Self-adaptive Coordination for Organizations of Agents in Information Fusion Environments

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Structure

Self-adaptive Coordination for Organizations of Agents in Information Fusion Environments

Objetives

- **Modelled on a planning system capable of adapting itself to the common objectives of the deliberative agents which participate in an organization.**

- **Related Concepts:**
  - Multi-agent systems.
  - Virtual organizations, adaptation and coordination.
  - Case-based reasoning systems.

Objetives

- We propose a planning model for building adaptive organizations of agents.
  - An organization of agents must have the ability to generate plans for their agents member and must pursue objectives in relation to their own interests.
- Then, we evaluate empirically the results obtained after applying the mechanism to application environments.

Agents and Multi-agents systems

- Deliberative agents and multiagent systems :
  - An agent is an autonomous entity endowed with certain capacities of humans.
  - The internal structure of agents is usually based on a model planner**.**
    - Planning systems use symbolic models of knowledge representation and reasoning to satisfy basic objectives for the development of a plan.

There will always be a goal to achieve and some actions that the agent will seek to do to get it.

MOTOR PLANNER

[Georgeff y Lansky, 1987]

Agents and Multi-agent systems

- "*An artificial society is defined as a set of interrelated and interacting artificial entities that are governed by certain rules and conditions.*" **[Mauro, 2003].**

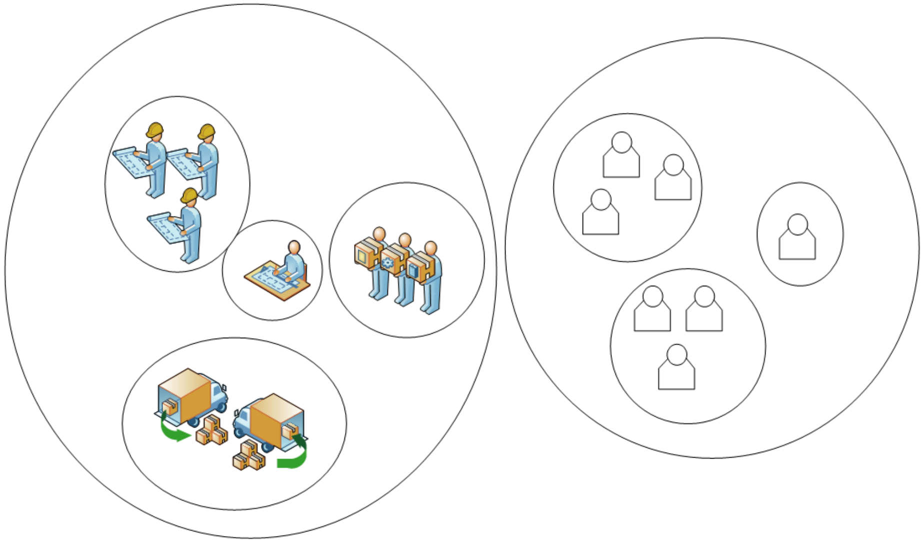
- Characteristics that define a society :
  - Purpose for which it is created.
  - Structure or definition of its parts.
  - Rules and regulations that govern and control the behavior of its members.

- ○ Individualistic view of the SMA: the agents are individual entities within a society located in a particular environment, ie, their behavior depend only on the reactions to the environment and the behaviors of other agents.
- ○ Collectivist view of the SMA: an agent within a society needs to consider not only their own behavior but also the behavior of the system as a whole and how the agents influence each other.

Virtual Organizations

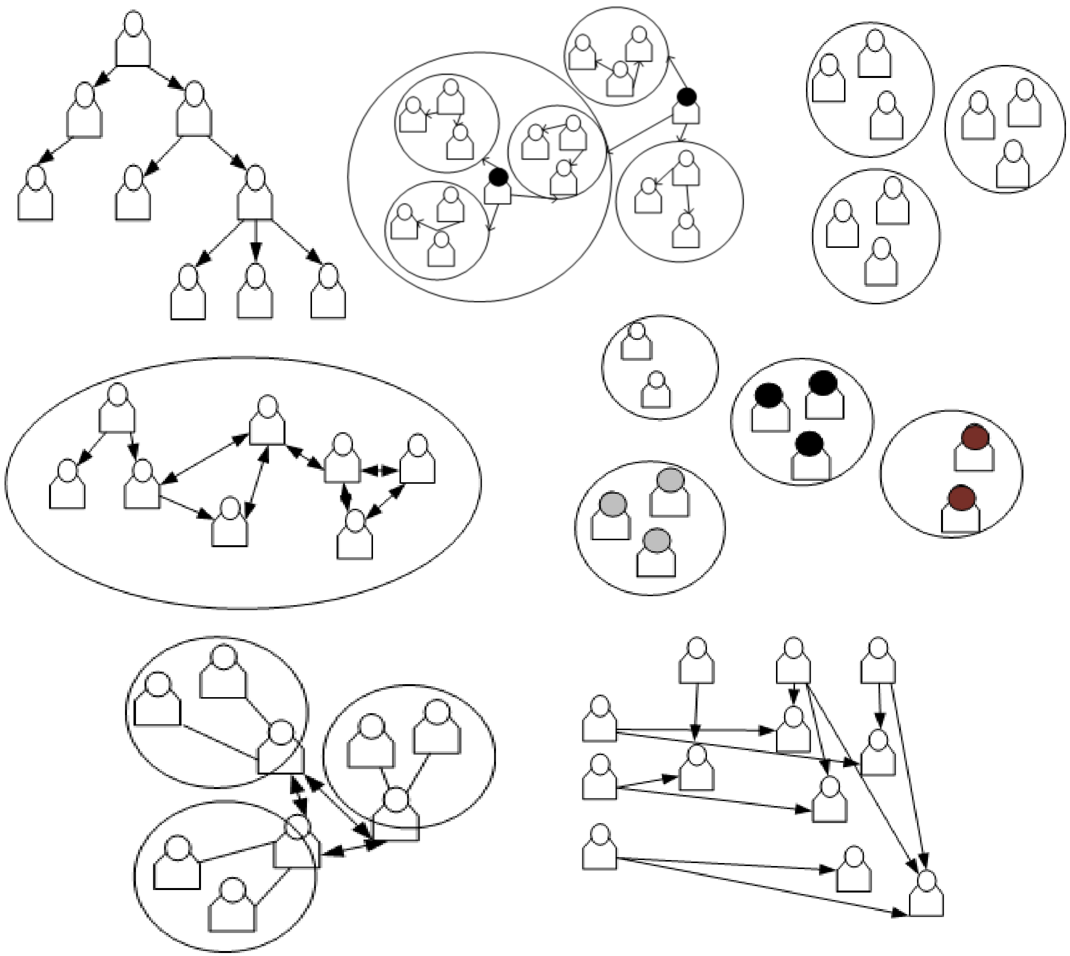
- Organizations of agents or agent **virtual organizations** (VO) may be considered open systems formed by the group and collaboration of heterogeneous entities and where there is a clear separation between structure and function to define how entities behave.**[Foster et al., 2001][Boella et al., 2005].**

" A Virtual Organization is a collection of individuals and institutions that need to coordinate their resources and services within institutional limits." [Foster et al., 2001] [Boella et al., 2005].



Virtual Organizations

- Organizational Concepts :



- Social entity
- Structure
- Funcionality
- Social norms
- Environment
- Dinamicy
- Social Adaptation
- Social learning

Virtual Organizations

- Coordination is a common point on all platforms to develop OV.

The coordination is the effort to administer interaction space of a MAS [Wegner, 1997][Busi et al., 2001].

planning of actions

plans that allow :

- **Know and predict the behavior of other agents in the system.**
- **Exchange intermediate results that lead to progress in solving the global task.**
- **Avoid redundant actions.**

Virtual Organizations

- **Adaptation**
- A virtual organization can be seen as a cooperative system, in that coordination is based on a **planning** and distribution of tasks.

- **Classic Systems**
  - Assume that the agent completely knows the environment
  - Assume that the actions won't fail
  - Assume that the environment changes only as a result of the agent's actions
- **Case-based Planning**
  - Use previous plans and sub-plans
  - It is possible to introduce temporal restrictions and resources into the problem
  - In dynamic planning: it allows the formalization of concepts such as "replanning" and "easily replannable plan".

