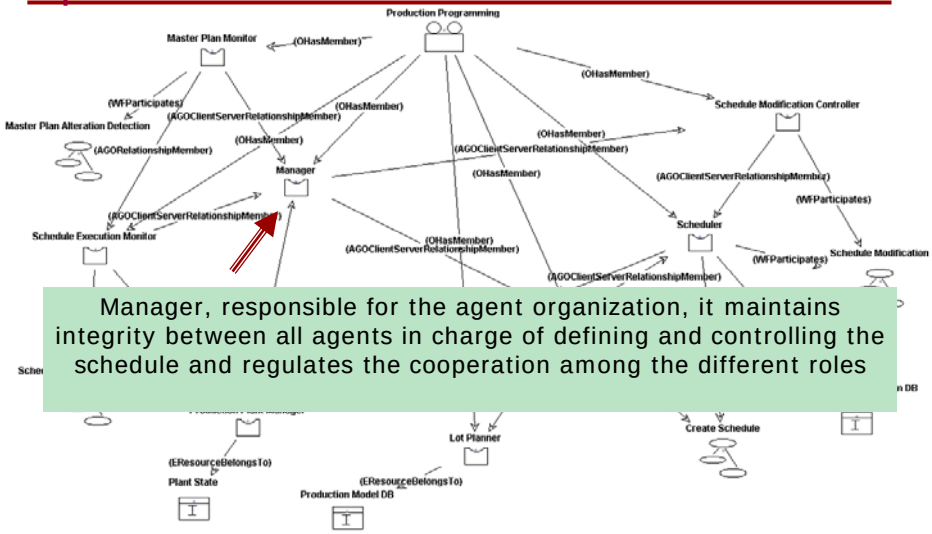
Organization model for the scheduling process



Manager, responsible for the agent organization, it maintains integrity between all agents in charge of defining and controlling the schedule and regulates the cooperation among the different roles

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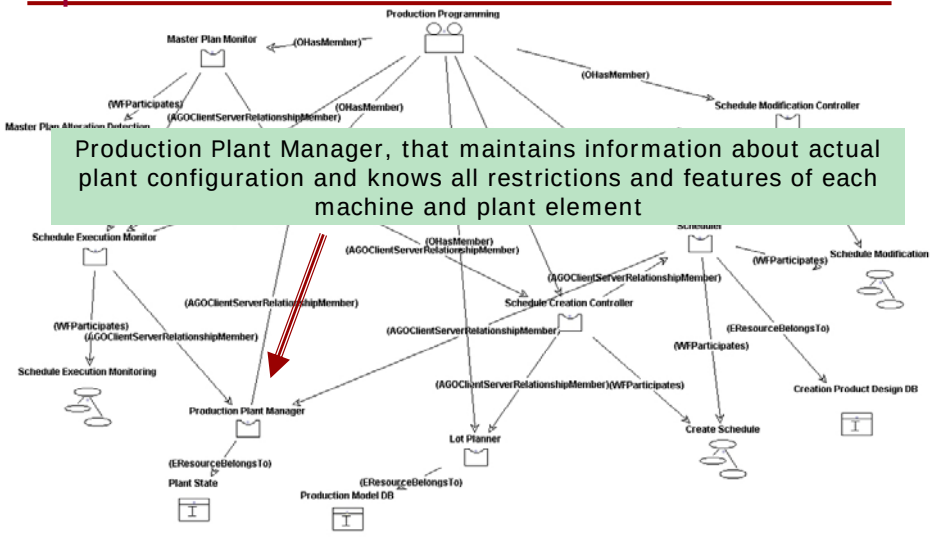
Organization model for the scheduling process



Production Plant Manager, that maintains information about actual plant configuration and knows all restrictions and features of each machine and plant element

