Agents and Artifacts: Multi-disciplinary Foundations

Multiagent Systems LS
Sistemi Multiagente LS

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1 Premises
   - Trans-disciplinary Research
   - Dangling Issues

2 Activity Theory
   - Background from Activity Theory
   - Lessons Learned: From AT to MAS

3 Distributed Cognition
   - Background from Distributed Cognition
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4 Sociology
   - Background from Sociology
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5 Computer Supported Cooperative Work
   - Background from CSCW
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6 (Cognitive) Anthropology & Ethology
   - Background from (Cognitive) Anthropology & Ethology
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# Multi-, Inter- Trans-Disciplinary Research

## From multi- to trans-disciplinary research

- Multi-disciplinary research means that multiple areas are involved in the same research activity—results are drawn from and concern different fields.

- Inter-disciplinary research means that models, methods and techniques are brought from one area to a different one—results mainly concern the latter area.

- Trans-disciplinary research means that models, methods and techniques are first brought from one area to a new one; then, once are suitably extended and generalised, results are brought back to the original area.
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Why X-Disciplinary Research?

Convergence of Scientific Research

- Complexity of systems (observed, modelled, constructed) is characterising more or less all of the human knowledge.
- The same patterns in observable phenomena, system structure & behaviour, scientific models, methods, and techniques, occur repeatedly in many heterogeneous research fields.

Convergence towards MAS

- Complexity of computational systems today matches complexity of biological, social, economical, organisational, ..., systems.
- Results from other areas dealing with complex systems may be useful / important / essential for computational systems & MAS in particular.
- Results from computational systems & MAS are already changing the way in which scientific activity is conducted in every other area.
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Questions to be Answered

We already learned something...

- ... about the reasons behind the agent abstraction,
- as well as some of its features

However, before a complete and precise definition could be given, some issues have to be clarified

We have to understand...

- ... if agents are the next thing after objects, what happens to objects, then? What about the paradigm shift?
- ... as object-oriented systems are made of interacting objects, are multiagent systems made of interacting agents—only?
- ... if societies and environment are essential to agent-oriented systems, how should they be handled in MAS modelling and engineering?
- ... if agents have to act, which are the objects of their acting?

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Origins of (Cultural-Historical) Activity Theory

- Born in the context of Soviet Psychology
- Rooted in the dialectic materialism by Marx & Engels
- Mostly by the work by Lev Vygotsky (1926-62) [Vygotskii, 1978]
- Broadly speaking, AT is a very general framework for conceptualising human activities – how people learn, how society evolves – based on the concept of human activity as the fundamental unit of analysis

Activity Theory nowadays

- Re-discovered and widely applied in Computer Science and related fields in the last years [Nardi, 1996]
- Mostly in fields like Computer Supported Cooperative Work (CSCW) and Human Computer Interaction (HCI)
- Brought to the MAS field by both Italian and Spanish groups
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Human Activity in AT

Main Focus of AT

- AT focuses on human activities
- within a social / organisational context
- as separated by their respective (physical and ideal) objects

Collaborative activities in AT

- Cooperation is understood as a collaborative activity
- A collaborative activity has one objective
- A collaborative activity is distributed onto several actors, who participate to the activity
- Explicit norms and rules regulate the relationships among individual participants’ work
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Mediated Interaction in AT

Every Human Activity...

- ... is found to be *mediated*...
- ... by mediating *artifacts*...
- ... of heterogeneous nature, either physical or psychological
  - operating procedures, heuristics, scripts, languages, ...
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Artifacts in AT

- **Artifacts are the tools that mediate actions and social interactions**
  - Artifacts mediate between individual participants and their environment.
  - Artifacts embody the portion of the environment that can be designed and controlled to support participants’ activities.
- As an observable part of the environment, artifacts can be monitored along with the development of the activities.
  - To evaluate overall system performance and
  - To keep track of system history.
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Role of Artifacts in AT

- Artifacts can be either *physical* or *cognitive*—or, they may have a twofold nature
  - example of physical artifacts are shelves, doors, phones, whiteboards, ...
  - example of cognitive artifacts are operating procedures, heuristics, scripts, languages, ...
  - examples of artifacts with a twofold nature (physical / cognitive) are operating manuals, computers, ...
- Artifacts are both a *means* but also a *product* of social activity, so they embody a set of social practise
  - their design and structure reflect a history of particular use in some given social / organisational context
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Artifacts as Enablers and Constrainers of Activities

- As mediating tools, artifacts have both an *enabling* and a *constraining* function.
  - **Enablers**: artifacts expand out possibilities to manipulate and transform different objects.
  - **Constrainers**: the object is perceived and manipulated through the artifact not ‘as such’ but within the limitations set by the artifact itself.