Structure

Motivation

- Introduction
- Agent Organizations

Organizational Model

- CBP-BDI Agents
- Hybrid Dynamic Planning Mechanism for Virtual Organizations

Evaluation and Conclusions

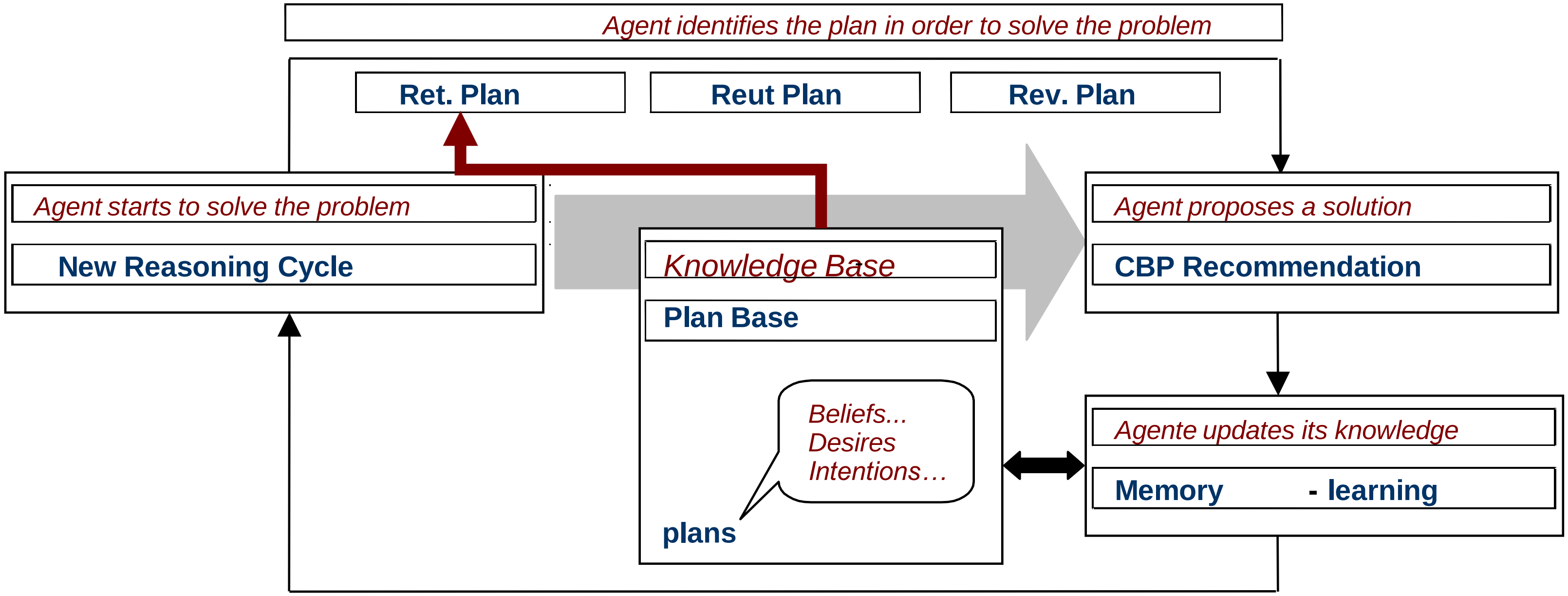
- Case Study
- Results
- Conclusions

BDI Agents

- CBR-BDI Architecture
  - BDI Agent – Case-Based Planner

Plan-case: <Problem, Solution, Result>
Problem: initial_state
Solution: secuence of <action, [intermediate state]>
Result: final_state

BDI Agent (beliefs, desires and intentions)
Beliefs: states
Desires: set of <final_state>
Intenction: sequence of <action>



CBP Agent

- Deliberative agents for dynamic systems
  - Agent - BDI
    - CBR-BDI Agent
      - Planner: CBP
        - Generates – the most replannable intentions
        - Generation of plans at runtime

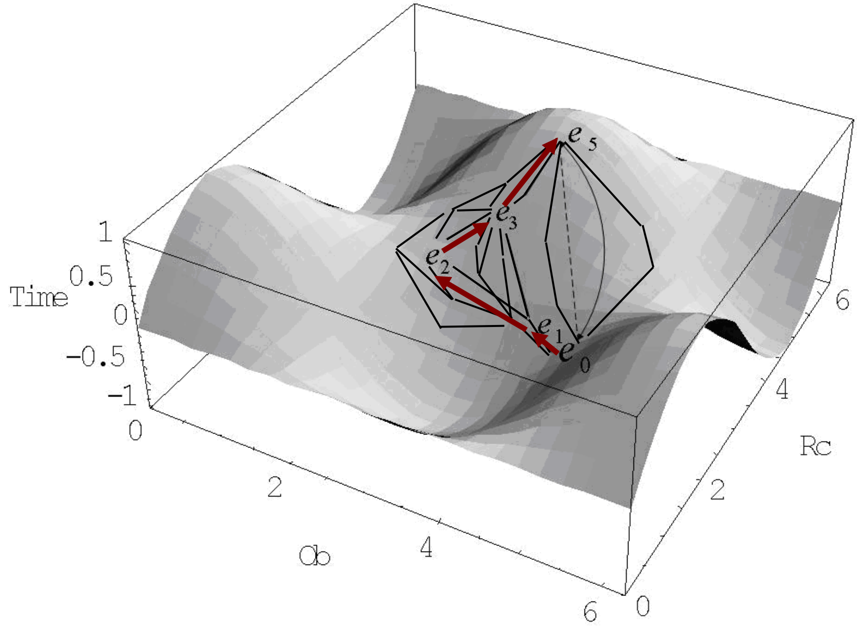
MRPI

(Most RePlannable Intention)

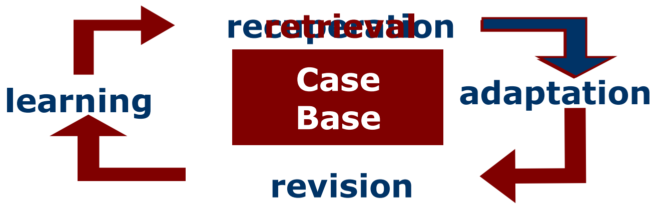
- Agent capable of:
  - Generating solutions at runtime
  - Working autonomously
  - Interracting with the user
  - Managing multiple objectives
  - Learning continuously

CBP Agent

- Planning model at runtime
  - Case-Based Planning – OPTIMUM PLAN
- It calculates the plan that can be most easily modified in the case of it being necessary to modify the original plan
  - The most replannable intention (*MRPI*)



The geodesic in n dimentions is the curve that has **constant slope with respect to the temporal restricion**.



CBP Agent

Retrieval

- We retrieve those plans that include elements that are found in the objective plan.

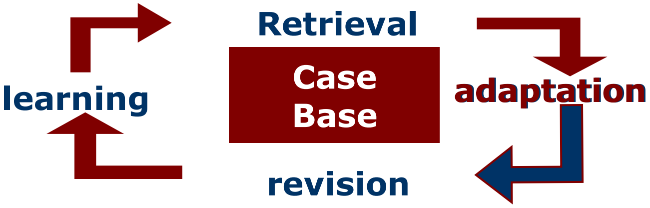
E^i is the set of tasks to be carried out in order to reach the objective i

$$E^i = \left\{ e_0^i, \cdots, e_h^i \right\}$$

$$C_r = \bigcup_{j,i} \left(e_{jr}, t_{jr} \right) / E^i = \bigcup_{i=0}^{h} \left(e_j^i, t_j \right) \subseteq C_r, \qquad t_{jr} \leq t_j \;\; \forall j$$

Stored plans are retrieved which includet least the tasks of the new plan.

The cases associated with plan r are retrieved, so that the tasks of the new problem case will be included and the times of the new plan will be less of equal to the runtime of plan r.



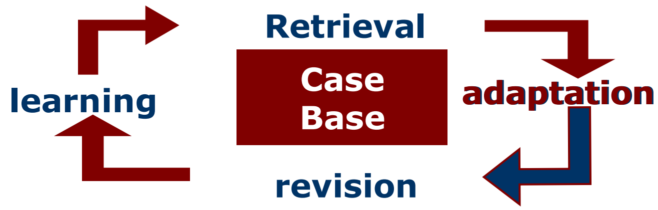
CBP Agent

Adaptation

- We calculate the hyperplane which includes all of the restrictions - B-splines
- We calculate the geodesic plans - Euler Theorem
- We calculate the optimum plan between the geodesic.
  - Using the Minimum Jacobi Field
  - Identifying the plan with the most density of plans around it.

