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The Beer Game as a Simple Example of an Agent-Based Management Simulation

Michal Wosko

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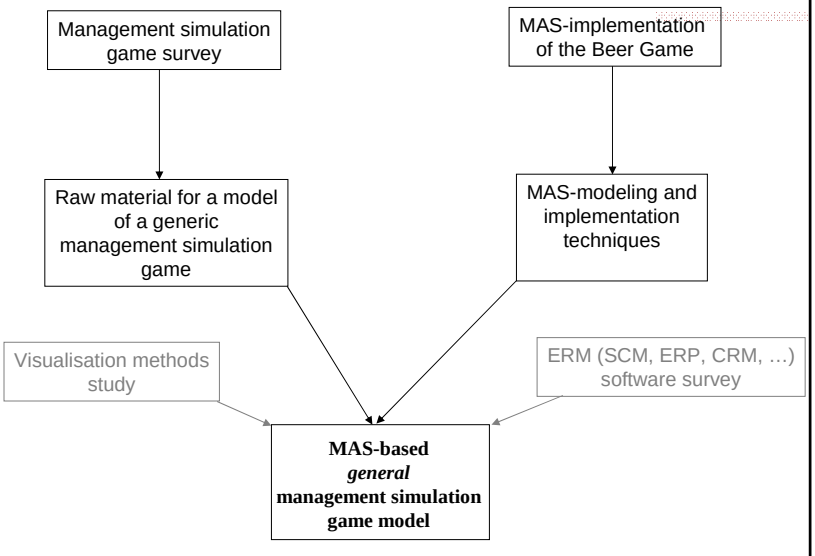
Work schema



The Beer Game as a Simple Example of an Agent-Based Management Simulation Michal Wosko Feb. 16th, 2006

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Contents, 1/2

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Contents, 2/2

* These fragments are based on:
„Agent-based simulation as refinement of discrete event simulation with special consideration of the example of automated guided vehicle systems", Dissertation (Ph.D. thesis) am Fachbereich Mathematik und Informatik der Freien Universität Berlin, Wolf-Ulrich Raffel, 2005 (Title translation from German: MW)

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1.1. Foreword on simulations, 1/4

Understanding of simulations games - ***push and pull dichotomy***.

Traditional teaching systems are „push": students have little or no control in the process.

Games, on the other hand, are „pull": learners are pulled into the learning process and encouraged to participate. Learners actually determine the learning process when they use simulation games.

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1.1. Foreword on simulations, 2/4

Simulation and simulation games are experiential learning processes where knowledge is created by the transformation of experience (Saunders, 1997). Usually the process is cyclic.

6 basic underlying *assumptions*:

1. learning is defined by the process and not by the outputs
2. learning is based on experience
3. learning must include conflict
4. learning is a process of adopting a discovered "world"
5. feedback between the learner and the environment is required
6. learning creates knowledge.

1.1. Foreword on simulations, 3/4

Attributes related to the nature of the simulation:

1. Simulations enable time compression
2. Feedback can be immediate
3. Simulations are an inexpensive training tool
4. Simulations can be familiar since they are well spread
5. Realism motivates
6. Realism adds new perspectives to uncertainty
7. Simplification enables focus on the main issues
8. Simulation permits inexpensive experimentation

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.1. Foreword on simulations, 4/4

Conclusions and lessons from simulation games:

- Participants make strong and stable connections between theory and reality
- Simulations teach analytical methods
- Simulations provide unbiased results
- Players tend to continue to search for relevant information, even after the game is over
- Lessons survive for longer time periods

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.2. Management games

Players:

1. „classic" management games:
   usually in competing teams, sometimes in the old fashioned form of a board game
2. simulation games:
   man „against" machine/software

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1.2.1. Taxonomy of games, 1/2

Generally, business games can be classified by:

- pedagogical purpose
- number of decisions
- types of decisions
- number of companies involved in the game
- number of products
- amount of computerization
- amount of interactivity
- time frame for decision
- and more.