- A simple example: a driving wheel
  - **Enabler**: enables me to change direction while driving a car.
  - **Constrainer**: allows me only one way to change direction while driving a car.
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AT identifies a three-layered structure for social (collaborative) activities [Bardram, 1998, Engeström et al., 1997]

- The three layers are labelled as
  - co-ordinated
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**AT Layers: The Picture**

- **Co-construction**
  - Implementation: Stabilising the Objective of Work

- **Co-operation**
  - Reflection on the Means of Work
  - Routinisation: Stabilising The Means of Work
  - building artifacts

- **Co-ordination**
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Layers for Collaboration Activities in AT

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Co-ordination in AT

- The *co-ordinated* aspect of work captures the *normal* and routine *flow of interaction*
- Participants follow their *scripted roles*, each focusing on the successful performance of their actions, implicitly or explicitly assigned to them.
- Participants share and act upon a common object, but their individual actions are only externally related to each other.
- *Scripts* coordinating participants’ actions are not questioned or discussed, neither known and understood in all their complexity.
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The co-operative aspect of work concerns the mode of interactions in which actors focus on a common object, thus share the objective of the activity.

Here, actors do not have actions or roles explicitly assigned to them.

With regard to the common object, each actor has to balance his/her own actions with other agent actions, possibly influencing them to achieve the common task.

At the co-operation level:
- the object of the activity is stable and agreed upon;
- the means for realising the activity is not yet defined.

The means for realising a collaborative activity—the artifacts—are then the object of the co-operative activity, and its results as well.
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- A collaborative activity is not to be seen in general at one single level.
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Outline

1 Premises
   - Trans-disciplinary Research
   - Dangling Issues

2 Activity Theory
   - Background from Activity Theory
   - Lessons Learned: From AT to MAS

3 Distributed Cognition
   - Background from Distributed Cognition
   - Lessons Learned: From Distributed Cognition to MAS

4 Sociology
   - Background from Sociology
   - Lessons Learned: From Sociology to MAS

5 Computer Supported Cooperative Work
   - Background from CSCW
   - Lessons Learned: From CSCW to MAS

6 (Cognitive) Anthropology & Ethology
   - Background from (Cognitive) Anthropology & Ethology
   - Lessons Learned: From (Cognitive) Anthropology & Ethology to MAS
Agents are not the Only Abstractions Needed

Basic Abstractions: Agents plus Artifacts

- Adopting AT as a conceptual framework for MAS social activities has led to recognise that agents are not the only basic abstractions to model and build MAS [Ricci et al., 2003]
- Artifacts, too, are necessary [Ricci et al., 2006]
  - to enable and constrain agent actions
  - to mediate agent interactions with other agents and with the environment
  - to model and shape MAS environment
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Artifacts are essential—in MAS, too

- AT investigation is relevant in MAS since it points out that artifacts are essential to enable and govern agent actions and interactions within a MAS
  - by enhancing agent capabilities to act
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Role of environment

- AT emphasises the fundamental role of the environment in the development of complex systems
- Also, AT suggests that artifacts are the essential tools [Weyns et al., 2007, Viroli et al., 2005]
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Coordination Artifacts

Artifacts for collaboration and coordination

- *Coordination artifacts* are artifacts used in the context of collaborative activities, mediating the interaction among actors involved in the same social context [Ricci et al., 2003]
- Coordination artifacts can be either *embodied* or *disembodied*, referring to respectively physically or cognitive/psychological artifacts
- Coordination artifacts are social artifacts shared by agents in a MAS, which are meant to enable and govern the interaction among agents, and between agents and their environment

Coordination artifacts & media

- Coordination artifacts represent a straightforward generalisation of the notion of coordination medium, as coming from fields like coordination models and languages and distributed AI
- Examples include abstractions like tuple spaces, channels, blackboards, but also pheromone infrastructures, e-institutions, ...
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**co-construction** — agents understand and reason about the (social) objectives (goals) of the MAS, and build up a model of the social tasks required to achieve them—this also involves identifying interdependencies and interactions to be faced and managed.

