Multi Agent Systems

Principles and applications

Zahia Guessoum
Cédric Buron

Definitions and principles

Multi Agent Systems

An agent is:

- **Proactive**: It does not need to be stimulated/activated to act;
- **Adaptive:** It interacts with its environment and takes its changes into account;
- **Social:** It interacts with other agents;

Multi Agent Systems (MAS)

A MAS is a set of situated autonomous agents, able to get organized in a dynamic and adaptive way[1]. It consists of:

- Agents: the description of the internal architecture of the system operating entities,
- Environment: elements depending on the domain to structure the external interactions between the system entities
- Interactions: elements to structure the internal interactions between the system entities
- Organisation: elements to structure entities in the MAS

[1] Yves Demazeau. From interactions to collective behaviour in agent-based systems. *In Proceedings of the first European Conference on Cognitive Science*, Saint-Malo, France, 1995.

Multi Agent Systems

Agents:

- Reactive vs cognitive: has the agent a symbolic representation of its environment or does it only react to stimuli?
- Hardware/software: is it a robot or a pure software entity?
- Cooperative vs competitive: does it look for the common good or its own good?

Environment:

- Discrete or not
- Finite or infinite resources?

Multi Agent Systems

Interaction:

- Direct: *via* the environment
- Redirect: by messages passing?

Organization:

- Emergent and/or provided by the designer
  - examples: ant-based and role and group-based models

Related domains and difference

Multi Agent Systems are not [2]:

- Distributed systems (organisation, coordination)
- Actor-based systems (proactiveness)
- Artificial intelligence (social aspect)
- Game theory/economy (autonomy)

But they may be related to all or some of these domains!

[2] Michael Wooldridge: *An introduction to multiagent systems*. John Wiley & Sons, 2009.

Some applications

Application of MAS

- Simulation
- Distributed problem solving
- Software Engineering paradigm

Simulation

"Biological" simulation:

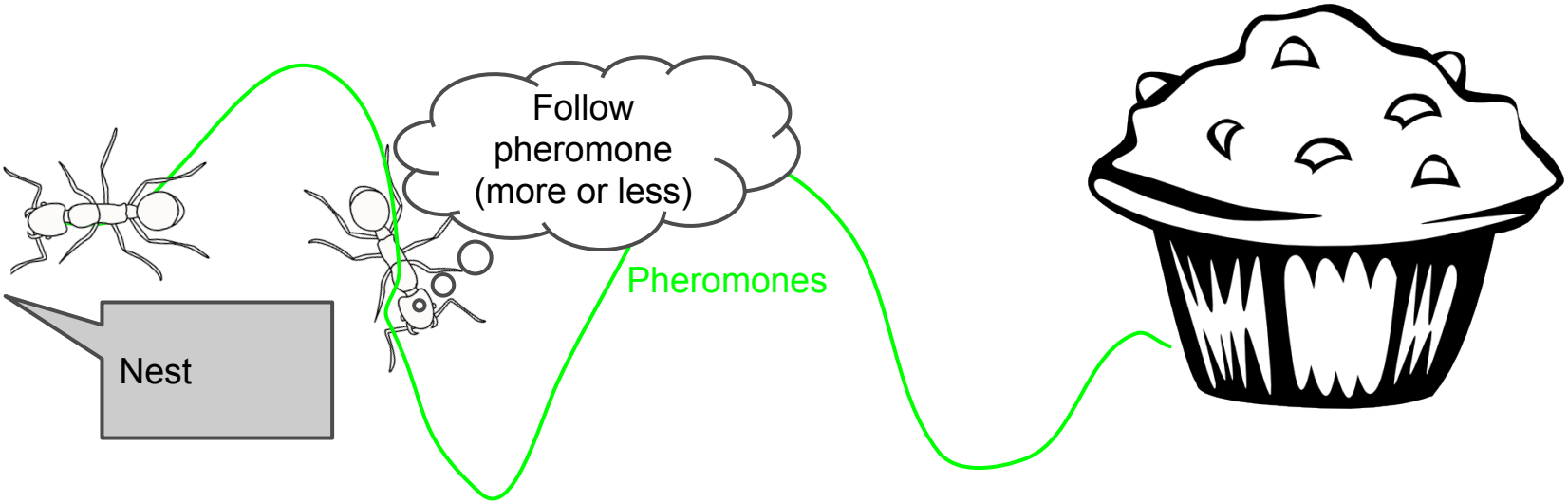
Models:

- Ants [5]
  - EthoModeling Framework[6, 7]
  - Sorting ants [8]
- Groups of animals (flocks, herds, schools…)[9]

Applications:

- Independant explorer robots [10]
- Chess player [11]

