Artefacts and Workspaces for the Engineering of Multiagent Systems

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Initial Claim

- Shaping *shared workspace* is a key issue in *human organisations*
- In the same way,
  - *shaping* the *environment* in terms of the *artefacts* constituting the *agent workspace* is a central issue in the *engineering* of a multiagent system (MAS)

Outline

- we motivate and introduce the notions of
  - artefact for MASs
  - agent workspace
- we discuss some cognitive aspects of the relationship between agents and artefacts
- we sketch the basic elements of a theory of artefacts
- we draw some consequences in terms of theory and practice of MAS engineering

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Basic Notions: Environment, Artefacts (and Workspaces)

Humans Do Not Live in the Wild

- … mostly, today
- Our *environment* is essentially built up to satisfy our needs / help us fulfil our goals
- Even though the physical world where humans as a species were born was more or less hostile…

Why Agents in the Wild?

- [Maybe unconsciously drawing from the (justified) criticisms and early failure to Symbolic AI]
- We seem inherently convinced that "real" agents actually live in "real" worlds, where
  - horrible things happen, and
  - nothing will work
- [and maybe, also, someone thinks that this is a problem for industry, not for academia]

Agent Environment is not such an Horrible Place

- At least, it does not *need* to be such
  - there is a middleground between highly-simplified artificial environments, and the "wild" unpredictability of real world
- And, what is "real world" for agents, after all?
  - agents may live both in virtual and physical environments
    - in principle, both can (partially) be engineered
    - most agent environments are a mixture of virtual and physical

Environment is a Resource for Agents

[P.E. Agre, 1975]
"Structure of the world compensates for the weakness of cognitive architectures"
- Environment is a resource for MAS engineers, too

How do We Build Human Environment?

- Contributions from Human Sciences
  - less "extreme" views of the environment are possible
- Main observation
  - human organisations support their (collaborative) activities by shaping the environment where the activities are performed
  - shaping the **workspace** is a key issue in human collective activities [Susi 2001, Schmidt 2004]

Workspaces & Artefacts

- Workspaces are structured in terms of **artefacts**
- Artefacts are the tools that *enable* and *constraint* any collaborative activity
  - by embodying an history of social practice in their design and physical shape
- As tools, they extend users' ability to perform their tasks and achieve their goals
  - either physically or cognitively

Activity Theory (AT)

- AT is a conceptual framework modelling **human organisations** in terms of the **individual** and **social activities** carried on
  - "human activities can be analysed and understood only by considering both humans and their context, as the set of mediating tools they use"

Artefacts in AT

- Central to AT is the notion of **artefact**
  - any (complex) human activity is *mediated*
    - embodied and disembodied mediating artefacts
    - from languages and protocols to maps, checklists, blackboards, communication media, …
- Artefacts embody a set of *social practices*
  - their design, structure and behaviour reflects an *intention* and a *history* of particular use

Artefacts as Enablers and Constrainers

- By mediating any human activity, artefacts have both an **enabling** and a **constraining** function
  - artefacts expand user's abilities to manipulate & transform the surrounding environment
  - artefacts bound the possible interactions by their very structure & construction

What does AT Suggest?

- Artefacts are a quite general & powerful notion
  - encompassing both physical and cognitive tools
    - they can be used as a uniform framework for both language and tools
- Artefacts are powerful abstractions around which agent systems can be built
  - organisation, societies, …
  - as both enabling and constraining tools for agent activities
- Focus
  - what kind of tools / artefacts can help making individual and collective activities achieve their goals?

First Questions

- What *is* exactly an artefact?
- What *sort* of tools / artefacts can help making individual and collective activities in a MAS achieve their goals?

A Note

- Artefacts (of some sort) are already pervasive in MASs
  - *resources*
    - physical resources, third-party Web services
  - *coordination*
    - blackboards, connectors, "stigmergic ground"
  - *organization*
    - e-institutions, agent coordination contexts, …
  - …

A Simple MAS Meta-Model

- Agents + Artefacts
  - MAS are made of **agents** and **artefacts**
    - as OO-systems are made of objects (and classes)
  - Agents are used to model *individual activities*
  - Artefacts are used
    - to *glue individual activities* in *social activities*, and
    - to mediate *agent-environment interaction*
- This is the "static" of a MAS…
  - how do we model dynamics–*interaction* in a MAS?

