Exploiting Data Mining techniques for improving the Efficiency of Agents for Supply Chain Management

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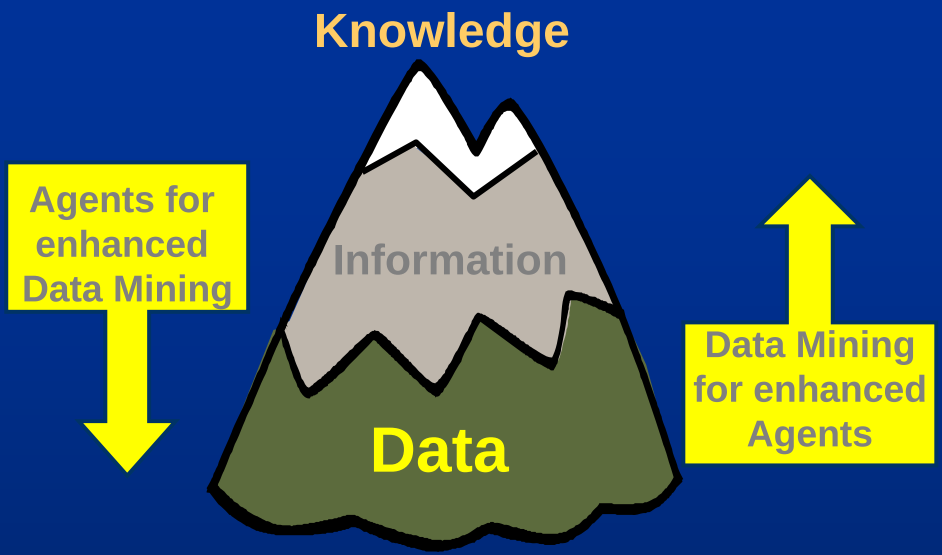
Agent Intelligence & Data Mining

Data Mining ⟷ Intelligent Agents

Merging Technologies

- Software agents have been repeatedly used for executing DM tasks
- DM results can be also **dynamically incorporated** to MAS



The inductive nature of DM and the lack of appropriate tools hinder the unflustered incorporation of knowledge to MAS

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Presentation Outline

- Agent Intelligence through Data Mining
- Agents for Supply Chain Management
- Trading Agent Competition
- Agent **MerTACor**
  - ✓ Architecture – Modules
  - ✓ Methodology
- Evaluation of **MerTACor**'s bidding mechanism
  - ✓ Pre-processing, Training, Meta-classification
  - ✓ Comparison to the fail-safe mechanism
  - ✓ Results – evaluation
- Conclusions

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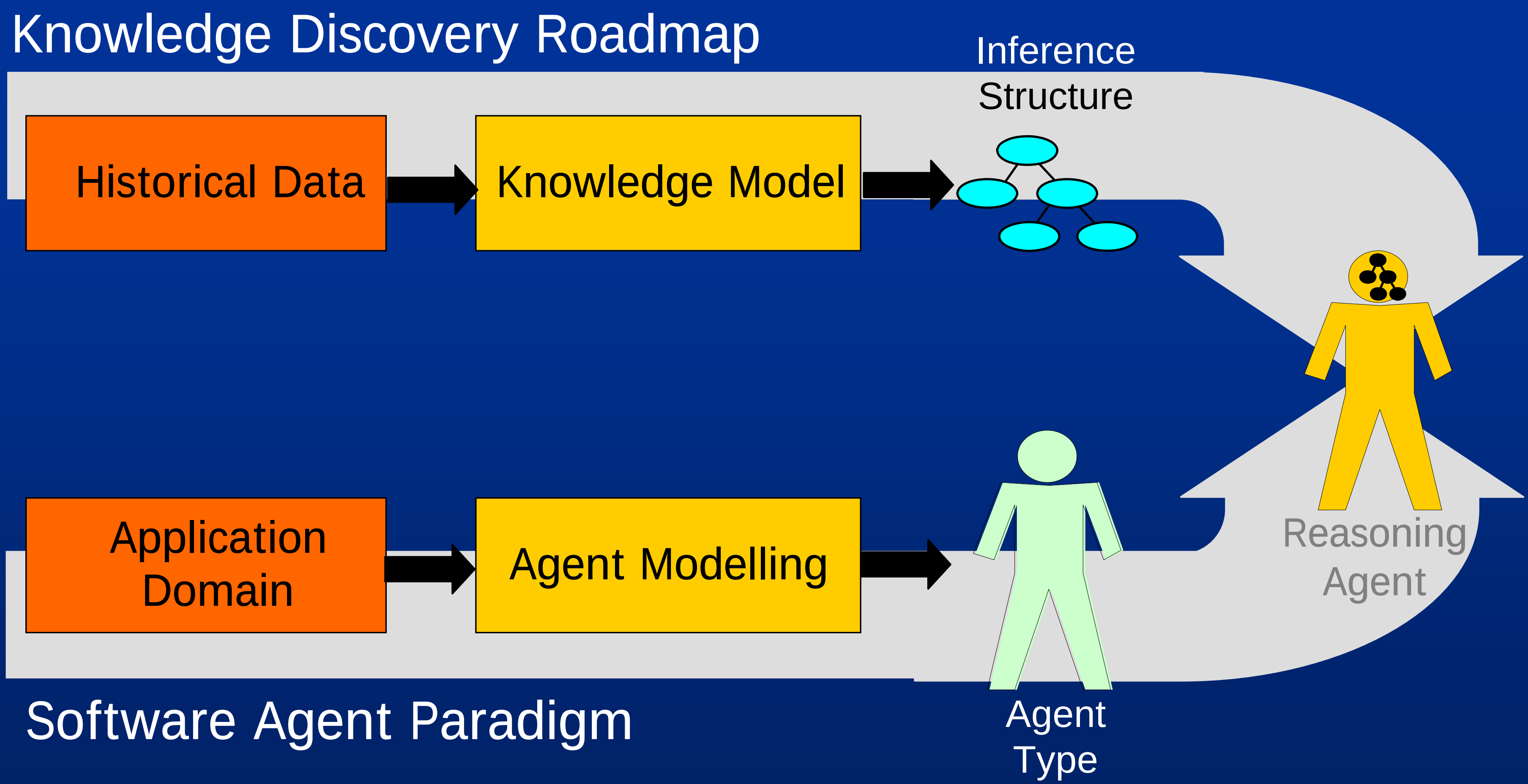
Agent Intelligence through Data Mining



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Definition of Agent Training

Agent Training: The process of **dynamically incorporating** DM-extracted knowledge models to SAs and MAS

Retraining: The process of **dynamically replacing** an agent's knowledge model with an enhanced one