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1.2.1. Taxonomy of games, 2/2

According to Packer & Glass-Husain (1997), the categorizing criteria are:

- interface complexity
- details complexity
- dynamics complexity

Many atomic or compound details
-> games with high detail- complexity: more challenging and more development time required

- thus sometimes erroneously believed to be more realistic

Complex underlying mathematical model
-> games with a high detail complexity

High interface complexity
-> easier to learn and play

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1.1. Management games, 2/4

Encompassed are some of the decisions taken during normal business operation by the management of a company within a market:

1. Product management – choice / specification of:

- product portfolio, for production and marketing
- optimum* production quality, with consideration of:
  - raw material prices
  - quality-determined production costs
  - targeted profit

-> Production quantities
-> Product pricing

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1.1. Management games, 3/4

Encompassed are some of the decisions taken during normal business operation by the management of a company within a market:

2. Financial management – decisions about:
- investments
- credit

3. Interaction with the labour market:
- employing
- training and retraining of personnel
- dismissing

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1.1. Management games, 4/4

Encompassed are some of the decisions taken during normal business operation by the management of a company within a market:

4. Competition and cooperation:
- decisions about production profile and price policy depending on competition's behaviour in the given market segment
- decisions about mergers and other forms of cooperation

5. Other modelled business-related procedures:
- accounting
- taxation and related
- ...

1.2. Supply Chain / SCM, 1/3

Supply Chain - logistic chain, logistics network, supply network :

a coordinated system of entities, activities, information and resources involved in moving a product or service from supplier to customer / target market

Basic entities: manufacturer/service provider, distributor, retail outlet(s), customer

Products' and services' flow is in the direction from the provider to the customer;

Money – in the opposite direction;

Information primarily like money (orders, for instance); information accompanying merchandise is transmitted with it (delivery note) or in the opposite direction (dispatch notification).

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.2. Supply Chain / SCM, 2/3

Objectives of the SCM:

- orientation towards end customers through better satisfying their needs
- quick adaptation to changing markets
- avoiding „out-of-stock" situations
- keeping inventory (warehouse stock) as low as possible
- simplifying delivery and overall flow
- shortening delivery time

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.2. Supply Chain / SCM, 3/3

Supply Chain Management (SCM)

Target: a long-term (strategic), mid-term (tactical) and short-term (operational) improvement of effectivity in industrial/business supply chains

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1.3. The MIT Beer Game, 1/3

Developed by Jay W. Forrester in the 60s at the Sloan School of Management of the Massachusetts Institute of Technology (MIT) and since then countless times played all over the world in different configurations by players of different formation

Clearly a limited and very simplified – compared to reality – learning environment; still very useful in pointing out pretty complex problems, which can arise even in relatively simple systems

In the Packer/Glass-Husain threedimensional categorization the Beer Game has high detail-complexity, very low interface complexity and medium level of dynamics complexity.

1.3. The MIT Beer Game, 2/3

Rules:

1. 4 supply chain members: retailer, wholesailer, distributor, factory; every 2 of them are „*neighbours*" in the chain
2. played in *rounds* – 1 week length
3. every player owns a warehouse (=~ *inventory*) and the information about the quantity of merchandise, which has been ordered from him in the current round (*orders*), and about his own *backorders* (about the merchandise, which was ordered from him in the past rounds, but still has not been delivered)
4. ordered merchandise, being available in the inventory, must be always delivered (a backorder will arise only, if orders are received, which are bigger than the inventory status)
5. only orders and stock are sent, no information, and only between neighbours in the chain
6. a sent order arrives at destination in 1 round, sent stock in 2

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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"A general model of agent-based management simulation games and its integration in learning management systems."

1.3. The MIT Beer Game, 3/3

...rules:

7. orders and stock are sent at the end of each round as necessary
8. order quantity is given by a special function (order strategy)
9. at the end of each round costs for every player are calculated (holding an inventory and having backorders)
10. simplification: no representation of the production process, including raw material supply, for the factory, and none of the sales for the retailer

Schema of the chain:

Fig 2.1.1. The Beer Game schema, source "Remodeling the Beer Game as an Agent-Object-Relationship Simulation", Luin, Tulba, Wagner [LTW03]

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.5. Examples of management simulations/management games

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KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

1.5.1. The Hulia Game*, 1/5

* Source:
[RR00]: „Multiplayer, Internet and Java-based simulation games: learning and research in implementing a computerized version of the 'Beer Distribution Supply Chain Game'", Gilad Ravid and Sheizaf Rafaeli, Graduate School of Business, University of Haifa

