Interactions sur le fonctionnement dans les systèmes multi-agents ouverts et hétérogènes

Interactions about Actions in Open and Heterogenous Multi-Agent Systems

Soutenance d'Habilitation à Diriger des Recherches

Nicolas Sabouret

Lundi 20 novembre 2009
Agents that can understand what they are doing

- What they can do
- How and Why
- When
- etc

Explanations

Symbolic AI reasoning

Introspection

in

Real World situations (ex: Ambient Computing)

Open & Heterogeneous Multi-Agent Systems
Problematics (cont.)

- Distributed
  - System behaviour ← entities + *interactions*
  - Need to combine functionalities
- Open
  - Services can (dis)appear *at runtime*
- Loosely coupled
  - → no a priori information about others
- Heterogeneous
  - Inconsistent models for data & actions
  - Agent interactions *and* Human-Agent interactions
Two problems

Service composition

- Explicit goal → *dynamic choreography*
- Implicit goal → *learning interactions*

Management of semantic heterogeneity

- Incompatible representations → *dynamic semantic interpretation*

Introspection!

Very simple problems often turn out very difficult to solve...
Outline

- Related work in...
  - Service composition
  - Semantic heterogeneity
  - Reinforcement learning & interactions

- The VDL model
- Service composition
- Learning interactions
- Semantic heterogeneity
- Conclusion & future work
Related work

Open & Heterogenous MAS

Service composition
Semantic Heterogeneity
Reinforcement learning & Interactions

Introspection
Service composition

Coalition formation

Ontologies of Services

Planing
- [Durfee, 01] → task-oriented
- [Wu, 03] → H TaskNets
- [Traversore, 04] → planing on service ontology

Negociation protocols
- [Paurobally, 05]

[Shehory, 99]
[Traversore, 04]

[OWL-S, 04]
[WSDL, 03]

Service Oriented Architectures

Service orchestration & choreography

[Moreau, 08] → syntactic service orchestration

Choreography
- [Peltz, 03]

Planing on service ontology

[Müller, 06] → workflow description

Multi-Agent coordination

[Shehory, 99]
[Aknine, 02]

→ goal description

task-oriented

Negociation protocols
Service composition

Tasks decomposition

Reasoning

Choreography (static)

Orchestration

Service composition
Service composition

- Existing work
  - A priori task decomposition
  - A priori known set of possible actions
    → static service choreography
- Open MAS
  → dynamic service choreography
- Discover tasks at runtime
  → instrospection
  → interaction model
Related work

Open & Heterogenous MAS

Service composition

Semantic Heterogeneity

Reinforcement learning & Interactions

Introspection
Semantic Heterogeneity

KR model

Ontology engineering

Semantic Heterogeneity

Ontology alignment

Thesaurus [WN, 98]
Semantic Networks
Ontologies [OWL, 04]

Structure-based

[Valencia, 04]

[Breitman, 05]

Semantic negotiation

[van Diggelen, 06]
(Anemone)

Reference ontology

[Ichise, 03]

 Instance-based

[Aleksowski, 06]

[Laera, 07]
→ MAS protocol for onto alignment

Reference ontology
Semantic Heterogeneity

- Reference ontology
  \(\rightarrow\) concept anchoring

- Semantic negotiation
  \(\rightarrow\) dynamic alignment

- Open & loosely coupled MAS
  \(\rightarrow\) impossible or incomplete alignments

- Dynamic understanding of concepts
  \(\rightarrow\) Introspection
  \(\rightarrow\) Interaction protocol
Related work

Open & Heterogenous MAS

Service composition  Semantic Heterogeneity  Reinforcement learning & Interactions

Introspection
Learning & Interactions

- Interaction protocols for learning
  Data exchange $\rightarrow$ learning acceleration

- Open MAS
  $\rightarrow$ Learning interactions
  - Learning when to interact
    [Melo & Veloso, 08]
  - Learning what to interact
    [Kasai & al., 08]
Learning & Interactions

- Asynchronous & open
  - Memory
  - Introspection
  - Interaction protocols

Multi-Agent Systems

Delegation

Asynchronism

POMDPs

Memory [Dutech, 03]

SMDPs

MDPs

Reinforcement Learning

Other agents
Introspection & Interaction models for reasoning about actions in open & heterogeneous MAS
Introspection & MAS Interactions for...