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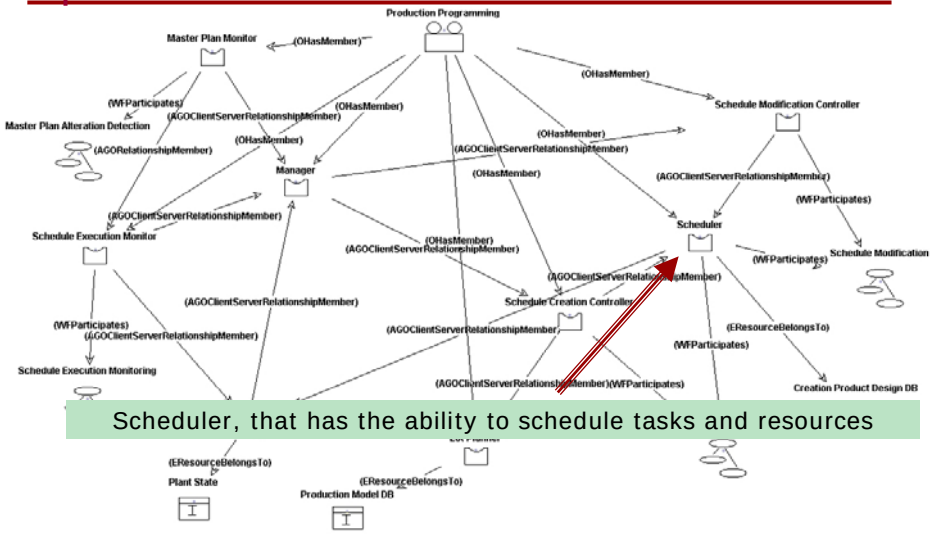
Organization model for the scheduling process



Scheduler, that has the ability to schedule tasks and resources

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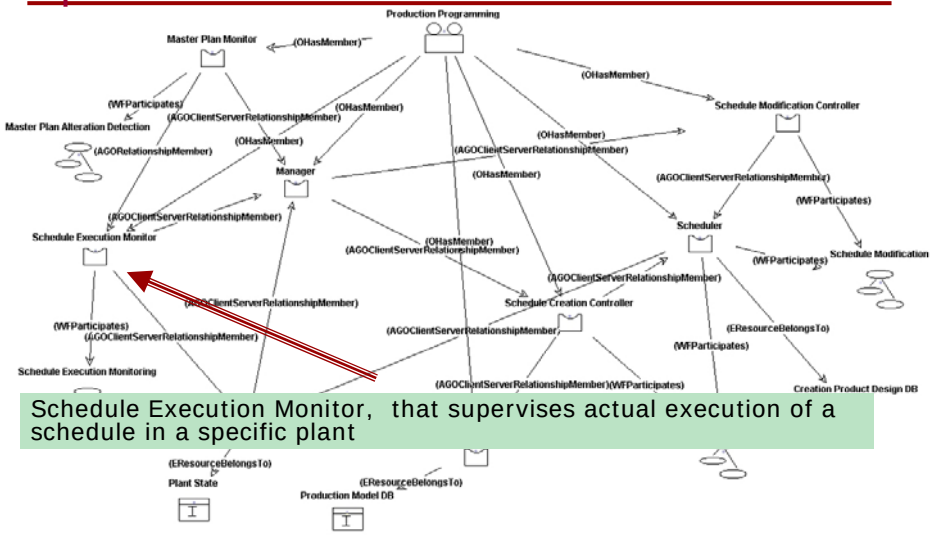
Organization model for the scheduling process



Schedule Execution Monitor, that supervises actual execution of a schedule in a specific plant

