

Valencia
24 January 2010

Purposive Multi-Agent Systems

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INTRODUCTION

Introduction

- Challenge
- Vowels

MAS Series of Events

- IWDAI –Distributed Artificial Intelligence (USA)
- MAAMAW – Agents in Multi-Agent World (Europe)
- MACC – MAS and Concurrent Computing (Japan)
- JFSMA – MAS (French Speaking Countries)
- ICMAS – MAS (World)
- DIMAS – Decentralized Intelligent MAS (Poland)
- ADAIMAS - DAI and MAS (Australia)
- PDAI - Parallel and DAI (India)
- IAWDAIMAS – DAI & MAS (C. & S. America)
- DAIMAS – DAI and MAS (Russia)
- IWMAS – MAS (North-America)
- CEEMAS – MAS (C. & E. Europe)
- AAMAS – AA & MAS (World)
- IAT – Intelligent Agent Technology (World)
- EUMAS – MAS (Europe)
- ICAART – Agents and Artificial Intelligence (World)
- PAAMS – Practical Applications of Agents and MAS (World)
- PRIMA – Principles of Practice in MAS (World)

User Centered Emergent Creativity [Demazeau 03]

Grand challenge

- User centred adaptive ICT systems, or
- From production tools to creation tools
- Emergent real-time ICT usage

Working hypothesis

- Users are either human or virtual agents

Research themes

- The process and the economy of creation
- Real-time user-centred exploitation of data
- User modelling, personalization, and trust
- Interaction, collaboration, organisation
- Emergence, composition of functionality
- The creator becoming the real designer
- A way to evaluate properly such systems

Y. Demazeau, “Créativité Emergente Centrée Utilisateur” (keynote), 11èmes JFSMA, pp. 31-36, Hermès, Hammamet, Novembre 2003

VOWELS A E I O Decomposition [Demazeau 95]

Agents

- internal architectures of the system 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

VOWELS Oriented Design

The Declarative Principle

$$\text{MAS} = A + E + I + O$$

The Functional Principle

$$\text{Function(MAS)} = \sum \text{Function(entities)} \\ + \text{Emergence Function}$$

The Recursive Principle

$$\text{entity} = \text{basic entity} \sqcup \text{MAS}$$

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

FROM USABLE MAS TO USEFUL MAS

Introduction

- Challenge
- Vowels

From Usable MAS to Useful MAS

- Playing with the vowels
- Multi-agent oriented programming
- Examples

Playing with 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

POPORGS: Populations [Demazeau 96]

The **Population** structure is the set of agents, the set of possible behaviors of the agents, and the set of all interaction processes between agents

$$\text{Pop} = (\text{Ag}, \text{Bh}, \text{Ip}; \text{bc}, \text{ic})$$

Ag : set of agents

Bh : set of behaviors agents are able to perform

Ip : set of interaction processes

bc : $\text{Ag} \rightarrow P(\text{Bh})$, behavioral capability,
bc(a), set of behavior a is able to perform

ic : $\text{Ag} \times \text{Ag} \rightarrow P(\text{Ip})$, interaction capability,
ic(a₁,a₂), set of interaction processes
agents a₁ and a₂ may perform together

POPORGS: Organisations

The **Organization** structure is composed of organizational roles and organizational links

$$\text{Org} = (\text{Ro}; \text{Li})$$

Ro is defined in a relational way

- e.g. $\text{Ro} \subseteq \text{Lp} \times \text{Gp}$: global processes (Gp) and local processes (Lp), the role is the part of agent's behavior that is integrated in the global process.
- e.g. $\text{Ro} \subseteq \text{Fo} \times \text{Lv}$: foci of interest (Fo), representation levels (Lv), the role is the agent's behavior for a given focus at a given level.

$$\text{Li} \subseteq \text{Ro} \times \text{Ro}$$

POPORGS: Pop $\not\propto$ Org

The suitable relation between the Pop and the Org is the system's organization implementation

It is any relation $\text{imp} = \text{Pop} \not\propto \text{Org}$, on $(\text{Ro} \times \text{Ag}) \cup (\text{Li} \times \text{Ip})$,
 $\text{Pop} = (\text{Ag}, \text{Bh}, \text{Ip}; \text{bc}, \text{ic})$, $\text{Org} = (\text{Ro}; \text{Li})$.

