ENSAO / MAS COURSE

Oujda
15 October 2019

MAS Course 01

Yves Demazeau
Yves.Demazeau@imag.fr

CONTENTS

SIGMA (academic project) [Baeijs 96]

A reactive multi-agent approach to cartographic generalization LIFIA-INPG (F), IGN (F)

Interaction and organisation modelling to study their reciprocal interdependencies

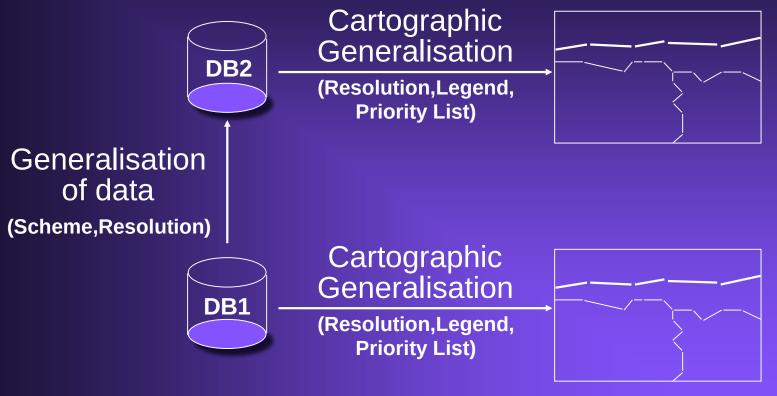
Approach

- The development of successful method
- Operators to transform data and changes of scale
- interactive validation by users (geographers)
- Implementation on C/C++ on Sun WS - LAN/XENOOPS

Ch. Baeijs, Y. Demazeau & L. Alvares, “SIGMA: Application of Multi-Agent Systems to Cartographic Generalization”, in Agents Breaking Away, 7th Eur. Workshop on Modelling Autonomous Agents in a Multi-Agent World, MAAMAW'96, pp. 163-176, 1996.

SIGMA & AGENT

SIGMA : Types of Generalisation



SIGMA : Problem aspects

Domain

Partial automatizing of cartographic generalization

- Creation of a readable and useful cartographic map from a geographical database given the aim of the map (pre-order) and using a non-holistic approach
- Modelling agents, interactions and organizational structures, and studying the convergence

SIGMA : Problem aspects

Domain

Partial automatizing of cartographic generalization

- Creation of a readable and useful cartographic map from a geographical database given the aim of the map (pre-order) and using a non-holistic approach
- Modelling agents, interactions and organizational structures, and studying the convergence effects

Problem

Extension of the PACO paradigm

- Geographical objects are represented by a collection of "geographical entities" which "may" become agents
- Introduction of organizational knowledge to study their impact on a local level (behavior of the agents) as well as on a global level (convergence of the system)

SIGMA : Problem aspects

Domain

Partial automatizing of cartographic generalization

- Creation of a readable and useful cartographic map from a geographical database given the aim of the map (pre-order) and using a non-holistic approach
- Modelling agents, interactions and organizational structures, and studying the convergence

Problem

Extension of the PACO paradigm

- Geographical objects are represented by a collection of "geographical entities" which "may" become agents
- Introduction of organizational knowledge to study their impact on a local level (behavior of the agents) as well as on a global level (convergence of the system)

SIGMA Individual Aspects

Environment

- Geographical entities placed on a 2D grid, initially corresponding to the raw data (World of Reference)
- Active work on a copy (Active World) of the initial world to offer the opportunity to later geographical verification mechanisms

SIGMA Individual Aspects

Environment

- Geographical entities placed on a 2D grid, initially corresponding to the raw data (World of Reference)
- Active work on a copy (Active World) of the initial world to offer the opportunity to later geographical verification mechanisms

Agents

- A geographical entity becomes an agent as soon as its position in the organization (its mass) is important enough with respect to the aim of the map
- Each agent possesses several self-controlled scopes:
  - Perception (local environment)
  - Communication (class, object, proximity, groups)
  - Action (class, object, proximity, groups)

SIGMA Individual Aspects

Environment

- Geographical entities placed on a 2D grid, initially corresponding to the raw data (World of Reference)
- Active work on a copy (Active World) of the initial world to offer the opportunity to later geographical verification mechanisms

Agents

- A geographical entity becomes an agent as soon as its position in the organization (its mass) is important enough with respect to the aim of the map
- Each agent possesses several self-controlled scopes:
  - Perception (local environment)
  - Communication (class, object, proximity, groups)
  - Action (class, object, proximity, groups)

SIGMA Social Aspects

Interactions

- Between artificial agents (or objective groups)
  - Repulsion Force
  - Proportional Following (against local deformation of objects)
  - Unconditional Following (agents "sticking" together)
  - Change of symbolization
- Between the user and the agents (or subjective groups)
  - Change of symbolization
  - Formation or breaking of topological structures
  - Displacement of agents

SIGMA Social Aspects

Interactions

- Between artificial agents (or objective groups)
  - Repulsion Force
  - Proportional Following (against local deformation of objects)
  - Unconditional Following (agents "sticking" together)
  - Change of symbolization
- Between the user and the agents (or subjective groups)
  - Change of symbolization
  - Formation or breaking of topological structures
  - Displacement of agents

Organizations

- Pre-orders, figuring "power"- relationship between geographical classes
- Groups, consisting of agents sharing the same local environment to realize a common task

SIGMA Social Aspects

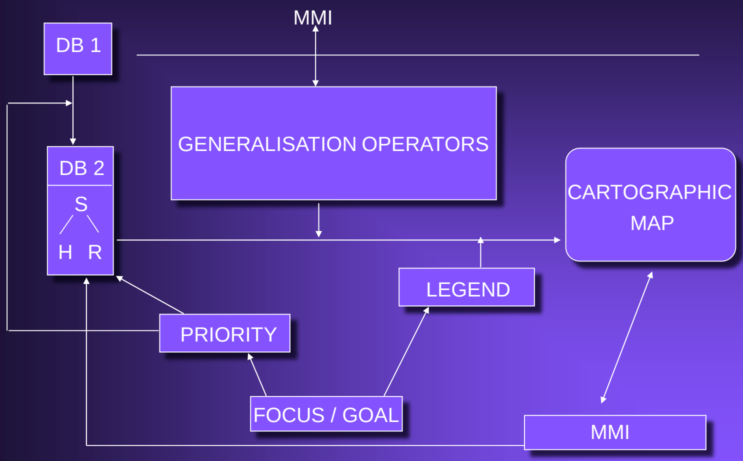
Interactions

- Between artificial agents (or objective groups)
  - Repulsion Force
  - Proportional Following (against local deformation of objects)
  - Unconditional Following (agents "sticking" together)
  - Change of symbolization
- Between the user and the agents (or subjective groups)
  - Change of symbolization
  - Formation or breaking of topological structures
  - Displacement of agents

