Scheduling the Supply Chain by Teams of Agents

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Overview

• Scheduling
• Supply Chain Management
• Supply Chain Scheduling Tasks
• Teams of Agents
• Application Framework
• Conclusions
Scheduling

\[ f(\text{R}, \text{P}, \text{O}, \text{HC}, \text{SC}, \text{E}, \text{G}, \text{PL}) \rightarrow \text{PL} \]

- \text{R}: Resources,
- \text{P}: Products,
- \text{O}: Orders
- \text{HC}: Hard Constraints
- \text{SC}: Soft Constraints
- \text{E}: Events
- \text{G}: Goal functions
- \text{PL}: Schedule (Plan) [valid, consistent, optimal]

Predictive, reactive, interactive tasks
Supply Chains, SCM

- Supply Chain: network of organizations involved in producing products or services: from raw material to retailer

- Supply Chain Management: coordinated cooperation of independent organizations to achieve competitiveness
# Supply Chain Scheduling

<table>
<thead>
<tr>
<th>Tasks</th>
<th>source</th>
<th>make</th>
<th>deliver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic</td>
<td></td>
<td></td>
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<tr>
<td>Tactical</td>
<td></td>
<td></td>
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<tr>
<td>Operational</td>
<td>Supply Chain Scheduling</td>
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## Decisions
- purchase, transportation, production, storage, inventory, coordination
Supply Chain Scheduling Problems
Example: Euro Coins

Federal Bank

Ronds, coin blanks

Mints

Central Banks

Security Transport

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Supply Chain Scheduling: Challenges I

- different production sites, transportation, storage
- **global scheduling**: distribution of orders to production sites including transport, suppliers, storage => supply chain
  - complex interdependencies between the production processes performed in different plants (precedence relations, preferences, different costs, alternatives)
  - information is cumulative and not precise (e.g. durations, capacities), using all details is not manageable
- **predictive and reactive scheduling**: regarding all the events on the different levels
Supply Chain Scheduling: Challenges II

- integration of local scheduling (already existing on plant level)
- new scheduling tasks: transportation/ storage scheduling
- coordination: scheduling activities on two or more levels have to be coordinated, esp. in the case of events affecting each other
- different goals
  - on the global level, e.g. meeting due dates, early detection of capacity problems
  - on the local level, e.g. optimize machine utilization or work in progress times
Global and Local Scheduling

Production Sites
- Site A
  - Machines: A1, A2, A3
  - ZP1
- Site B
  - Machines: B1, B2
  - ZP2
- Site C
  - Machines: C1
  - ZP3

Global Scheduler

Global Level

Local Level

Machines
- Site A
  - A1, A2, A3
  - Time: t0, t1
- Site C
  - C1
  - Time: t3

Vehicles
- Transportation
  - Time: t1, t2

Site A
- Machines
  - A1, A2, A3
  - Time: t0, t1
## Modeling Scheduling Tasks

<table>
<thead>
<tr>
<th></th>
<th>Global Scheduling</th>
<th>Transportation Scheduling</th>
<th>Storage Scheduling</th>
<th>Local Scheduling</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resources</strong></td>
<td>groups of resources, single plants</td>
<td>transportation vehicles</td>
<td>storage facilities</td>
<td>machines</td>
</tr>
<tr>
<td><strong>Products</strong></td>
<td>final products consisting of several intermediate products</td>
<td>transport of products using specific transportation vehicles</td>
<td>intermediate products, raw materials</td>
<td>intermediate products consisting of several production steps (operations)</td>
</tr>
<tr>
<td><strong>Orders</strong></td>
<td>external orders for final products</td>
<td>internal orders for transportation of intermediates</td>
<td>internal orders for storage of intermediate products</td>
<td>internal orders for intermediates</td>
</tr>
<tr>
<td><strong>Hard Constraints</strong></td>
<td>schedule all external orders, regard production requirements (one variant, precedence constraints, capacity)</td>
<td>schedule all orders, regard technical requirements (type of vehicle, transport capacity)</td>
<td>schedule all orders, regard storage requirements (place, type of facility, maximum duration)</td>
<td>schedule all orders, regard production requirements (one variant, precedence constraints)</td>
</tr>
<tr>
<td><strong>Soft Constraints</strong></td>
<td>meet due date, minimize transportation times/ costs, reduce inventory costs.</td>
<td>meet due dates, &quot;optimal&quot; vehicle utilization, minimize costs.</td>
<td>minimize inventory costs.</td>
<td>&quot;optimal&quot; machine utilization, meet due dates, minimize work-in-process</td>
</tr>
<tr>
<td><strong>Events</strong></td>
<td>global events, e.g. breakdown of machine groups</td>
<td>transport events, e.g. traffic delay</td>
<td>global events, e.g. capacity problems</td>
<td>local events, e.g. machine breakdowns</td>
</tr>
<tr>
<td><strong>Goals</strong></td>
<td>global goals, e.g. meet delivery dates</td>
<td>transportation goals, e.g. minimize costs</td>
<td>local goals, e.g. minimal costs</td>
<td>local goals, e.g. optimal machine utilization</td>
</tr>
</tbody>
</table>
## Multi-Site Scheduling: Communication