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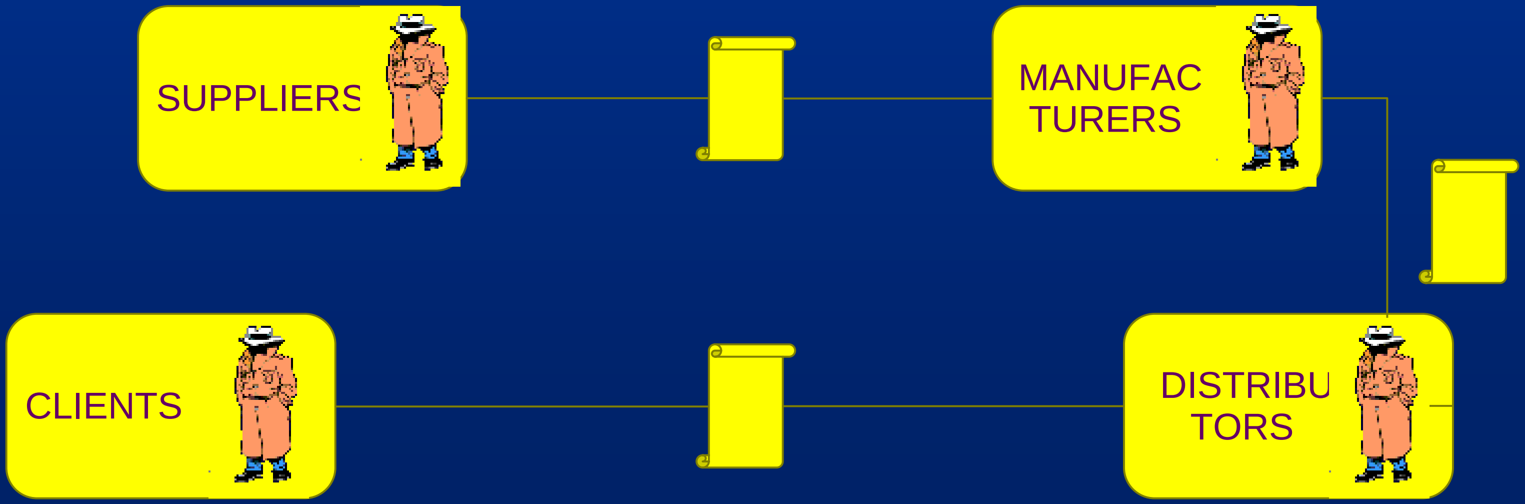
Agents for SCM

- Agent-based Supply Chain Management using Data Mining
- Ad-hoc techniques underline the need for a generic design and evaluation methodology



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TAC Overview
(Trading Agent Competition)

- Michigan University – 2000
- Swedish Institute of Computer Science (SICS) – 2002
- A quite realistic environment for benchmarking trading agents
- 2 games
  - ✓TAC Classic (Travel Game)
  - ✓TAC SCM (Supply Chain Management Game)

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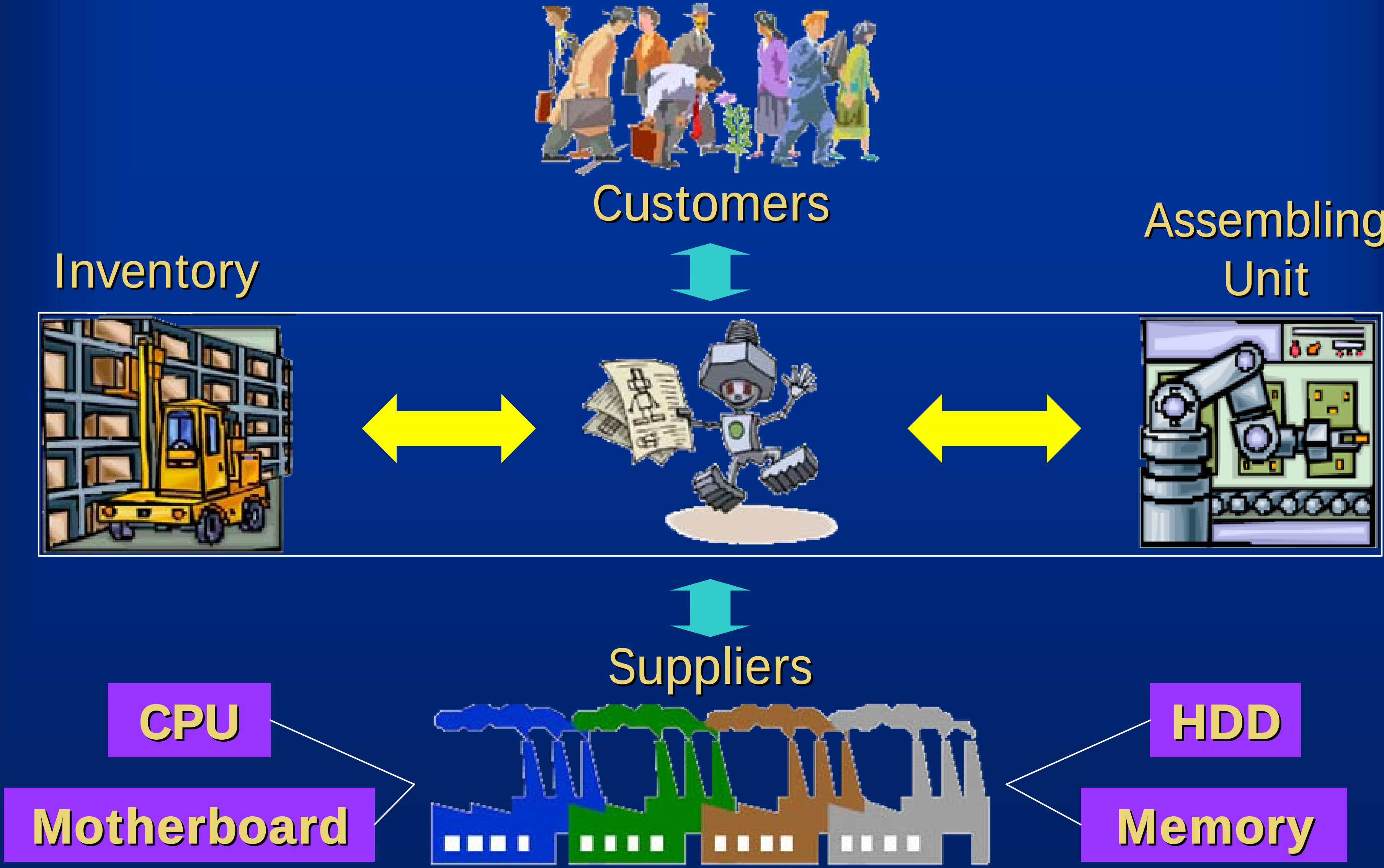
The TAC SCM Model