Organizations

- Pre-orders, figuring "power"- relationship between geographical classes
- Groups, consisting of agents sharing the same local environment to realize a common task

SIGMA : The Architecture of the System



SIGMA : Implementation and Results

Implementation

- Full implementation in C++ under Unix with acceptable results

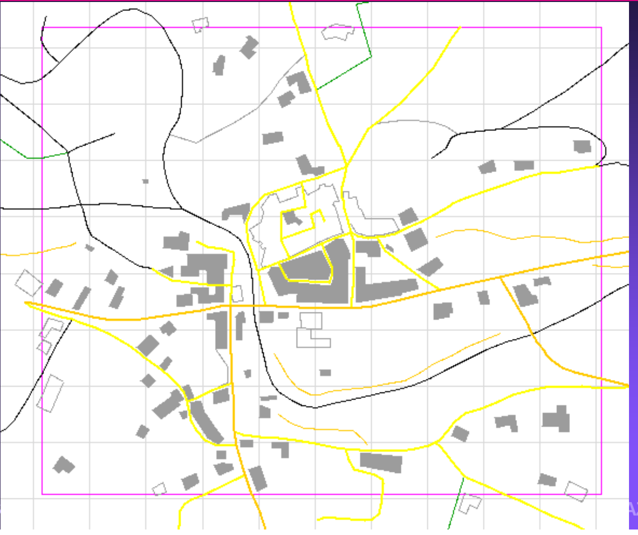
Results

- "Les Matelles": • 300 objects -> 1800 geo. entities acceptable results in quality and computation
- "Neighborhood of Les Matelles": • 2000 objects -> 15000 geo. entities • acceptable results in quality

Perspectives

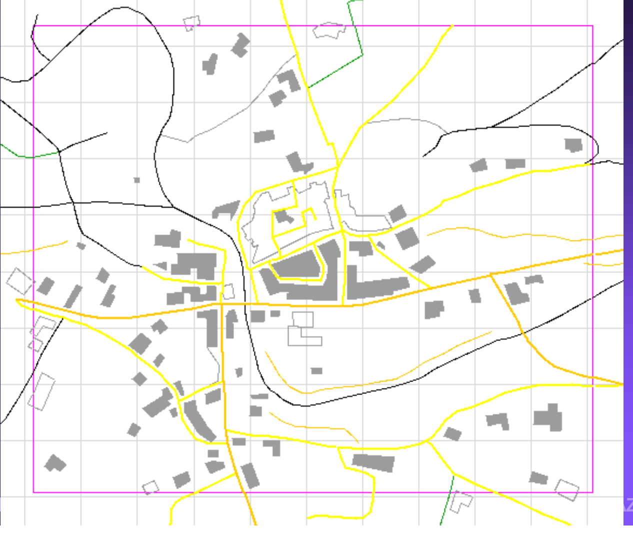
- Full explicitness of the organisational issues in the system
- Distribution/Parallelization of the system using XENOOPS
- Follow-up within the CEC-IT-LTR AGENT project

SIGMA : Les Matelles : initial map



CNRS

SIGMA : Les Matelles : final map



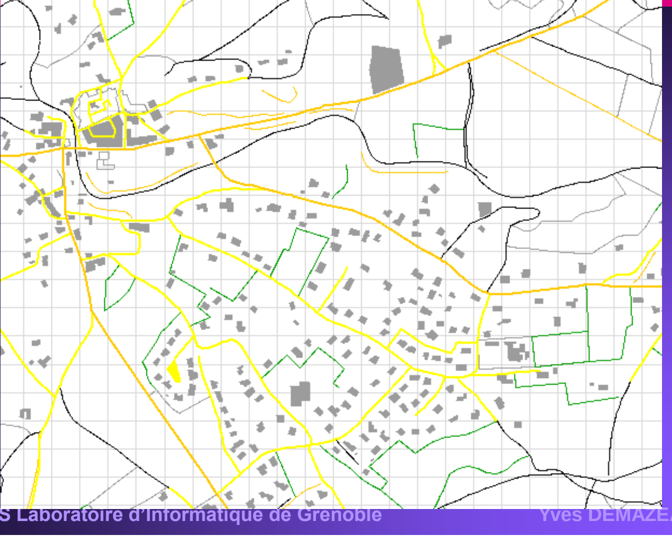
CNRS I

SIGMA : Les Matelles : Details

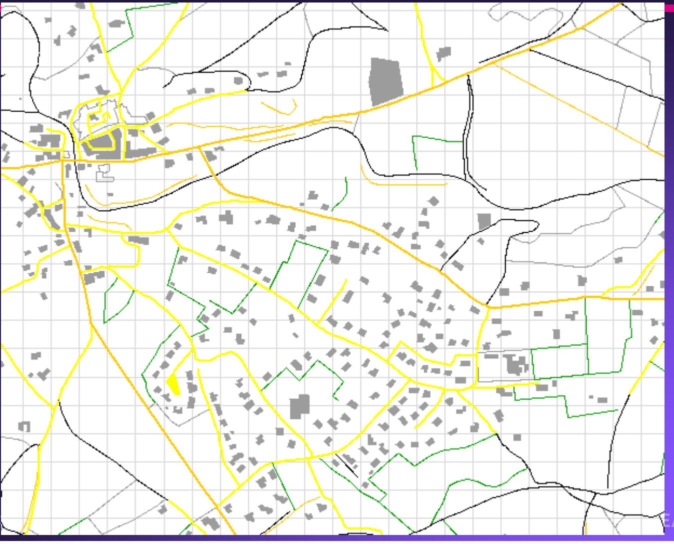
Before

After

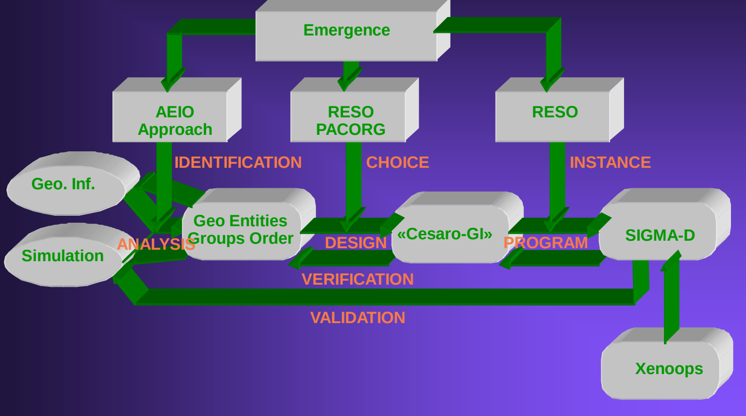
SIGMA : Les Matelles Surroundings : initial