- Service composition
- Semantic Heterogeneity
- Learning Interactions

Agent & Interaction Model
The VDL model

- XML tree rewriting \([\text{Gurevich, 95}]\)
- Data \(v(\text{val}) \rightarrow \text{softbody}\)
- Ontology (Concepts x Relations)
  - \(\text{typeof} \text{ and } \text{includes} \rightarrow IC(c) \ [\text{Seco, 04}]\)
  - Other relations \(\rightarrow p(R)\)
The VDL model (2)

- **Actions**
  - **Preconditions – effets**
    - Effects on data $\rightarrow v(\text{newval})$
    - Message sending $\rightarrow <\text{snd}, \text{perf(rcv,ct)}>$

- **Preconditions**
  - Events: $\text{evt}(x_1(\text{val}_1),...,x_n(\text{val}_n))$
  - Event patterns $\rightarrow \text{evt}(x_1,...x_n)$
  - Boolean preconditions $\rightarrow \text{vars}(p)$
    - Context
    - Context-Structure
    - Structure
Generative bottom-up

- Capacities = acceptable events
  - Precondition evaluation
    - $eval_e(p,evt) \rightarrow \text{true iff } p \in P_s \cup P_{cs}$ is true under $evt$
    - $eval_c(p) \rightarrow \text{true iff } p \in P_c$ is true

- VDL code introspection (using precondition and data structure)
  - generation of all syntactically possible events

  - Set of possible events $E$
    - $\forall p \in P_s \cup P_{cs}, eval_e(p,e) = true$
    - $\forall p \in P_c, eval_c(p) = true$

  - Set of currently impossible events $F$
    - $\exists p \in P_{cs}, eval_e(p,e) = false \lor \exists p \in P_c, eval_c(p) = false$

$$np(e) = \text{set of failed preconditions}$$
VDL interaction model

Sender: AID
Receivers: AIDs
Performative
Content
Conv-id
Message-id

Specific performatives
- query, inform, unknown
- request, agree
- impossible, assert-cannot
- assert-can, clarify, suggest
- what-can
- query-contraint
- not-understood, error

FIPA-ACL based

<snd,p(rcv,c)>
Interaction model (cont.)

- Query & al.

- Request & al.

Generalisation:

\[ \text{query-constraint}(X,C) \rightarrow \text{set of variables} \]
\[ \rightarrow \text{inform}(\{v_i=\text{val}_i\}) \]
Introspection & MAS Interactions for...

- Service composition
- Semantic Heterogeneity
- Learning Interactions
Service choreography

- Initial request
  - Service discovery
  - Dynamic choreography
- Final answer → initiator agent

Yasmine Charif
(2004-2007)
Service choreography

- Initiator - participants
- Delegation to all participants
  request → assert-can
  query-constraint → query
  → trigger sub-conversations
    - Waiting for answers
    - Convergence in EXPTIME
      → timeouts
  → Management of sub-conversations

Message history \(<id,m_0,M,R>\)
Protocols

init part

query-constraint

OPT

query

inform

ALT unknown

part 1

part 2

query

n

k + m ≤ n

part 1

part 2

ALT

k

inform

m

unknown

Agent

inform

or

unknown

history

answer to m_0

query-constraint

request

assert-can

init part

request

OPT

* query

assert-can

ALT assert-can

agree
Example

- Implemented in Java on the VDL platform (2006)
Introspection & MAS Interactions for...

- Service composition
- Semantic Heterogeneity
- Learning Interactions
Learning interactions

- Goal → reward function

Problems:
- Asynchronous → learn to wait
- Non-observable → POMDPs
- Delegation (request) → Memory

Limited to...
- 1 learning agent
- Performatives query & request
Learning interactions

- Acquiring requests
- Acquiring queries

\[ \text{Agt}_1 \xrightarrow{\text{add(request)}} \text{Agt}_2 \xrightarrow{\text{suggest}} \text{request} \]

\[ \text{Agt}_2 \xrightarrow{\text{what-can}} \text{E} \]

\[ \text{Agt}_1 \xrightarrow{\text{add(query)}} \text{Agt}_2 \]

\[ \text{vars}(p), p \in \text{NP} \]

+ timeouts
Learning interactions

- **Memory**
  - State + latest request(s) or query-result(s)
    - [McCallum, 96]
  - Iterative construction memory
    → Only some states are provided with a memory
Algorithm

At each step

\( \text{rand} < W \rightarrow \langle \text{snd} , \text{what-can} (\text{dest} , \emptyset) \rangle \)

OR

\( \text{evt}_{\text{answer}} \in ? A \)

\( \text{adjust } W \)

\( \text{rand} \geq W \rightarrow \text{prob}(a) = \frac{e^{Q(s,a)/T}}{\sum_{b \in A} e^{Q(s,a)/T}} \)

\( \text{adjust } Q(s,a) \)

\( \text{send message query} \) OR

\( \text{send message request} \) OR

\( \text{perform action} \)

\( \text{store answer} \)

\( \text{store action} \)

\( N \) cycles

Add memory to \( k \) most ambiguous states:

\[
\text{amb}(s) = \text{wait}(s) + \frac{1}{3} \left( \text{rang}_s \left| \text{up}(s) \right| + \text{rang}_s \left[ \frac{1}{|A(s)|} \sum_{a \in A(s)} \Delta q_a \right] + \text{rang}_s^{-1} \left[ q_{a_1} - q_{a_2} \right] \right)
\]
Preliminary experimentations

- Asynchronous learning of commands (*requests*) (2008)

Learner agent

Explorer agent (twice slower)

No memory
1 slot memory
2 slots memory → no progress
Preliminary experimentations

- Learning of interactions (*requests* & *queries*)
  
  (2009)

Learner agent

- random state change (*depending on heater*)
  - off/low/high (*request*)
  - stir/remove (*request*) / observe (*query*)

more → no improvement

- 1 slot memory
- 0 slot memory
- no query
Introspection & MAS interactions for...