Interaction in a MAS

- There,
  - agents *speak* with agents
    - agent *communication*
  - agents *use* artefacts
    - agent *operation*
  - artefacts *link* with artefacts
    - artefact *composition*
- This fully describes *interaction* within a MAS
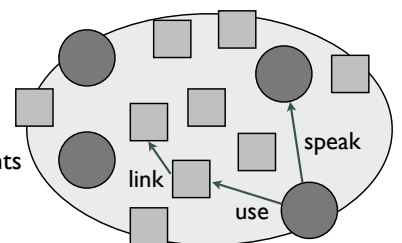
Artefacts & MAS Environment

- Two viewpoints over artefacts
  - "ground view": the agent viewpoint
  - "aerial viewpoint": the engineer viewpoint
- Agents use artefacts to interact
  - to affect / perceive their environment
  - to better achieve their own goals
- Engineers use artefacts to shape the agent environment
  - to make it fit agents
  - to make MAS goals easier to achieve

Agent Cognition and Artefacts

Tools & Evolution

- The **use of tools** has accompanied the evolution of the human species
  - from homo habilis to homo sapiens sapiens
- The development of **intelligence** as a distinguishing human feature is strictly **related to** the availability and development of **tools**
  - pre-historical development is more or less defined around the sort and quality of the tools adopted by human societies

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Tools & Intelligence

- Tools are **not exclusive of** the **human** species
  - beavers build dams, some birds live in artificial nests, …
  - some primates show some ability to find and use tools
- **Systematic** and social design and **use of tools** is however **typical of humans**
  - we typically take (explicitly / implicitly) **tool** use, selection & construction **as a revealing symptom of intelligence**
- Biologists make animals face tool use in order to understand their intelligence [Povinelli 2000]

Tools & Language

- Use of **tools** and **language** are the most distinct **expressions of human intelligence**
  - individual & social
- Language as a **social artefact**
  - shared, conventional representation of the world
  - amplifier of human abilities to
    - represent the world
    - interact socially
- Tools as an **environment artefact**
  - found / forged from the environment
  - amplifier of human abilities to affect the environment
    - to survive environment changes
    - to adapt the environment to human needs and goals

Homo Faber vs. Homo Symbolicus

- The development of some of the most "abstract" results of human culture cannot be conceived or explained without the physical artefacts
  - e.g., the evolution of numbers, arithmetics & geometry
- Homo Faber or Homo Symbolicus?
  - "Homo Symbolicus slowly developing his skills became Homo Faber" [Berggren 2004]
  - Somehow reminiscent of symbolic vs. non-symbolic approaches to AI
- **Agens Faber** or **Agens Symbolicus**?
  - … while we aim at intelligent agents?
  - it is then partly surprising, partly not, that we have a good theory and support for agent speech act, and not for physical actions

A Tool…

- … reveals **awareness**
  - of self, of the world
- … embeds a **goal**
  - incorporates a design
- … is stored for later use
  - its design incorporates a vision of its **use over time**
- … is used for **different goals** than the one it was designed for
  - its actual existence conceptually separated from its initial design
  - new uses
- … is used to **build new tools**
  - new meta-uses

Can Agents be Intelligent without Tools?

- A perspective on agent intelligence
  - analogy with the development and evolution of human intelligence
  - and its relation with tools
- A **theory** of **agent intelligence** should not be limited to modelling the inner rational process
  - such as the BDI model
- Instead, it should include not only the basics of practical reasoning, but also
  - a theory of the agent artefact
  - the means for artefact rational use, selection, construction, manipulation
- Reasoning about actions becomes easier if it is **reasoning about** agent **interaction with artefacts**

The **Agens Faber** idea

- Agent intelligence should not considered as separated by its ability to perceive and affect its environment
  - which is mediated (enabled / governed) by the artefacts
- **Agent intelligence**
  - in its most general acceptation
- is strictly **related to the artefacts** that enable / govern agent activities
  - in some sense, the Agent Faber notion is a **re-formulation** in terms of agents and artefacts of **Brooks' Situated Intelligence**

Cognitive & Social Action

[Castelfranchi & Conte 1995]
- Agents systems as goal-governed / goal-oriented systems
  - according to the fact that the goal is either explicit or implicit
- Individual goals are **internal** to agents
  - **External** goals belongs to the social / environmental context
  - and work as regulators for agent behaviours
- Agent systems also contain non-goal-oriented components / artefacts
  - that have no internal goals
  - but can be **used** by agents to achieve theirs
- Artefacts are designed to be used
  - to provide a certain **function**
  - to be used for a **destination** – an external goal attached in the use

Use & Use Value

- Use value
  - evaluation by the agent of artefact features and function
  - aimed at artefact **selection** for (future) use
- Two kinds of external goals are then attached to artefacts
  - use-value goal, driving artefact selection
  - use goal, driving artefact use

What can Agents do with Artefacts?