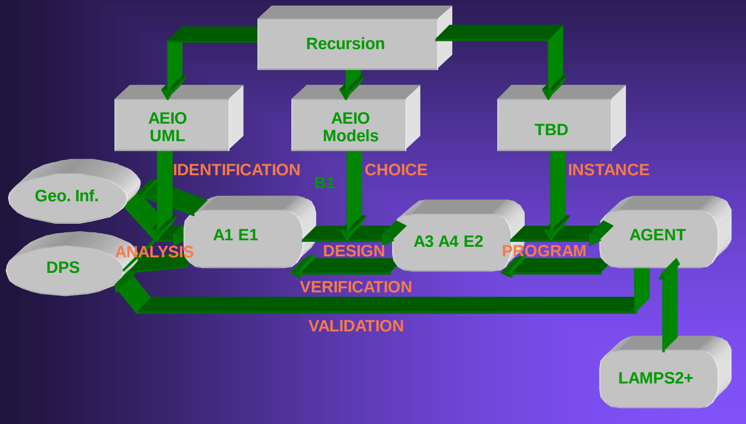
SIGMA: Les Matelles Surroundings : final



VOWELS : SIGMA-D



VOWELS : AGENT



AGENT Project (CEC 24939) (1) [Lamy 1999]

Automated generalisation to provide maps from cartographic databases

Automatic GEneralisation New Technology <u>IGN (F)</u>, LaserScan Ltd. (UK), LEIBNIZ-INPG (F), U. Zürich (CH), U. Edinburgh (UK)

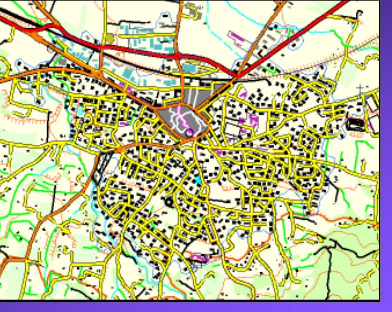
Approach

- COHIA agents, micro agents (independent generalisation), meso-agents (contextual generalisation), macro agents
- Simple IL interaction mechanisms but sophisticated generalisation operators
- Recursive organisations between agents
- Full implementation on GOTHIC/LAMPS2 - Sun WS and PC - LAN & WWW – Commercialized

S. Lamy, A. Ruas, Y. Demazeau, M. Jackson, W. Mackaness, & R. Weibel, "The Application of Agents in Automated Map Generalisation", 19th Int. Cartographic Conference, Vol 2, pp. 1225-1234, 1999.

AGENT Project (CEC 24939) (2)

AFTER



BEFORE

INTRODUCTION

Vocabulary : cf. agent [Pleiad 92]

	Agent Name	Ag. Structure	Ag. Reasoning	Ag. Behaviour
Sociology	specialist expert	ethic abilities	decision choice	leader, decider
AI	(meta)* K source (meta)* module (meta)* rule	KR control K goals functionalities	agent control inference	autonomous semi-directed produc. / cons. master / slave
Biology	ant	biological agent		leader cell
Cognitive Psy.	module		cognitive proces.	
Social Psy.	actor	intentional agent motivations capabilities	intentionality reason choice	rational, selfish selfless intentional

Vocabulary : cf. society [Pleiad 92]

	Society Name	Soc. Structure	Interac. Links	Ag. Interaction
Sociology	community	society organisation	hierarchical heterarchical anarchical	communication protocol
AI	(meta)* set	architecture - BB model - actor model	comm. network	comm. protocol - broadcast - direct / indirect - synchronous/a.
Biology	population	ecosystem frame		propagation
Cognitive Psy.	esprit (cognitive system)	society	mental repres.	
Social Psy.	group		interlocutor neighbour	dialog exchange

Vocabulary : others [Pleiad 92]

	Soc. Control	Reas. activities	System Behav.	Environment
Sociology	dictature democracy		cohab., coop., collab., compet., coherent, chaotic	
AI	centralised / decentralised hierarchical / heterarchical	goal sharing data sharing negociation conflict resolution	fixed programmed adaptative learnable	world
Biology		self-organisation equilibrium	emergent evolutive	
Cognitive Psy.	central system modular system	integration	learned / innate autopoiesis	universe
Social Psy.		interact., conflicts persuasion, sug., influence		

Taxonomy of DAI & MAS [Pleiad 92]

Primary Criteria

- Theory - Algorithmics - Programming
- Agents - Societies
- Internal Architecture - External Description

Taxonomy of DAI & MAS [Pleiad 92]

Primary Criteria

- Theory - Algorithmics - Programming
- Agents - Societies
- Internal Architecture - External Description

Secondary Criteria

- Agents Behavior : cognitive, reactive
- Agents Autonomy : dependent, semi-autonomous, autonomous
- Agents Adaptability : fixed, programmed, teachable, autodidact, emergent
- Exchanged Knowledge : indirect, facts, plans, intentions
- Society Behavior : problem solving, system simulation

Taxonomy of DAI & MAS [Pleiad 92]

Primary Criteria

- Theory - Algorithmics - Programming
- Agents - Societies
- Internal Architecture - External Description

Secondary Criteria

- Agents Behavior : cognitive, reactive
- Agents Autonomy : dependent, semi-autonomous, autonomous
- Agents Adaptability : fixed, programmed, teachable, autodidact, emergent
- Exchanged Knowledge : indirect, facts, plans, intentions
- Society Behavior : problem solving, system simulation

What is an Agent ?

External Definition : a **real** or **virtual** entity that evolves in an **environment**, that is able to **perceive** this environment, that is able to **act** in this environment, that is able to **communicate** with other agents, and that **exhibits** an **autonomous** behavior

---> the autonomy principle

---> autonomous agents, robots

The Autonomy Principle [Müller 95]

Natural Autonomy

Autonomy of a system as an organisation of processes able to maintain itself

Fox Snow Dive

https://www.youtube.com/watch?v=dP15zlyra3c

The Autonomy Principle [Müller 95]

Natural Autonomy
Autonomy of a system as an organisation of processes able to maintain itself

Fox Snow Dive
https://www.youtube.com/watch?v=dP15zlyra3c

Artificial Autonomy
Autonomy as the capability to exploit the actual circumstances to serve its purpose

Smart Bird
https://www.youtube.com/watch?v=nnR8fDW3llo

The Autonomy Principle [Müller 95]

Natural Autonomy
Autonomy of a system as an organisation of processes able to maintain itself

Fox Snow Dive
https://www.youtube.com/watch?v=dP15zlyra3c

Artificial Autonomy
Autonomy as the capability to exploit the actual circumstances to serve its purpose

Smart Bird
https://www.youtube.com/watch?v=nnR8fDW3llo

What is an Agent ?

External Definition : a **real** or **virtual** entity that evolves in an **environment**, that is able to **perceive** this environment, that is able to **act** in this environment, that is able to **communicate** with other agents, and that **exhibits** an **autonomous** behavior

---> the autonomy principle

---> autonomous agents, robots

Internal Definition : a **real** or **virtual** entity that **encompasses** some **local control** in some of its **perception** , **communication** , **knowledge acquisition** , **reasoning** , **decision** , **execution**, **action** processes.