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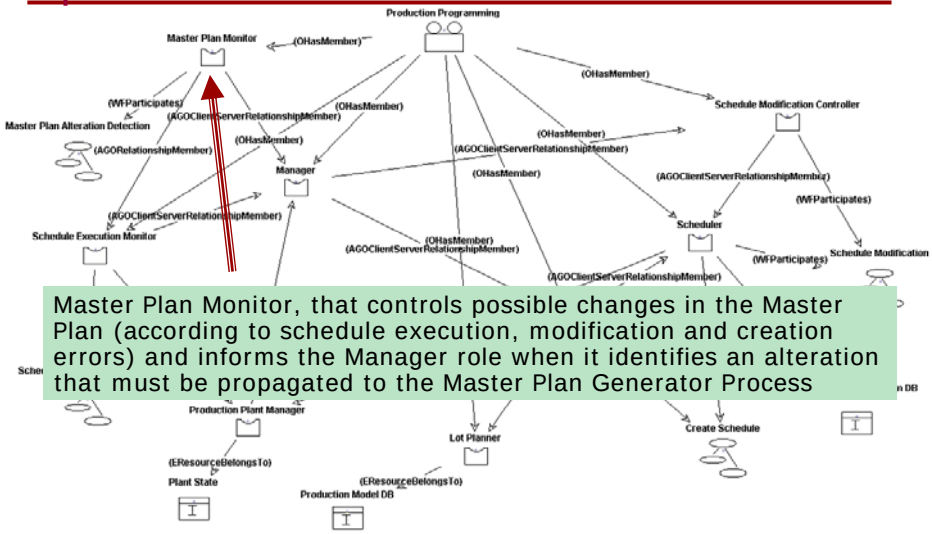
Organization model for the scheduling process



Master Plan Monitor, that controls possible changes in the Master Plan (according to schedule execution, modification and creation errors) and informs the Manager role when it identifies an alteration that must be propagated to the Master Plan Generator Process

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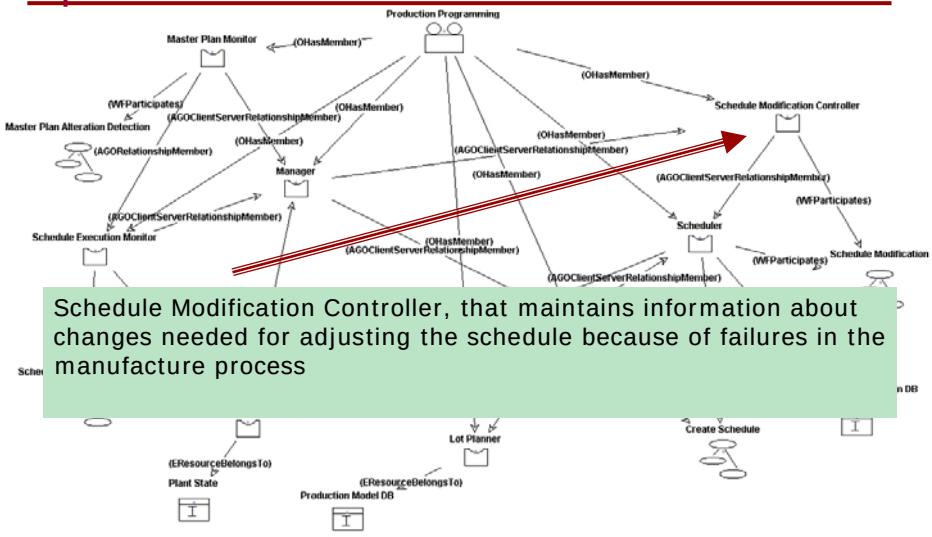
Organization model for the scheduling process



Schedule Modification Controller, that maintains information about changes needed for adjusting the schedule because of failures in the manufacture process