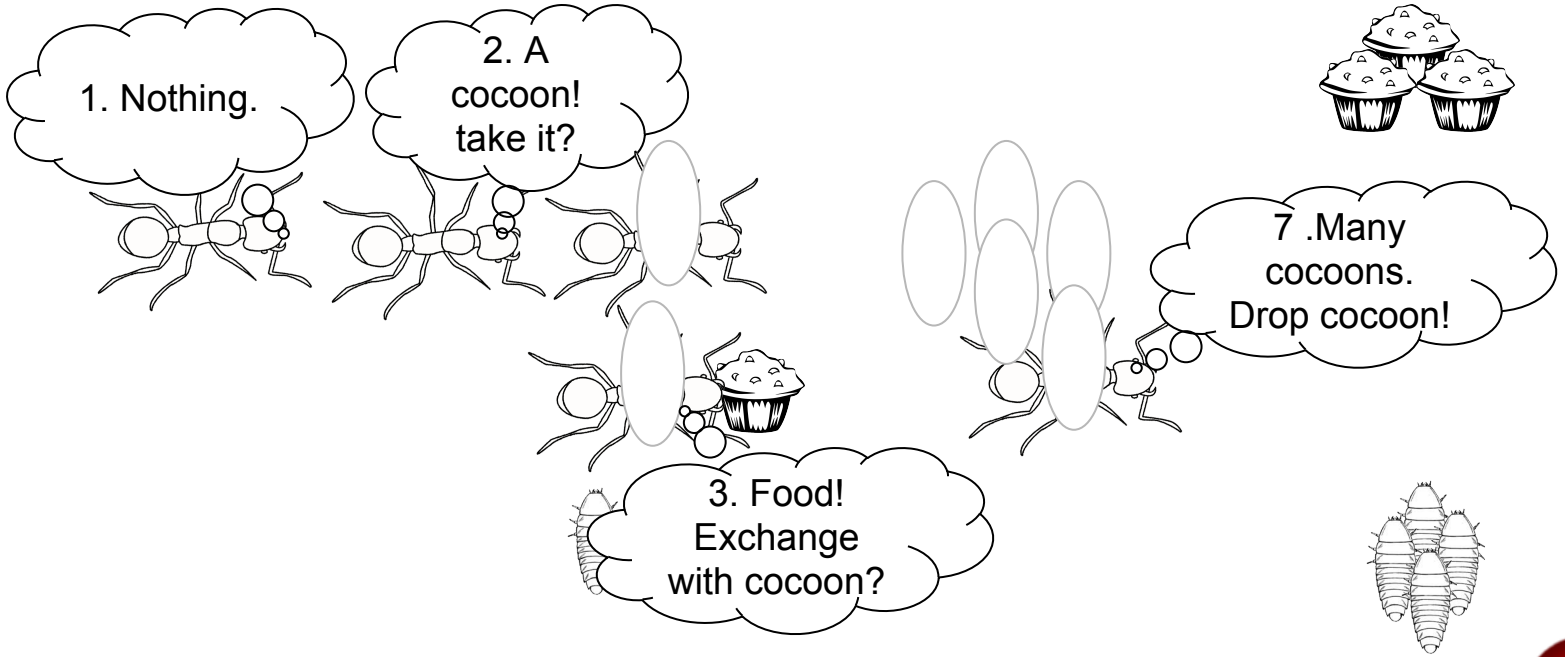
Ants – principles



Jean-Louis Deneubourg, Simon Goss and Jean-Michel Pasteels: The self-organizing exploratory pattern of the argentine ant. *Journal of Insect Behavior*, 3(2):159–168, 1990.