- **Use**
  - assigning a destination to the artefact
  - use follows selection
- **Selection**
  - driven by use value
  - evaluation of artefact features and function
  - when use fails, a new selection process may be started
  - selection may follow construction / manipulation
- **Construction / manipulation**
  - when selection fails, a new artefact should be constructed, or obtained by manipulation of an existing one
    - incorporating a new function in the artefact design

How can Artefacts Improve Agent Life?

- Key questions for the **Agens Faber**
  - How could agents *reason* about the *use* of artefacts?
  - How could agents *reason* to *select* which artefact to use?
  - How could agents *reason* to *construct* / adapt artefacts to use?
- Two extremes
  - agents are directly programmed to use specific artefacts
    - fits *closed* systems
  - intelligent agents look for and select artefacts, then use them
    - fits *open* systems

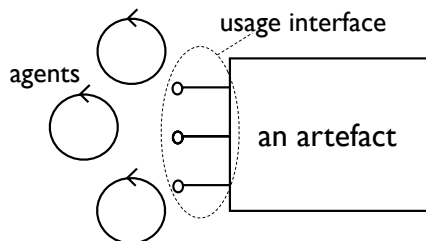# Cognitive Levels for Artefact Use by an Agent

- Who (agent / designer) needs to be *aware* of the artefacts?
  - **unaware** use
    - artefact used implicitly
  - **embedded** / programmed use
    - artefact selection & use explicitly programmed by the designer
  - **cognitive** use
    - artefact selection explicitly programmed by the designer
    - artefact use is up to the agent
  - **cognitive selection** & use
    - both artefact use & selection is up to the agent
  - **construction** & **manipulation**
    - agents become artefact designers
    - agents understand how artefacts work, and how to adapt their behaviour

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Towards a Theory of Artefacts for MASs

Artefacts for Rational Agents: Toward a Model

- What does a cognitive agent need to use / select an artefact effectively and efficiently?
  - **Function / service description (FD)**
    - (formal) description of what kind of function / service is provided by the artefact
    - helps in artefact selection
  - **Usage Interface (UI)**
    - set of operations that can be executed by agents to use the artefact
    - required for artefact use
  - **Operating Instructions (OI)**
    - (formal) description of how to use the artefact to obtain its services
    - help in artefact use
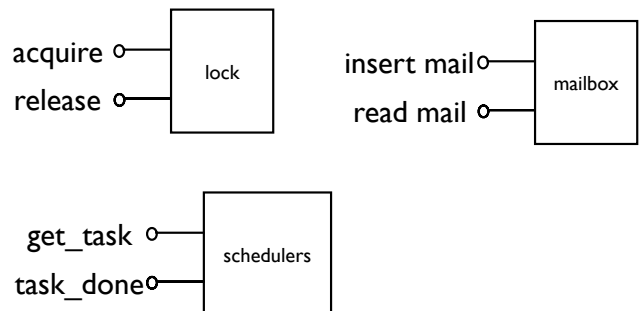   - connect rational agent capabilities with artefact behaviour
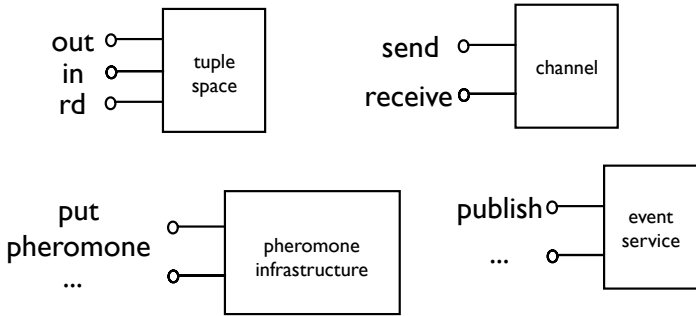

Artefacts Sketched

- Agents *select* artefacts according to their *function / service description*
- Agents *use operating instructions* to understand *how to use* the artefact
- Agents *use* artefacts by executing operations provided by artefacts through their *usage interface*


Examples of Simple Artefacts

Existing Mechanisms as Artefacts

out
in
rd
tuple space

send
receive
channel

put
pheromone
...
pheromone infrastructure

publish
...
event service

Isn't UI Merely the Old Way of Objects???