---> the delegation principle

---> mobile objects, personal assistants

The Delegation Principle [Demazeau 90]

Weak Delegation
KNOWLEDGE (missing descriptions, complementary descriptions, ...)

Medium Delegation
POSSIBLE SOLUTIONS or PLANS (agreement on a common solution, ...)

Strong Delegation
CHOICES or GOALS (requesting someone to do something, ...)

What is an Agent ?

External Definition : a **real** or **virtual** entity that evolves in an **environment**, that is able to **perceive** this environment, that is able to **act** in this environment, that is able to **communicate** with other agents, and that **exhibits** an **autonomous** behavior

---> the autonomy principle

Internal Definition : a **real** or **virtual** entity that **encompasses** some **local control** in some of its **perception** , **communication** , **knowledge acquisition** , **reasoning** , **decision** , **execution**, **action** processes.

---> the delegation principle

Agents and Multi-Agent Systems

External Definition : a **real** or **virtual** entity that evolves in an **environment**, that is able to **perceive** this environment, that is able to **act** in this environment, that is able to **communicate** with other agents, and that **exhibits** an **autonomous** behavior

---> the autonomy principle

Internal Definition : a **real** or **virtual** entity that **encompasses** some **local control** in some of its **perception** , **communication** , **knowledge acquisition** , **reasoning** , **decision** , **execution**, **action** processes.

---> the delegation principle

But there is no agent without any MAS !

What is a Multi-Agent System ?

Natural MAS

Ants building bridges
https://www.youtube.com/watch?v=4BdjxYUdJS8

What is a Multi-Agent System ?

Natural MAS

Ants building bridges
https://www.youtube.com/watch?v=4BdjxYUdJS8

Artificial MAS

Robot quadrotors
https://www.youtube.com/watch?v=_sUeGC-8dyk

What is a Multi-Agent System ?

Natural MAS

Ants building bridges
https://www.youtube.com/watch?v=4BdjxYUdJS8

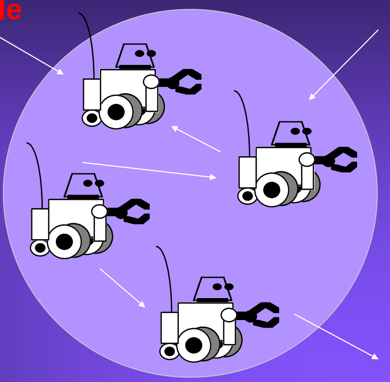
Artificial MAS

Robot quadrotors
https://www.youtube.com/watch?v=_sUeGC-8dyk

What is a Multi-Agent System ?

A set of possibly organized agents which interact in a common environment

---> the distribution principle



MAS main interests :

---> To extend classical mono-agent AI models and tools (A-centered)

---> To study specific multi-agent models and tools (MAS-centered)

MAS Micro and Macro Issues

Micro issues (Agent oriented)

- how do we design and build an agent that is capable of acting autonomously
- are oriented towards mental and environmental issues
- are typical of agent theories (Cohen & Levesque, Rao & Georgeff, Shoham, Singh, Wooldridge & Jennings, ...)

MAS Micro and Macro Issues

Micro issues (Agent oriented)

- how do we design and build an agent that is capable of acting autonomously
- are oriented towards mental and environmental issues
- are typical of agent theories (Cohen & Levesque, Rao & Georgeff, Shoham, Singh, Wooldridge & Jennings, ...)

Macro issues (MAS oriented)

- how do we get a society of agents to cooperate effectively?
- are oriented towards interactions and organisations issues
- are typical of multi-agent theories (Durfee, Ferber, Gasser, Hewitt, Lesser...)

MAS Micro and Macro Issues

Micro issues (Agent oriented)

- how do we design and build an agent that is capable of acting autonomously
- are oriented towards mental and environmental issues
- are typical of agent theories (Cohen & Levesque, Rao & Georgeff, Shoham, Singh, Wooldridge & Jennings, ...)

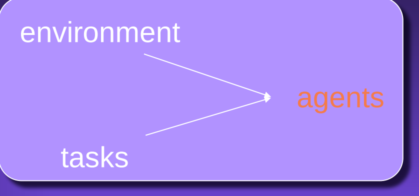
Macro issues (MAS oriented)

- how do we get a society of agents to cooperate effectively?
- are oriented towards interactions and organisations issues
- are typical of multi-agent theories (Durfee, Ferber, Gasser, Hewitt, Lesser...)

How to bridge between Micro and Macro Issues

Distributed Problem Solving

Global conceptual model
Global problem
Global success criteria



Division of :

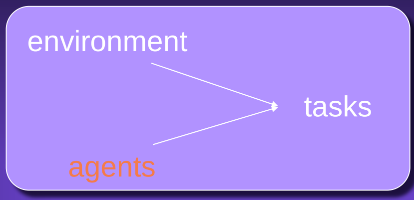
knowledge
resources
control
authority

Focus on the collaborative resolution of global problems by a set of distributive entities

society goals directed
input : tasks, environment
output : model of the distributed entities
schema to solve the tasks

Decentralized System Simulation

Local conceptual models
Local problems
Local success criteria



Division of :
- knowledge
- resources
- control
- authority

Focus on the coordinated activities of a set of agents evolving in a multi-agent world
- agent goals directed
- input : agents, environment
- output : tasks which can be solved
- schema to solve the tasks

Historical Roots

Hearsay II (1973)
- blackboard architecture

Actors (1973)
- language to describe complex control structures

Beings (1975) Society of Mind (1978)
- common agent structures

Contract Net (1982)
- decentralized hierarchical control

DVMT (1984)
- distributed interpretation, organisation

Reactive Robots (1986)
- subsumption architecture

Mace (1987)
- multi-agent environment

…

KBS-Ship (ESPRIT I II projects 1074 & 2163)

Shipboard Installation of Knowledge-Based Systems
Danish Maritime Institute (DK), East Asia Co (DK), Krupp Atlas (D), Nat'l Tech. Univ. Athens (G), Soren T. Lyngso A/S (DK), Lloyd's Register of Shipping (UK), Instituto Superior Technico (P)

Assist bridge and engine-room operators in duties ranging from voyage planning to diagnosis

Approach

- development of (few) KBS handling important functions (voyage planning, maintenance scheduling, alarm handling, loading planning) incorporating shipping regulations
- framework for communication and integration of these KBS

ARCHON (ESPRIT II project 2256)