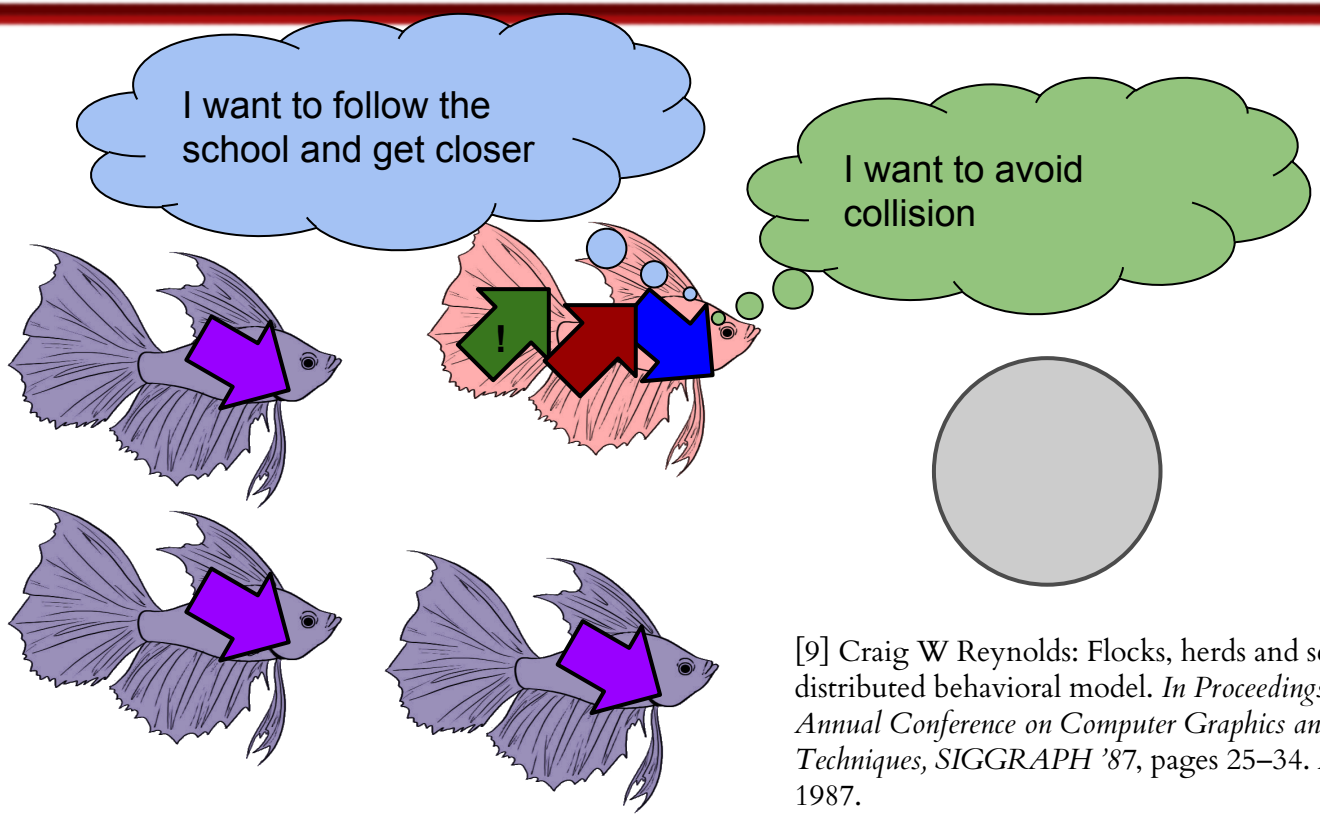
Sorting ants

Memory
cocoon
cocoon
cocoon
food
cocoon
Ø
Ø
Ø
Ø
Ø



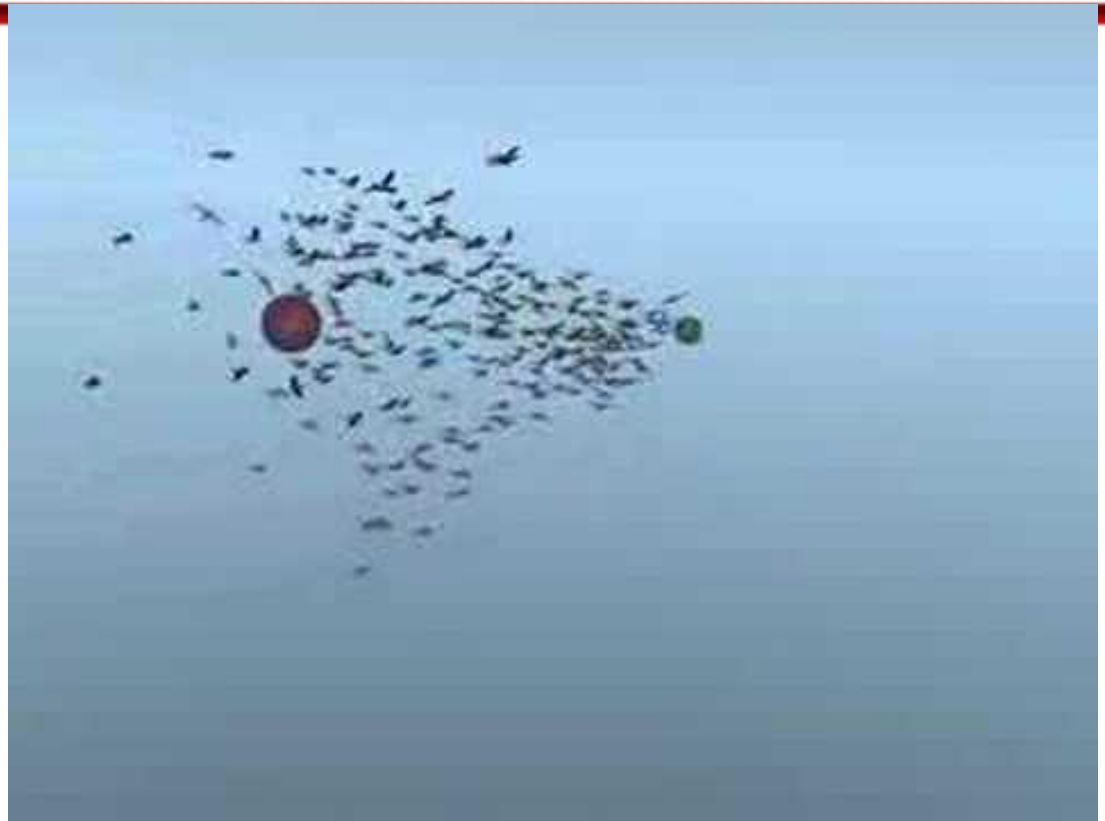
H Van Dyke Parunak. "go to the ant": Engineering principles from natural multi-agent systems. *Annals of Operations Research*, 75:69–101, 1997.

Flocks, herds and schools



[9] Craig W Reynolds: Flocks, herds and schools: A distributed behavioral model. *In Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH '87*, pages 25–34. ACM, 1987.

Flocks, herds and schools



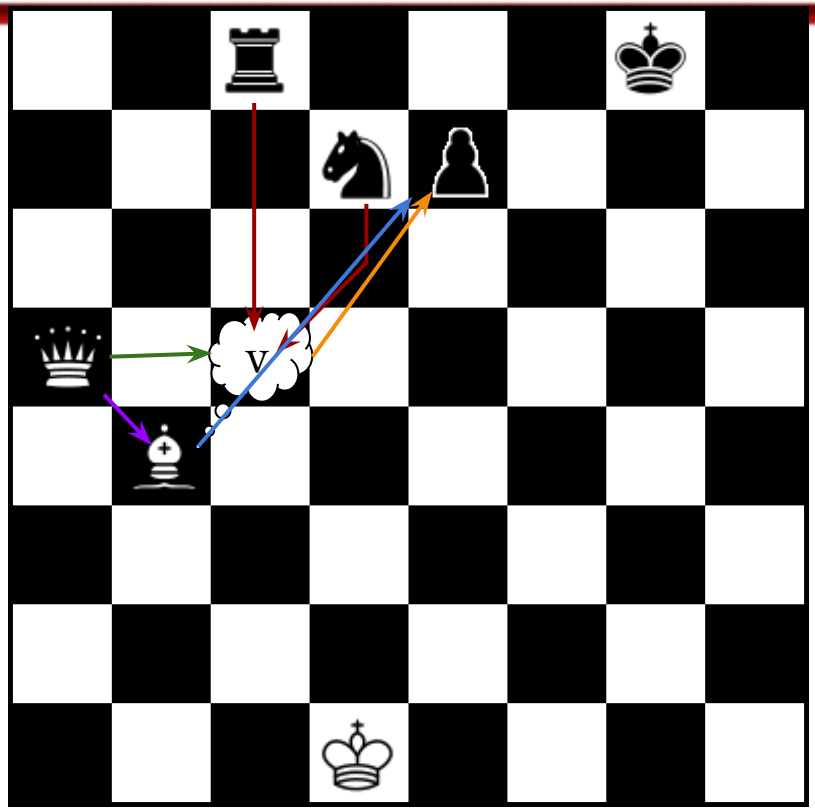
Back to the examples

Independant explorer robots

Luc Steels: Cooperation between distributed agents through self-organisation. *In IEEE International Workshop on Intelligent Robots and Systems '90. 'Towards a New Frontier of Applications'*, jul 1990.

When ants play chess

v = 10−20+1−10−1−3 = −23



Alexis Drogoul. When ants play chess (or can strategies emerge from tactical behaviours?). *In* Cristiano Castelfranchi and Jean-Pierre Muller, editors, *From Reaction to Cognition*, volume 957 de *Lecture Notes in Computer Science*, pages 11–27. Springer Berlin Heidelberg, 1995.

Simulation

Others:

- Massive battles
- Traffic

Massive – simulating life… and living deads

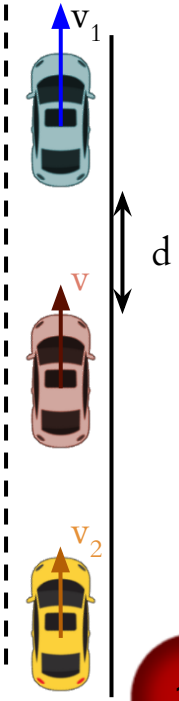
Software used in several games/movies

MASSIVE

ArchiSim: Traffic simulation

$$a \propto \alpha(v_1 - v_2) + \beta(d_{desired} - d)$$

acceleration take the neighborhood speed into account, the desired safe distance and the actual distance with the prior vehicle.



Stéphane Espié and Jean Michel Auberlet. ARCHISIM: A behavioral multi-actors traffic simulation model for the study of a traffic system including ITS aspects. *International Journal of ITS Research* n1 (2007): p7-16.