- if $(r,a) \in \text{imp}$, r is said to implemented by a
- if $(l,p) \in \text{imp}$, l is said to implemented by p

imp is said "proper" iff $\not\propto$ is an homomorphism.

- $\forall r \in \text{Ro}, \exists a \in \text{Ag} / (r,a) \in \text{imp}$, and r is properly implemented by some behavior $b \in \text{bc}(a)$
- $\forall l = (l_1, l_2) \in \text{Li}, \exists ip \in \text{Ip} / \{ (l, ip) \in \text{imp} \wedge \exists (a_1, a_2) \in \text{Ag} \times \text{Ag} / ip \in \text{ic}(a_1, a_2), (r_1, a_1) \in \text{imp}, (r_2, a_2) \in \text{imp}, \text{and } r_1, r_2 \text{ are properly implemented by the behaviors of } a_1 \text{ and } a_2, \text{ respectively} \}$

POPORGS : PopOrg

The Interior (= Population + Organisation) of a time-invariant multi-agent system is captured by a population-organization structure $\text{PopOrg} = (\text{Pop}, \text{Org}; \text{imp})$, where

- $\text{Pop} = (\text{Ag}, \text{Bh}, \text{Ip}; \text{bc}, \text{ic})$ is a population structure
- $\text{Org} = (\text{Ro}; \text{Li})$ is a organization structure
- $\text{imp} \subseteq (\text{Ro} \times \text{Ag}) \cup (\text{Li} \times \text{Ip})$ is an organization implementation relation as defined previously

Y. Demazeau & A. Rocha Costa, “Populations and Organizations in Open MAS”, 1st National Symposium on Parallel and Distributed AI, PDAI’96, Hyderabad, July 1996.

POPORG as an instance of $((\text{A} + \text{I}) + \text{O}) + \text{E}$ Oriented Programming

... to be compared with AOP [Shoham 93] IOP [Huhns 95]
Organisation OP [Lemaitre 98]

VOWELS Oriented Programming [Demazeau 97]

We defend an instance of MAOP, the VOWELS framework in which :

- 1/ to express the problem to solve independently of the domain
- 2/ to "vowellify" the problem in terms of A E I O, ...
- 3/ to choose understood frames of A, E, I, O, 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

The **Programming Principle**

MAS = $[A^*; E^*; I^*; O^*]$
+ (Recursion & Emergence) Mechanism

VOWELS Oriented Programming [Demazeau 97]

The Declarative Principle

$$\text{MAS} = A + E + I + O$$

The Functional Principle

$$\text{Function(MAS)} = \sum \text{Function(entities)} \\ + \text{Emergence Function}$$

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$$\text{entity} = \text{basic entity} \mid \text{MAS}$$

The Programming Principle

$$\text{MAS} = [A^*; E^*; I^*; O^*] \\ + (\text{Recursion \& Emergence}) \text{ Mechanism}$$

Y. Demazeau, “Steps towards Multi-Agent Oriented Programming” (slides Workshop), 1st International Workshop on Multi-Agent Systems, IWMAS '97, Boston, October 1997.

Multi-Agent Oriented Programming

Not Object-Oriented Programming

- S = Objects + Message passing

Not Logic nor Expert Systems Programming

- S = Knowledge + Inference Mechanism

Not Ontology-Oriented Programming

- S = Knowledge + Problem Solving Methods

Not exactly Agent-Oriented Programming

- S = BDI Agents + KQML (Interactions)

Not exactly (((A + I) + O) + E)-Oriented Programming

- S = ((A + I) + O) + E

But VOWELS Programming

- S = [A*; E*; I*; O*] + (Recursion & Emergence) Mechanism

But ...