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TAC SCM game details

- 6 PC assembling agents competing with each other
- 8 suppliers (2 for each component)
- 220 virtual trading days
- 15'' / day · 220 days = 55' (real time)
- SICS server on the Internet (Customers, Suppliers, Bank)
- Agents acting autonomously
- Winner: Biggest revenue

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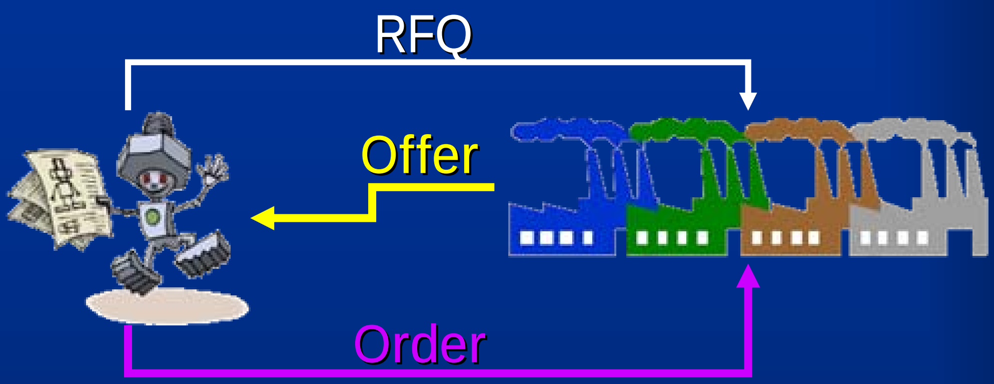
Transactions

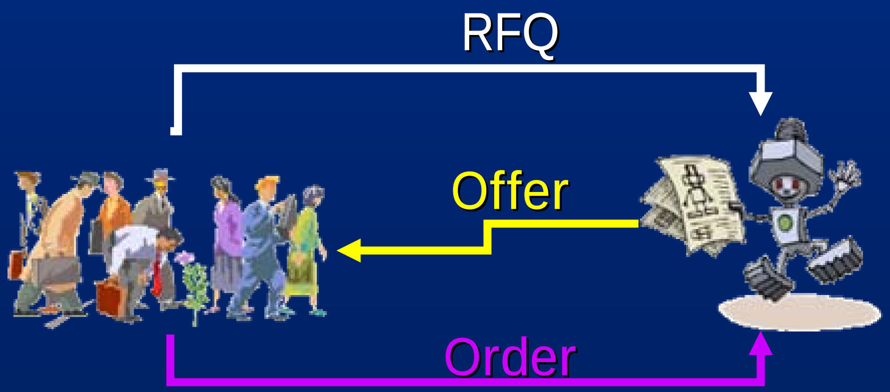
1. Request For Quote
2. Offer
3. Order

Agents ← → Suppliers



Customers ← → Agents

First Price Sealed Auctions



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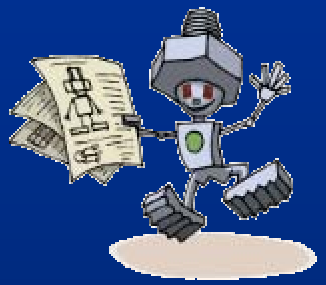
TAC SCM - Challenges

Suppliers

- Where should I buy from?
- What offer should I make?
- When should I replenish my inventory?

- Ability to change supplier in case of unreliability
- Inventory management
- Minimize cost

Optimal production scheduling as quickly as possible



15'' decision time

Customers

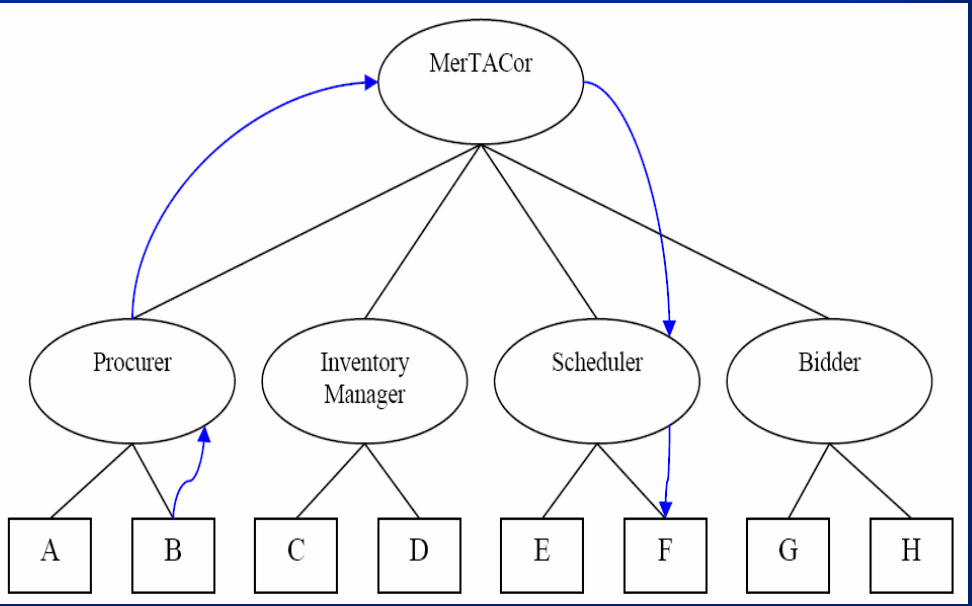
- Can I forecast the fore-coming winning bids?
- What prices do my competitors offer?
- In which market range can I increase prices?

- Perceive the dynamicity of demand and re-adjust marketing strategy according to the new data
- Take advantage of market opportunities
- Maximize profit

Agent MerTACor SCM

- Assembling strategy: **assemble-to-order**
- Inventory strategy: **demand-driven inventory**
- Factory simulator
- Sales strategy: **Based on data mining on historical data**

- Modular design:
  - ✓ Supply management (**Procurer**)
  - ✓ Inventory management (**Inventory Manager**)
  - ✓ Factory scheduling (**Scheduler**)
  - ✓ Customer management (**Bidder**)



Technologies used

- Sun Java 2 SE 1.4.2
- SCM Agentware (SICS)
- MATLAB
- WEKA (Waikato Environment for Knowledge Analysis)

MerTACor: *mercator* = merchant (latin)

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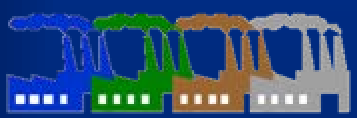
Procurer

- Everyday transactions with suppliers
- 3-type Component procurement:
  - Normal: Replenish inventory levels
  - Critical: Cover production line needs
  - Proactive: Obtain components at a low cost