Distributed problem solving

Coordination mechanism [12, 13]:

- Auctions
- Bargaining
- Contract nets [14]

Auctions

Negotiation (1-n)

Multiple types:

- English auctions (classical ones)
- Blind auctions (Same as Kinvo, but with a third part)
- Dutch auctions (open descending)
- Vickrey auctions (sealed, at the second price)

Strategies:

- Classical auctions: buyers encouraged to propose a low price (guess the price proposed by other players)
- Vickrey auctions: optimal strategy: propose the real estimation

Bargaining

Negotiation between two agents (1-1)

Goal: decide the price of the item and the buyer

Quite a complex process, consisting in two parts:

- The protocol (providing the authorized actions)
- The strategy (the way of getting the best outcome)

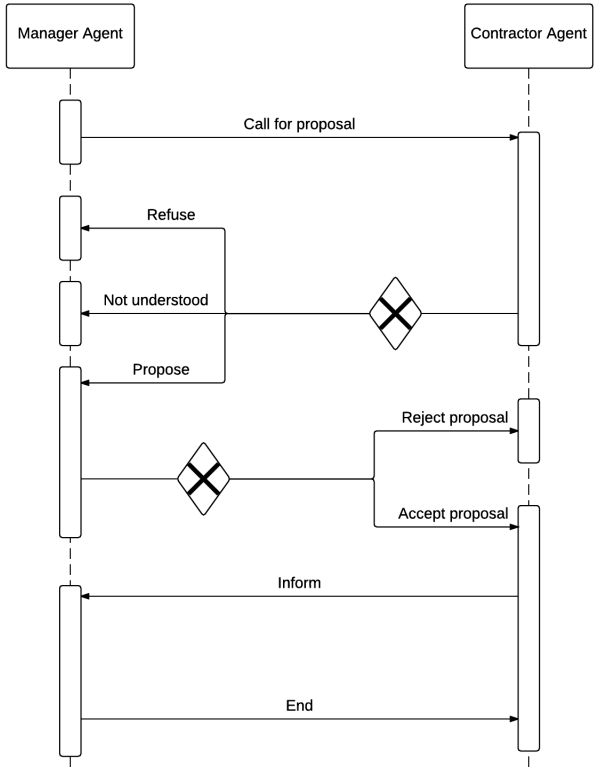
Protocol issues:

- Feedback?
- Threats? Promises?

Usual techniques:

- Based on machine learning
- Based on Game Theory

Contract nets



Specific to MASs.

Identical to bargaining, but (1-n)

Idea: a *Manager* has a tasks to complete, and try to distribute it among *Contractors*

Manager decomposes the task into subtasks and propose them to *contractors*

Contractors choose tasks they want to accomplish between those proposed by *managers*

Managers chooses the *contractors* among the ones that answered

Reid G Smith: The contract net protocol: High-level communication and control in a distributed problem solver. *IEEE Transactions on Computers*, C-29(12):1104–1113, Dec

Distributed problem solving

Applications:

- E-commerce
- Resource allocation

N.B.: these mechanisms can also be applied to simulation:

- Work market [17]…

E-commerce

MAGMA(Minnesota AGent Marketplace Architecture)[15]

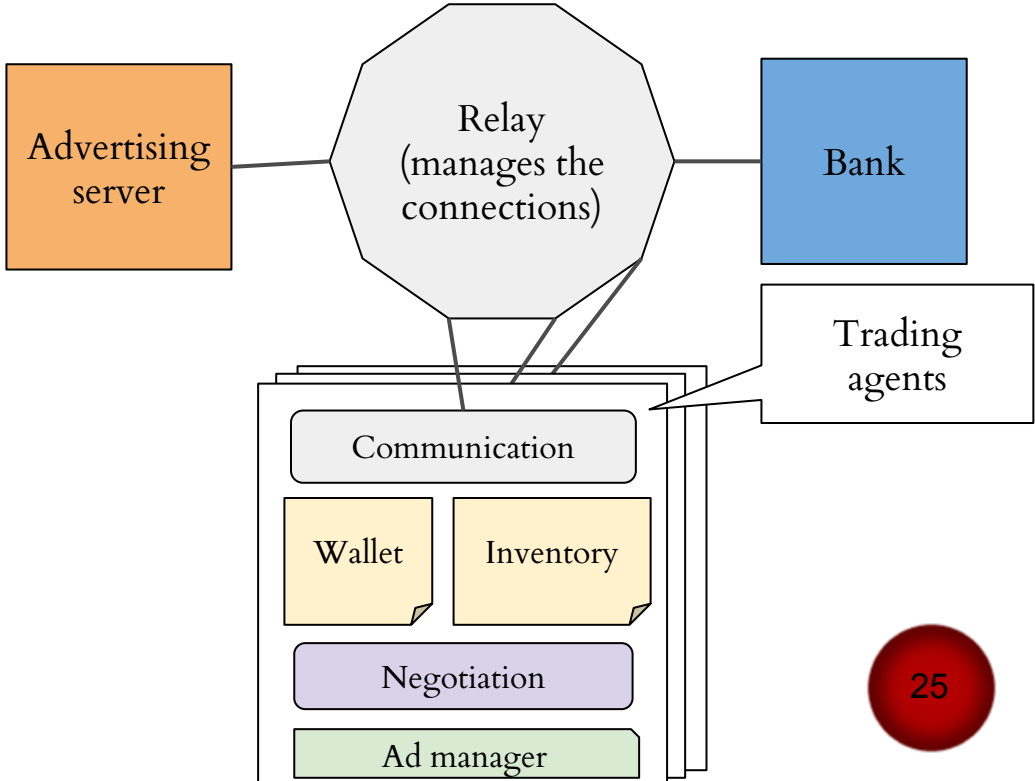
Advertising server: all goods to sale

Wallet: all information from Ad server/Bank

Inventory: track of all goods owned by the agent

Negotiation: switch automatic (Vickrey)/manual mode (negotiation)

Ad manager: track of ads sent to Ad server/allows to send new ones



Resource allocation

Many issues to consider [16]:

Pareto optimality

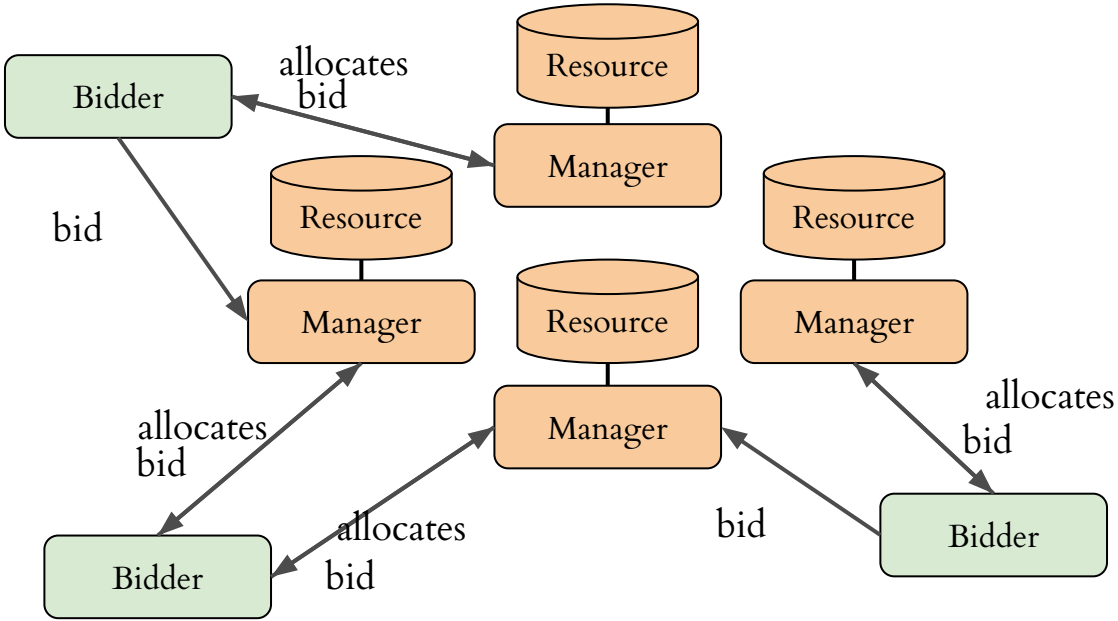
Social welfare

Protocol (Contract-net, auctions)

Complexity/Convergence

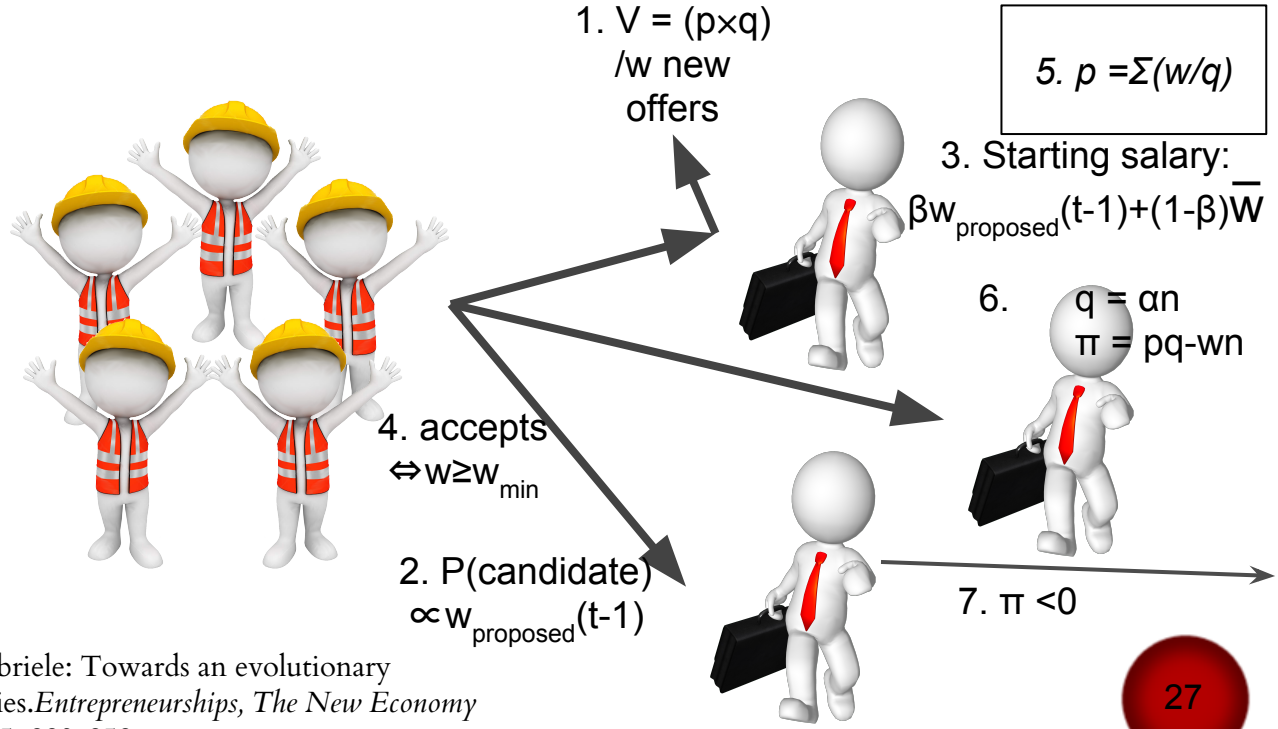
Preference representation

Examples of concrete applications: satellites, manufacturing (machines)



Work market

p: price of the product
q: quantity of product
w: salary
$\bar{w}$: average salary
β: negotiation strength
α: productivity
n: number of workers
π: profit



Giorgio Fagiolo, Giovanni Dosi, and Roberto Gabriele: Towards an evolutionary interpretation of aggregate labor market regularities.*Entrepreneurships, The New Economy and Public Policy*. Springer Berlin Heidelberg, 2005. 223-252.