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

Automated generalisation to provide maps from cartographic databases

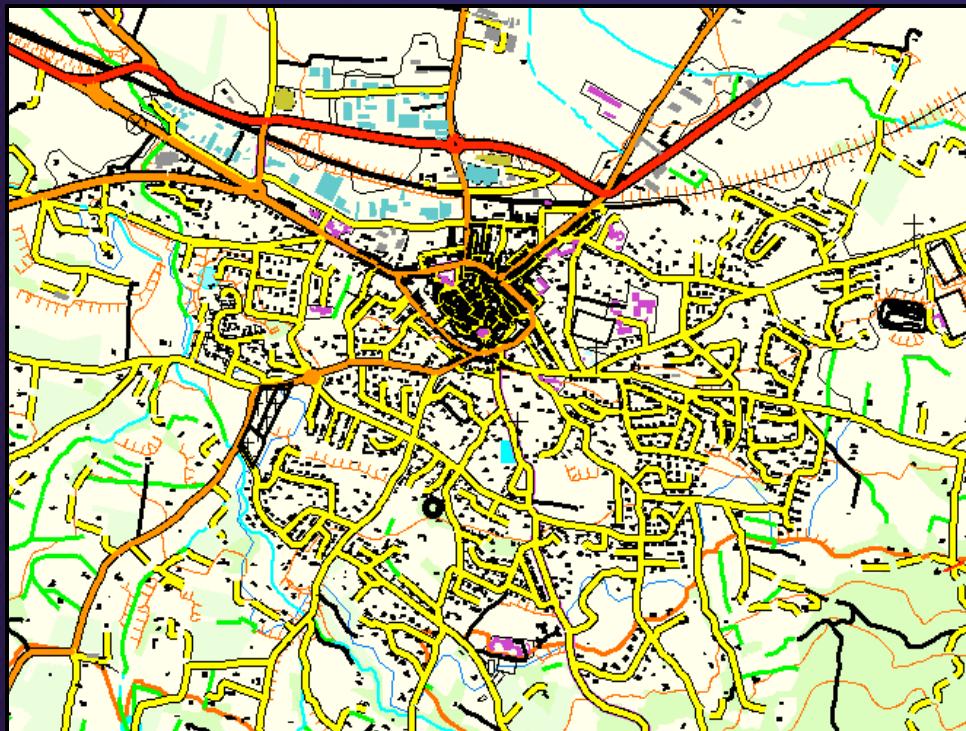
**Automatic GEneralisation New Technology IGN (F),
LaserScan Ltd. (UK), LEIBNIZ-INPG (F), U. Zürich (CH), U.
Edinburgh (UK)**

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

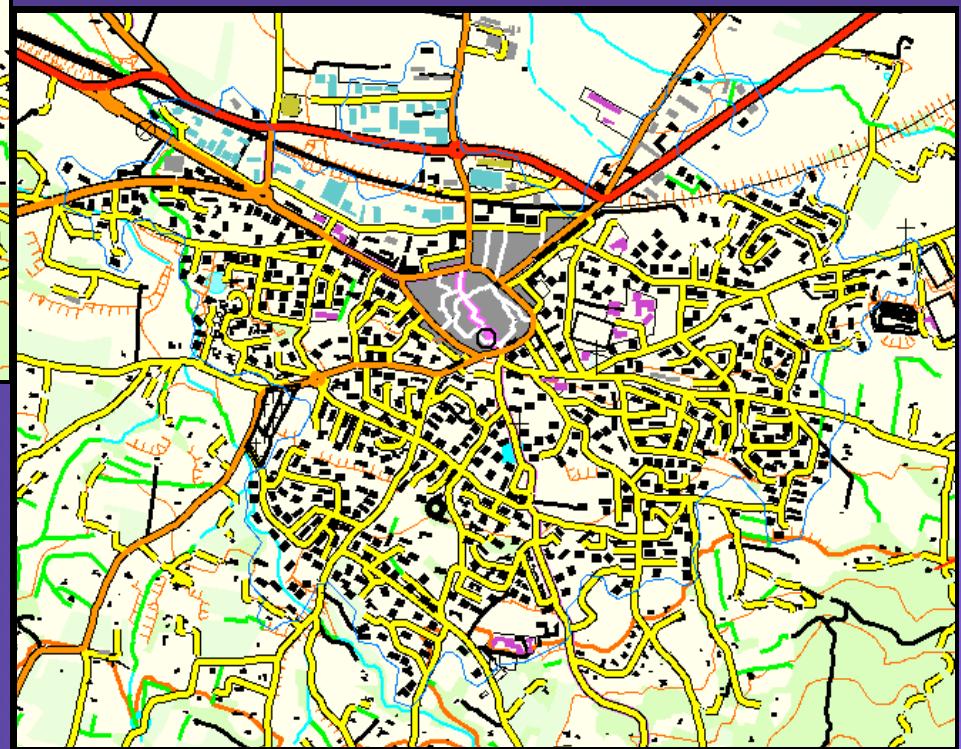
S. Lamy, A. Ruas, Y. Demazeau, M. Jackson, W. Mackaness, & Robert Weibel, "The Application of Agents in Automated Map Generalisation", 19th International Cartographic Conference, Vol 2, pp. 1225-1234, August 1999.