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Co-ordination: both intelligent and non-intelligent agents could coordinate

Any agent (either intelligent or not) can simply exploit artifacts to achieve its own goals by simply taking artifacts as they are, and use them.

Co-operation: intelligent agents could change artifacts to change MAS

Intelligent agents could possibly reason about the nature of the artifacts as well as on the level of achievement of their goals, and take the chance to change or adapt the artifacts, or even to create new ones whenever useful and possible as the result of either an individual or a social activity.

Co-operation: MAS engineers could embody social intelligence in artifacts

In the same way, MAS engineers can use artifacts to embody the “social intelligence” that actually characterises the systemic/synergistic (as opposed to compositional) vision of MAS [Ciancarini et al., 2000], but also to observe, control, and possibly change MAS social behaviour.
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AT Layers for MAS: The Picture

- **co-construction**
  - identifying the social objectives & tasks

- **co-operation**
  - designing & building the coordination artifacts for social task achievement

- **co-ordination**
  - using the coordination artifacts
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Cognition transcends individuals

- Intelligent processes in human activity go beyond the boundaries of individual actors
- Knowledge is not confined within human minds
- Cognition transcends individual cognition

Knowledge representation transcends individuals

- Knowledge representation does not pertain individual humans only
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Cognitive artifacts: a definition [Norman, 1992]

those artificial devices that maintain, display, or operate upon information in order to serve a representational function and that affect human cognitive performance

Cognitive artifacts are...

- ...a product of human design and work
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**System view**

Individuals plus artifacts altogether as a (functional) subsystems

- Understanding activities requires to consider (cognitive) actors and (cognitive) artifacts altogether
- Actions are sometimes mediated sometimes targeted to artifacts, and cannot be fully understood without them

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Individuals as subsystems affected by artifacts

- Practical reasoning is deeply affected by artifacts
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Environment has a key role in distributed cognitive systems

- In distributed cognitive systems, the nature of the environment
  - on the one hand, depends on the artifacts and tools that shape it
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Work environment

- How do we define a working environment for individuals and organisations?
  - It mostly depends on the tasks that have to be carried on inside
- Real work environments are a complex superposition of social, cultural, cognitive, and physical constraints
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What is the purpose of an activity?

- A dominant assumption is that the point of activity is to change the environment in a way that (presumably) leads to goal satisfaction.
- Many actions however do not make sense under this assumption:
  - most communication actions, but not only them;
  - for instance, people undertake actions to save attention, memory and computation; people recruit external elements to reduce their own cognitive effort by distributing computational load.
  - This makes sense if people is situated.
- As a result, environment design should not merely be aimed at helping people to achieve their goals:
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   - Dangling Issues

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Cognition & knowledge representation do not belong to agents only
- Objects & tools in the environment may participate to the cognitive processes
- Structure of MAS environment may explicitly represent knowledge

Cognition & knowledge representation are distributed in the environment
- Artifacts are essential parts of the MAS cognitive processes
- Cognitive artifacts encapsulate knowledge as explicitly represented
Agent View vs. MAS View

**Personal / agent view**
- Once artifacts are exploited, they change the way in which agents act and reason about action.

**System / MAS view**
- In order to understand and possibly evaluate agent (social) action within a MAS, one should consider agent(s)+artifact(s) altogether.
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(Cognitive) artifacts shape MAS environment

- Artifacts determine the structure of MAS environment
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Cognitive interpretation of (social) action [Conte and Castelfranchi, 1995]

- Agents in a society can be generally conceived as either goal-governed or goal-oriented entities
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Not every entity involved in (social) actions has a goal

- Within a society, there are entities that are explicitly designed to provide a function
- Artifacts are such objects
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On the Relation Between Agents & Artifacts
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Use & use value

- When facing an artifact, an agent may adopt different perspectives
- Evaluating an artifact for use, to select it among many others, and then to use it, to achieve agent’s own goals, are two different matters
- Different sorts of external goals are associated by an agent to an artifact
  use value: the use-value goal, according to which the artifact should allow user agents to achieve their objective—this drives the agent selection of the artifact
  use: the use goal, which directly corresponds to the agent internal goal—this guides the actual usage of the artifact
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How could an agent deal with an artifact?