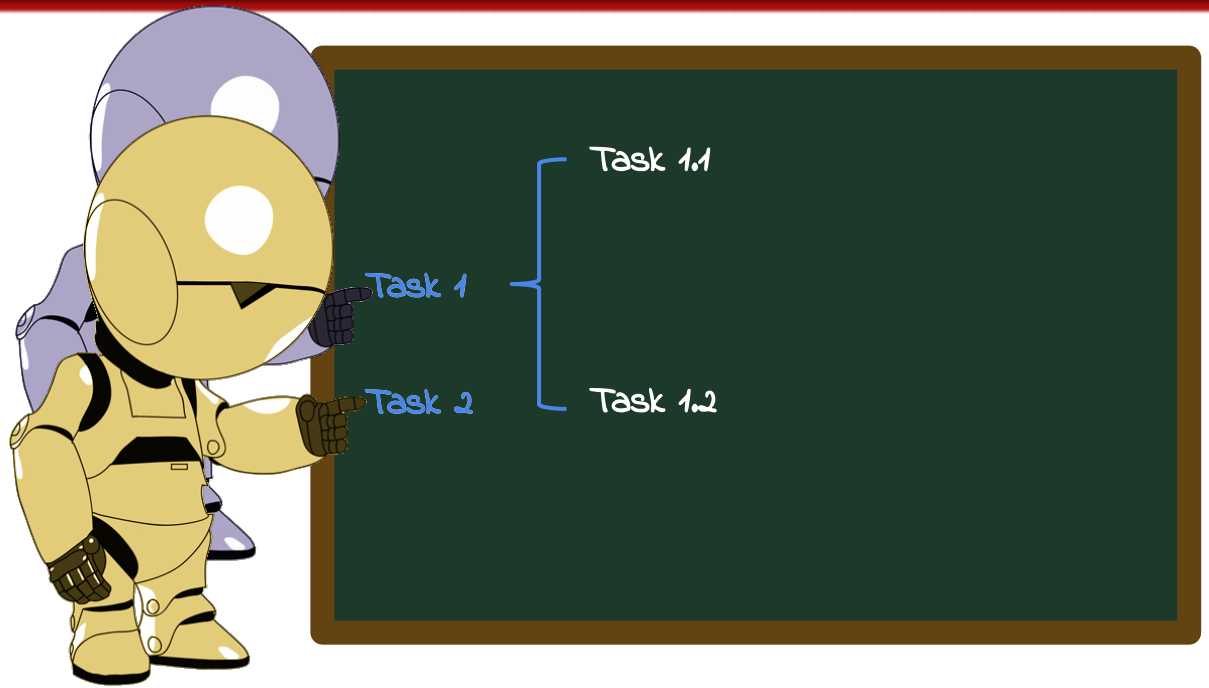
Distributed problem solving

- Also possible without negotiation

Example:

- Interaction through blackboard[19]

Blackboard



Daniel D. Corkill. Blackboard systems. *AI expert* 6.9 (1991): 40-47.

Agent Oriented Programming

Programming paradigm

No objects ⇒ agents

Standards (FIPA)[21]

Examples

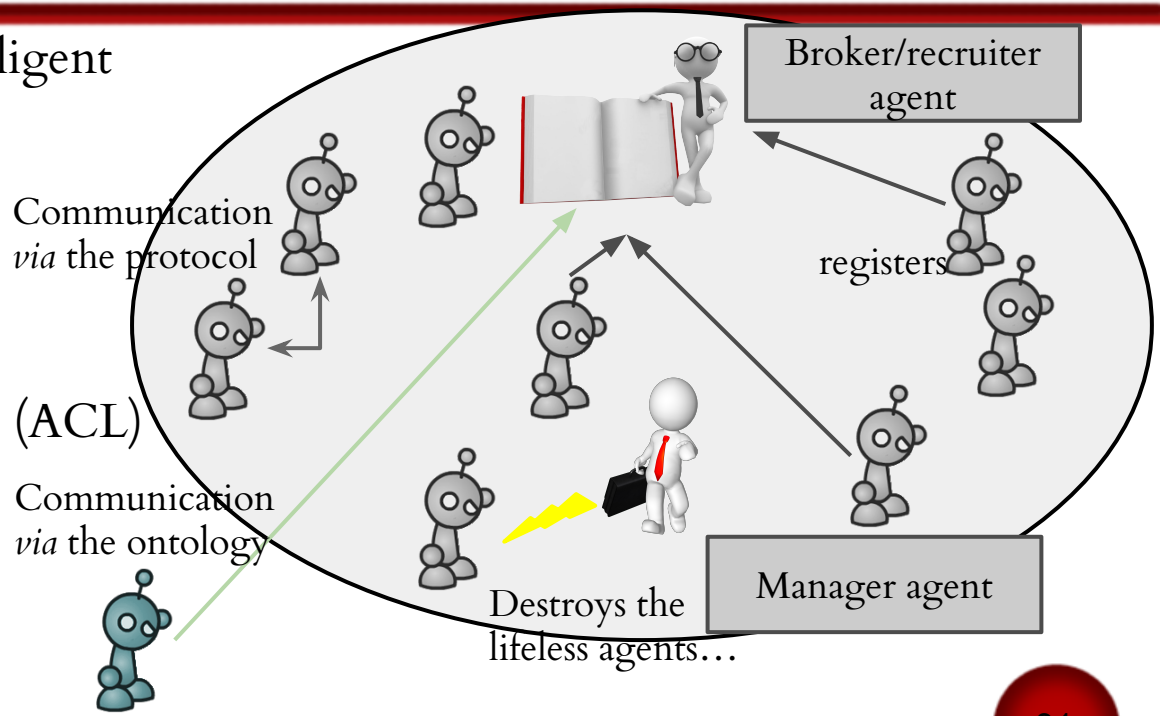
- Agent-0 [22]
- JADE [23]
- JACK [24]

Nicholas R. Jennings. On agent-based software engineering. *Artificial intelligence* 117.2 (2000): 277-296.

Recommendations of the FIPA

The FIPA (Foundation for Intelligent Physical Agent) recommends to include:

- An agent to manage the platform
- A “yellow pages” agent
- A communication protocol (ACL)
- A content language
- An ontology



Specification, FIPA Inform Communicative Act. Foundation for Intelligent Physical Agents, 2000.

Agent-0

"Toy" language, created in 1993

Starting point of Agent Oriented Languages

Consists in 3 types of languages:

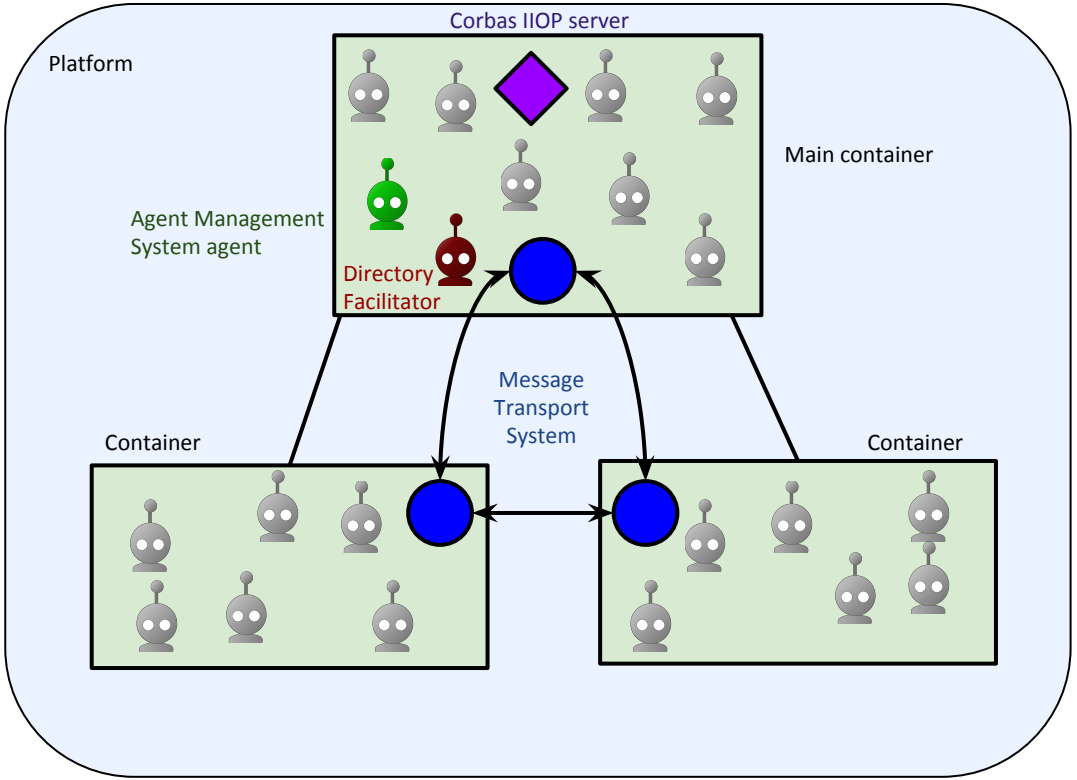
- Beliefs
- Messages
- Commitments

Not FIPA compliant (posterior)

Compiler written in Lisp

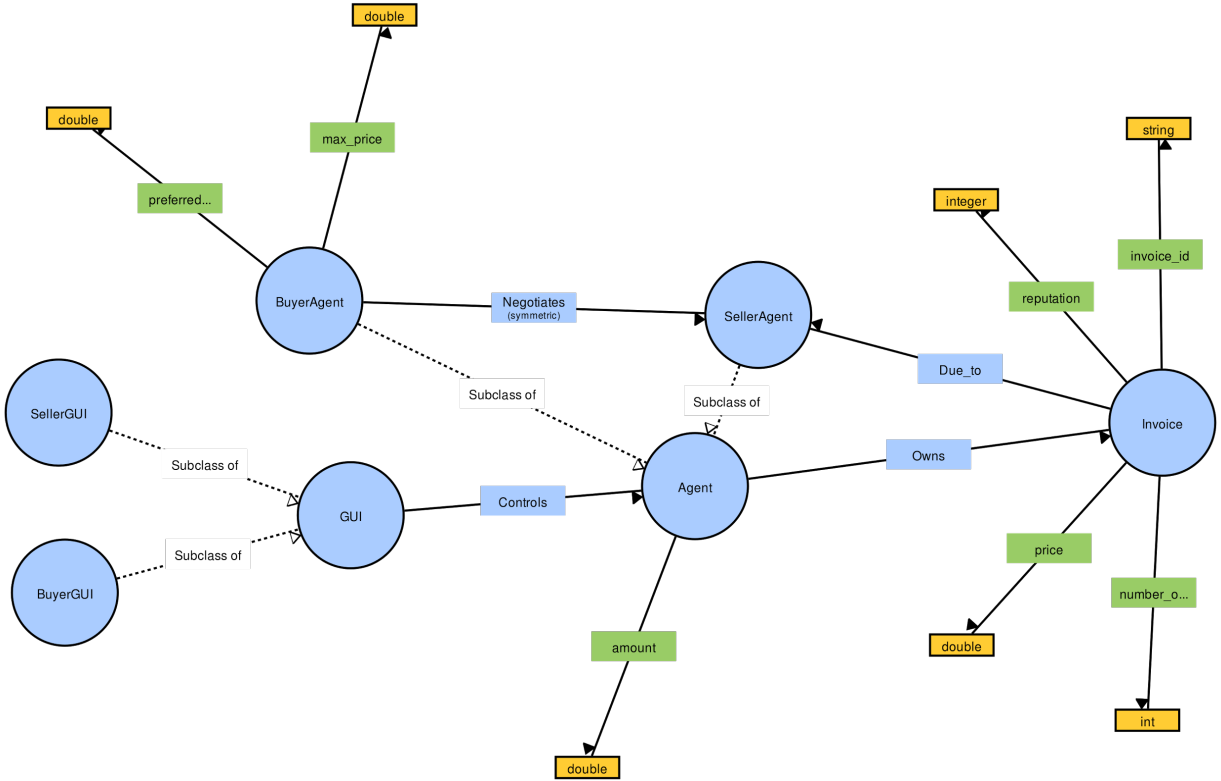
Yoav Shoham. An overview of agent-oriented programming. *Software agents*, 1997, vol. 4.

JADE



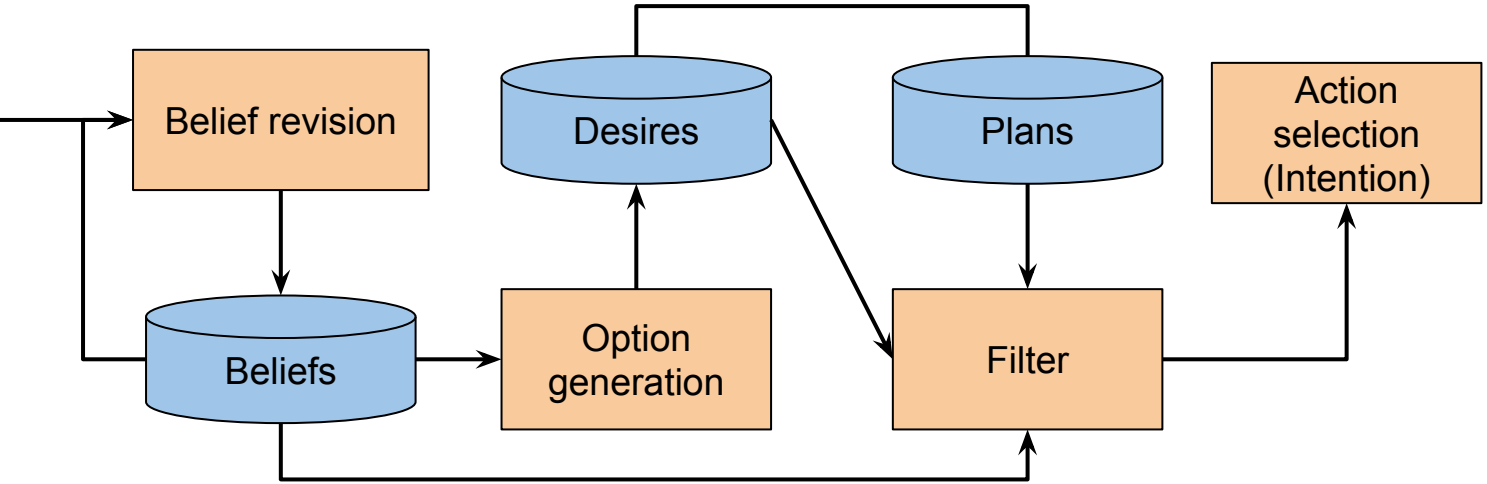
Fabio Luigi Bellifemine, Giovanni Caire, and Dominic Greenwood. *Developing multi-agent systems with JADE*. John Wiley & Sons, 2007.