- Replanning
  - In the case of interruption Bellman's Principle of Optimality is used (An optimum plan is formed by optimum sub-plans)

CBP Agent



Adaptation

Action function

$$a_j : \underset{e_i}{E} \underset{\rightarrow}{\rightarrow} \underset{a_j(e_i)=e_j}{E}$$

Set of actions carried out by an agent

$$Agent\ \ A = \{a_A(t)\}_{t \in T \subseteq N}$$

Agent plan (defined from the action function)

$$p_A : \underset{(t, a_A(t))}{TxA} \underset{\rightarrow}{\rightarrow} \underset{p_A(t)}{A}$$

$$p_A(t_n) = \sum_{i=1}^{n} a_{iA}(t_i - t_{i-1})$$

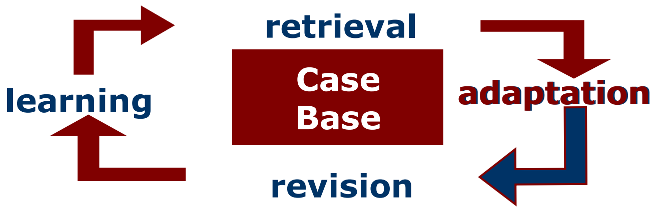
$$p_A(t_n) = \int_{t_0}^{t_n} a_A(t)dt$$

Efficiency of the plan

$$E_{ff} = \frac{\#(O^{'} \cap O)}{\# R^{'}}$$

Accumulation of resources

$$Ob'(t_i) = \int_a^{t_i} O'(t)dt \qquad Rc'(t_i) = \int_a^{t_i} R'(t)dt$$



CBP Agent

Adaptation

Action function $a_j : \underset{e_i}{E} \underset{\to}{\to} \underset{a_j(e_i)=e_j}{E}$

Set of actions carried out by an agent $Agent\ A = \{a_A(t)\}_{t \in T \subseteq N}$

Agent plan (defined from the action function) $p_A(t_n) = \int_{t_0}^{t_n} a_A(t)dt$

Efficiency of the plan $E_{ff} = \frac{\#(O' \cap O)}{\#R'}$

Accumulation of Resources $Ob'(t_i) = \int_a^{t_i} O'(t)dt \quad Rc'(t_i) = \int_a^{t_i} R'(t)dt$

Efficiency of the plan,

(for a dimension)

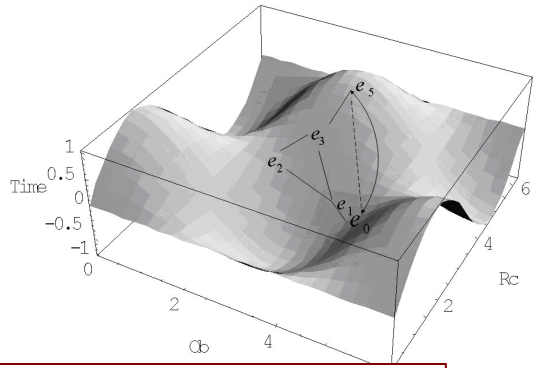
$$\frac{d}{dt}p(t) = cte \Leftrightarrow \lim_{\Delta \to 0} \frac{\Delta O(t)}{\Delta R(t)} = cte$$

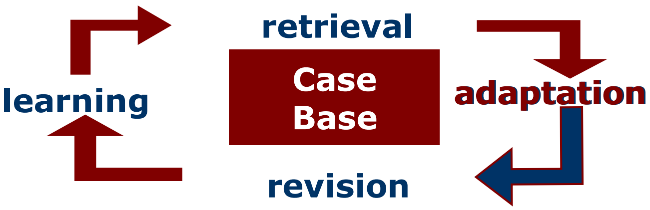
In more than one dimension there will be a geodesic curve. Curves that have a constant slope with respect to time.

Euler Theorem - Calculates geodesic plans

L is the distance function in R^3

$$\begin{cases} \frac{\partial L}{\partial R_1} - \frac{d}{dO}\frac{\partial L}{\partial R_1'} = 0 \\ \frac{\partial L}{\partial R_2} - \frac{d}{dO}\frac{\partial L}{\partial R_2'} = 0 \end{cases}$$





CBP Agent

Adaptation

The Jacobi fields are calculated for all of the geodesic plans identified previously

$$\lim_{t\to 0}\{h_t(s)=g_0(s+t)\}=\lim_{t\to 0}\{h(s,t)\}=\frac{\partial g_0}{\partial t}\Big|_{(s,0)}=\frac{dg_0}{ds}\equiv J_{g_0}(s)$$

The geodesic of the Minimum Jacobi Field is calculated (Optimum Plan)– MRPI

$$G(e_0,p_1,\cdots,p_n)=p^* \Leftrightarrow \exists n\in N \,/\, J_{g_n}\equiv J_{g^*}=\underset{n\in N}{Min}\, J_{g_n}$$

Bellman's Principle of Optimality: the union of optimum sub-plans is an optimum plan.

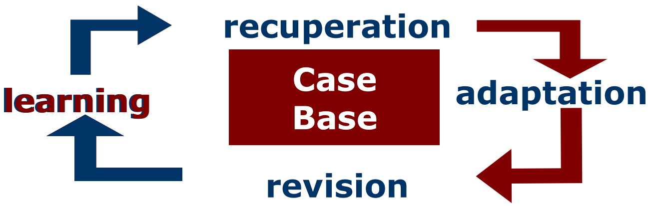
Replanning

A geodesic plan satisfies Bellman's Principle of Optimality. Each part of the plan (between two consecutive points) is geodesic.

The global Jacobi minimum is constructed from the various minimum Jacobi "sub" fields.

$$J_{\min}(t)=\{J_{\min}(t_1-t_0),J_{\min}(t_2-t_1),\cdots,J_{\min}(t_n-t_{n-1})\}$$

CBP Agent



- The efficiency of the plan takes into account the objectives stored in function of the resources used and determines whether or not the plan is stored.

Efficiency of the plan

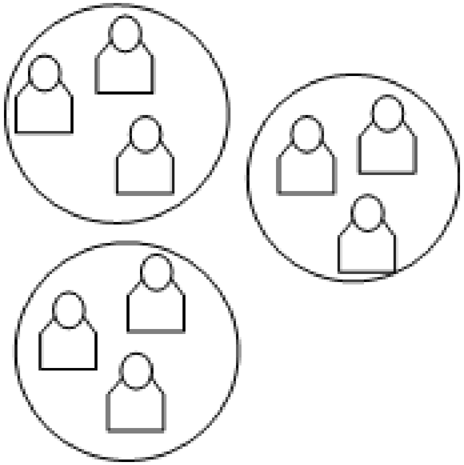
$$E_{ff}^{p^*} = \frac{\#(O'_{p^*} \cap O)}{\# R'_{p^*}}$$

Storage

$$Si \ E_{ff}^{p^*} \geq tolerancia$$

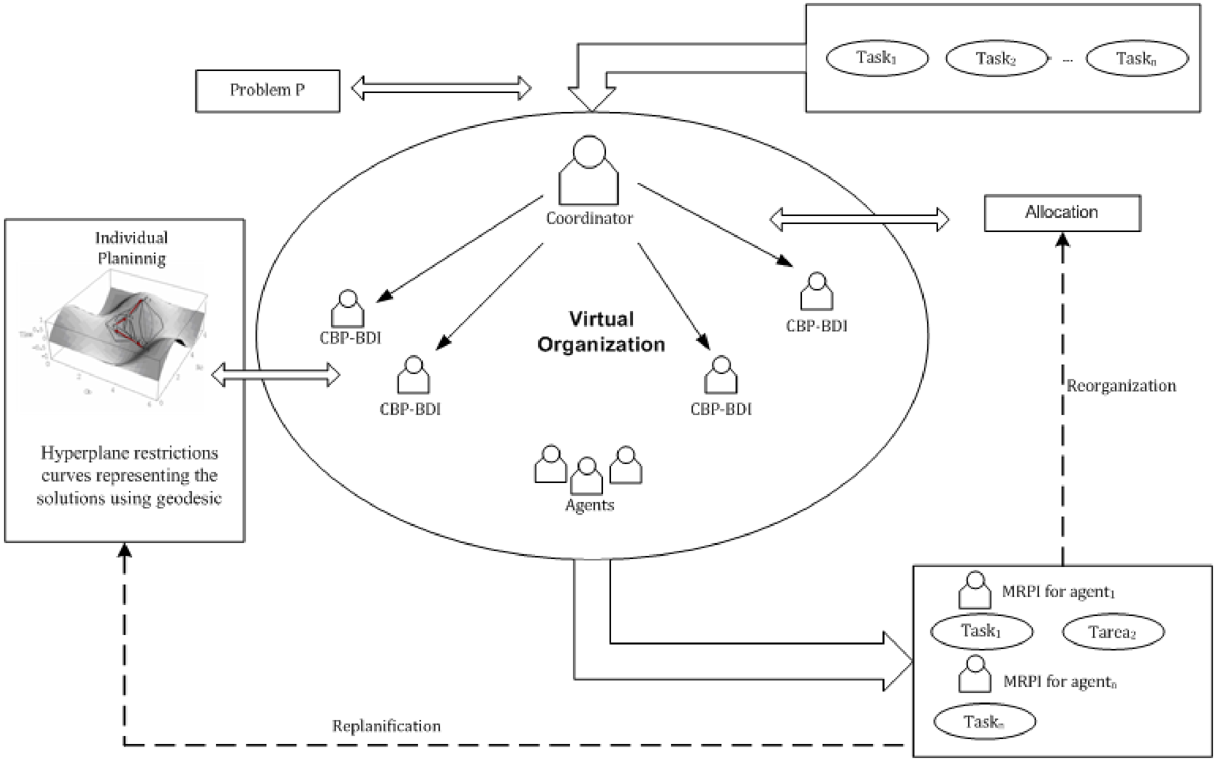
Hybrid Dynamic Planning Mechanism for Virtual Organizations

- Until now: individual CBP-BDI agent.
- Starting from now: the problems and objectives to be achieved are given by the organization and its restrictions.
- Which actions are carried out by each agent?
- Roles, norms.



Hybrid Dynamic Planning Mechanism for Virtual Organizations

- The concept of *global planning* is used to describe the search for a solution that allows the storage of a final state which satisfies a series of system requirements.