AGENT Project (CEC 24939) (2) [Lamy 1999]



BEFORE

AFTER



ATRONS Project (with USD - Henrik Lund)

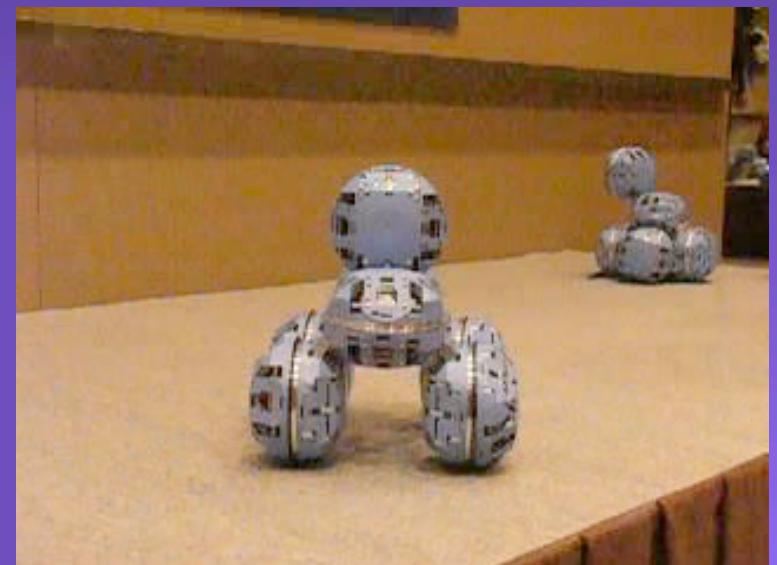
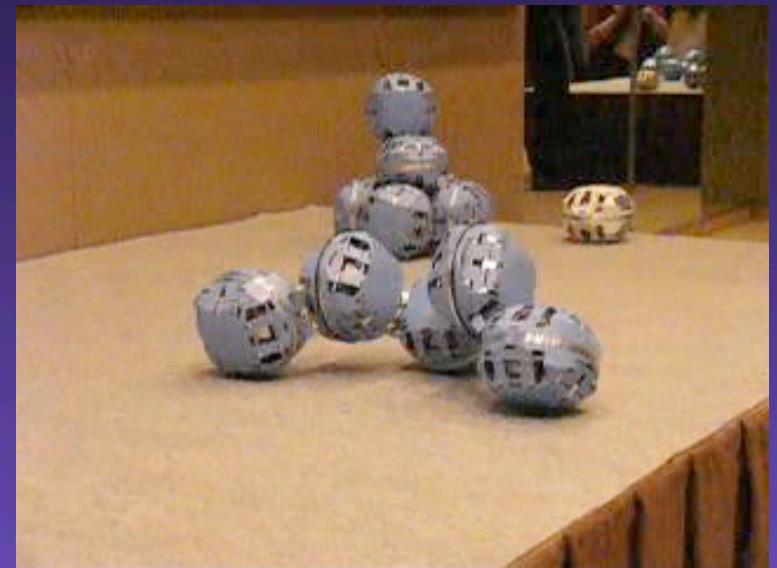
**High level Programming language
for
Reconfigurable modular robotics**