„Hulia" [Hebrew] = „a chain link" and „a special team"

- developed at the Graduate School of Business, University of Haifa, ref. [RR00]

- based on the Beer Game
- simulates the systems dynamics in a SC
- each player performs the role of a single link in the chain
- *several* chains (= teams of players) *compete* with each other
- each competing chain has 4 links

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1.5.1. The Hulia Game, 2/5

- played in multiple repeated simulated rounds or „days"
- every simulated "morning" the retailer is informed of the daily demand and so on
- time lag between ordering and receipt and between shipping and receiving of products

- each player *has local information*, information regarding his or her activities, but *not global* (system) information
- *future demand* is *unknown*

also: players *may not communicate anything* except order quantities

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1.5.1. The Hulia Game, 3/5

Cost structure is such that players are *lead to believe* that they can succeed.

Without communication / *information sharing* the task is *not so simple*.

Besides *preventing information sharing* (at all), here regarded as „cheating" - through online implementation – „Hulia" also offers an opportunity of conducting SCM experiments through manipulating, controlling, collecting and researching in the informal channels of information transfer (by keeping logs of all the transactions including information flows).

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1.5.1. The Hulia Game, 4/5

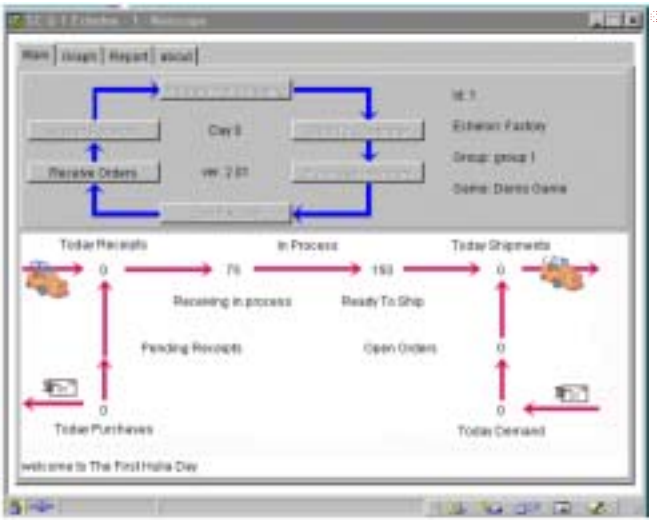

Fig. A Screenshot of the Hulia Game, source [RR00]

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1.5.1. The Hulia Game, 5/5

Outcome:

-used (widely) in actual business/SCM exercises

- performance and learning results consistent with results reported in the literature after a statistically reliable number of runs

- ongoing analysis of logs and research on effects reached through manipulations spoken of.

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1.5.2. Mageur, 1/4

*Source: [Cas02] - „Management Game Mageur", Rommert J. Casimir

Originally **MA**nagement **G**ame of **E**rasmus **U**niversity **R**otterdam, but alternatively **MA**nagement **G**ame for **EUR**ope

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1.5.2. Mageur, 2/4

Modeled entities, processes and issues:

- companies
- business units, like factories, warehouses, retail outlets
- (product) markets, including marketing, decisions on advertising
- labour markets (employment)
- own financial management and interaction with banks (loans, deposits, taxes)
- investments in technology and market research

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1.5.2. Mageur, 3/4

Gameplay:

A company does not start as a *going concern, but with 15 million (euro) starting capital* available in cash.

1st round: companies can create factories by investing in projects, for which data are distributed by the game administrator (using its starting capital and, if necessary, additional loans).

A factory starts producing in the year after its foundation - no production or sales decisions in the 1st round.

After production has started a sales office must be created in the same business unit to sell the product (it starts selling in the year it is created)

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1.5.2. Mageur, 4/4

Gameplay…:

Products automatically transported from the factory to the sales office within a business unit, but cannot be transported between business units.

From the 2nd round a management team must divide its attention between:
- *short-term decisions* (setting the number of employees, determining price, amount of production, and advertising budget for products, determining the credit limit)
- *long-term planning* (research expenditure, creation or closing of factories and sales offices or closing of entire business units, long-term financial planning).