- There are at least three different ways an agent can exploit an artifact:
  - **use** by merely using it, according to its function, and associating it to a destination
  - **selection** by selecting it for future use, according to its function, its possible future destinations, and the agent's goals and plans
  - **construction & manipulation** by adapting & changing an existing artifact, or by creating a new one for future use, thus designing its function, according to its possible future destinations, and the agent’s goals and plans
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Goals in MAS

Agents have goals

- **Strong agency**: Agents have explicitly-represented goals.
- **Weak agency**: Agents have implicitly-represented / encoded goals.

Artifacts have functions

- Artifacts have no internal goals.
- Artifacts have a pre-designed function.
- An artifact is associated with an external goal (its destination) by agents in the act of using it.
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Agents & Artifacts Interacting

Aspects of agent-artifact relationship

**use** An agent can use an artifact, according to its use goal, associating it with a destination

- **aware use** because the agent is aware of the artifact’s function
- **unaware use** because the artifact’s use is encoded in the agent by the programmer / designer

**selection** An agent can select an artifact for future use, according to its use-value goal, reasoning about its possible future destinations and use goals

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- or, an agent can create *ex-novo* a new artifact with an agent-designed function according to some required use-value goals and to its possible future destinations
Basic choices to make in agent design

- Should an agent be aware of artifact’s behaviour and structure, and of how to use them?
  - should an agent be able to reason and deliberate about artifact use?
- Should an agent be aware of artifact’s function and possible uses?
- Should an agent be able to act over artifacts to modify them and adapt their function?
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Computer Supported Cooperative Work (CSCW)

Basic issues in CSCW

- CSCW aims at automating human cooperative work through computational procedures
- However, two diverging strategies are currently emerging [Schmidt and Simone, 2000]
  - automation stressing computational procedures to automate coordination of activities
  - flexibility stressing the flexibility of computational procedures with respect to intelligent coordination by collaborating actors
- The former approach emphasises coordination by the computational entities ruling collaboration, the latter coordination by intelligent collaboration entities
- Main problem: the two strategies diverge, they should instead converge
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Automation vs. Flexibility: Key Issues in CSCW

Mutual awareness for flexibility

- Mutual awareness means that the actors of a collaboration activity affect and mutually perceive the other actor’s activities through the shared workspace.
- The so-called common field of work can reveal / conceal portions of the collaboration activities to the participants.
- Mutual awareness is then the basis for opportunistic, ad hoc alignment and improvisation, which ensure flexibility to collaborative activities.
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- *Coordinative artifacts* are the rulers of collaboration
- They work more as *constrainers* rather than as *commanders*
- By giving structure to the common field of work, coordinative artifacts encapsulate those coordination responsibilities that are better to be *automatised* in order to achieve efficiency in cooperation
- In all, coordinative artifacts work as *constrainers* and *not* as *commanders*
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- Western anthropology has long dwelt on such a point
- The relation between language, use of tools, and evolution of intelligence has long been neglected [Hewes and Arcos, 1993]

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- Evidence of co-evolution of language and tools use along with human intelligence is overwhelming in modern anthropological studies [Gibson and Ingold, 1993].
Use of tools is not an exclusive feature of humans

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- When using a tool, a creature shows it is able to distinguish and identify itself from the world around.
- The use of a tool reveals awareness of self, and of the environment as well.
  - Whenever a tool is built with a goal, it is stored for further/repeated use, it is used for building new tools, etc.
- Tools are at the same time the first and the most distinctive expression of human intelligence, along with language.
- They are the most powerful amplifiers of the (both individual and social) human ability to affect the environment—to survive environment change, first, and to change the environment for the human purposes, then.
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Andrea Omicini (Università di Bologna)
The Logocentric Philosophical Bias in MAS

Agent capacity of language as the main sign of agent intelligence?

- Research on MAS still dwells on the *logocentric bias*
- Intelligent *use of tools by agents* is typically neglected
  - as a stunning example, FIPA (Foundation for Intelligent Physical Agents) just ignore pragmatic / physical agent actions, and only focuses on agent communication actions

Agent ability of developing and using tools as a sign of agent intelligence

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Agents and Artifacts: Multi-disciplinary Foundations

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