Hybrid Dynamic Planning Mechanism for Virtual Organizations

Suppose that the common objective of the "m" agents has "n" states or tasks.

$$a_{ij} = \begin{cases} 1 \text{ si al agente "i" se le asigna la tarea "j"} \\ 0 \text{ en otro caso} \end{cases}$$

Each agent has its own profile.

State "j", for each agent "i" with $i \in \{1, \cdots, m\}_{m \in \mathbb{N}}$

Each coordinate of the tuple refers to a feature that defines it.

z_{ij} -tupla

$$Eficiencia = \frac{N^o \text{ puntos visitados}}{\sum_{i=1}^{m} \sum_{j=1}^{n} c^i_{t_{ij} z_{ij}} \cdot a_{ij}}$$

In all of the assignment problems, an objective function is defined to minimize or maximise.

A new efficiency function is introduced, with which we seek to visit a large number of points while incurring the least possible cost.

$$Max \frac{N^o \text{ puntos visitados}}{\sum_{i=1}^{m} \sum_{j=1}^{n} c^i_{t_{ij} z_{ij}} \cdot a_{ij}}$$

t_{ij} **time that it takes for the agent "i" to carry out the state or task "j".**

$$t_{ij} = \underset{k}{Máx}\{t_{ijk}\}$$

***t* indicates the time it takes for planning agent "i" to carry out task "j" for agent "k";**

Hybrid Dynamic Planning Mechanism for Virtual Organizations

We define the restrictions of the problem:

1. We want each state to be carried out by an agent, which for each state "k" means

$$\sum_{i=1}^{m} a_{ik} = 1 \quad \forall k \in \{1, \cdots, n\}$$

2. We want each state to be made within a limited time. We suppose that state "k" has been made in a time t_k. The restriction would be:

$$\sum_{i=1}^{m} t_{ik} a_{ik} \le t_k \quad \forall k \in \{1, \cdots, n\}$$

***3.* Each state "k" needs a series of resources for its execution, these resources all agents don't have.**

Hybrid Dynamic Planning Mechanism for Virtual Organizations

Fixed state "k", we will need r_h^k **resources with** $h \in \mathbb{N}$**, will be** $r_v = \max\{r_h^k\}_{h\in\mathbb{N}}^{k=1,\cdots,n}$

The variables $\{r_x^k\}_{x\in\{1,\cdots,w\}}$ $\forall k \in \{1,\cdots,n\}$ **are defined in binary form**

$$r_x^k = \begin{cases} 1 \; si \; el \; agente \; "k" \; necesita \; el \; recurso \; "x" \\ 0 \; en \; otro \; caso \end{cases}$$

The agent that makes state "k" has to have, as a mimimum, the resources necessary to carry out state "k", hence the fixed state "k", for each resource of the set the following set is defined:

$$\sum_{i=1}^{m} r_{ix} a_{ik} \geq r_x^k \quad \forall k \in \{1,\cdots,n\}; \forall x \in \{1,\cdots,w\}$$

$\{r_{ix}\}_{x\in\{1,\cdots,w\}}$ $\forall i \in \{1,\cdots,m\}$ ***These variables are binary:***

$$r_{ix} = \begin{cases} 1 \; si \; el \; agente \; "i" \; tiene \; el \; recurso \; "x" \\ 0 \; en \; otro \; caso \end{cases}$$

Hybrid Dynamic Planning Mechanism for Virtual Organizations

4.- Each agent "i" has a mimimum and maximum time of work, depending on the type of agent, these times are denoted respectively by:

$$t_i^{Turn\ on} \text{ and } t_i^{Turn\ off}$$

$$t_i^{Turn\ on} \leq \sum_{j=1}^{n} t_{ij} \leq t_i^{Turn\ off} \quad \forall i \in \{1, \cdots, m\}$$

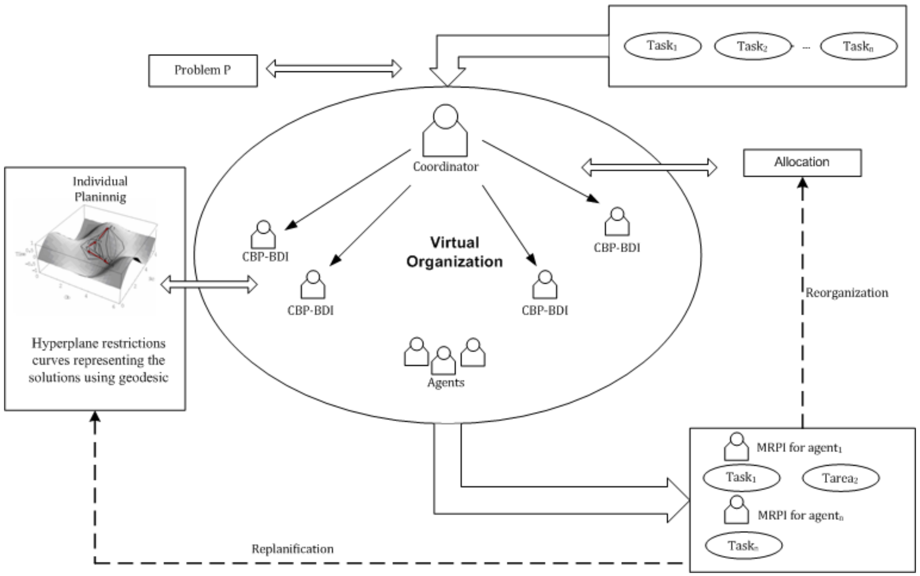
5.- Each time that we assign tasks to an agent, we want it to carry our a minimum number of tasks. This number depends on the type of agent.

$$\sum_{j=1}^{n} a_{ij} \geq NumberTask_i \quad \forall i \in \{1, \cdots, m\}$$

We obtain the global plan composed by all of the tasks and the organizational agents who are going to carry them out. Each organizational agent knows the tasks that it has to carry out. These agents, of the CBP-BDI type integrate the 4 stages seen previously.

Hybrid Dynamic Planning Mechanism for Virtual Organizations

1. Change in the agent:
   1. Replanning
   2. Reorganization
2. Change in the structure of the society. Reorganization
3. Change of norms. Reorganization.



The plan chosen by each planning agent is the optimum, i.e., the most replannable plan.

Structure

Self-adaptive Coordination for Organizations of Agents in Information Fusion Environments

Objectives and State of the Art

- Objetives
- State of the Art

Motivation

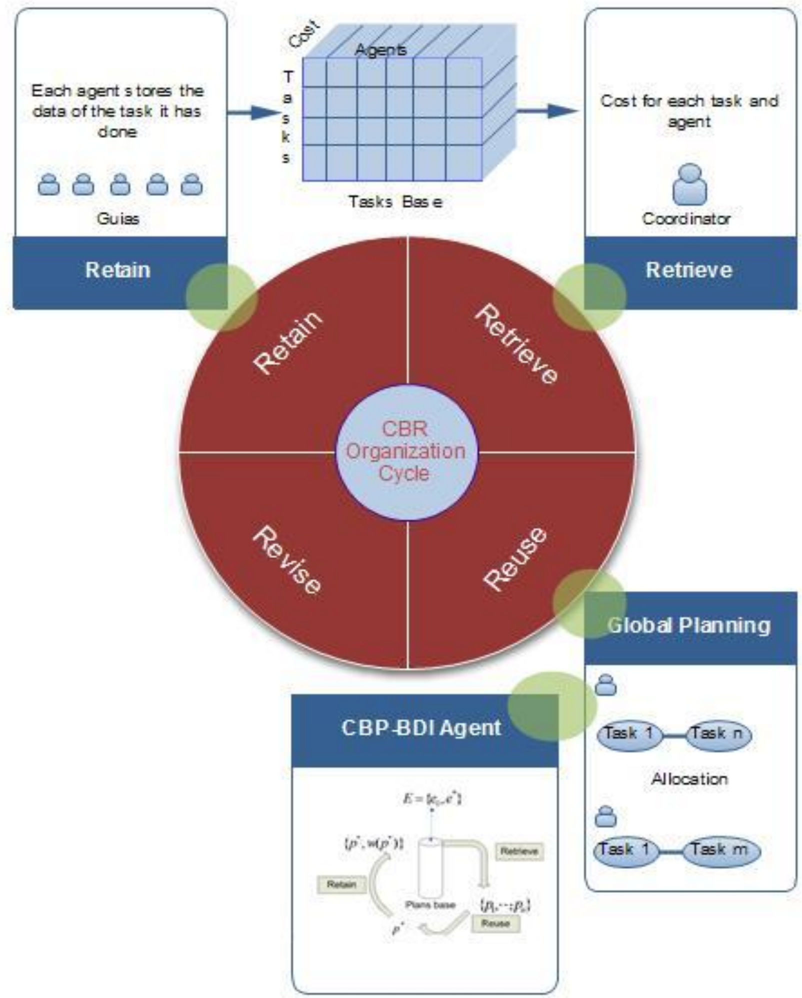
- CBP-BDI Agents
- Adaptive planning in OV