From the 5th round, factories can become technically obsolete (need for new investments); economically even earlier.

1.5.3. Infogame, 1/6

*Source: [Cas03] - „Infogame", Rommert J. Casimir

Game for education and research in information systems development.

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.5.3. Infogame, 2/6

Taxonomy of games according to Casimir:

- *management games:* global production orders are given, such as *produce 10,000 tons of product X during this period, with Y workers and Z machines;* results also in a global form, such as: *9500 tons of product X were produced during this period with...*

- *simulation games* model:
  - a *process industry:* players decide on production per day and results are reported on the same time scale
  - a ***job shop***, players decide what job should be executed next when a job is finished, supplies have arrived, or a machine; results of jobs are reported separately after the end of each job

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1.5.3. Infogame, 3/6

Infogame models a ***job shop***, production is controlled by a rule stating that a given amount, the *order quantity,* of a product must be produced when the stock falls below a given level (*reorder level)*, and the requisite resources (materials, machines and manpower) are available. For each job, results may be reported in detail.

=>

Elements of the 2 types of games: both of *simulation games** and *management games**.

*Casimir's taxonomy

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1.5.3. Infogame, 4/6

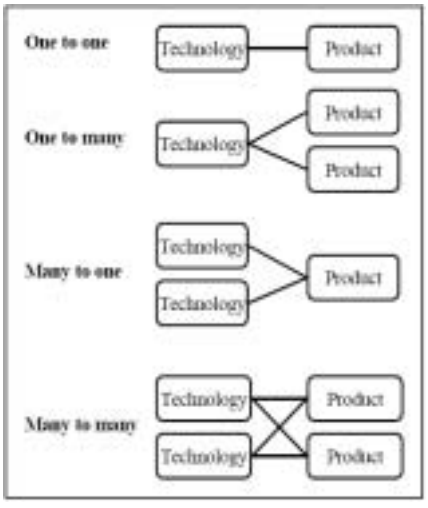

Fig. 1.5.3.1. Possible company designs in Infogame, [Cas03]

1.5.3. Infogame, 5/6

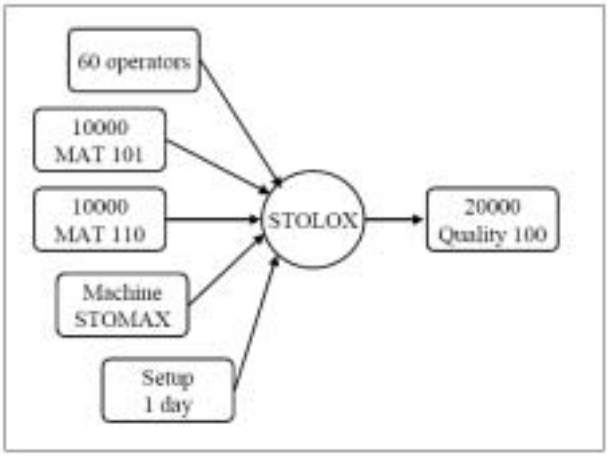

Fig. 1.5.3.1. Production graph in Infogame, [Cas03]

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.5.3. Infogame, 6/6

Players take the role of *middle managers making decisions in a limited area*, such as production

but they *also* assume the role of *top managers* (normally unconcerned with the company's day to day problems and details, but looking at the „whole picture").

=>

A number of similarities with MAGEUR; difference: detailed simulation of production and marketing + players are responsible for basic data processing

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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1.5.4. LINKS SCM, 1/5

*Source: [Cha05] – „LINKS Supply Chain Management Simulation", Randall G. Chapman

LINKS SCM simulation encompasses all major supply chain elements: suppliers, manufacturers, distributors, retailers, and end-users.

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1.5.4. LINKS SCM, 2/5

LINKS firms:
- manufacture and distribute products
- provide ***post-sale customer service*** via regional service centers.

The indirect retailer and direct e-commerce channels in LINKS provide a rich and challenging competitive milieu for SCM.