Architecture for Cooperative Heterogeneous Online Systems Krupp Atlas (D), Amber Computer Systems (G), Electricity R&D Ctr (UK), Framentec (F), Iberduero (E), Queen Mary & Westfield College (UK), Univ. do Porto (P), Volmac (NL), Univ. Amsterdam (NL), CERN (CH), Ispra (I), Nat'l Tech. Univ. Athens (G), Univ. Libre de Bruxelles (B), Labein (E)

Architecture for Cooperative Expert Systems for Industrial Applications

Approach

- development environment implementing concepts of cooperation and interaction on virtual machine
- application in two large-scale demonstrators (domain of managing electrical power grids)

Secondary classification : Reactive vs. Cognitive

Function(MAS) = ∑ Function(A) + Collective Function

The Cognitive Side	The Reactive Side
few heterogeneous	many homogeneous
coarse-grained	fine-grained
cognitive agents	reactive agent
explicit goals	implicit goals
decoupling agents	coupling agents
sequential processes	parallel processes
symbolic approaches	subsymbolic approaches
focusing on representation	focusing on behavior

balance

MAS Applications

Computer-Aided Design
Computer Vision
Decision Support
Electronic Commerce
Enterprise Modelling
Interactive Games
Manufacturing Systems
Natural Language Processing
Network Monitoring
Office and Home Automation
Robotics Control
Societies Simulation
Spatial Data Handling
Telecommunication Routing
Traffic Management

MAS Characteristics

Natural decomposition of action, perception, or control, sharing of resource, environment, ...

No constraint about the heterogeneity of agents

Agents are perceived as being autonomous entities behaving rationally

No constraint about the grain of the agent model

Need for 3 or more coordinating agents or environments : interactions, organization, ...

MAS Characteristics [OFTA 04]

		Autonomy		
Artificial Intelligence	Knowledge Sharing	Decentralisation	Distribution	Distributed System
		Interaction		
Artificial Life	Adaptation	Organisation	Personnalisation	Human Computer Interaction
		Situatedness		
Software Agent	Delegation	Openness	Intelligibility	Software Engineering
		Emergence		

METHODOLOGY

MAS Methodology

= Approach + Model + Tools + Problem + Domain

MAS Methodology

= Approach + Model + Tools + Problem + Domain

= Analysis + Design + Development + Deployment

Analysis	Identify both the domain and the problem
↓ Design	Get rid of the domain / Define the solution
↓ Development	Implement the solution / Plug the domain
↓ Deployment	Install and situate the solution in the domain

MAS Methodology

= Approach + Model + Tools + Problem + Domain

= Analysis + Design + Development + Deployment

Analysis	Identify both the domain and the problem
↓ Design	Get rid of the domain / Define the solution
↓ Development	Implement the solution / Plug the domain
↓ Deployment	Install and situate the solution in the domain

MAS methodology

Australia
- Georgeff (Melbourne), Padgham (Melbourne)…

France
- Boissier (St Etienne), Demazeau (Grenoble), ...

Japan
- Kendall (Kyoto)

Netherlands
- Treur (Amsterdam), ...

New Zealand
- Winikoff (Otaga)

Spain
- Garijo (Telefonica), Pavon (UCM), ...

United Kingdom
- Jennings (Southampton), Wooldridge (Liverpool), …

…

MAS methods vs. Knowledge methods

Knowledge (Representation) Methods meaning...
- KADS, CML, KSM [Molina 95]...

Characteristics of the KR Methodology
- mainly declarative specifications
- control lays in the system inference engine

Characteristics of the MAS Methodology
- both declarative and computational specifications [Glaser 96], ...
- control lays in processing units and an emergence engine
  - (agent) control lays in the processing units [Occello 97], ...
  - (MAS) control lays in the system emergence engine, this engine involves the processing units with a recursion principle, whichever they are agents, environments, interactions, organisations [Demazeau 95], ...

MAS methods vs. Object methods

Object Methods meaning...

- OO analysis and design, modelling, implementation

Characteristics of the Object Methodology

- continuity Approach / Modelling / Implementation
- ...

Characteristics of the MAS Methodology

- no full continuity Approach / Modelling / Implementation
  - MAS is not (yet?) an implementation model
  - Agents just begin to have their own languages [Shoham 93], [Thomas 95], ... but the programming is not always based on Agents [Demazeau 97]
  - MAS design is based on existing languages and programming paradigms [Poggi 94], ...
  - towards multi-agent oriented programming [Demazeau 97], ...
- ...

MAS methods vs. Object methods

Characteristics of the Object Methodology

- object classes
- inheritance mechanism
- no organisation nor group primitives
- objects are built first, and then their dynamics
- ...

Characteristics of the MAS Methodology

- Agents, Environments, Interactions, Organizations [Demazeau 95], ...
- component groups, recursive mechanism [Fisher 94], [Kinny 96], [Occello 97], ...
- organisation and group primitives [Occello 97], ...
- entry point of the design is not unique nor imposed [Demazeau 97], ... even it often corresponds to agents
- ...

MAS methods vs. Object methods

Characteristics of the Object Methodology

- environment of an object does not exist, even if the environment of an object system does
- fixed Data Interaction Model
- global control, RPC mechanism,

Characteristics of the MAS Methodology

- MAS are situated, the real environment differs from the perceived environment [Moulin 95], [Kendall 95], ...
- free Data interaction Model [Demazeau 95], ...
- global (protocols) [Demazeau 95], [Koning 98], ... and local control (agent's decision) [Shoham 93], [Kendall 95], ...

MAS methods vs. Components methods

Components Methods meaning...

- Components meaning JavaBeans, MS-COM, ...

Characteristics of the Components Methodology

- continuity Approach / Modelling / Implementation
- fixed Data Interaction Model between components
- no organisation nor group primitives
- components are built first, and then their dynamics

Characteristics of the MAS Methodology

- no full continuity Approach / Modelling / Implementation
- free Data interaction Model [Demazeau 95], ...
- organisation and group primitives [Occello 97], ...
- entry point of the design is not unique nor imposed [Demazeau 97], ... even it often corresponds to agents

MAS methods vs. Components methods

Some common features between the methods

- introspection, persistence, mobility of basic entities
- event-driven communication between entities
- entities design and integration into applications

Characteristics of the Components Methodology

- customisation of entities at design time only
- existing de facto standards towards interoperability
- application independent reusable interoperable entities

Characteristics of the MAS Methodology

- possible dynamic allocation of roles during run time
- efforts to standardisation through the FIPA foundation
- still frequently application dependent entities

Agent Unified Modeling Language (AUML)

AUML is part of a standardization effort done by FIPA under the auspices of IEEE to create new diagrams and stereotypes for specific agent concepts when UML is not enough.