Evaluation and Conclusions

- Case Study
- Results
- Conclusions and Future Work

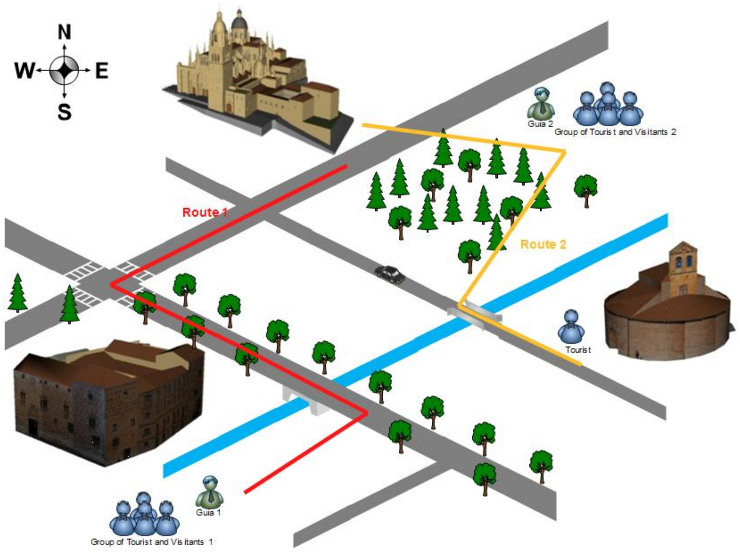
Evaluation and Conclusions

- Case Study: guide services for tourists.
- Guide Agents
- Coordinator Agents
- CBR which coordinates the organizational tasks.
- Each CBP-BDI guide agent, has a cycle in which it will obtain its optimum plan individually.



Evaluation and Conclusions

- Case Study: ***TouristOrg*** - an organization-based multi-agent system



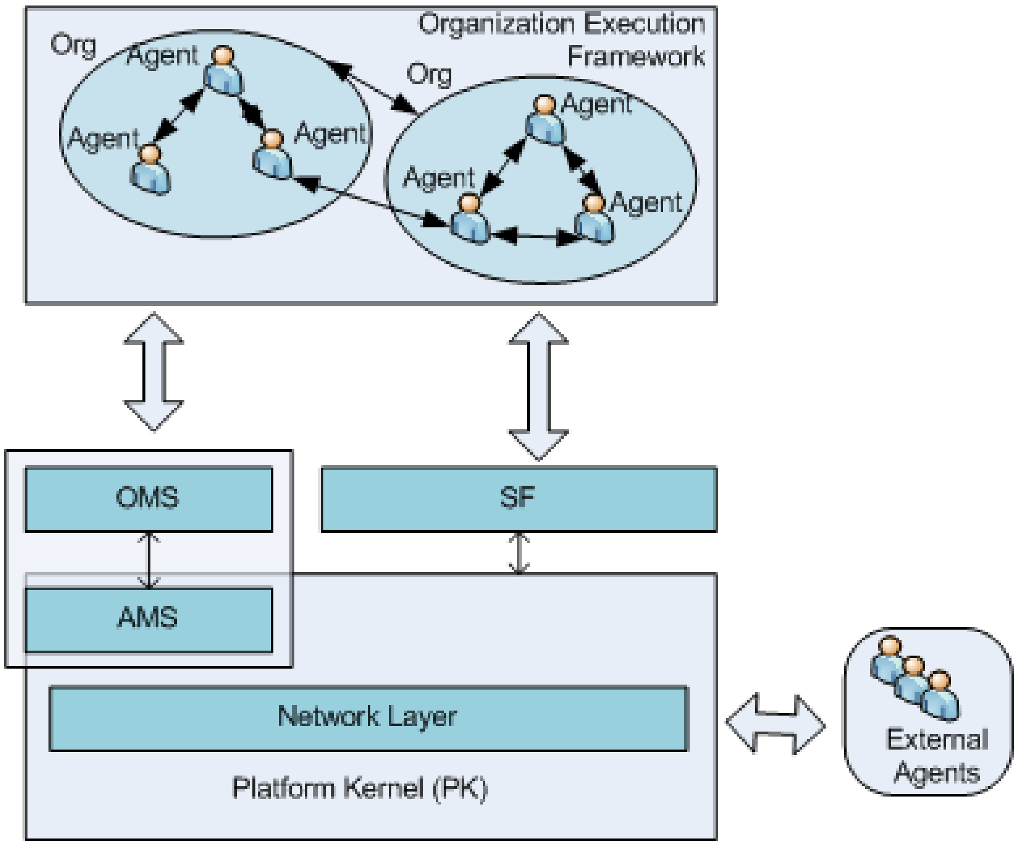
- Roles in the organization:
  - **Tourist**
  - **Monument**
  - **Guide**
  - **Visitor**
  - **Coordinator**
  - **Notifier**
  - **Manager**

- Virtual World in which the inventories of a documented set of cultural heritage will be available.
- GORMAS **has been used** [Argente, 2008] as a methodology of design and also **THOMAS** [Carrascosa et al., 2009] [Giret et al., 2009] as final platform of development.

THOMAS Outline

- THOMAS is an abstract architecture for large scale, open multi-agent systems.
  - It is based on a services oriented approach.
  - It is focuses on the design of virtual organizations.
  - It uses the FIPA architecture, expanding its capabilities with respect to the design of the organization.

THOMAS Outline



- SF → autonomous entities to register service descriptions as directory entries.

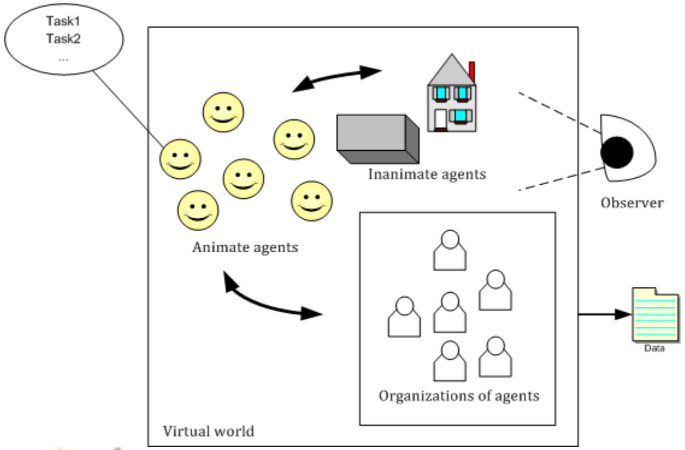
- OMS→ responsible for administrating :
  - structural components
  - execution components
  - OMS handles the lists:
    - *UnitList*
    - *RoleList*
    - *NormList*
    - *EntityPlayList*
- PK→ basic services on a multi-agent platform

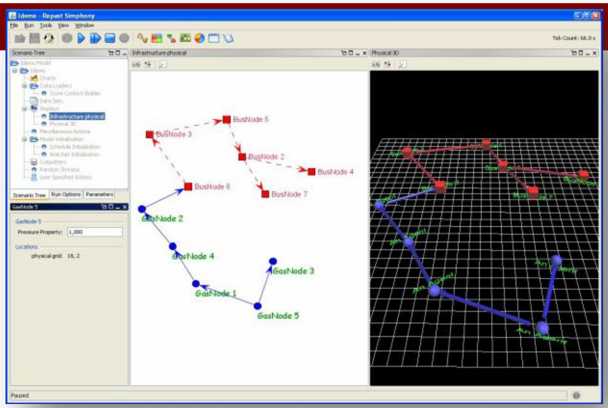
THOMAS Outline

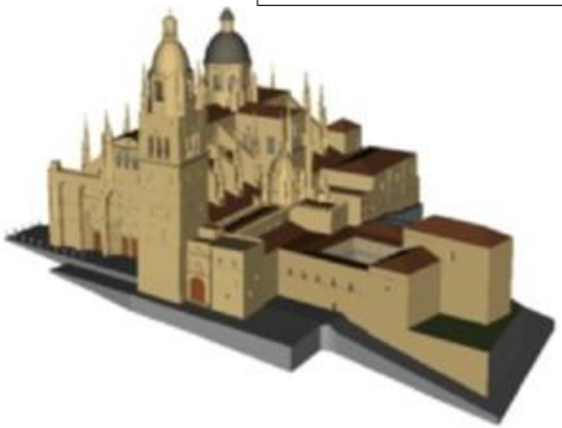
- Before: the development of MAS was typically based on a design that focuses on each agent independently.
- Now: new focus in which the design is directed at the organizational aspects of the agents, establishing two descriptive levels: the organization and the agent.

Evaluation and Conclusions

- **Simulation**
- REPAST (*Recursive Porous Agent Simulation Toolkit)*







Evaluation and Conclusions

- **Evaluation**
- Planning example

$$E_g = \{e_0^g, \cdots, e_h^g\}$$

Tasks carried out by a group of tourists and visitors "g" in order of priority.

$$E = \bigcup_g E_g = \{e_0, \cdots, e_n\}$$

Problem: E represents the complete set of tasks that must be completed.