### LOGISTICS --> GLOBAL
- new/ changed orders
- other events (e.g. capacity changes)

### GLOBAL --> LOCAL
- global schedule
  - order
  - product
  - intermediate to be produced
  - machine group or plant to be used
  - time window for production in local plant
  - amount of intermediate
- precedence relations to preceding/ following intermediates
- rescheduling information (in the case the order has been replaced)
- events

### LOCAL --> GLOBAL
- local realization
  - order
  - product
  - intermediate to be produced
  - scheduled time interval
  - machine group to be used
- events (e.g. breakdowns)
- (proposal for rescheduling)

### SHOP FLOOR <-- LOCAL
- local schedule
- events (e.g. breakdowns)
Agents

- Agent = Software system with:
  - **autonomy**: operates without direct interference by other systems, has control over its behavior and its internal state
  - **social capabilities**: agents behave and interact with other agents
  - **reactivity**: perceive their environment and react to changes
  - **proactivity**: capable of taking the initiative in a goal-directed fashion
  - **intelligence**: problem solving knowledge -> intelligent agent

- Multi-Agent System
  - set of communicating agents

- Problems
  - communication overhead
  - integration of user
  - local vs. global goals
  - control paradigm
Supply Chain Scheduling: Concept I

- Coordinated scheduling on different hierarchical levels
- Business units/ resources represented by scheduling agents
- Teams of agents solving scheduling tasks
- Each agent has specific scheduling knowledge
- Communication via contract net, direct communication or blackboard
Supply Chain Scheduling: Concept II

Supply Chain

Enterprise

Plant

Area

Resource Group

Resource

Material Flow

Scheduling Orders

Scheduling Agent / Business Entity

Supply Hierarchy
Teams of Agents

Definition:
Group of agents working together to solve a specific Problem

Advantages:
- Reduce communication overhead
- Design control loops
- Similarity to business structures
- Component based development
- Reduce complexity
- Different communication models within one system
Supply Chain Scheduling: Concept III

Supply Chain

Enterprise

Team1

Plant

Team2

Area

Resource Group

Resource

Material Flow

Scheduling Orders

Team3

Scheduling Agent/ Business Entity
Process Model

1. Analysis of real world scenario
2. Mapping business units/ resources to agents
3. Adding associations and teams
4. Design of agents
5. Select agent platform
6. Implement agents
7. Integrate agents
8. Test
Steps 1 & 2: Mapping
Step 3: Teams (1) – Global Team
Step 3: Teams (2)
Step 4: Agent Template

1. Agents Name
2. Agents represents:
   (focal company, machine group, ...)
3. Responsibility:
   (global scheduling, coordination, ...)
4. Team: to which team it belongs
5. Scheduling tasks
   (global schedule, transportation schedule, ...)
6. Scheduling knowledge
   (view on database, specialized algorithms, ...)
7. Scheduling strategy
   (EDD, avoid bottlenecks, ...)
8. Cooperation: which kind of cooperation with which partners
# Step 5: Scheduling Methods

<table>
<thead>
<tr>
<th>Task</th>
<th>Methods investigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Scheduling</td>
<td>Heuristics, Constraints, Genetic Algorithms, Fuzzy-Logic</td>
</tr>
<tr>
<td>Global Reactive Scheduling</td>
<td>Interactive, Heuristics, Genetic Algorithms, Constraints</td>
</tr>
<tr>
<td>Local Predictive Scheduling</td>
<td>Constraints, Heuristics, Genetic Algorithms, OR-Systems, Iterative Improvement (SA, TA, Grand Deluge), Neural Networks</td>
</tr>
<tr>
<td>Local Reactive Scheduling</td>
<td>Interactive, Heuristics, Constraints, Multi-Agent Systems</td>
</tr>
<tr>
<td>Transportation Scheduling</td>
<td>Heuristics, Constraints, OR-Systems</td>
</tr>
<tr>
<td>Storage Scheduling</td>
<td>Heuristics, OR-Systems</td>
</tr>
<tr>
<td>Coordination</td>
<td>Contract Net, Blackboard, (Direct, Indirect)</td>
</tr>
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</table>
Step 6, 7, 8: Agent Platform

- Framework for scheduling agents
- Agent core with frozen and hot spots
Agent Framework

Agent core: basic features e.g. event handling, integrating components
• Database interface (di): connection to a relational database
• Communication interface (ci): basic communication (message passing) between agents and human schedulers
• Scheduling component interface (si): integration of different scheduling components implementing scheduling strategies to be used
• Contract net interface (cni): basic features of the contract net protocol are provided
• Schedule improvement interface (ii): improvement strategies for the schedule can be incorporated

Database: a relational database system, e.g. Oracle or MySQL
Communication: Messages are packed and unpacked, events are generated
Scheduling: all kinds of scheduling strategies
Contract: extensions of the contract net protocol needed
Improvement: all kinds of improvement strategies
Step 6, 7, 8: Agent Platform

Agent core with frozen and hot spots

- **Main control cycle**

  IF new events THEN interrupt improvement AND event-handling
  IF idle THEN schedule improvement

  event-handling means:
  IF database request THEN call database interface
  IF scheduling task THEN call appropriate scheduling algorithm
  AND perform negotiation if necessary
Conclusion

Supply Chain Scheduling Approach

- Scheduling decisions on the operational level
- Resource based hierarchical ordering of agents
- On each level sufficient knowledge to make good scheduling decisions
- Hierarchical ordering and teams of agents to reduce communication

Realization

- Java-based framework for scheduling agents