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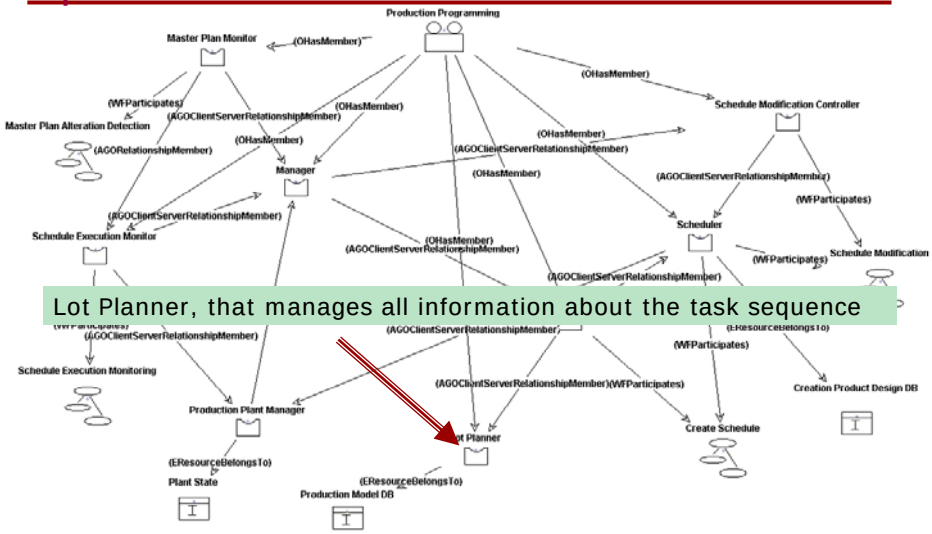
Organization model for the scheduling process



Lot Planner, that manages all information about the task sequence

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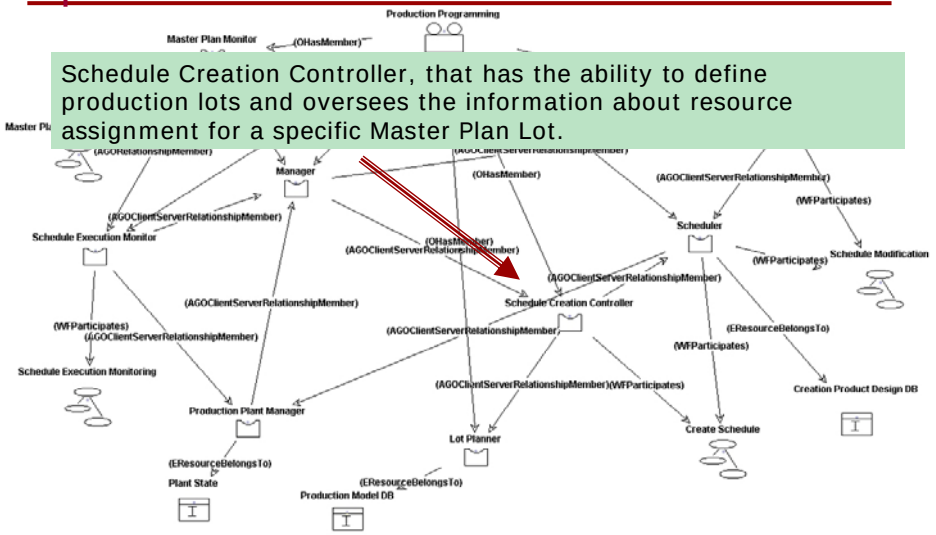
Organization model for the scheduling process

Schedule Creation Controller, that has the ability to define production lots and oversees the information about resource assignment for a specific Master Plan Lot.



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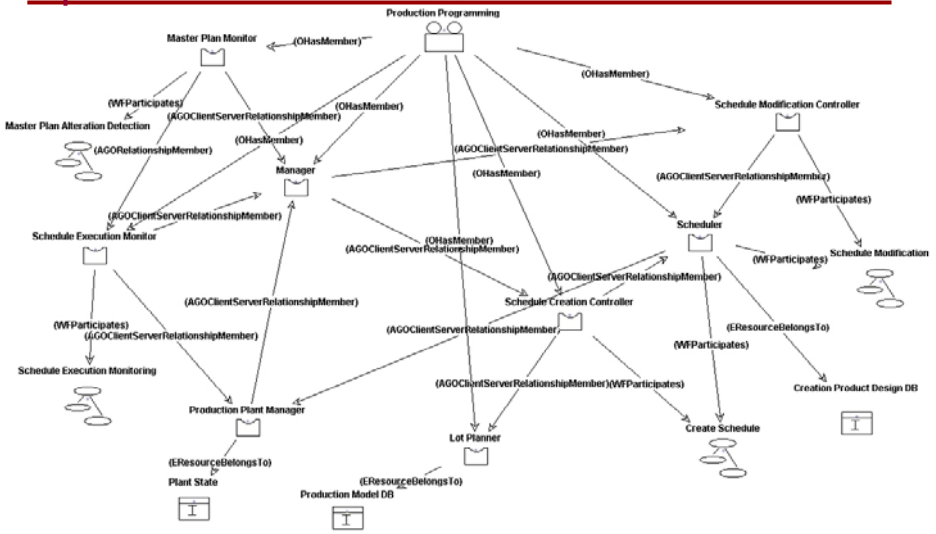
Organization model for the scheduling process