VOWELS approach

- ATRONS as A, evolving in a 3D Environment
- I given IR sensors and physical grippers
- O as a problem to solve
- or a function to emerge

Applications

- Technological :
- to demonstrate modular robotics
- Scientific : to support emergence engineering



ATRONS Project (with USD - Henrik Lund)



FROM USEFUL MAS TO USED MAS

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From Useful MAS to Used MAS

- The purpose of the domain
- The purpose of the end-user
- Examples

The purpose of the Domain

$((A + E) + I) + O)$

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

The purpose of the Domain

MAS are not always A-centered !

$((\text{A} + \text{E}) + \text{I}) + \text{O}$

Robotics Science

$((\text{A} + \text{I}) + \text{O}) + \text{E}$

Social Science

$(\text{E} + \text{A}) + (\text{I} + \text{O})$

Life Science

$((\text{I} + \text{O}) + \text{A}) + \text{E}$

Military Science

$((\text{O} + \text{I}) + \text{E}) + \text{A}$

Economic Science

The purpose of the User

But is the User at its right place ?

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

((((A + I) + O) + E) +U) **Social Science**

((E + A) + (I + O)) +U) **Life Science**

((((I + O) + A) + E) +U) **Military Science**

((((O + I) + E) + A) +U) **Economic Science**

VOWELS A E I O U Decomposition [Demazeau 03]

Agents

- internal architectures of the system 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

Users

- internal architectures of the end-user processing entities

VOWELS Oriented Programming

The Declarative Principle

$$\text{MAS} = A + E + I + O + U$$

The Functional Principle

$$\text{Function(MAS)} = \sum \text{Function(entities)} \\ + \text{Emergence Function}$$

The Recursive Principle

$$\text{entity} = \text{basic entity} \mid \text{MAS}$$

The Programming Principle

$$\text{MAS} = [A^*; E^*; I^*; O^*; U^*] \\ + (\text{Recursion \& Emergence}) \text{ Mechanism}$$

Y. Demazeau, “Créativité Emergente Centrée Utilisateur” (keynote), 11èmes Journées Francophones sur les Systèmes Multi-Agents, pp. 31-36, Hermès, Hammamet, Novembre 2003.

The purpose of the user and the purpose of the domain

The user should be at its right (?) place !

$((((U + A) + E) + I) + O)$ **Robotics Science**

$((((U + A) + I) + O) + E)$ **Social Science**

$((E + (U + A)) + (I + O))$ **Life Science**

$((I + O) + (U + A)) + E)$ **Military Science**

$((O + I) + E) + (U + A))$ **Economic Science**

Even if MAS are not always $((U + A)$ -centered !

Interactive Games

General Case

- ---> A to be replaced by (U + A)

Handling

- The goal is to master emergence, to optimize a cost
- The understanding of the whole system has to be easy
- The (E)nvironment has to be as realistic as possible
- ---> E to be replaced by (U + E)

Strategy

- The goal is to use and to plan the use of resources
- The visualisation of the interactions is highly desirable
- The key parameters of the game are (I)nteractions
- ---> I to be replaced by (U + I)

Role

- The goal is to increase the competences of the User
- Competences of the characters have to be visualized
- The (O)rganisation constitutes the entry of the game
- ----> O to be replaced by (U + O)

The purpose of the user and the purpose of the domain

From U as consumer...

$((((A + E) + I) + O) + U)$

Good old MAS

To U as a partner...

$((((A + U) + E) + I) + O)$
 $((((A + U) + I) + O) + E)$
 $((E + (A + U)) + (I + O))$
 $((((I + O) + (A + U)) + E)$
 $((((O + I) + E) + (A + U))$

Robotics Science
Social Science
Life Science
Military Science
Economic Science

Towards U as a creator...