- Artefacts and Usage Interface
  - in a sense, it is just the usual way we build systems with object, components, interfaces…
  - but here objects (or whatever) are not simply interacting with other objects
    - UI is Old-Way-of-Objects, OI and FD has meaning only in the New-World-of-Agents
- Also, this is at least a simple way to say that "all that came before agents" needs not to be *patched* into MAS
  - through some low-level mechanism or infrastructure support
  - it is easily subsumed by the agents + artefacts view of MAS
    - agents use objects, components, services, …, and *now* this fits the agent paradigm
- Now, I can design an artefact as an object
  - but knowing it will be exploited by a (cognitive) agent
    - something old, something new, something borrowed, something blue

Operating Instructions (OI)

$D :=$
$(!get;?rep(\varphi);($
$(!tell(\varphi));?rep+$
$!tell(\neg\varphi);?rep$
$+$
$D);$
$)) \parallel D$
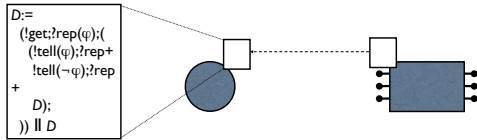
- OI are like a manual for a device
  - they tell what can/should be done, step-by-step (operationally)
  - they provide information on the **rational meaning** of doing so
- Each rational agent associates OI to an artefact
  - how?
- (Some) OI are supposed to be known to the agent
  - they could be hardcoded in the agent
  - they could dynamically be inspected & interiorised
  - they could be learned by observation or test

A Possible Formal Framework for OI

- Hybrid
  - multi-modal logic for modelling agent mental states
  - process algebra for modelling interaction
- A transition system for modelling the artefact
  - driven by agent interactions
  - labelled by preconditions and effect on agent mental states

Some Details on OI

- OI define a procedure, an interactive behaviour
  - obtained by specifying
    - action execution ($!\alpha$), perception of completion ($?\pi$)
    - sequential composition (";")
    - parallel composition ("‖")
    - choice ("+")
    - recursive calls (D)
  - e.g.: $D := (!\alpha_1;?\pi_1;\alpha_2;?\pi_2) + (!\alpha_3;(?\pi_3;D+?\pi_4))$
- Annotated with subjective information as well
  - *actions*: annotated with preconditions on agent mental state
    - e.g. $\alpha = send(\varphi)_{Bel\varphi}$ (should believe φ before acting)
  - *completions*: annotated with effects on agent mental state
    - e.g. $\pi = receive(\varphi)_{Bel\neg\varphi}$ (should believe $\neg\varphi$ when perceiving)

A Formal Framework for Agents using OI

- Axiomatic style à la FIPA
  - axioms on
    - planning, satisfiability, scheduling, mental state
    - but I save you from the formal details…
  - any agent satisfying those axioms can use OI coherently
    - follows the protocol, step-by-step
    - knows how the artefact evolves
    - exploits preconditions/effects to act rationally
- The point here is
  - we need a model for artefacts
  - a model for rational agents
  - but mostly a **model for rational agents using artefacts**

Cognitive Levels
of Artefact Use – Revisited

- Embedded / programmed use
  - agents exploit artefacts without any cognition about that
  - UI and OI can be used for design- and run-time validation
- Cognitive use
  - agents do have a representation of the OI state (in beliefs)
  - use it to step-by-step select actions to execute through UI
  - accordingly exploit preconditions and effects in the OI
- Cognitive selection & use
  - also have a representation of the FD for some artefacts
  - decide which is compatible with current beliefs + intentions
- Construction & manipulation
  - further properties are required
  - some features of the "feature list" may help – next slide…

Features of Artefacts

- Artefacts may feature a number of useful properties
  - which could also help us classifying artefacts
- **Inspectability**
  - context-awareness
- **Controllability**
  - monitoring and debugging
  - usage & management working modality
- **Malleability**
  - agents & humans can adapt artefact behaviour
- **Linkability**
  - composition of artefacts
- **Predictability** & **verifiability**
  - verifying properties of agent interaction through artefact behaviour