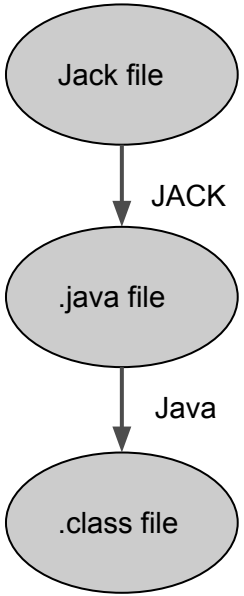
JADE – Demo


double
double
max_price
preferred...
BuyerAgent
Negotiates
(symmetric)
SellerAgent
Subclass of
Subclass of
SellerGUI
Subclass of
GUI
Controls
Agent
Owns
Invoice
Subclass of
BuyerGUI
amount
double
integer
string
invoice_id
reputation
Due_to
price
number_o...
double
int

JACK

- "BDI" formalism (Beliefs, Desires, Intentions)
- Mostly focused on simulation
- DSL based on Java.





Nick Howden, Ralph Rönnquist, Andrew Hodgson, Andrew Lucas. JACK intelligent agents-summary of an agent infrastructure. *5th International conference on autonomous agents*. 2001.

References - Principles

[1] Yves Demazeau. From interactions to collective behaviour in agent-based systems. *In Proceedings of the first European Conference on Cognitive Science*, Saint-Malo, France, 1995.

[2] Michael Wooldridge. *An introduction to multiagent systems*. John Wiley & Sons, 2009.

[3] Jacques Ferber, and Jean-François Perrot. *Les systèmes multi-agents : vers une intelligence collective*. InterEditions, 1995.

[4] Jean-Pierre Briot and Yves Demazeau, editors. *Principes et architecture des systèmes multi-agents*, volume 217. Hermès Science Publications, 2001.

References - Biological simulations

[5] Jean-Louis Deneubourg, Simon Goss and Jean-Michel Pasteels: The self-organizing exploratory pattern of the argentine ant. *Journal of Insect Behavior*, 3(2):159–168, 1990.

[6] Alexis Drogoul and Jacques Ferber. Multi-agent simulation as a tool for modeling societies: Application to social differentiation in ant colonies. *In* Cristiano Castelfranchi and Eric Werner, editors, *Artificial Social Systems*, volume 830 of *Lecture Notes in Computer Science*, pages 2–23. Springer Berlin Heidelberg, 1994.

[7] Alexis Drogoul, Bruno Corbara and Steffen Lalande: *Artificial Societies: the computer simulation of social life*, chapitre MANTA: New experimental results on the emergence of (artificial) ant societies, pages 160–179. UCL Press, 1995.

[8] H Van Dyke Parunak. "Go to the ant": Engineering principles from natural multi-agent systems. *Annals of Operations Research*, 75:69–101, 1997.

References – Biological simulations

[9] Craig W Reynolds: Flocks, herds and schools: A distributed behavioral model. *In Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH '87*, pages 25–34. ACM, 1987.

[10] Luc Steels: Cooperation between distributed agents through self-organisation. *In IEEE International Workshop on Intelligent Robots and Systems '90. 'Towards a New Frontier of Applications'*, jul 1990.

[11] Alexis Drogoul. When ants play chess (or can strategies emerge from tactical behaviours?). *In* Cristiano Castelfranchi and Jean-Pierre Muller, editors, *From Reaction to Cognition*, volume 957 de *Lecture Notes in Computer Science*, pages 11–27. Springer Berlin Heidelberg, 1995.

References - Economy

[12] Tuomas W Sandholm: Distributed rational decision making. *In Multiagent Systems*, pages 201–258. MIT Press Cambridge, 1999.

[13] Nicholas R Jennings, Peyman Faratin, Alessio R Lomuscio, Simon Parsons, Michael Wooldridge and Carles Sierra: Automated negotiation: Prospects, methods and challenges. *Group Decision and Negotiation*, 10(2):199–215, 2001.

[14] The contract net protocol: High-level communication and control in a distributed problem solver. *IEEE Transactions on Computers*, C-29(12):1104–1113, Dec 1980.

[15]Maksim Tsvetovatyy, Maria Gini, Bamshad Mobasher, Zbigniew Wieckow Ski et Wieckow Ski : Magma: An agent based virtual market for electronic commerce. *Applied Artificial Intelligence*, 11(6):501–523, 1997.

[16]Yann Chevaleyre, Paul E Dunne, Ulle Endriss, Jérôme Lang, Michel Lemaitre, Nicolas Maudet, Julian Padget, Steve Phelps, Juan A Rodriguez-Aguilar, et Paulo Sousa. Issues in multiagent resource allocation. *Informatica (Slovenia)*, 30(1):3–31, 2006.

[17] Giorgio Fagiolo, Giovanni Dosi, and Roberto Gabriele: Towards an evolutionary interpretation of aggregate labor market regularities.*Entrepreneurships, The New Economy and Public Policy*. Springer Berlin Heidelberg, 2005. 223-252.

References

[18] Stéphane Espié and Jean Michel Auberlet. ARCHISIM: A behavioral multi-actors traffic simulation model for the study of a traffic system including ITS aspects. International Journal of ITS Research n1 (2007): p7-16.

[19] Daniel D. Corkill. Blackboard systems. *AI expert* 6.9 (1991): 40-47.

[20] Nicholas R. Jennings. On agent-based software engineering. *Artificial intelligence* 117.2. 2000. 277-296.

[21] Specification, FIPA Inform Communicative Act. Foundation for Intelligent Physical Agents, 2000.

[22] Yoav Shoham. An overview of agent-oriented programming. *Software agents*, 1997, vol. 4.

[23] Fabio Luigi Bellifemine, Giovanni Caire, and Dominic Greenwood. *Developing multi-agent systems with JADE*. John Wiley & Sons, 2007.

[24] Nick Howden, Ralph Rönnquist, Andrew Hodgson, Andrew Lucas. JACK intelligent agents-summary of an agent infrastructure. *5th International conference on autonomous agents*. 2001.

Thank you for your attention