$((((U + (O + I)) + E) + A)$

Future MAS

PLAYWARE Project (with USD - Henrik Lund)

An interactive playground that recognizes and adapts to children

VOWELS approach

- Children as A, evolving in a 2D Environment
- I given tactile sensor and visual actuators
- O as a dynamic structure arising during time

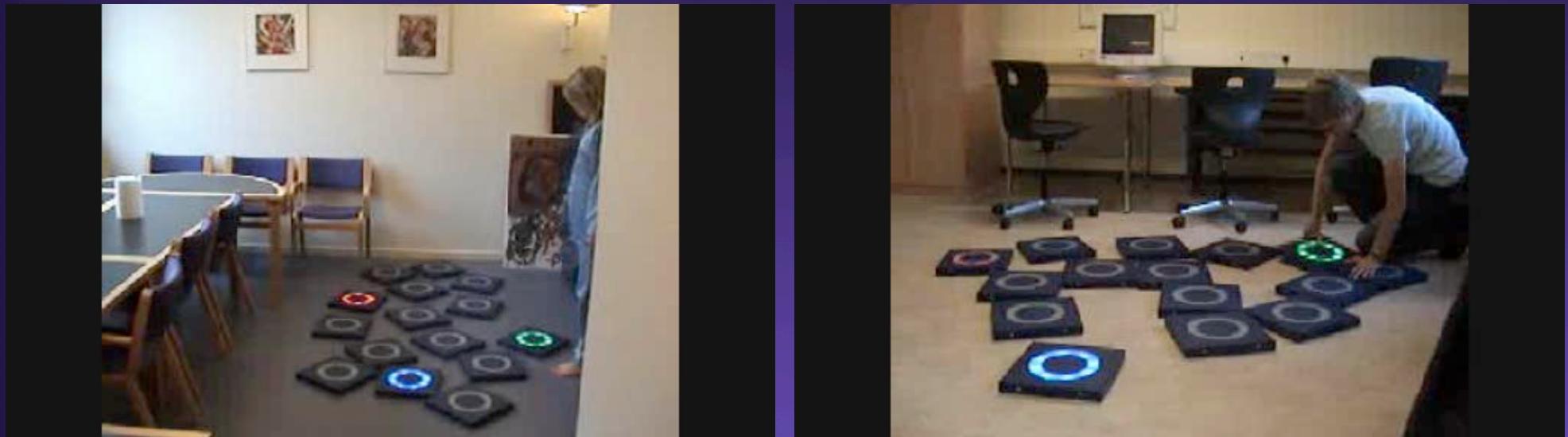
Applications

- Societal : tools to train children
- Scientific : to assist healthcare



F. Hammer, A. Derakhshan, Y. Demazeau & H. Lund, “A Multi-Agent Approach to Social Human Behaviour in Children’s Play”, 6th International Conference on Agent Technology, IAT’06, pp. 403-406, IEEE/WIC/ACM, Hong-Kong, December 2006.

PLAYWARE Project (with USD - Henrik Lund)



M@trice Active Project (with U. Paris 1 - Lavaud)

VOWELS approach

- Extension of PACO to a 3D world environment
- Elements as A, evolving in a 3D Environment
- I and O wrt Kandinsky's rules of painting

Applications

- Pedagogical : to explain and to explore Kandinsky
- Artistic : to support Kandinsky's like painting
- Creative : multi-user collaborative framework

Y. Gufflet & Y. Demazeau, "Applying the PACO paradigm to a 3-D artistic creation", 5th International Workshop on Agent-Based Simulation, ABS'04, pp. 121-126, SCS, Lisbon, Portugal, May 2004.

M@trice @ctive

CONCLUSION

Introduction

- Challenge
- Vowels

From Usable MAS to Useful MAS

- Playing with the vowels
- Multi-agent oriented programming
- Examples

From Useful MAS to Used MAS

- The purpose of the domain
- The purpose of the end-user
- Examples

Conclusion

- Future MAS
- Research Agenda

Playing with VOWELS

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PhD Van Aeken	O + A	SMAMS
PhD Ribeiro	I + A	DIM
PhD Ricordel	Development	VOLCANO
PhD Tavares	Planning	
PhD Deguet	Emergence	
PhD Piolle	((U + I) + O) + E	PAW
PhD Joumaa	Evaluation	MASPAJE
PhD Crepin	((U + O) + I) + E	HIPPO
PhD Lacomme		

Evolution of Agents and Multi-Agent Systems

Robotics Agents
Mobile Agents
Software Agents
Interface Agents
Service Agents
User Agents

...