Assume there are 10 guides. Randomly selecting a Guide i∊{1,• , 10}, (specifically, i=3), the task assignment according to their profile is:

(1) Agent Task: Visit the cathedral with tourist group 2 ; =30 min.

(2) Agent Task: Take tourist group 2 to the aqueduct ; =15 min.

(3) Agent Task: Take tourist group 2 to the hermitage ; =10 min.

(4) Agent Task: Visit the hermitage ; =10 min.

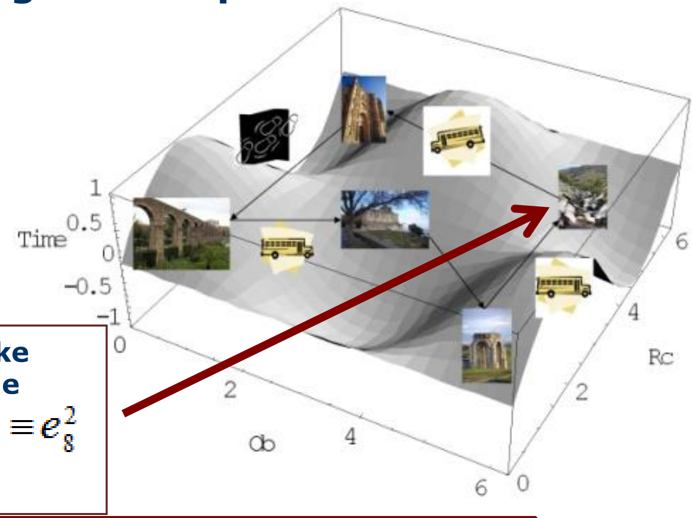
(5) Agent Task: Take tourist group 2 to the Roman city ; =20 min.

(6) Agent Task: Visit the Roman city ; =30 min.

(7) Agent Task: Take tourist group 2 to the ravine ; =50 min.

(8) Agent Task: Hike along the ravine with group 2 ; =20 min.

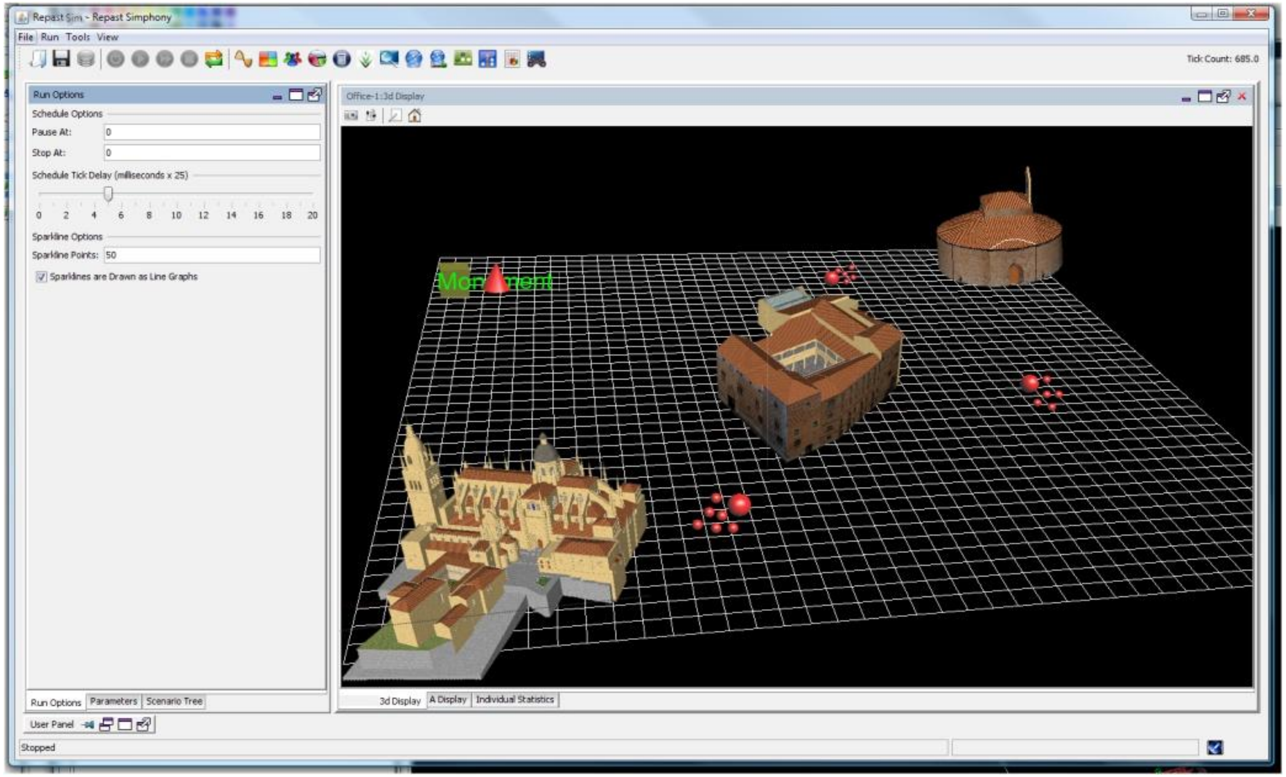
(9) Agent Task: Return to the cathedral with group 2 ; =10 min.



Agent Task: Hike along the ravine with group 2; $\equiv e_8^2$

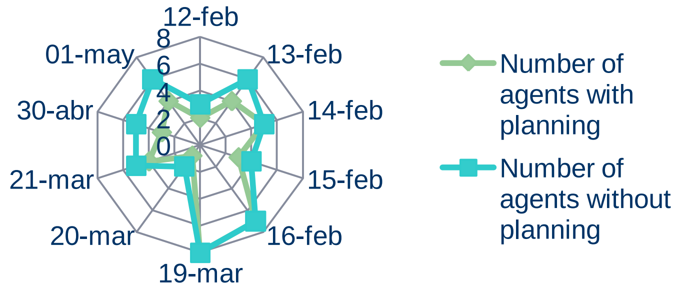
Evaluation and conclusions

- Experimental results
- Simulations running the planning mechanism
  - 7 guide agents, 6 tourist enclaves and 20 tourist/visitor agents is made available



Evaluation and conclusions

- Simulations
- The experiments consisted of a series of simulations running the planning mechanism.
- Tests: visiting the **same tourist point, in the same day; for the same number of tourists per group,** in one group the planning mechanism was used and in the other it was not.
- The colour green represents the average of guide agents required every day using the planner, and in blue, without using it.



Evaluation and conclusions

- Conclusions

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- Study of multi-agent systems from an organizational point of view along with some related areas among which coordination and planning agents, intelligent virtual agents systems and case-based reasoning.
- We have developed an integrated model in which an architecture of agents can perform actions based on a model of social planning in an organization of agents.
- The proposed model has been applied to a case study. It has been proven the validity of the methodology and the reasoning and planning mechanisms presented.