Great component demand → High component prices

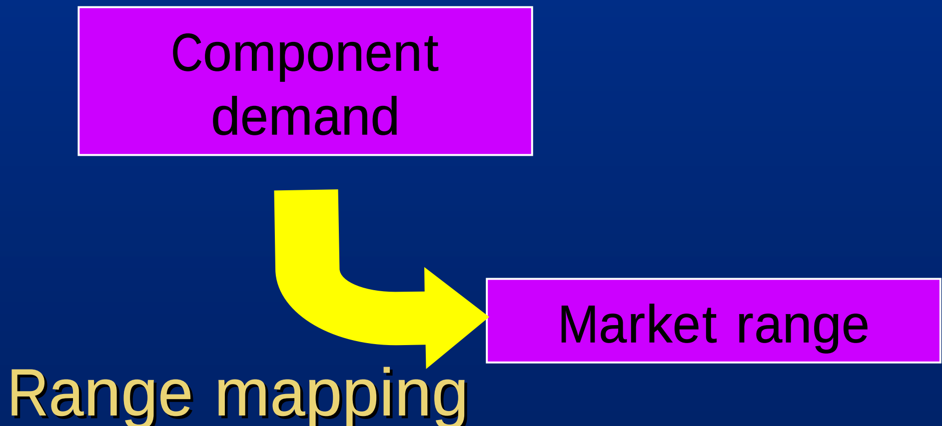
Initial procurement strategy

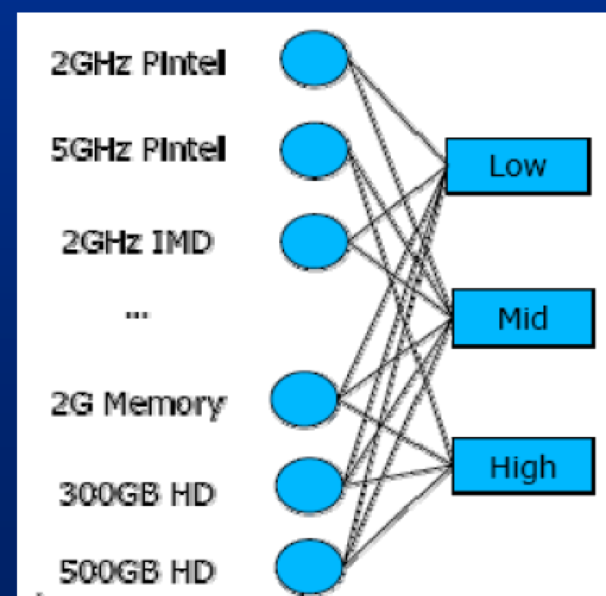
1st day: Small quantities, immediate initiation of the PC assembling process

2nd day: Large quantities

Inventory Manager

- Minimum quantities stored (assemble-to-order strategy)
- Dynamic, demand-driven inventory replenishment
- Map component demands to market ranges





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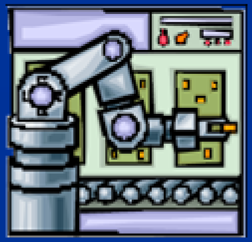
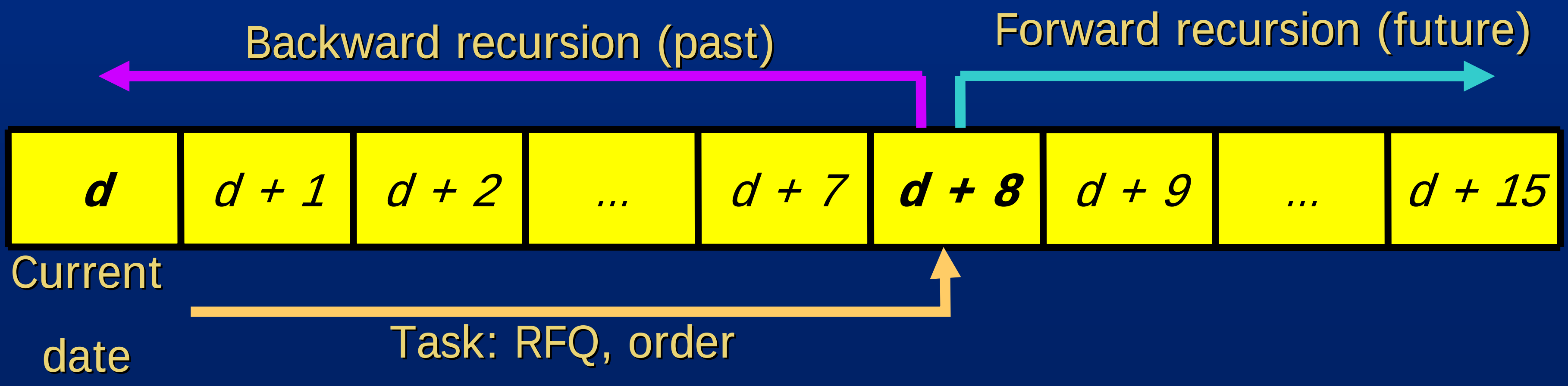
Scheduler



- Schedules production and shipping
- Processes orders & RFQs
  - ✓ Sorts orders
  - ✓ Decides on the optimal offer set
- Simulates assembling unit processes (Simulator)
  - ✓ Bilateral recursion
  - ✓ Virtual dynamic inventory
  - ✓ 2000 – 20000 simulation cycles / day
  - ✓ Response time < ILP time



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Bidder

- Make offers to customers
- Sort RFQs with respect to expected profit

  Profit = Offer price – Component cost – Inventory Cost
- Core task: Find the winning bid
  - ✓ On-line Reinforcement Learning model
    - Trial & Error method: Reward (winning bid) & punish (lost order)
    - Problem: Not many experiments
  - ✓ Off-line Data Mining training model

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Characteristics of an intelligent system

- Defined by Landauer and Bellman (2000):
  - ✓ Adaptability
  - ✓ Problem identification
  - ✓ Association of information
  - ✓ Identification of assumptions
  - ✓ Learning
  - ✓ Modeling and prediction
  - ✓ Symbolic language

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Creating an intelligent system

✓Problem identification ✓Identification of assumptions	Game specifications!
✓Adaptability ✓Association of information ✓Learning ✓Modeling and prediction	Data Mining model!
✓*Symbolic language*	*Not applicable*

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Evaluation methods used in bibliography

- Ad-hoc evaluation metrics for agent-based Supply Chain Management solutions
- Performance is measured in terms of profit
- Algorithms / mechanisms are compared to other heuristics-based approaches
- Dumke, Koeppe and Wille (2000) define the following metrics at agent working level:
  - ✓ Communication
  - ✓ Interaction
  - ✓ Learning
  - ✓ Adaptation
  - ✓ Negotiation
  - ✓ Collaboration
  - ✓ Coordination
  - ✓ Cooperation
  - ✓ Self-reproduction
  - ✓ Performance
  - ✓ Specialisation

Evaluating the system's intelligence

- Learning
- Adaptation
- Performance

Data Mining model!

