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Purposive
Multi-Agent Systems

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- 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)
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- 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

CNRS - Laboratoire d’Informatique de Grenoble
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**
\[ \text{Function} (\text{MAS}) = \sum \text{Function} (\text{entities}) + \text{Emergence Function} \]

The **Recursive Principle**
\[ \text{entity} = \text{basic entity} \mid \text{MAS} \]

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

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<th>PhD</th>
<th>Boissier</th>
<th>(A + I) + O</th>
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<td>Sichman</td>
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</tbody>
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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**\text{ : set of agents}
- **Bh**\text{ : set of behaviors agents are able to perform}
- **Ip**\text{ : set of interaction processes}
- **bc**\text{ : Ag ---\(\rightarrow\) P(Bh), behavioral capability, bc(a), set of behavior a is able to perform}
- **ic**\text{ : Ag x Ag ---\(\rightarrow\) P(Ip), interaction capability, ic(a1,a2), set of interaction processes agents a1 and a2 may perform together}
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 \( \Join \) Org

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

It is any relation \( \text{imp} = \text{Pop} \Join \text{Org} \), on \((\text{Ro} \times \text{Ag}) \cup (\text{Li} \times \text{Ip})\),
Pop = \((\text{Ag}, \text{Bh}, \text{Ip}; \text{bc}, \text{ic})\), 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 \(p\)

\(\text{imp}\) is said "proper" iff \(\Join\) 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 \(b \in \text{bc}(a)\)

- \(\forall l = (l_1, l_2) \in \text{Li}, \exists ip \in \text{Ip} \{ (l,ip) \in \text{imp} \land \exists (a_1,a_2) \in \text{Ag} \times \text{Ag} / ip \in \text{ic}(a_1,a_2), (r_1,a_1) \in \text{imp}, (r_2,a_2) \in \text{imp}, \text{and} r_1, r_2 \text{ are properly implemented by the behaviors of } a_1 \text{ and } a_2, \text{ respectively}\} \)
The Interior ( = Population + Organisation ) of a time-invariant multi-agent system is captured by a population-organization structure PopOrg = (Pop, Org; imp), where

- Pop = (Ag, Bh, Ip; bc, ic) is a population structure
- Org = (Ro; Li) is a organization structure
- imp ⊆ (Ro x Ag) ∪ (Li x Ip) is an organization implementation relation as defined previously


POPORG as an instance of (((A + I) + O) + E) Oriented Programming

... to be compared with AOP [Shoham 93] IOP [Huhns 95] Organisation OP [Lemaitre 98]
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
MAS = A + E + I + O

The Functional Principle
Function(MAS) = Σ Function(entities) + Emergence Function

The Recursive Principle
entity = basic entity | MAS

The Programming Principle
MAS = [A*; E*; I*; O*] + (Recursion & Emergence) Mechanism

Multi-Agent Oriented Programming

Not Object-Oriented Programming
- \( S = \text{Objects} + \text{Message passing} \)

Not Logic nor Expert Systems Programming
- \( S = \text{Knowledge} + \text{Inference Mechanism} \)

Not Ontology-Oriented Programming
- \( S = \text{Knowledge} + \text{Problem Solving Methods} \)

Not exactly Agent-Oriented Programming
- \( S = \text{BDI Agents} + \text{KQML (Interactions)} \)

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

But VOWELS Programming
- \( S = [A^*; E^*; I^*; O^*] + (\text{Recursion} \& \text{Emergence}) \text{ Mechanism} \)

But …
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

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

Introduction
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From Usable MAS to Useful MAS
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- Examples

From Useful MAS to Used MAS
- The purpose of the domain
- The purpose of the end-user
- Examples
The purpose of the Domain

- (((\text{A} + \text{E}) + \text{I}) + \text{O}) \quad \text{Robotics Science}
- (((\text{A} + \text{I}) + \text{O}) + \text{E}) \quad \text{Social Science}
- ((\text{E} + \text{A}) + (\text{I} + \text{O})) \quad \text{Life Science}
- (((\text{I} + \text{O}) + \text{A}) + \text{E}) \quad \text{Military Science}
- (((\text{O} + \text{I}) + \text{E}) + \text{A}) \quad \text{Economic Science}
The purpose of the Domain

MAS are not always A-centered!

- $(((A + E) + I) + O)$: 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 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
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
MAS = A + E + I + O + U

The Functional Principle
Function(MAS) = \sum Function(entities)
+ Emergence Function

The Recursive Principle
entity = basic entity I MAS

The Programming Principle
MAS = [A*; E*; I*; O*; U*]
+ (Recursion & Emergence) Mechanism

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 in 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…

\[ (((A + U) + E) + I) + O \]  Robotics Science
\[ (((A + U) + I) + O) + E \]  Social Science
\[ (E + (A + U)) + (I + O) \]  Life Science
\[ (((I + O) + (A + U)) + E \]  Military Science
\[ (((O + I) + E) + (A + U)) \]  Economic Science

Towards U as a creator…

\[ (((U + (O + I)) + E) + A \]  Future MAS
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

PLAYWARE Project (with USD - Henrik Lund)
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

CONCLUSION

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- Examples

From Useful MAS to Used MAS
- The purpose of the domain
- The purpose of the end-user
- Examples

Conclusion
- Future MAS
- Research Agenda
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## Evolution of Agents and Multi-Agent Systems

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<th>Artificial Intelligence</th>
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<tr>
<td>Mobile Agents</td>
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<td>Software Engineering</td>
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<td>Interface Agents</td>
<td>HC Interfaces</td>
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<td>Service Agents</td>
<td>Internet Computing</td>
</tr>
<tr>
<td>User Agents</td>
<td>Creative Computing</td>
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...  

**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

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References about Useful Multi-Agent Systems

THEORY


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


APPLICATIONS

References about Used Multi-Agent Systems

THEORY


APPLICATIONS