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1.5.4. LINKS SCM, 3/5

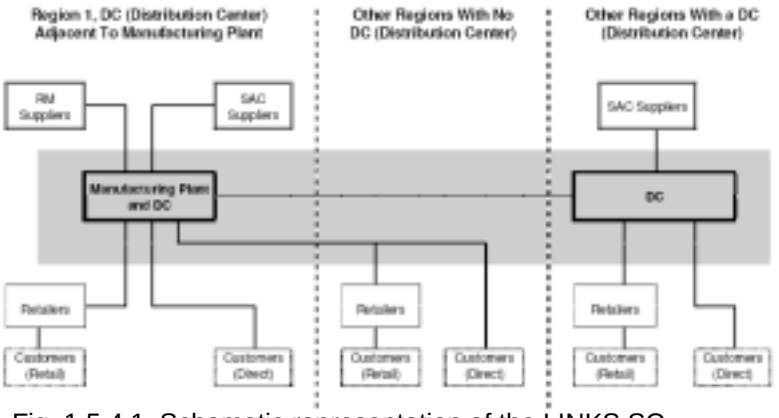

Fig. 1.5.4.1. Schematic representation of the LINKS SC "DC" = distribution center, "RM" = raw materials, "SAC" = sub-assembly components (used for production, postponed production, and replacement parts); shaded area in this exhibit is the direct responsibility of the LINKS manufacturers.

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1.5.4. LINKS SCM, 4/5

Gameplay:

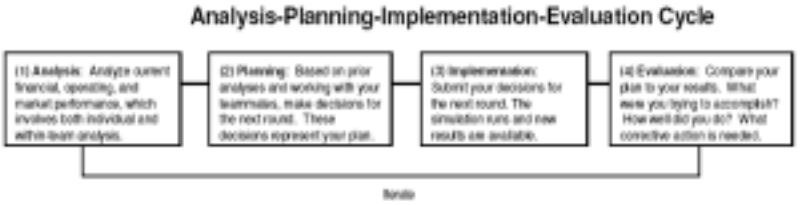

Fig. 1.5.4.2. Gameplay in LINKS SCM as cycle: analysis, planning, implementation, evaluation [Cha05]

Decision period (cycle length) in LINKS is one calendar month
Detailed info available but only about recent past

The Beer Game as a Simple Example of an Agent-Based Management Simulation Michal Wosko Feb. 16th, 2006

1.5.4. LINKS SCM, 2/5

Firms in LINKS manage (==represented entities and processes are):

- Product development
- Procurement (purchasing/sourcing)
- Manufacturing
- Distribution and warehousing
- Transportation
- Customer service
- Generate demand
- Forecasting
- Information technology
- Research studies

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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2. The Beer Game as multiagent simulation

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

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2.1. The MIT Beer Game as MAS – the model, 1/4

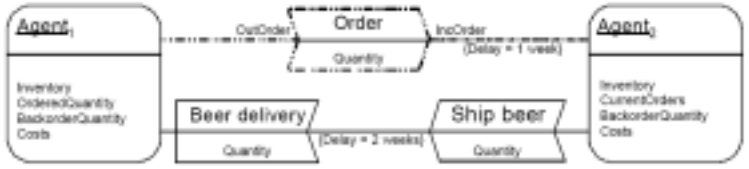

Fig 2.1.2. IFD (Interaction Frame Diagram) of 2 [from a total of 4] Agents in the Beer Game, source "Remodeling the Beer Game as an Agent-Object-Relationship Simulation", Luin, Tulba, Wagner [LTW03]

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2.1. The MIT Beer Game as MAS – the model, 2/4

Reaction rule			
R1: ship outstanding orders	ON IF THEN [DO] [CAUSING] ELSE	Event StateCondition R1C1 Action StateEffect StateCondition R1C2 Action StateEffect	EndWeek Inventory >= (Ordered+Backorder) Ship(Ordered + Backorder) Inventory = Inventory@pre – (Ordered + Backorder@pre) Ordered = 0 Backorder = 0 [Inventory < (Ordered + Backorder)] Ship(Inventory@pre) Backorder = Backorder@pre + Ordered – Inventory@pre Inventory = 0 Ordered = 0
R2: order stock	ON IF DO [CAUSING]	Event StateCondition Action StateEffect	EndWeek true Send(Order(ComputeQuantity())) ()

The Beer Game as a Simple Example of an Agent-Based Management Simulation Michal Wosko Feb. 16th, 2006

A presentation held as proceeding of Ph.D. thesis

"A general model of agent-based management simulation games and its integration in learning management systems."