- Interaction
- Negotiation
- Communication
- Collaboration
- Coordination
- Cooperation

Game specifications!

- Self-reproduction

Not applicable

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Evaluating the algorithm

Data Mining → Predict the winning price of a bid → Agent efficiency

Knowledge model vs. fail-safe mechanism

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Use of data mining to predict the winning bid

PC Auction

PC Type

...

Quantity

Current date

Price of the PCs on the previous date

Find

The minimum attribute set that can be used to represent the current auction, with respect to previous auctions

Historical data

So that

Forecast the winning bid of the auction

Pre-processing

- Remaining attributes:
  - ✓Demand
  - ✓Reserve Price
  - ✓Maximum price for last 2 days
  - ✓Minimum price for previous day
- Two datasets:
  - ✓One-third (1/3) of the initial instances
  - ✓One-eighth (1/8) of the initial instances

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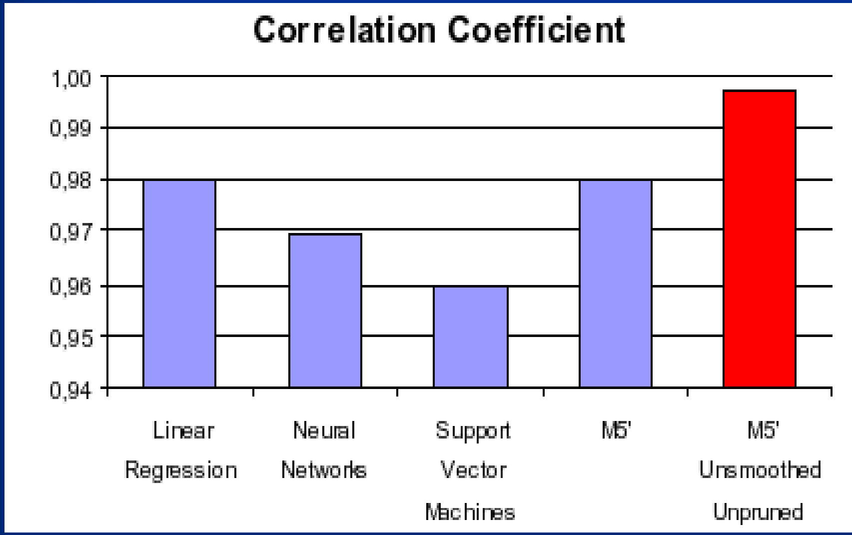
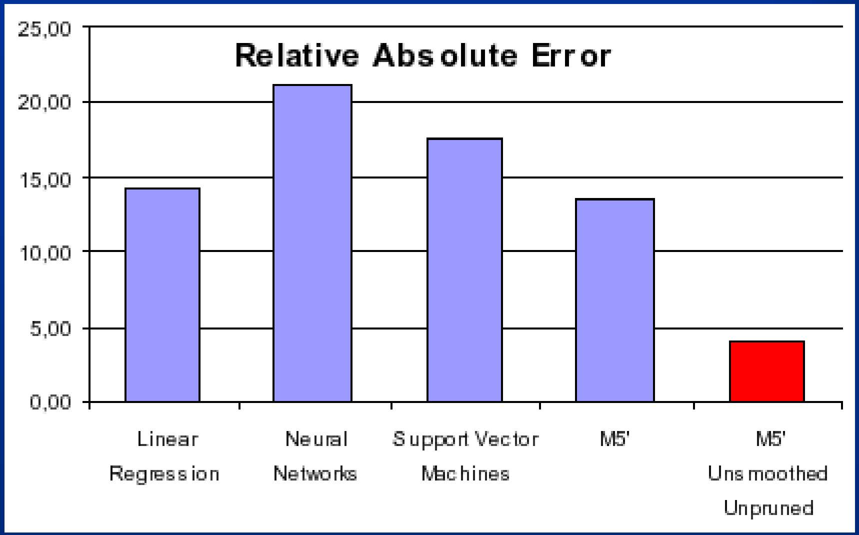
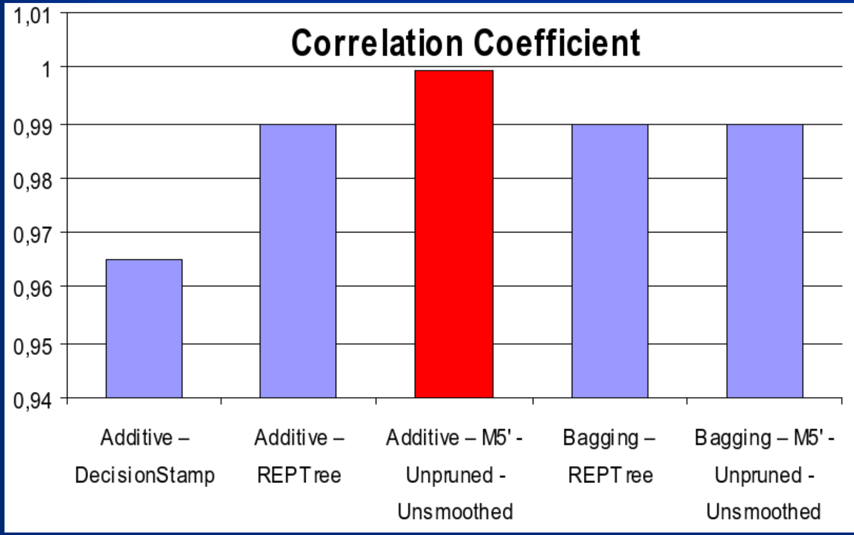
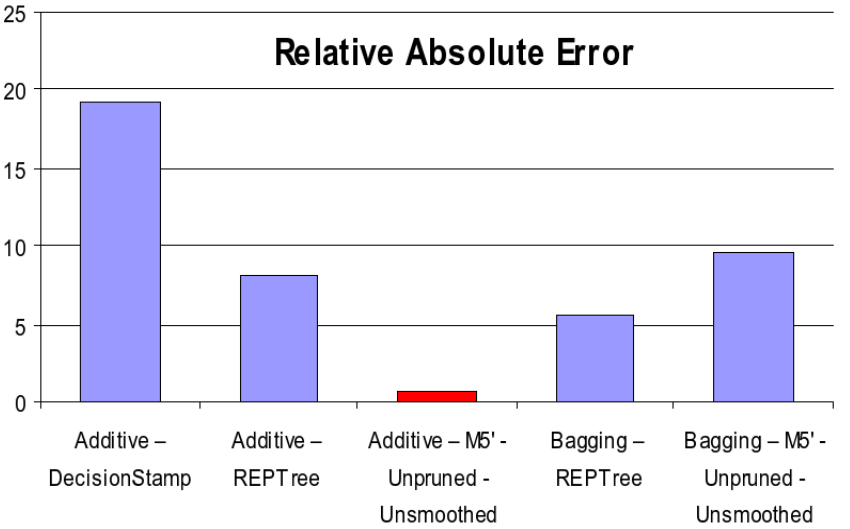
Training