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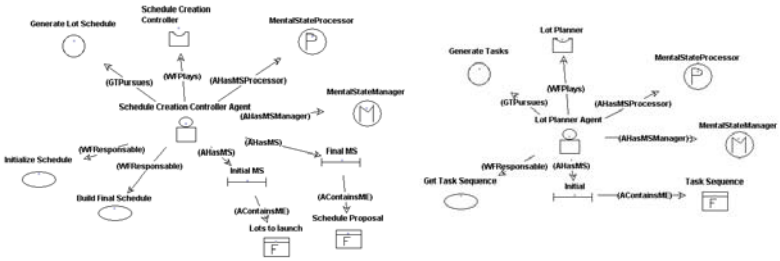
Agents



- Regarding agent models, a specific agent has been assigned to each role identified in the organization model. For each agent, its goals, tasks and mental states have to be associated.
  - The Schedule Creation Controller agent is in charge of generating a new lot schedule, so it has to initialize the schedule and then build a final proposal.
  - The Lot Planner agent provides the task sequence for a specific lot.

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Scheduler

In the scheduler two main agents has been defined:

Jobs

Machines and other resources

Each agent has its goals and includes three components:

- The knowledge base consists of the domain knowledge and needed data.
- The functional component consists of computational procedures for decision-making.
- The control unit consists of protocols that provide the mechanism for agents to communicate with each other. The protocols of all agents together constitute the system coordination approach.

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Job agent

- A Job Agent communicates with Machine Agents and makes routing decision by selecting a machine for each operation.
- A Job Agent maintains a list of machines for each operation. It also has the following knowledge to formulate a bid in the Machine Agent:
  - the number of uncompleted operations,
  - the remaining processing time of an operation that is currently processing on the machine,
  - the priority of the job
  - the uncompleted processing time of a job.
  - ...
- The data contained in Job Agent knowledge base consists of the job ID, due date, release time, earliness cost, tardiness cost, and process planning of each job.

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Machine agent (resource)

- Each machine is represented by an Agent. Every Machine Agent is responsible for the decisions related to job sequencing.
- A Machine Agent has the knowledge of its status (idle or busy), queuing jobs, number of finished tasks and total machine busy time. The data contained in Machine Agent knowledge base consists of the machine ID, machine type, machine capabilities, cost of each machine...

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Ongoing work

- At the present a prototype of the scheduler is beeing developed using JADE* for a small hybrid flowshop (three stages 4-2-3) with 40 jobs and integrating it to the other parts of the platform.
- Simulation studies will be carry out to compare the robustness of the system with the existing approaches

*http://jade.tilab.com/

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Remarks

A great deal of effort has been spent developing methods to generate optimal production schedules.

Typically, such papers formulate scheduling combinatorial optimization problems. However, the number of papers on rescheduling is lower than the static problem.

This presentation has reviewed some basic concepts needed in dynamic and stochastic systems and necessity to do more research in thi field.

MAS implementation to shceduling problems are scarce.

A Dynamic Production Planning/Scheduling Platform based in multi-agent philosophy has been defined.

We are working in developing the parts of the MAS and their integration.

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Thanks for your attention