KEYWORDS: MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

2.1. The MIT Beer Game as MAS – the model, 3/4

Reaction rule			
R3: receiving an order	ON IF DO [CAUSING]	Event StateCondition Action StateEffect	Order *true* () Ordered = Ordered@pre + Order.Quantity
R4: receiving beer	ON IF DO [CAUSING]	Event StateCondition Action StateEffect	Delivery *true* () Inventory = Inventory@pre + Delivery.Quantity
R5: calculating costs	ON IF DO [CAUSING]	Event StateCondition Action StateEffect	EndWeek *true* () Cost = Cost@pre + (Inventory * IC) + (Backorder * BC)

Tab 2.1.1 Reaction rules of the Beer Game in OCL, source "Remodeling the Beer Game as an Agent-Object-Relationship Simulation", Luin, Tulba, Wagner [LTW03]

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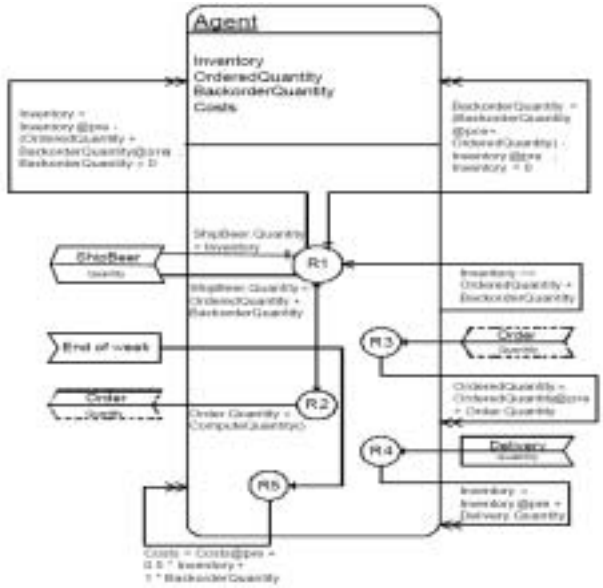
2.1. The MIT Beer Game as MAS – the model, 4/4



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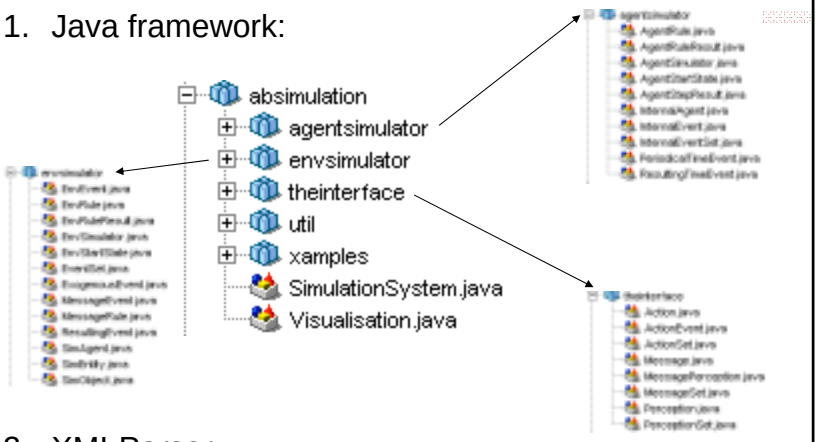
2.2. The Absimulation simulation framework, 1/2

1. Java framework:



2. XMI-Parser:
   1. Generation of AbsimML-Code from XMI*
   2. Generation of Java-Code from AbsimML

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2.2. The Absimulation simulation framework, 2/2

The Absimulation framework follows the AOR modeling schema.