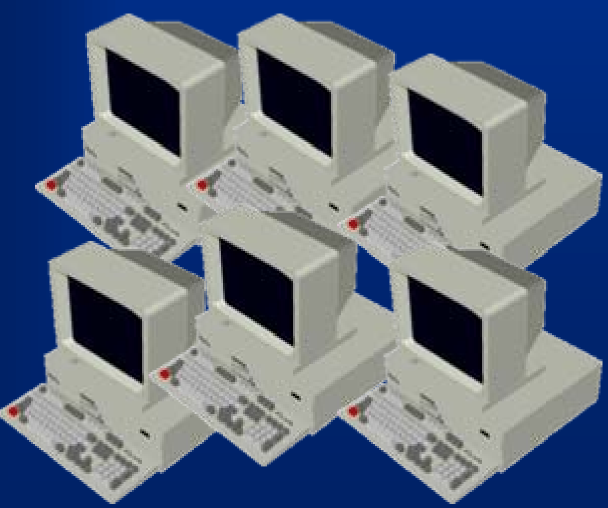
Meta-classification





Start – End effects

- Start effect:
  - ✓Trying to build up an initial inventory



- End effect:
  - ✓Trying to sell any remaining stock items

Fail-safe mechanisms

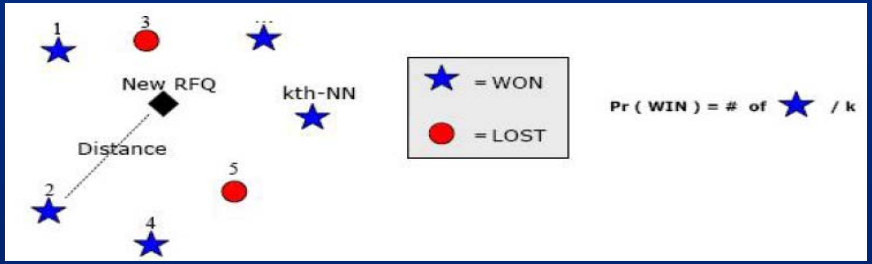
<u>Following mechanism that monitors prices</u>

- ✓ Monitors other agents' prices
- ✓ For each pair {PC type,Reserve price} estimate a price using linear regression

➡ Deal with the "Start" & "End" effect

<u>k-NN algorithm for on-line estimation of the probability to accept offer</u>

- ✓ Find k similar RFQs



➡ Maximization of the assembling unit performance

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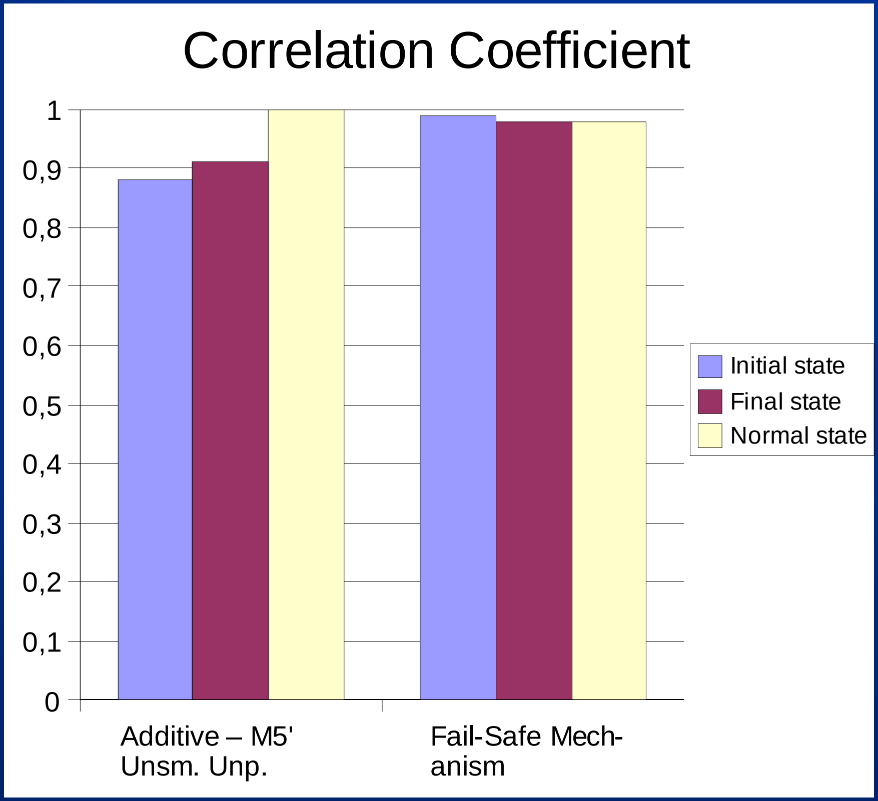
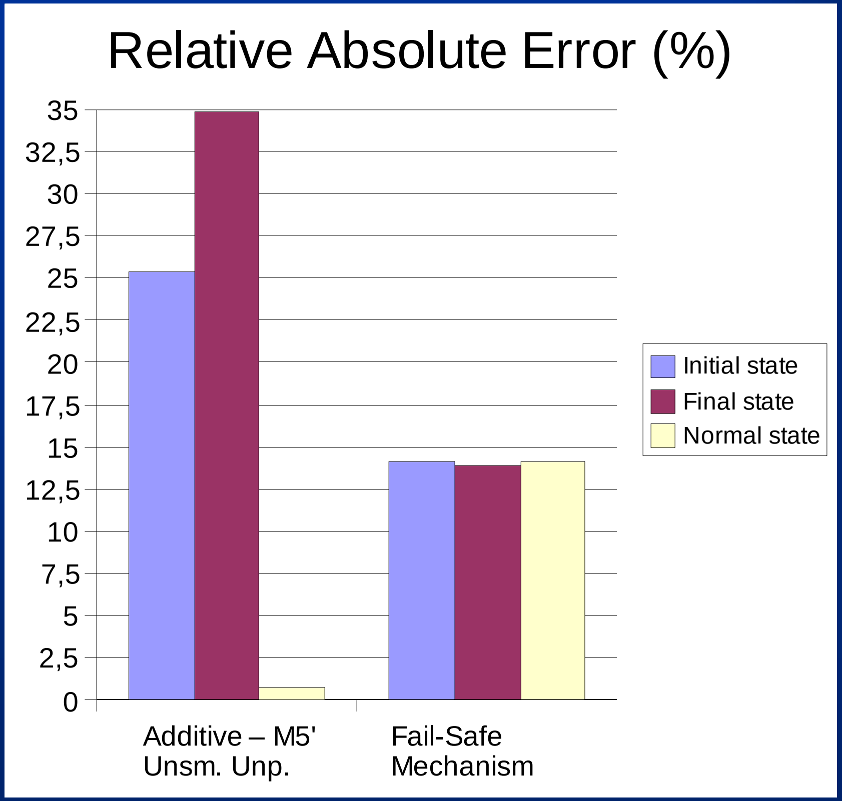
DM vs Follower