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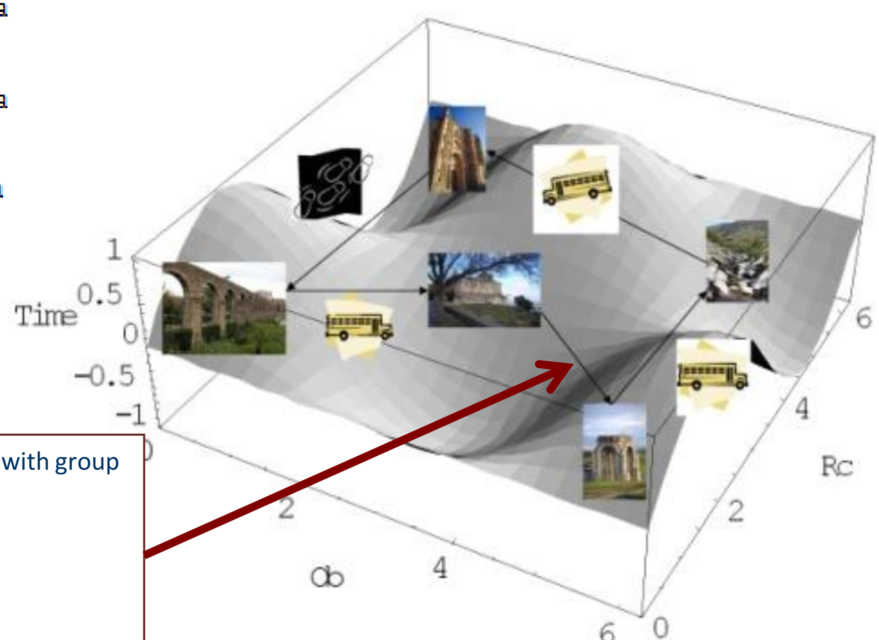
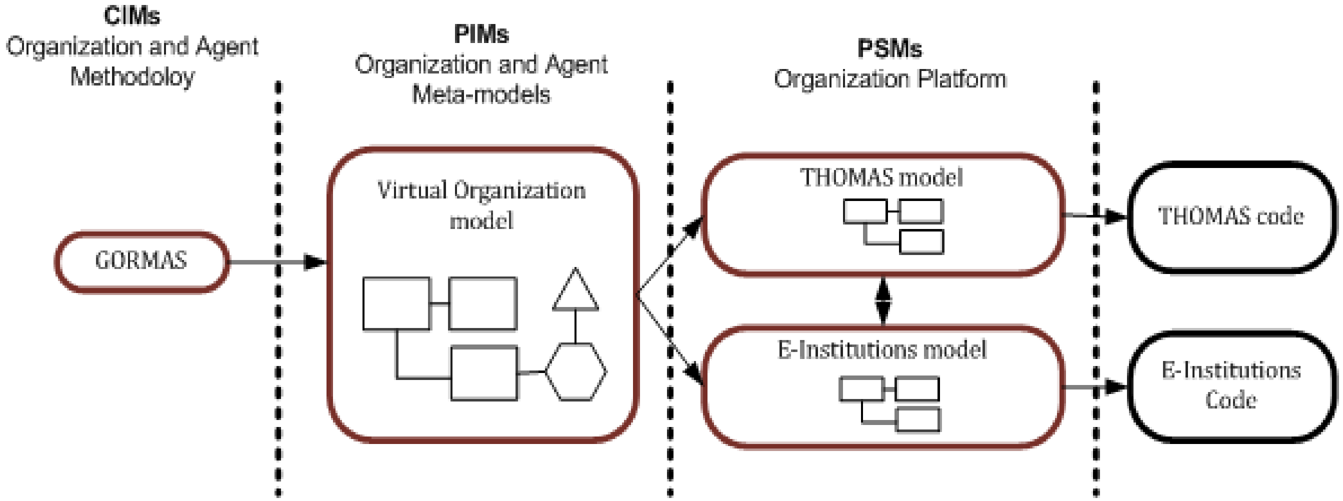
1. Agent Task: Visita con el grupo de turistas 2 en la catedral $\equiv e_1^2$; t_{31} =30 min.
2. Agent Task: Llevar al grupo de turistas 2 al acueducto $\equiv e_2^2$; t_{32} =15 min.
3. Agent Task: Llevar al grupo de turistas 2 a la ermita $\equiv e_3^2$; t_{33} =10 min.
4. Agent Task: Visita a la ermita $\equiv e_4^2$; t_{34} =10 min.
5. Agent Task: Llevar al grupo de turistas 2 a la ciudad romana $\equiv e_5^2$; t_{35} =20 min.
6. Agent Task: Visita a la ciudad romana $\equiv e_6^2$; t_{36} =30 min.
7. Agent Task: Llevar al grupo de turistas 2 a la garganta min.
8. Agent Task: Senderismo con el grupo 2 en la garganta min.
9. Agent Task: Llevar al grupo de turistas 2 de vuelta a la t_{39} =10 min.



Agent Task: Walking with group 2 in the gorge ;

Evaluation and Conclusions

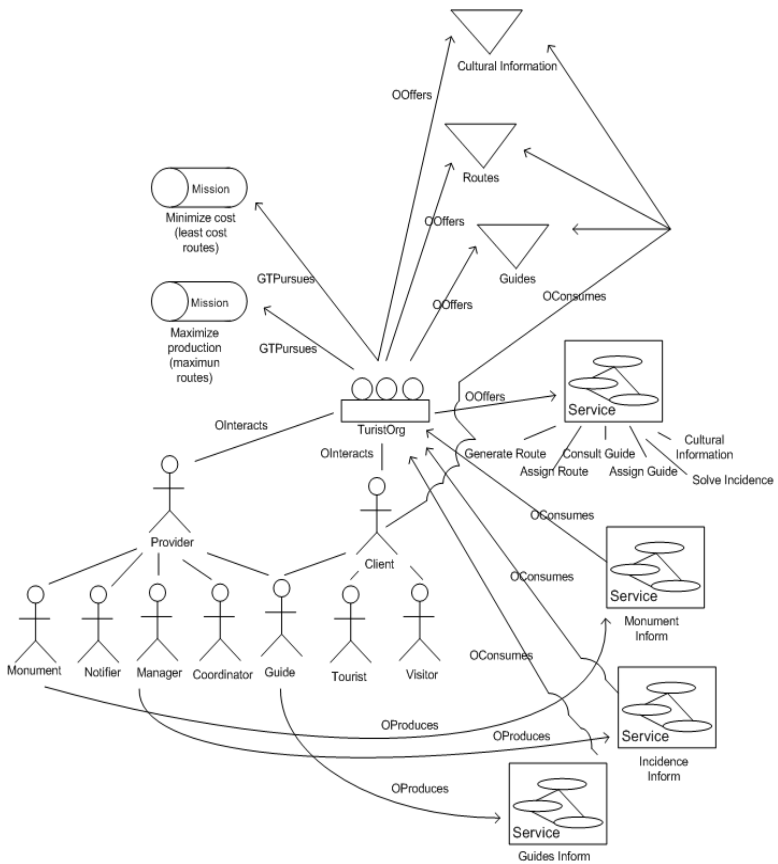
- **Analysis and Design**
- MDD (*Model Driven Development)*
- GORMAS (*Guidelines for Organization-based MultiAgent Systems*)
  - Model Creation
  - Platform Selection
  - System Generation

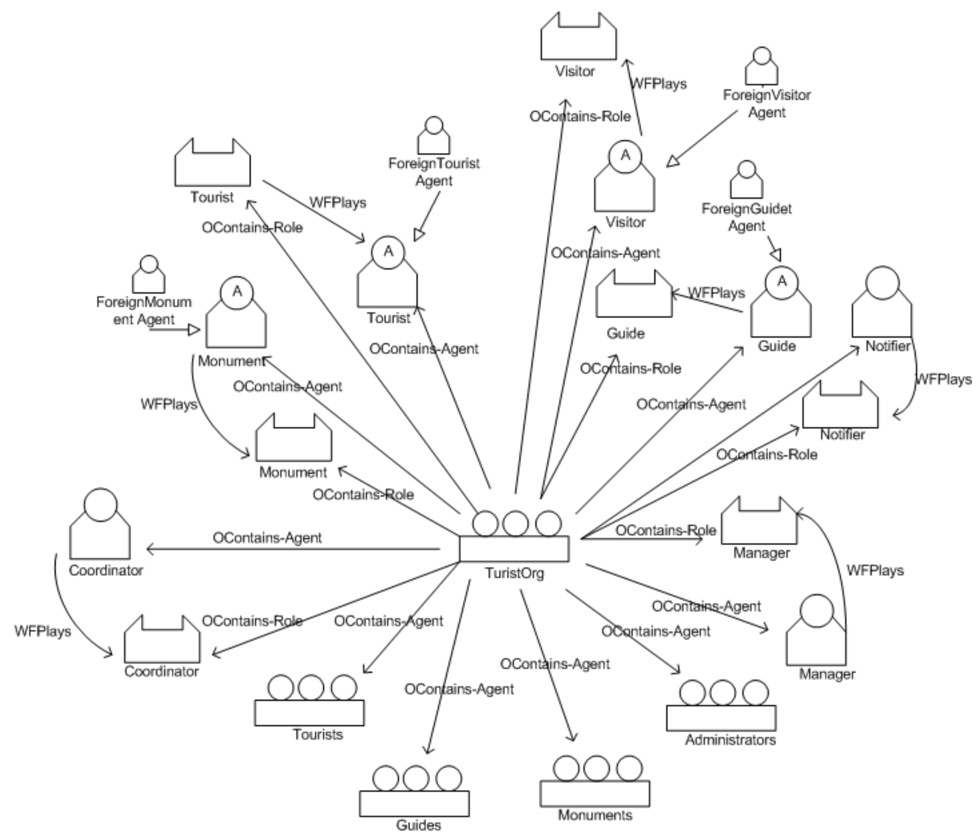


[Agüero et al., 2009]

Evaluation and Conclusions

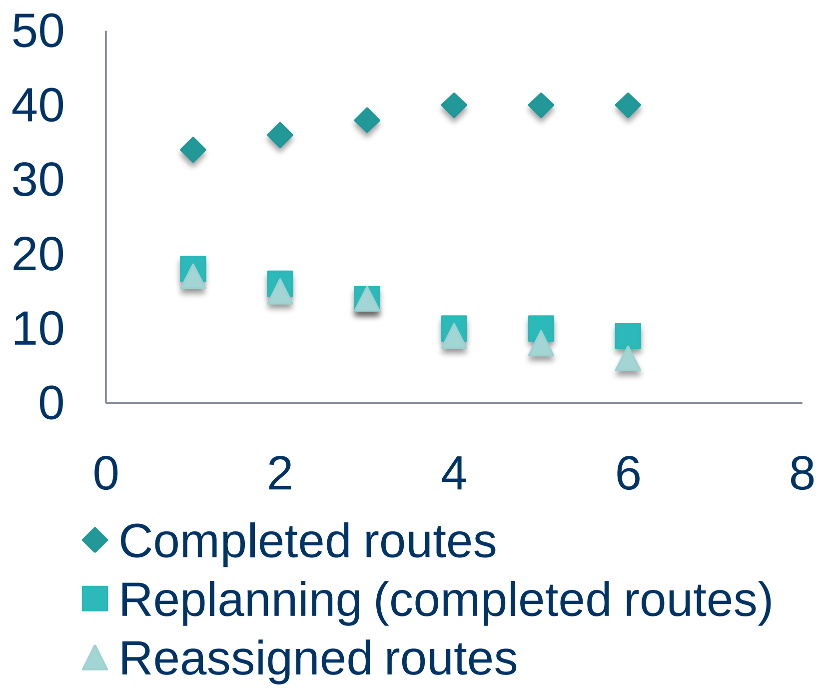
- **Analysis and Design**
- GORMAS (*Guidelines for Organization-based MultiAgent Systems*)





Evaluation and Conclusions

- Experimental Results
- Learning
- The number of plans completed with success increases as the system resolves new cases.
- The number of reallocations decreases as the system acquires experience.
- The percentage of incomplete assigned plans decreases from 19.1% to 6.5%. These data demonstrate the system's large capacity for adaptation as it acquires experience.