Artefacts Immersed in MAS

- Altogether
  - the model of artefacts for rational agents
  - the artefact feature list
- give us some criteria for artefact description & classification
- However
  - such criteria refer to the artefact as an individual entity
  - not as something immersed in a MAS
- Criteria for artefacts immersed in a MAS are needed
  - still rooted in the idea of artefacts shaping the agent space of interaction / the agent environment
  - toward agent worspaces

For a Taxonomy of Artefacts

- In general, many artefacts exist in a MAS at a given time
  - each one providing its own function /service, and handling a responsibility in an automatic way
- It is then useful to identify and denote different kinds of artefacts, which might require specialised treatments
  - special programming languages
  - special / additional features
  - different roles in an AOSE methodology

First Level of a Taxonomy

- Taxonomy
  - individual artefacts
    - handling a single agent
  - social artefacts
    - handling a number of agents
  - resource artefacts
    - handling resources
- Examples: following!
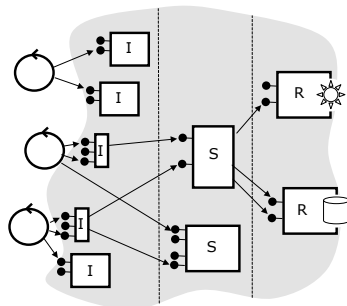
Agent Coordination Contexts
as Individual Artefacts

- Individual artefacts are largely inspired by ACC
- Theory
  - control policy specified by the "ACC algebra"
    - supporting protocols and rational preconditions/effects
    - "ACC: [policy] specification & enactment [SCP Journal]
    - organisation & security abstraction
- Practice
  - ACC implemented in TuCSoN infrastructure
    - through a logic-based management of actions
    - "ACC: from theory to practice" [AT2AI-2004]
- Organisation
  - ACC as a basic brick to provide for role-base organization (RBAC-MAS)
    - "ACC: organization & roles" [AAECC Journal]

Tuple Centres as Social Artefacts

- Tuple centres as programmable tuple spaces
  - inspectable, malleable, linkable, predictable & verifiable
- As an artefact for rational agents
  - [Usage interface] out, in, rd, set_spec, get_spec operations
  - [Function /service description] expressed in ReSpecT logic based language, in forms of reactions to communicating events
  - [Operating instructions] <not explicit> implicitly described by the ReSpecT tuple centre formal specification
- Provided as coordination abstractions by the TuCSoN Coordination Infrastructure
  - in the same way as ACCs
  - technology available as an open source project

"Enhanced" Tuple Centres as Resource Artefacts

- Experiments with standard Internet services
  - mail, FTP, web servers
  - by interfacing them / accessing them via modified TuCSoN tuple centres
- Actually, no other coherent approach for this issue
  - there is also a doubt about the possibility of a general coherent approach to this issue: maybe resource artefacts are there for this very reason

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Artefacts, Workspaces and MAS Engineering

Defining the Meta-model

- An agent is a computational entity
  - encapsulating control flow
  - along with a *criterion* to drive control
    - say, a task, a goal, …
    - so, *autonomous* by definition
- An artefact is a computational entity
  - without its own control flow
    - so, it is *reactive* by definition
    - has its own function and behaviour
  - which can be *used* by agents for their own purposes
- Artefacts define the agent workspace
  - or Field of Work, or … [Susi 2004, Schmidt 2005]
  - they represent the *articulation* of the agent environment
    - encapsulating the *responsibilities* delegated to the agents' workspace


SE & PL

- New classes of (programming) languages come from paradigm shifts in software engineering
  - new meta-models / new ontologies for artificial systems build up new spaces
  - new spaces have to be "filled" by some suitably-shaped new (class of) technologies–first of all, programming languages
- The typical procedure
  - first, existing languages are "stretched" far beyond their own limits, and become cluttered with incoherent abstractions and mechanisms
  - then, academical languages covering only the some of the issues are proposed
  - finally, new well-founded languages are defined, properly covering new spaces

