Agent-Oriented Supply-Chain Management
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SCM

Why is it difficult?

- A complex network with various entities having different, conflicting objectives
- Finding best system wide-strategy is hard
  - Global Optimization is difficult
- Managing Uncertainty
  - Matching supply and demand
  - Inventory and back-order levels fluctuate greatly
  - Forecasts are almost always wrong
Volatility in the Electronics & Semiconductors Supply Chain

Year

% Change, Year-to-Year

Worldwide Semiconductor Manufacturing Equipment Sales
Worldwide Semiconductor Shipments
Electronics, Computing and Communications Equipment Output
GDP World
GDP USA
From Make-to-Stock Model…. [Dutta]
….to Assemble-to-Order Model

- Suppliers
- Assembly
- Configuration

• Push-pull Strategy
Agent Technology

- **Agent Communication Languages**
  - KQML (USA), FIPA-ACL (Europe): language and protocol for exchanging information and knowledge
  - Will standardization help in all applications?
  - Agent-to-Human interaction?

- **Social Knowledge Management**
  - How to acquire, manipulate, store and exploit social knowledge, centrally, in agents?
  - Separation between social interaction know-how and individual problem-solving know-how

- **Coordination mechanisms**
  - Cultural Assumption problems? Too strong? Other e.g.?
  - Market mechanisms, investigation of truthfulness, trust, CNP
  - Optimization over entire supply chain and uncertainty at various levels?
Agent Technology (contd...)

- **Coordination Language**
  - It is a multi-agent system anyway?
  - Is finite state automata to represent conversations just hard coding?

- **Conversation plans – Logistics Execution**
  - Is it optimal? Multiple-solutions? What about global state?
  - Would these conversation models be used both internally and externally?

- **Individual Agent Architectures**
  - Reasoning Process

- **Agent Community Architectures**
  - Organization, roles, hierarchy

- **Agent Spawning**
Agent Technology (contd...) 

- **Multi-agent planning** - Decomposition and task distribution.
  - Why centralize functions of logistics agents?
  - Individual agents’ conflict resolution? What if overlap occurs?
- **Knowledge management**
  - Knowledge sharing and ontologies
- **Negotiation Strategies**
  - Auction mechanism design
- **Learning** – Does it happen?
- **Monitoring, meta-reasoning, fault tolerance, failure**
- **Coalition Formation and Teamwork** – Necessary even after coordination?
- **Large multi-echelon SCM** – Can present approach scale to it?
- **Anytime Algorithms**
Framework for modeling single-agent sequential decision making

**Definition:** An agent that takes a view of the environment and generates actions that affect the environment.

**Goal:** How an agent can learn an optimal behavioral strategy

**MDP:** \( \langle S, A, R, T \rangle \)

Set of States: \( S \), Set of Actions: \( A \)

Reward Function: \( R : S \times A \rightarrow \mathbb{R} \)

State Transition Function: \( T : S \times A \rightarrow \Pi(S) \), \( T(s, a, s') \)

Optimal value of state: \( V^*(s) = \max_{\pi} E \left( \sum_{t=0}^{\infty} \gamma^t r_t \right) \)

Optimal Value Function is unique and is soln of:

\[
V^*(s) = \max_a \left( R(s, a) + \gamma \sum_{s' \in S} T(s, a, s') V^*(s') \right), \quad \forall s \in S
\]

Optimal Policy: \( \pi^*(s) = \arg \max_a \left( R(s, a) + \gamma \sum_{s' \in S} T(s, a, s') V^*(s') \right) \)
Other Questions

- Linear combination of criteria and value iteration convergence
- “Global criterion” to compute to reorder the rules in current state
- Possible performance metrics
  - Actual Demand/Forecasted Demand
  - Inventory turn-over ratio
  - Others?
- Effect of coordination strategies
  - Gains from delivery plans, notification - Modest? Non-agent comparison?
  - Two local maxima
- Optimal error recovery mechanisms
- Modeling Supply Chain Dynamics: A Multi-agent Approach
  - Swaminathan et al, 1997, Decision science
The MIT Beer Game

- **Players**
  - Retailer, Wholesaler, Distributor and Manufacturer.

- **Goal**
  - Minimize system-wide (chain) long-run average cost.

- **Information sharing**
  - Mail.

- **Demand**
  - Deterministic.

- **Costs**
  - Holding cost: $1.00/case/week.
  - Penalty cost: $2.00/case/week.

- **Leadtime**: 2 weeks physical delay

1. New shipments delivered.
2. Orders arrive.
3. Fill orders plus backlog.
4. Decide how much to order.
5. Calculate inventory costs.
Bullwhip Effect Example (P & G)

Lee et al., 1997, Sloan Management Review