AUML extends UML with :

- Agent class diagram
- Interaction diagrams : AUML Interaction diagrams frequently used to model communication between agents
- Organization diagram

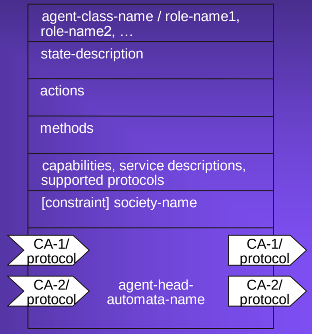
Work in progress :

- Few diagrams
- No tool
- No validation algorithm
- Based on semi-formal semantics of UML: space for ambiguity

Agent UML Agent Diagram

UML Class diagram with some additions:

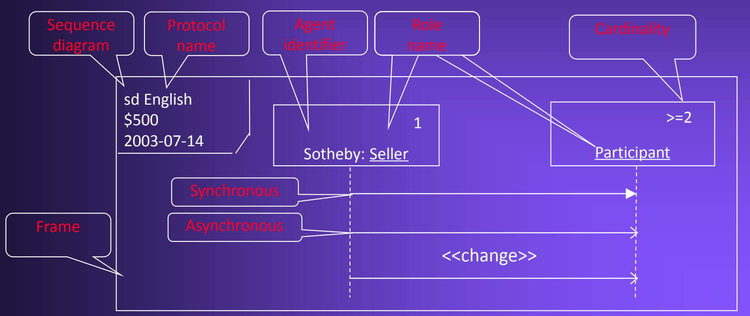
- New compartments to specify services, capabilities, incoming and outgoing messages
- Agent behavior on receiving and sending messages
- Agent role and group



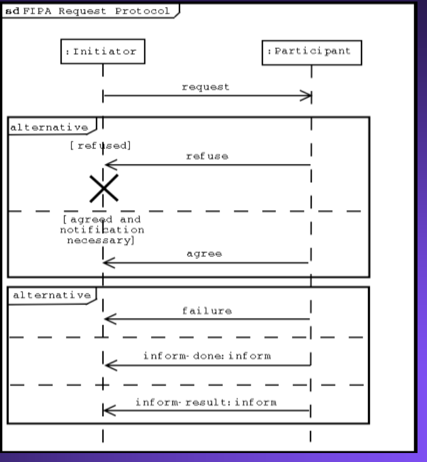
Agent UML Interaction diagram (1)

UML 2.0 Interaction diagram with some additions:

- Agent role and group are added
- Cardinality on message sending
- Blocking and non-blocking constraints
- Actions on message receiving



Agent UML Interaction diagram (2)



How MAS Methodology is different ? (start)

An enriched knowledge representation methodology with computational specifications, a decentralized control and an emergence engine

An enriched but incomplete object methodology

- with extended classes (A, E, I, O), organizations, recursion, where design is not always agent-based
- with situated agents, free interactions, local control,
- where programming is not always agent-based
- Without Analysis / Design / Implementation continuity

An close component methodology, more flexible but still to be standardized

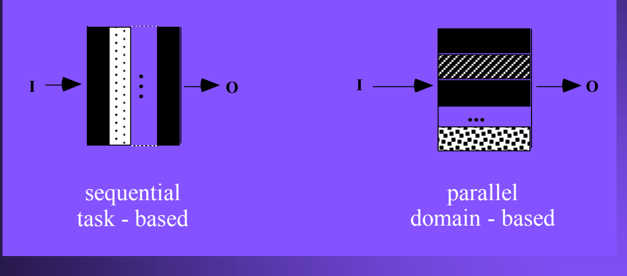
An enriched UML methodology which is not restricted to the design of systems

ANALYSIS

Problem Decomposition [Alvares 98]

The decomposition is based on a specialization

- To solve the problem partially for any case
- To solve the problem entirely for some cases

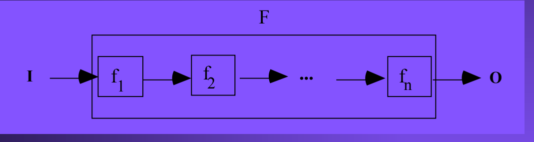


L. Alvares, P. Menezes & Y. Demazeau “Problem Decomposition: An Essential Step for Multi-Agent Systems”, 10th Int. Conference on Systems Research, Informatics and Cybernetics, ICSRIC’98, Baden-Baden, 1998

Sequential or Task-based

Example To prepare an examination subject, we can divide the work in three subproblems

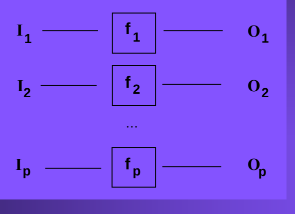
- To determine the number of questions by topic
- To really conceive each question
- To revise the questions



**$F(I) \dashrightarrow O : f_n R \ldots R\ f_2\ R\ f_1(I) \dashrightarrow O$,
where R is a temporal relation between the functions, and can be "precedes" or "succeeds"**

Parallel or Domain-based

Example To prepare an examination subject, we can imagine some domain division like by type of question (to fill in, discursive, multiple choice, ...) or by subject (topic)



$I = I_1 \cup I_2 \cup \ldots \cup I_m,\ O = O_1 \cup O_2 \cup \ldots \cup O_n,\ f_i(I_i) \dashrightarrow O_i$

Comparative Properties

	extrinsic task-based	sequential domain-based	parallel
agent competence and behavior	same	different	different
allowance of parallelism	yes	no	yes
allowance of Agent simplification	no	yes	yes
type of decomposition	quantitative	qualitative	qualitative
communication between agents	minimal	maximal	minimal
Your own criteria	XXX	XXX	XXX

Using many criteria (1)

The criteria are not mutually exclusive, we can combine them

At every level, the decomposition criteria are exclusive

Example To prepare an examination subject

- Determine the number of questions and the respective value by topic (sequential)
- There will be people to prepare questions about topic t1 and people to prepare questions about topic t2 (parallel)
- In topic t1, there will be discursive and simple choice questions (parallel).
- There will be people to revise all questions (sequential)
- Each question will be revised for technical aspects and for linguistic aspects (parallel)

Using many criteria (2)

The problem is decomposed into :

- 1 determine topics 2 prepare questions 3 revise questions

The subproblem 2 is decomposed into

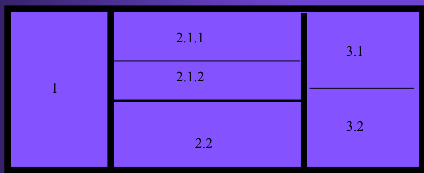
- 2.1 topic t1 2.2 topic t2.

The subproblem 2.1 is decomposed into

- 2.1.1 discursive questions 2.1.2 simple choice questions.

The subproblem 3 is decomposed into

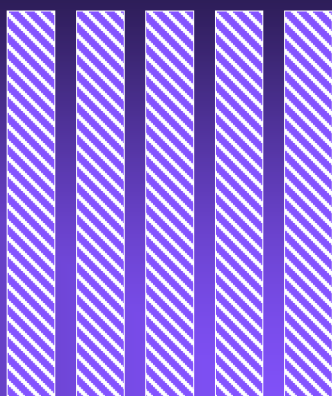
- 3.1 technical review; 3.2 linguistic review.