Evaluation and Conclusions

- **Evaluation**
- Planning Example

1. Each agent has a profile: . Fixing state “j”, for each agent “i” with $i\hat{I}\{1,\ldots,m\}_{m\hat{I}N}$, z_{ij}-tuple is defined,where each coordinate of the tuple refers to a characteristic which it is defined by, i.e., the vector which stores the profile of an agent Guide in the virtual world.
2. In the belief memory we have the time used for each task described as t_{ij} time it takes for Guide agent “i” to complete “j”, being $t_{ij}=Max_k\{t_{ijk}\}$ where t_{ijk} indicates the time it takes for agent “i”, to carry out task “j” for tourist “k”.
3. Selection of Guide with the most suitable profile.
4. From this moment, the planning process begins. The Guide agent should take into account the time available and the time required for each task that it has been assigned.

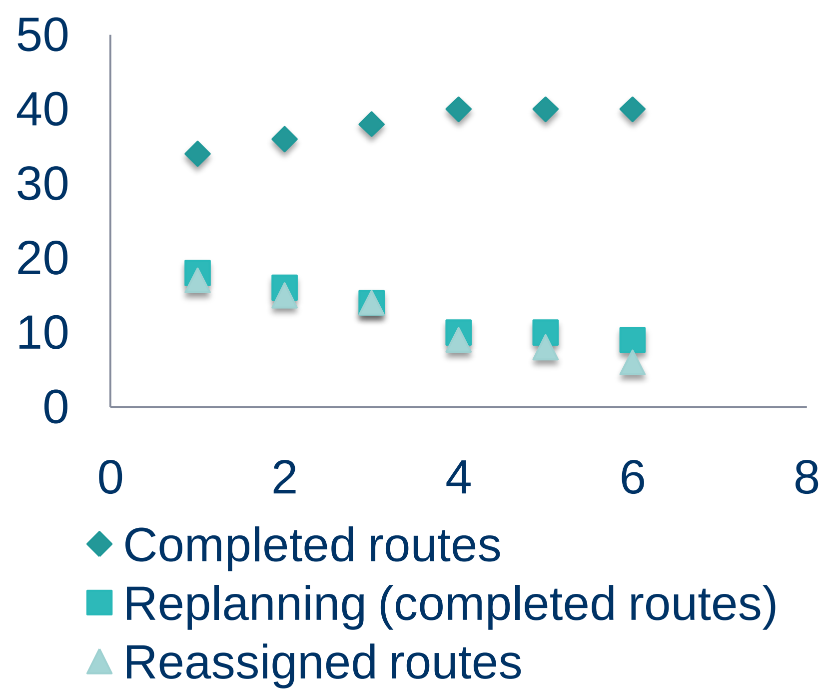
Task	Data
TaskId	66
TaskType	23
TaskDescript	Visit cathedral
TaskPriority	3
TaskGoal	0
TaskIncidents	0
TouristId	6
GroupTouristId	2
TouristIdiom	Spanish
MinTime	13:00
MaxTime	13:45
TaskResources	Tickets cathedral

Evaluation and conclusions

- Future work
- **OVAMAH Project**: to advance and contribute solutions mainly in aspects associated with reorganization.
  - ImprovemenT of THOMAS.
  - Improvement of the proposed mechanism
  - Improvement in simulation.
  - New practical problems.
    - THOMAS Project: Métodos Técnicas y Herramientas para Sistemas Multiagente Abiertos”) TIN2006-14630-C03-03, otorgado por el Ministerio de Ciencia e Innovación. http://thomas-tin.usal.es/
    - OVAMAH Project: (Organizaciones Virtuales Adaptativas: Mecanismos, Arquitecturas y Herramientas) TIN 2009-13839-C03-03, otorgado por el Ministerio de Ciencia e Innovación. Proyectos de Investigación Fundamental No Orientada

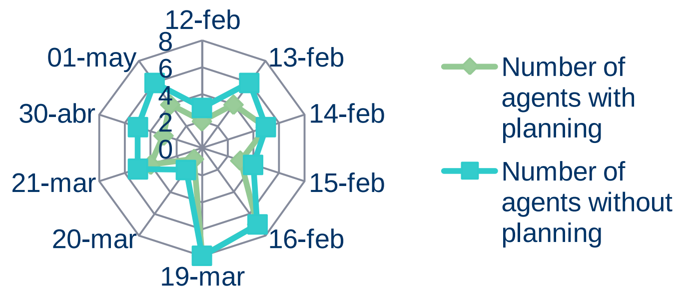
Evaluación y conclusiones

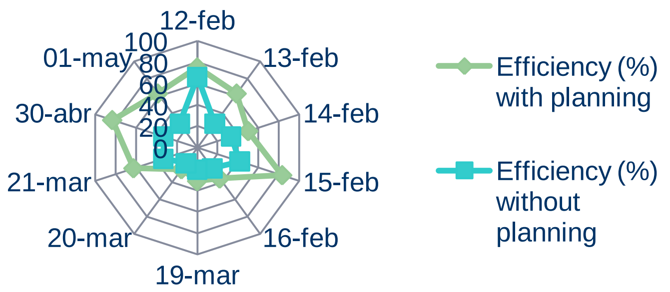
- Resultados experimentales
- Aprendizaje
- El número de planes que se completan con éxito crece a medida que el sistema resuelve nuevos casos.
- El número de reasignaciones desciende a medida que el sistema adquiere experiencia.
- El porcentaje de planes asignados no completados desciende desde un 19,1% a un 6,5%. Estos datos demuestran la gran capacidad de adaptación del sistema a medida que adquiere experiencia.



Evaluation and Conclusions

- Simulations
- The tests have consisted of a series of simulations executing the planning mechanism of tasks.
- One *tick* takes one real second, so the simulation of 2 months and 18 days is equivalent to approximately 31.2 real minutes.





Evaluation and Conclusions

Platforms\Features		JADE[17]	AMELI[18]	MADKIT[19]	JACK TEAMS[20]	S-MOISE+[21]	AEI	RETSINA	THOMAS
Model	Agent	*	**ISLANDER[22] (EI)		**JACOB[23]		**ISLANDER	*	**GORMAS[24]
	Organization		**ISLANDER(EI)		**JDK[25]		**ISLANDER	*	**GORMAS
	Services	*	**ISLANDER(EI)		**JDK		**ISLANDER	*	**GORMAS
Functional	BDI Model	*		**[26]	*		**aBuilder	*[27]	*
Taxonomic	Group			*	*	*	**AMELI	*	*
	Topology		(EI)[28]	HOLONS	**[29]	*	**AMELI	*	*
	Roles		*	*	*	*	**AMELI	*	*
	Interactions	*	*	*	*	*	**AMELI	*	*
Normative	Norms		*	**JESS[30]		*	**AMELI	*	*
Dynamics	Agent Joining		*	*	*	*	**AMELI	*	*
	Role Enactment		*	*	*	*	**AMELI	*	*
	Behavior control	*	*	*	*	*	**AMELI	*	*
	Org. Joining		*	*	*	*	**AMELI	*	*
	Adaptation						*		*
Coordination	Planning				**JPL [31]			HTN[32]	*
	Optimums Planning								*
	Replanning							HTN	*
	Reorganization					*			*
Agent Simulation	Simulation 2D	**		*	*		**Simdei[33]		**
	Simulation 3D	**					**Simdei		**

THOMAS *'MeTHods, Techniques and Tools for Open Multi-Agent Systems*

Evaluation and Conclusions

- Conclusions

- **Knowledge Exchange**. During the development process of this work, a great effort has been made to obtain feedback from different researchers and research groups in areas related to the subject.

  – THOMAS Project ("THOMAS: Methods Techniques and Tools for Open Multi-Agent Systems") TIN2006-14630-C03-03, granted by the Ministery of Science and Innovation. http://thomas-tin.usal.es/

  – OVAMAH Project: (Adaptive Virtual Organizations: Mechanisms, Architectures and Tools) TIN 2009-13839-C03-03, granted by the Ministery of Science and Innovation. Non-Oriented Fundimental Research Projects