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Algorithms evaluation

- ***Linear Regression*** *imposes a linear relationship on the data*
- ***Support Vector Machines*** *needs an a priori knowledge of the mapping function*
- ***Neural Networks*** *produce extremely complicated models and require parameter tweaking*
- ***Additive Regression*** *is an enhancement over* ***Bagging***
- *The combination of* ***M5'*** *and* ***Additive Regression*** *was optimal for our data!*

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MerTACor at the finals

- The best 6 agents compete on 16 games
- Different – competitive strategies
- Very strong demands – low revenues
- MerTACor finished 3^{rd}

Place	Agent	Average Score	Affiliation
1	TacTex-05	4.741 M	The University of Texas at Austin
2	SouthamptonSCM	1.604 M	University of Southampton
3	MerTACor	546 272	Aristotle University – CERTH / ITI
4	Deep Maize	-220 503	University of Michigan
5	MinneTAC	-311 844	University of Minnesota
6	Maxon	-1.985 M	Xonar

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TAC 2005

TAC SCM Team – Agent MerTACor SCM
- Giannis Kontogounis
- Kyriakos Chatzidimitriou
- Andreas Symeonidis

TAC Classic Team – Agent MerTACor Classic
- Panos Toulis
- Dionysis Kehagias

Team Leader
- Professor P. Mitkas

Representing
- Electrical and Computer Engineering Dept. – Aristotle University of Thessaloniki
- Informatics and Telematics Institute – CERTH

MerTACor Synopsis

- Minimized inventory costs
- 98.88% order satisfaction
- Medium performance (60.63%) of the assemble-to-order factory strategy
- Supplier contracts were very expensive

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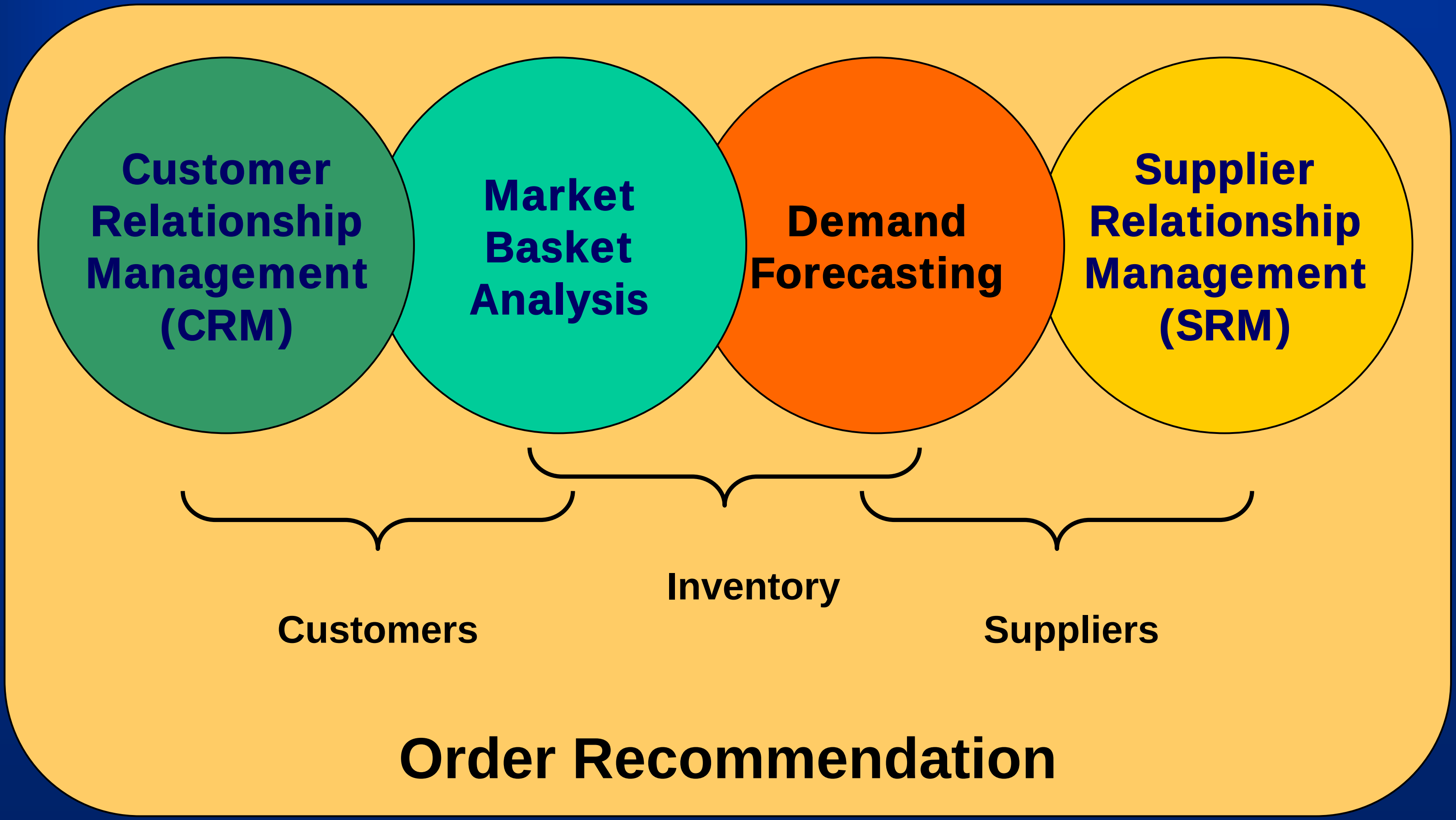
An integrated environment