Artificial Intelligence
Telecommunications
Software Engineering
HC Interfaces
Internet Computing
Creative Computing

...

MAS assuming Closed Environments
MAS integrating Open Environments
MAS including Human Agents (CSCW, ITS)
MAS for the benefit of Human Agents

...

Research agenda : Service to the person

Both the purpose of the user and the one of the domain have to be taken in parallel...

Protecting personal data, managing multiple identity, towards cognitive trust (**delegation**) ...

Reasoning under uncertain and incomplete models such as partial BDI models... (**social reasoning**)

Static (**personnalisation**) and dynamic adaptation (**real time**) of service composition

Evaluating MAS systems from a CS point of view and from a usage point of view (**evaluation**)

Purposive MAS will also have to be able to deal with real-time and real-size issues...

Citizen Agents (MAGMA project)

To support everyday's life of every citizen

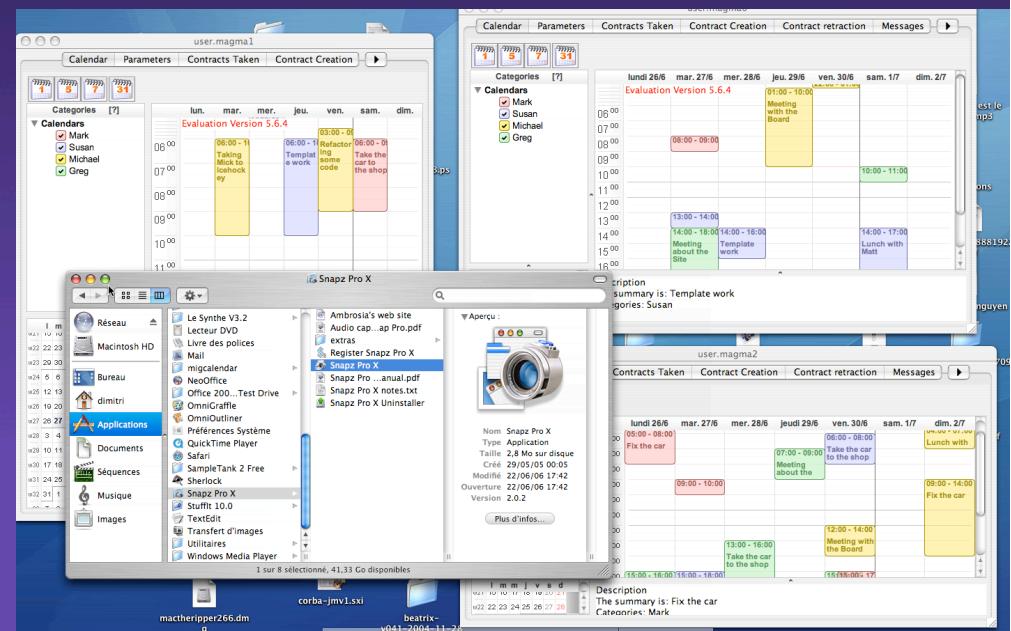
VOWELS approach

- One personal assistant per life domain, being the A
- E: Importance and urgency
- I : Sharing, Trusting, Negotiating
- O : Family, Team, Consortium

Applications

- Leisure : citizen as a consumer
- Finance : citizen as a partner
- Administration : citizen as a provider

Y. Demazeau, D. Melaye, M.-H. Verrons, "A Decentralized Calendar System Featuring Sharing, Trusting and Negotiating ", 19th International Conference on Industrial, Engineering & Other Applications of Applied Intelligent Systems, IEA/AIE'06, Annecy, June 2006.



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