Implemented are the following:

- internal and external agents (*agentsimulator*.InternalAgent, *envsimulator*.ExternalAgent)
- reaction rules for internal agents (*agentsimulator*.AgentRule)
- rules for the environment simulator and external agents (*envsimulator*.EnvironmentRule)
- events:
  - internal events (*agentsimulator*.ResultingTimeEvent)
  - external events (*envsimulator*.*):
    - exogenous (ExogenousEvent)
    - resulting (ResultingEvent)
    - Action(s) including communicative acts (Message)
    - Perception(s) of the listed events

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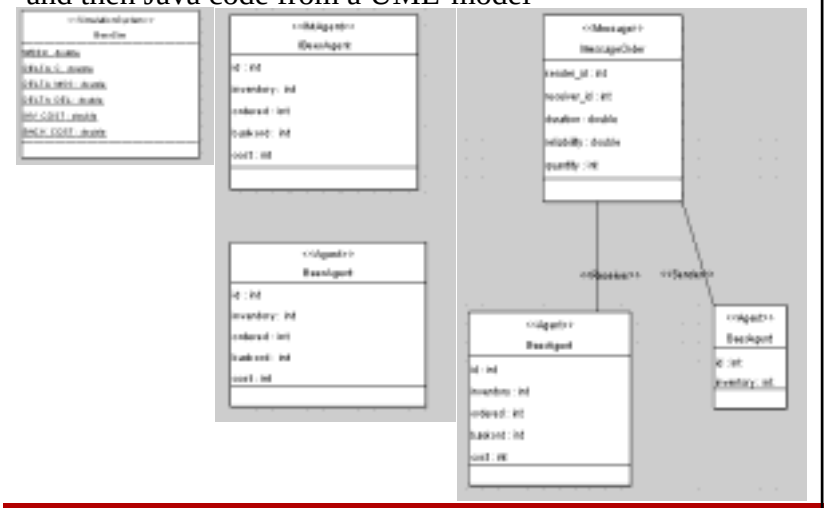
2.3. Implementation, 1/3

Should-have-been-procedure: generation of AbsimML- and then Java code from a UML-model



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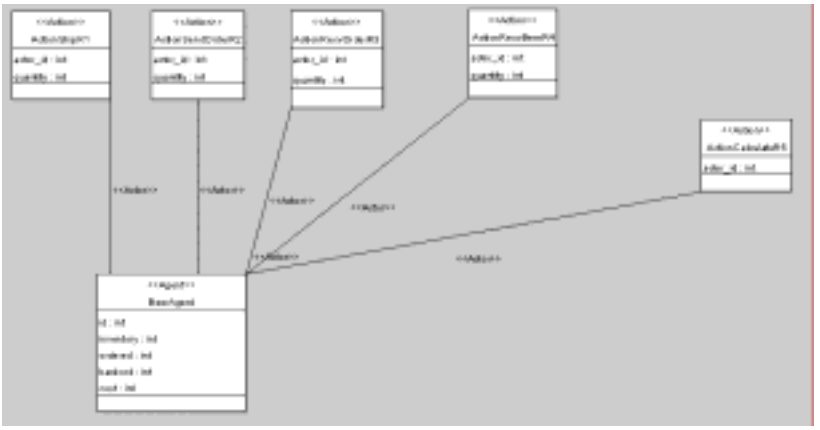
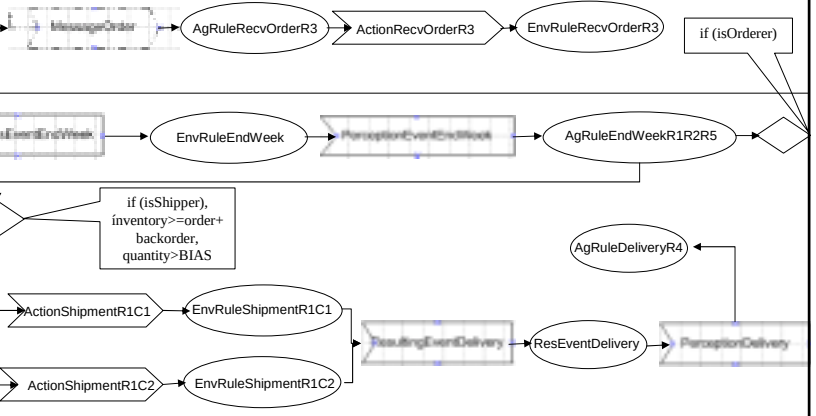
Should-have-been-procedure: generation of AbsimML- and then Java code from a UML-model



Not undertaken because of (initial) technical problems with the execution of the parser program

2.3. Implementation, 3/3

=> Direct use of the Absimulation framework (*Was*-procedure: opportune interfaces implemented directly in Java), following this schema*:



KEYWORDS:
MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

2.4. Simulation run, 1/2

[**START**]
{Retailer;1=0, Factory;4=3, Distributor;3=2, Wholesaler;2=1}
Next event: beer2.**ExEventEndWeek**
agentid: 4
...
Perception: beer2.**PerceptionEndWeek**: Factory 4
...
Chosen internal rule of agent Factory 4:
beer2.**AgRuleEndWeekR1R2R5**
...
Next event: message: beer2.**MsgOrder**: Distributor 3 -> Factory 4
beer2.MsgOrder: Distributor 3 -> Factory 4
ordered: 4
...
Perception: absimulation.theinterface.MessagePerception: Factory 4
beer2.MsgOrder: Distributor 3 -> Factory 4
ordered: 4
…
Next event: action: beer2.**ActionShipmentR1C1** from Factory 4
beer2.ActionShipmentR1C1: Factory 4
quantity: 4
Chosen rule: beer2.**EnvRuleShipmentR1C1**
…

KEYWORDS:
MIT Beer Game, Supply Chain, Simulation games, Management games, Multiagent Systems, MAS, AORML, Agent-Oriented Modeling, Absimulation Framework, Java

2.4. Simulation run, 2/2

...
Next internal event from agent Distributor 3: beer2.**PerceptionDelivery**: Distributor 3
quantity: 4
Chosen internal rule of agent Distributor 3: beer2.**AgRuleDeliveryR4**
...
beer2.IBeerAgent 1
inventory: 5
ordered: 0
backord: 0
cost: 6.0
beer2.IBeerAgent 2
inventory: 4
ordered: 4
backord: 13
cost: 19.5
beer2.IBeerAgent 3
inventory: 4
ordered: 4
backord: 11
cost: 14.0
beer2.IBeerAgent 4
inventory: 84
ordered: 4
backord: 0
cost: 290.0

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2.5. Open questions

Target was:

not a full implementation of the Beer Game, but rather *getting to know* MAS modeling techniques

⇒ limited functionality without all constraints
⇒ no research of ordering strategies
⇒ no optimization of the chain (information exchange, avoiding the bullwhip effect, and so on)

Besides: no reprasentation of agents' KB, of a memory model whatsoever, no adaptation of agents and no initiative

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3. Perspective

Areas of study/future work:

- Visualisation – not just of simulation end-effects, but primarily giving a live-feedback during the simulation run
- Other modeling approaches
- Integration of a simulation framework with existing ERM (ERP/CRM/SCM) software solutions
- interactive simulation
- memory model for software agents
- goal-oriented agents:
  non only just reactive, but proactive (with own initiative) - ?
- integration with LM systems

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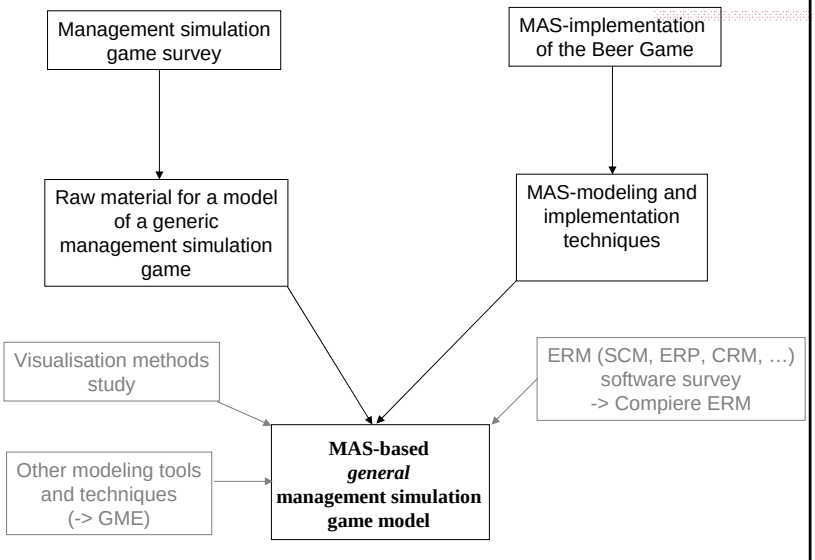
Work schema (bis)



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Thank You for Your kind attention! ☺