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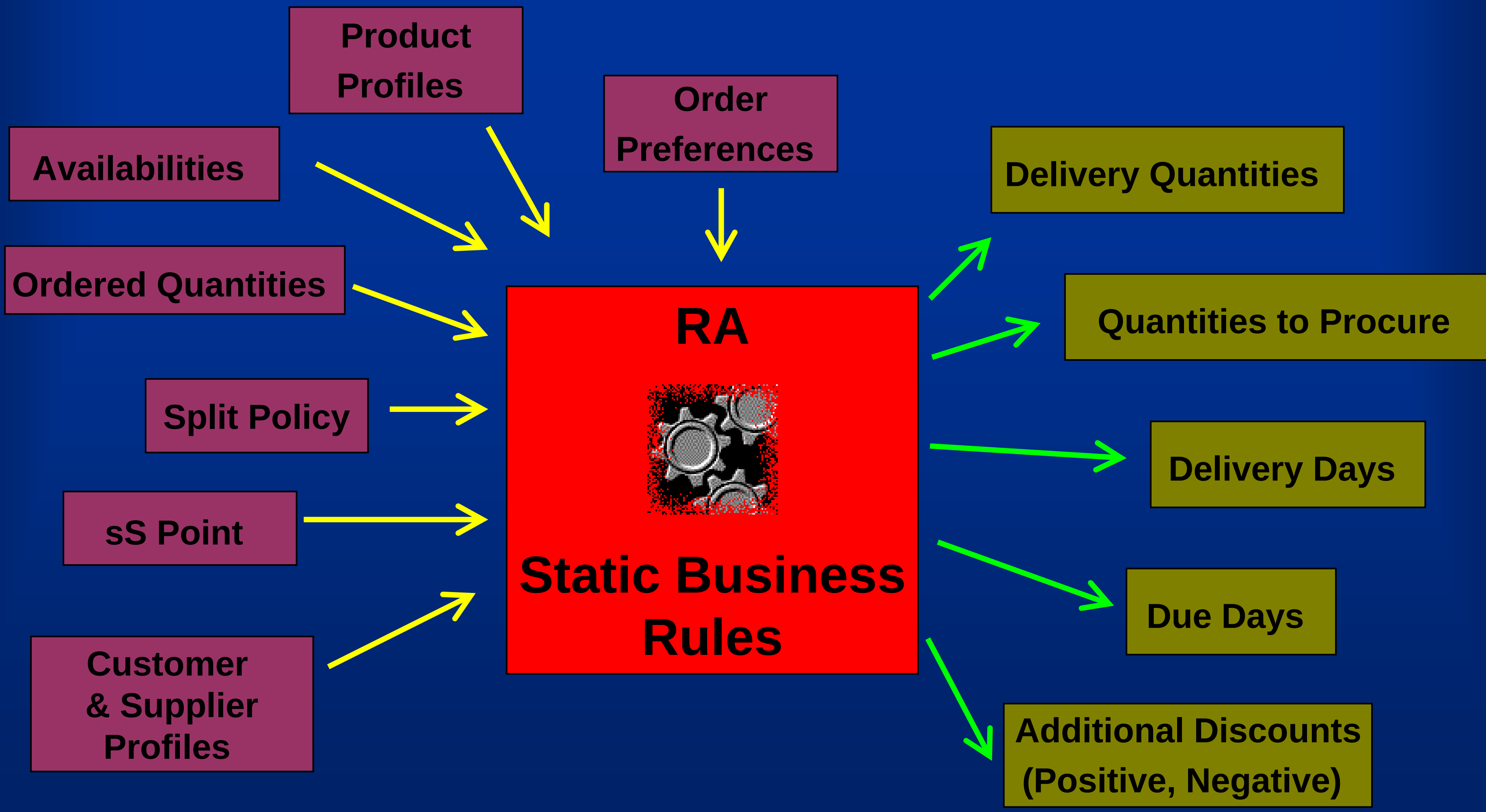
Final Recommendation



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Conclusions (1/2)

- Added value without rebuilding or reengineering the system
- Reduction of work effort through adaptability of business rules and automatic generation of the recommendation
- Reusable and customizable system (match different ERP platforms with minimum effort)

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Conclusions (2/2)

Improvement	Classic ERP	ERP + DKE
Market Basket Analysis	No	Yes
Recommendations	Indirectly, through reports	Automatically
Autonomy	No	Yes
Adaptability	Low	High
Customer Management & Pricing Policy	No	Yes
Supplier Management	No	Yes

Why agents for SCM?

- Natural fit. Multi-role multi-entity problem.
- SCM/CRM systems generate and maintain large databases which are conducive to DM.
- The incorporation of DM-extracted knowledge models can be a **dynamic** and **automated** process, providing MAS with increased flexibility.
- The presented methodology extends the application range of inductive logic models.
- **Retraining** is possible, a fact that is of great importance for discovering and dealing with new trends in incoming data.

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Open Issues

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Data mining and intelligent agents

- How to determine **safety** and **soundness** in multi-agent systems
- How to specify a methodology for developing intelligent (through data mining) multi-agent applications
- When and how to perform agent **retraining**

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Data mining and intelligent agents

- How to develop self-improving agents through DM
- How to develop tools and techniques for data mining agent behavior
- How to specify DM metrics that take **semantics** seriously into account
- How to **evaluate** agent “intelligence”

The contribution

- ✓We created a top-performing Supply Chain Management intelligent agent
- ✓We evaluated a set of Data Mining algorithms to produce a knowledge model for our agent
- ✓We sketched a methodology for efficient Data Mining-enhanced Supply Chain Management agents

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More information

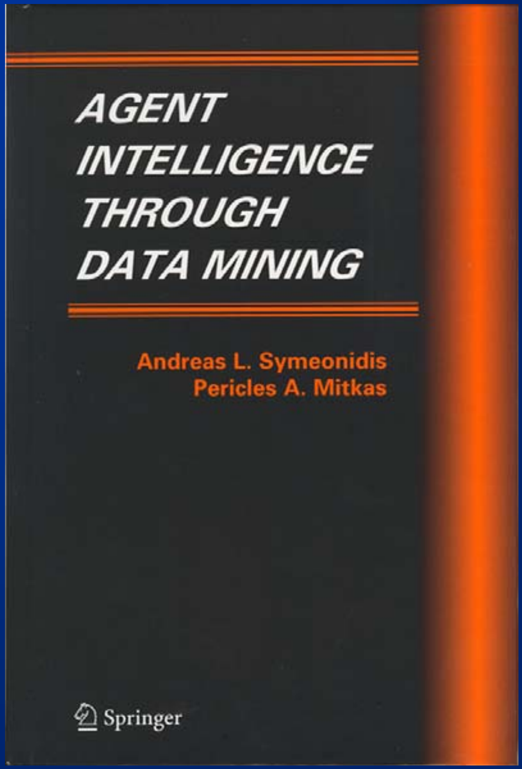
- Mertacor Web site:

  http://issel.ee.auth.gr/MertacorWeb/

- A new Book (August 2005)
  - ✓ **Agent Intelligence through Data Mining**

    by Andreas Symeonidis & Pericles A. Mitkas

    Springer Science & Business Media



- Thursday’s tutorial on
  - ✓ **Knowledge Extraction for Improving Agent Efficiency**