Service composition  
Semantic Heterogeneity  
Learning Interactions
Semantic heterogeneity

- Incomplete alignment
  → agent-agent interactions
  → human-agent interactions (ordinary users)

- Limited to requests

- Architecture:

  - Human user
  - Agent
  - OpenNLP
  - WordNet
  - Alignment
  - capacities generation
  - capacities selection
  - answer manager
  - semantic relatedness measure
  - VDL
  - code & context
  - ontology

Laurent Mazuel (2005-2008)
Semantic relatedness measure

\[ \sum_{(x,r,y) \in \text{sp}(c,c')} w(x,y) \times p(r) \]

For typeof.includes:

\[ |IC(c) - IC(c')| \]

\[ \sum_{p \in T_{\min}(\text{path}(c,c'))} W(p) \]

\[ \min_{p \in \pi(c,c') \lor hso(p) = \text{true}} W(p) \]

Patterns of valid pathes

[StOnge, 98]

Semantic similarity measure

[Jiang & Conrath, 98]

Generalization to other Unique Type Paths

\[ p(r) \times \frac{|\text{path}_r(c,c')|}{|\text{path}_r(c,c')| + 1} \]
Capacities scoring

- Concepts anchoring

\[ app(e_{req}, e_{cap}) = Q(e_{req}) \times \max_{S \in \Pi(C_{req}, C_{cap})} \left( \sum_{(c_r, c_c) \in S} rel(c_r, c_c) \right) \]

Quality of alignment or NL analysis

Set of possible couples (filtered using the VDL structure)

semantic relatedness measure

answer manager

capacities selection

capacities generation

Distance between clouds of concepts

→ Capacity scoring

evt(c_1(val_1),...c_n(val_n))

External event (aligned) e_{req}

Internal capacity e_{cap}
Answer selection

- Build the set of best capacities

\[ E_{\text{req}}(rcv) = \{ e_{\text{cap}} \in E(rcv) \mid p_E - \text{app}(e_{\text{req}}, e_{\text{cap}}) \leq \epsilon \} \]

\[ F_{\text{req}}(rcv) = \{ e_{\text{cap}} \in F(rcv) \mid p_F - \text{app}(e_{\text{req}}, e_{\text{cap}}) \leq \epsilon \} \]

- Two thresholds [Maes, 94]
Example

- Cube-world based
  - Two agents, shared world, 2 representations
  - Impossible/incomplete alignment

Take red polygon
Example (cont.)

- Implemented on the VDL platform in 2007

```
Agent A

request(1,1,{take,red,polygon})
clarify(1,1,{take,big,polygon},
{take,medium,polygon},
{take,small,polygon})
request(1,2,{take,small,polygon})
clarify(1,2,{take,zone1},
{take,zone2})
confirm(1,3,{take,zone1})

Agent B

request(1,1,{take,polygon})
clarify(1,1,{take,big,square},
{take,medium,square},
{take,small,triangle},
{take,small,square})
request(1,2,{take,small,triangle},
{take,small,square})
clarify(1,2,{take,cell1},
{take,cell2})
confirm(1,3,{take,cell1})
agree(1,3)
```
Conclusion & Prospects
Conclusion

- Reasoning about actions and interactions
  - Agent-Agent interactions
  - Human-Agent interactions
- Instrospection of agents' capacities
  - Service composition
  - Learning interactions
  - Semantic heterogeneity
- Openness, heterogeneity, loosely couple, distribution
Future work

- Composition vs Semantic heterogeneity
  - Message not understood → 2 possible methods
  - Heuristics to choose?

- Learning interactions
  - Discover data unseen by request-impossible
  - New memory structure
  - Semantic interpretation
    → heuristics for relevant data/actions
Future work

- Extend the current model
  - Service composition with advanced constraints
  - Semantic heterogeneity for other performatives
  - Generalisation of learned behaviours
- Reasoning about time
  - Past and future interactions
  - Other performatives
- Environment (Eric Platon)
  - Unknown environment
  - Indirect interactions in the composition process
- Communicate about unknown actions and data
  → learning new behaviours!
Thank you!

Eric

Yasmine

Laurent

Shirley