SATURNE : Vertical foci of attention

Explicitly designed
cf. characteristics

- contours
- highlights
- range data
- stereo vision
- regions
- ...



SATURNE : Horizontal levels of representation

Abstraction

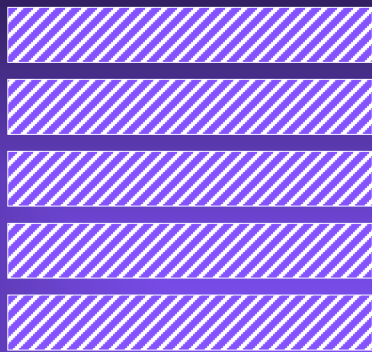
cf.
representation

+

Decentration

cf.
referential

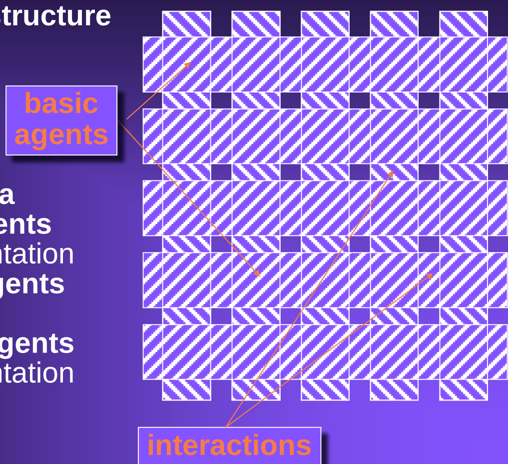
scene
object
scene features
image features
images



SATURNE : Agents and Society of Agents

Organisational structure
horizontal links
vertical links

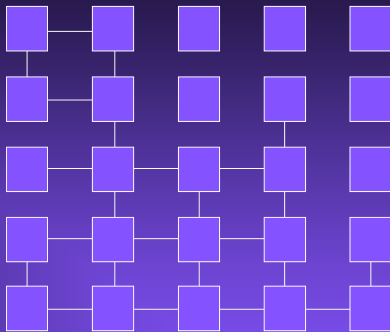
Interaction media
between foci agents
levels of representation
between level agents
foci of attention
between basic agents
levels of representation
x foci of attention



SATURNE Behavior : Scene Understanding

Input
image
(environment)
basic agents

Output
scene understanding
(global goals)



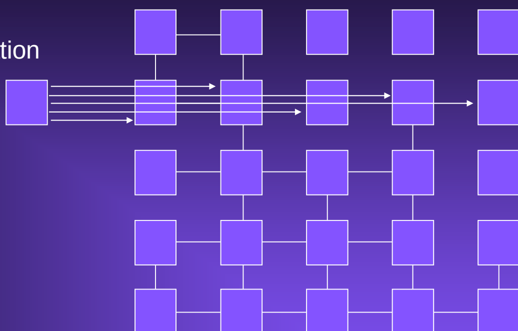
Data driven
No explicit goal
No centralised representation
Information exchange towards local coherence

Decentralised System Simulation

SATURNE Behavior : Recognition Localisation

Input
recognition, localisation
(global goals)
Image
(environment)

Output
basic agents



Goal directed
Explicit goal
Purposive, centralised representation
Information exchange towards global coherence

Distributed Problem Solving

The COHIA (or KR x KP) Approach

Structuring the knowledge representation

- Criteria : abstraction and decentration
- Horizontal decoupling levels of representation
- Vertical first-hand **interactions** : perception

Structuring the knowledge processing

- Criteria : foci on space, time, features, models, tasks
- Vertical decoupling into foci of attention
- Horizontal second-hand **interactions** : communication

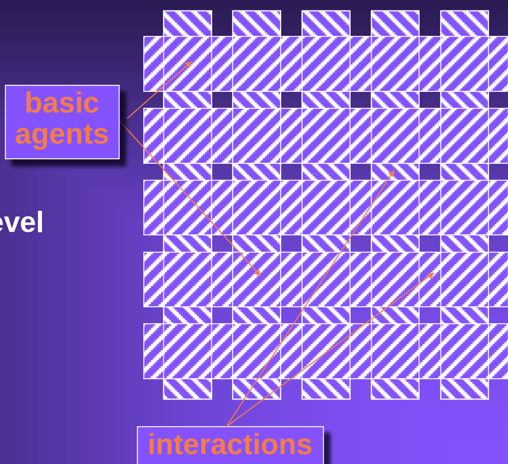
Identifying the basic entities of the system

- Definition : intersection of level-agents & focus-agents
- Choices : **agents**, **organisation**, **environment** models

Identifying the behavior of the system

- System simulation : driven by the nature of the agents
- Problem solving : guided by the goals of the society

The COHIA (or KR x KP) Approach



Interactions within the same level

Interactions between levels

Organisation
horizontal links
vertical links

VOWELS

VOWELS A E I O Decomposition

Agents
- internal architectures of the processing entities

Environment
- domain-dependent elements for structuring external interactions between entities

Interactions
- elements for structuring internal interactions between entities

Organisations
- elements for structuring sets of entities within the MAS

MAS, Emergence, Recursion [Demazeau 95]

The Declarative Principle

MAS = A + E + I + O

The Functional Principle

Function(MAS) = ∑ Function(entities)
+ Emergence Function

The Recursive Principle

entity = basic entity | MAS

Y. Demazeau, "From Cognitive Interactions to Collective Behaviour in Agent-Based Systems", 1st Conference on Cognitive Science, Saint-Malo, pp. 117-132, 1995.

Recursive modelling of agents and societies

AGENT

- **static side :** representation of the world, of the competences, beliefs, plans, intentions, goals of the agent itself and of others
- **dynamic side :** perception, communication, resolution, decision, execution capabilities
- **control :** regulation of the agent activity, data driven and/or goal directed

SOCIETY

- **static side :** organisation structure, basic interactions, communication mode
- **dynamic side :** communication protocols, more generally interaction protocols
- **control side :** regulation of the society activity, data driven and/or goal directed

MAS Applications

Computer-Aided Design
Computer Vision
Decision Support
Electronic Commerce
Enterprise Modelling
Interactive Games
Manufacturing Systems
Natural Language Processing
Network Monitoring
Office and Home Automation
Robotics Control
Societies Simulation
Spatial Data Handling
Telecommunication Routing
Traffic Management

VOWELS : Domains and Problems

Computer-Aided	Design
Computer	Vision
Decision	Support
Electronic	Commerce
Enterprise	Modelling
Manufacturing	Systems
Natural Language	Processing
Network	Monitoring
Office and Home	Automation
Robotics	Control
Societies	Simulation
Spatial Data	Handling
Telecommunication	Routing
Traffic	Management