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Remember the Global Picture…
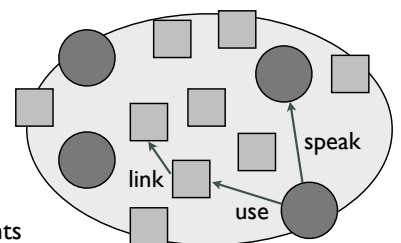
- In a MAS
  - agents *speak* with agents
  - agents *use* artefacts
  - artefacts *link* with artefacts
- New spaces for programming languages

Spaces for PL in AOSE

- Languages to *Be*, Languags to *Interact*
- Languages to Be
  - languages for agents
    - agent programming languages
      - 3APL
  - languages for artefacts
    - *artefact programming languages*
      - *ReSpecT*
- Languages to Interact
  - languages to speak
    - ACLs
  - languages to operate (use, acting over artefacts)
    - models for agent actions over artefacts (OI)
  - languages to link
    - which should be somehow consistent with the action and the artefact models

Which Languages Then?

- Languages to shape artefacts
  - language to program artefact behavious, first of all
  - and then, languages to use them, and link them
- Roughly speaking…
  - a coordination language à la Linda is a language to operate on artefacts
  - Reo is mostly a language to link artefacts
  - ReSpecT was born as a language for (programming) artefacts
- Languages to model agent responsibilities and actions
  - in terms of communications and operations
- For instance:
  - RBAC-MAS models responsibilities in terms of agent roles and of an abstract action model
  - ACLs typically models only communicative actions, with no regards for physical actions (operations) and responsibility

Engineering Interaction with Artefacts

- The sciences of MAS interaction are many
  - coordination, security, organisation, negotiation, cooperation, etc.
- Interaction in a MAS is first of all agent interaction
  - interacting autonomous flows of control
- Artefacts are mediators
  - enablers / rulers for agent interaction
    - Activity Theory, cognitive sciences, CSCW, HCI…
- So
  - artefacts play a central role in managing interaction in MAS

Coordination, Organisation & Security in MAS

- "Can this agent speak to that agent / use that artefact?"
  - "In case, will it (deliberate to) speak / use?"
- Said that, we have seen them all
  - it is more generally "*managing interaction in a MAS*"
  - Coord/Org/Sec–they all aim at shaping the space of agent interaction
    - to define its admissible space at design time (Organisation/Security flavour)
    - to govern its dynamics at run time (Coordination/Security flavour)
- Main point here
  - artefacts are our instruments to articulate & shape MAS enviromennt
    - to define the agent workspace
    - to manage agent interaction
- In artefacts, coordination/organisation & environment clash
  - shaping the environment with artefacts
  - embodying coordination /organisation

Interaction in MAS

- How to manage interaction within MAS with artefacts?
  - where are coordination / security / organisation?

Schmidt's Artefacts

- From CSCW many relevant contributions
  - coordinative vs. representation artefacts in an organisation workspace [Schmidt 2005]
  - coordinative artefacts have a behaviour that is used to coordinate and manage activities in an organisation
  - representation artefacts have a (possibly inscribed) state that records some partion of the organisation (activity)
- Coordination and organisation concerns are easily mapped
  - even though quite roughly
- We may use our ReSpecT tuple centres for both
  - as an experiment…

ReSpecT Tuple Centres

CE

- Two FOL theories
  - ordinary & specification logic tuples
- Two views over the artefact
  - looking at the Theory of Coordination makes it a coordinative artefact
  - looking at the Theory of Communication makes it a representation artefact
- Experiment: an organisation tuple centre for each workspace
  - where the structure is represented declaratively as a FOL Theory
  - ACCs released to requesting agents based on the OrgTC's current knowledge
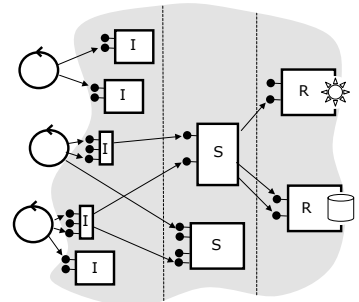 - this can be used as a basis of a Computational Institution

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Layering the Workspace

CE

- Taxonomy
  - individual artefacts
    - handling a single agent
  - social artefacts
    - handling a number of agents
  - resource artefacts
    - handling resources
- A form of *layering* for workspaces seems to emerge
  - suggesting a methodological pattern

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Artefacts / Languages for "Organisation"

CE

- Individual artefacts seem the best place for ruling individual agent interaction
  - on the basis of "organisational" concerns
- Our example: Agent Coordination Contexts (ACC)
  - filtering any perception/action/communication btw. agent and environment
- Which language here?
  - typically declarative – KR-style
    - for our "quasi static" perception of organisation
  - either process algebra denotation, or FOL rules [RBAC-MAS on AAECC]
    - modelling agent admissible actions
- "Declarative", however, does not mean static
  - "organisation" may change
  - agents may reason over (organisation) artefacts and change their state

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Artefacts / Languages for "Coordination"

CE

- Social artefacts seem the best place for ruling social interaction
  - on the basis of objective coordination concerns
- Our example: tuple centres
  - embodying coordination in their (coordinative) behaviour
- Which language here?
  - typically operational (event-driven)
    - for our "dynamic" perception of coordination
    - interaction happens, the artefacts react appropriately
  - ReSpecT is FOL, however
    - but the semantics is given operationally
- "Operational", too, does not mean static
  - "coordinative behaviour" may change over time
  - agents may reason over (coordination) artefacts and change their behaviour

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Artefacts / Languages for "Security"

CE

- Resource artefacts may be a good place for ruling access to resources
  - on the basis of security concerns
- Etc. etc.
  - OK, fine with this, the picture should clear now

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Artefacts in AOSE

CE

- A meta-methodology
  - MAS engineers define *responsibilities* of a MAS
    - global / partial
      - decomposition process
  - Responsibilities are expressed in terms of goals / tasks / functions
    - cognition / deliberation vs. automatisation
  - Responsibilities are correspondingly assigned to
    - agents & agent societies
    - artefacts, workspaces, environment
- Environment engineering through artefacts & workspaces
  - separating computation and interaction in the MAS engineering process
    - [à la Wegner / Gelernter]
    - agents / computation, artefacts / interaction
- Work in progress: SODA + artefacts [Molesini, ESAW 2005]

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SIKS-days 2005, Utrecht, 11/11/2005   66

Conclusions and Perspectives

In Short

- Agents and artefacts are the two basic abstractions for MAS
  - agents model task-/goal-oriented activities, artefacts provide "functions"
  - artefacts mediate (enable and govern) agent interaction
  - artefacts shape agent environment by articulating the agent workspace
- Artefacts are essential to support and promote agent intelligent behaviour
  - **Agens Faber**
  - a model for artefact, agents, and rational agents using artefacts
- Artefacts may feature a number of relevant properties
  - which can be used to either classify or engineer them
- Artefacts may play different roles in a MAS
  - a taxonomy for artefacts / a layering for workspaces
  - artefacts for AOSE methodologies: engineering MAS interaction space

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Ongoing Work in Cesena

- Artefact-based AOSE methodologies (A. Molesini)
- Artefacts for Self-* MAS (L. Gardelli)
- Cognitive stigmergy through artefacts (A. Ricci)
- A model for cognitive exploitation of artefacts (M. Viroli)
- A general computational model for artefacts (A. Omicini)
- Computational Institutions & legal artefacts (E. Denti, R. Rubino)
- Specialised artefacts: e-learning, workflow, … (A. Natali)
- Artefacts for agent-based simulation (…)
- Intelligent agent-based portals (…)

The CArtAgO Project

- **C**ommon "**Art**efact for **Ag**ents" **O**pen infrastructure
  - Model & technology for a general-purpose artefact-oriented agent infrastructure
- An open project led by A. Ricci & M. Viroli in Cesena
  - partners till now
    - Vienna (P. Petta, B. Jung)
    - Zurich (M.I. Schumacher)
    - Tokio / Paris (E. Platon)
    - Leuven (K. Schelfthout, D. Weyns)
    - Milan (G. Vizzari, S. Bandini)
    - … still open!
- Start-up event
  - AT2AI-5 at EMCSR 2006 (University of Vienna, 18-21 April 2006)
    http://www.ofai.at/~paolo.petta/conf/at2ai5/

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- **a**gent, **l**anguages and **i**nfrastructures in **CE**sena
- myself, A. Natali, A. Ricci, M. Viroli, E. Denti
  - + a growing number of young & brilliant people
- take a look at
  http://www.alice.unibo.it
  - still beta, but already working and online
- papers other old things for now at
  http://lia.deis.unibo.it/~ao/pubs/

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Question Time

Artefacts and Workspaces for the Engineering of Multiagent Systems

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