MAOP and Domain Orientation

(((A + E) + I) + O)	Robotics Science

MAOP and Domain Orientation

(((A + E) + I) + O)	Robotics Science
(((A + I) + O) + E)	Social Science

MAOP and Domain Orientation

(((A + E) + I) + O)	Robotics Science
(((A + I) + O) + E)	Social Science
((E + A) + (I + O))	Life Science

MAOP and Domain Orientation

(((A + E) + I) + O)	Robotics Science
(((A + I) + O) + E)	Social Science
((E + A) + (I + O))	Life Science
(((I + O) + A) + E)	Military Science

MAOP and Domain Orientation

(((A + E) + I) + O)	Robotics Science
(((A + I) + O) + E)	Social Science
((E + A) + (I + O))	Life Science
(((I + O) + A) + E)	Military Science
(((O + I) + E) + A)	Economic Science

MAOP and Domain Orientation

(((A + E) + I) + O)	Robotics Science
(((A + I) + O) + E)	Social Science
((E + A) + (I + O))	Life Science
(((I + O) + A) + E)	Military Science
(((O + I) + E) + A)	Economic Science

VOWELS Oriented Programming

I defend an instance of Multi-Agent Oriented Programming, VOWELS, which consists :

- 1/ To express the problem independently of the domain

VOWELS Oriented Programming

I defend an instance of Multi-Agent Oriented Programming, VOWELS, which consists :

- 1/ To express the problem independently of the domain
- 2/ To "vowellify" the problem in terms of A E I O U, ...

VOWELS Oriented Programming

I defend an instance of Multi-Agent Oriented Programming, VOWELS, which consists :

- 1/ To express the problem independently of the domain
- 2/ To "vowellify" the problem in terms of A E I O U, ...
- 3/ To choose understood frames of A, E, I, O, U, dynamics, and recursion

VOWELS Oriented Programming

I defend an instance of Multi-Agent Oriented Programming, VOWELS, which consists :

- 1/ To express the problem independently of the domain
- 2/ To "vowellify" the problem in terms of A E I O U, ...
- 3/ To choose understood frames of A, E, I, O, U, dynamics, and recursion
- 4/ To leave VOWELS "emergence engine" complete the missing bricks by itself and build the appropriate MAS...

VOWELS Oriented Programming

I defend an instance of Multi-Agent Oriented Programming, VOWELS, which consists :

- 1/ To express the problem independently of the domain
- 2/ To "vowellify" the problem in terms of A E I O U, ...
- 3/ To choose understood frames of A, E, I, O, U, dynamics, and recursion
- 4/ To leave VOWELS "emergence engine" complete the missing bricks by itself and build the appropriate MAS...
- 5/ ... To be deployed as self on a distributed settling...

VOWELS Oriented Programming

I defend an instance of Multi-Agent Oriented Programming, VOWELS, which consists :

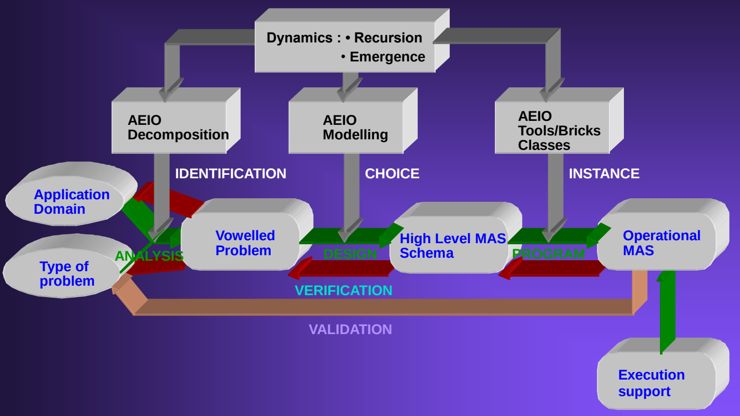
- 1/ To express the problem independently of the domain
- 2/ To "vowellify" the problem in terms of A E I O U, ...
- 3/ To choose understood frames of A, E, I, O, U, dynamics, and recursion
- 4/ To leave VOWELS "emergence engine" complete the missing bricks by itself and build the appropriate MAS...
- 5/ ... To be deployed as self on a distributed settling...
- 6/ ... To be settled and used interactively

VOWELS Oriented Programming [Demazeau 97]

I defend an instance of Multi-Agent Oriented Programming, VOWELS, which consists :

- 1/ To express the problem independently of the domain
- 2/ To "vowellify" the problem in terms of A E I O U, ...
- 3/ To choose understood frames of A, E, I, O, U, dynamics, and recursion
- 4/ To leave VOWELS "emergence engine" complete the missing bricks by itself and build the appropriate MAS...
- 5/ ... To be deployed as self on a distributed settling...
- 6/ ... To be settled and used interactively

VOWELS : General Approach



Playing with the VOWELS

PhD	Boissier	(A + I) + O	ASIC
PhD	Sichman	A + O	DEPNET
PhD	Ferrand	((A + I) + O) + E	SANPA
PhD	Baeijs	((A + E) + I) + O	SIGMA
PhD	Van Aeken	O + A	SMAMS
PhD	Ribeiro	I + A	DIM
PhD	Ricordel	Development	VOLCANO
PhD	Tavares	Planning	
PhD	Deguet	Emergence	
PhD	Piolle	(((U + A) + I) + O) + E	PAW
PhD	Joumaa	m Observation	MASPAJE
PhD	Crepin	(((U + O) + I) + A) + E	HIPPO
PhD	Lacomme	Dynamics	
PhD	Lamarche	M Observation	

ROBOTICA: Autonomous Agents [Cetnarowicz]

ROBOTICA: Decentralised Agents

ROBOTICA: Centralized Agents

COMPLEMENTARY REFERENCES

Complementary references

A useful foundational application in the MAS domain

P. Cohen, M. Greenberg, D. Hart & A. Howe, "Trial by Fire: Understanding the Design Requirements for Agents in Complex Environments", AI Magazine, Vol. 10, No 3, pp. 32-48, AAAI Press, 1989.

A paradigm contemporary to VOWELS, organisation oriented

J. Ferber, O. Gutknecht, and F. Michel, "From Agents to Organizations: An Organizational View of Multi-Agent Systems", Agent-Oriented Software Engineering IV, LNCS 2935, pp. 214-230, 2004.

A descendent of VOWELS, organisation oriented

M. Hannoun, O. Boissier, J. Sichman, Cl. Sayettat, "MOISE: An Organizational Model for Multi-agent Systems", IBERAMIA-SBIA 2000, pp. 156-165, 2000.

A more recent approach, much more interaction oriented

Y. Kubera, Ph. Mathieu, S. Picault, "IODA: an interaction-oriented approach for multi-agent-based simulations", Journal on Autonomous Agents and Multi-Agent Systems, Vol. 23, pp. 303-343, 2011.