1. Epistemological Premises
   - How Much Science in Computer Science & MAS?
   - On the Notion of Definition

2. Agents: Definitions & Conceptual Framework
   - Autonomy
   - Definitions
Outline

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What is Science in Computer Science?

A general definition of scientific activity might be not enough

- Hard & soft sciences typically deal with worlds that are given, and have to be understood, modelled, and possibly predicted in their behaviour
- “Computational worlds” have to be both modelled and constructed
- Concepts, methods, and tools from other sciences, and from “classical” epistemological approaches are surely essential, but might not suffice

What is peculiar to Computer Science?

- Formal models should follow the same “lines” as, say, mathematical or logical formalisations
- Models of the physical systems should follow the same approach as, say, models in Physics
- However, the core of computational systems is human-designed, and obeys to human-conceived laws—unlike, say, physical or biological systems
On the Notion of Definition

Out of the mess
- Many different & diverging definition for the notion of agent around
- Typically, a list of not well-defined properties
- “Definitory” properties are often indistinguishable from desirable ones
- Orthogonality between defining features is not even considered

How should one choose / build a definition?
- We should first make clear what are the required / desirable properties of a definition
- Only after, try to define our entities
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What is a Definition?

From Wikipedia

- A definition is a form of words (*definiens*) which states the meaning of a term (*definiendum*)
- Definition by *genus* and *differentia*
  - *genus* (the family) of things to which the defined thing belongs
  - *differentia* the features that distinguish the defined thing from other things of the same family

Rules for definition by genus and differentia

- A definition must set out the essential attributes of the thing defined
- Definitions should avoid circularity
- The definition must not be too wide or too narrow
- The definition must not be obscure
- A definition should not be negative where it can be positive
Explanation in the Sciences of Nature

Occam’s Razor

- The explanation of any phenomenon should make as few assumptions as possible, eliminating, or “shaving off,” those that make no difference in the observable predictions of the explanatory hypothesis or theory.
- In short, when given two equally valid explanations for a phenomenon, one should embrace the less complicated formulation.
- When multiple competing theories have equal predictive powers, one should select the one introducing the fewest assumptions and postulating the fewest hypothetical entities.

Lex Parsimoniae

*Entia non sunt multiplicanda praeter necessitatem* (entities should not be multiplied beyond necessity)
Definition in the Sciences of Artificial

Explanation vs. definition

- In the sciences of nature, *phenomena* are just to be observed, described, and possibly predicted, and *noumena* to be possibly understood
  - definition is just a premise to theory and explanation, to build up *models* for natural systems

- In the sciences of artificial, noumena are to be created
  - definition is the foundation for systems, and gives *structure* to *artificial worlds*
  - there, Occam’s Razor and the Lex Parsimoniae may apply to definition instead of theory and explanation
Lessons Learned: Definition by Genus and Differentia

Some rules of thumb

- **genus**: A definition should clearly delimit the domain of discourse.
- **differentia**: A definition should allow what is in and what is out to be clearly determined.
- **rules**: A definition should follow the rules for definition by genus and differentia.
  - essentiality, no circularity, neither wide nor narrow, no obscurity, no unneeded negativity.
Lessons Learned: Occam’s Razor & Lex Parsimoniae

Other rules of thumb

- **minimal assumptions** A definition of an entity should make as few assumptions as possible.
- **minimal complication** Given two equally valid definitions for an entity, one should embrace the less complicated formulation.
- **lex parsimoniae** Definitions should not be multiplied beyond necessity.
  - Definitory features should not be multiplied beyond necessity.
Agents: Definitions & Conceptual Framework

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Autonomy as the Foundation of the Definition of Agent

**Lex Parsimoniae: Autonomy**
- Autonomy as the only fundamental and definitory feature of agents
- Let us see whether other typical agent features follow / descend from this somehow

**Computational Autonomy**
- Agents are autonomous as they *encapsulate* (the thread of) *control*
- Control does not pass through agent boundaries
  - only data (knowledge, information) crosses agent boundaries
- Agents have no interface, cannot be controlled, nor can they be invoked
- Looking at agents, MAS can be conceived as an aggregation of multiple distinct *loci* of control interacting with each other by exchanging information
(Autonomous) Agents (Pro-)Act

**Action as the essence of agency**
- The etymology of the word *agent* is from the Latin *agens*
- So, agent means “the one who acts”
- Any coherent notion of agency should naturally come equipped with a model for agent actions

**Autonomous agents are pro-active**
- Agents are literally active
- Autonomous agents encapsulate control, and the rule to govern it
  → Autonomous agents are pro-active by definition
    - where pro-activity means “making something happen”, rather than waiting for something to happen
Agents are Situated

The model of action depends on the context

- Any “ground” model of action is strictly coupled with the context where the action takes place
- An agent comes with its own model of action
- Any agent is then strictly coupled with the environment where it lives and (inter)acts
- Agents are in this sense are intrinsically *situated*
Are Agents Reactive?

- Any model of action is strictly coupled with the context where the action takes place.
- Any action model requires an adequate representation of the world.
- Any effective representation of the world requires a suitable balance between environment perception and representation.

→ Any effective action model requires a suitable balance between environment perception and representation.

- However, any non-trivial action model requires some form of perception of the environment—so as to check action pre-conditions, or to verify the effects of actions on the environment.
- Agents in this sense are supposedly reactive to change.
Are Autonomous Agents Reactive?

Reactivity as a (deliberate) reduction of proactivity

- An autonomous agent could be built / choose to merely react to external events
- It may just wait for something to happen, either as a permanent attitude, or as a temporary opportunistic choice
- In this sense, autonomous agents may also be reactive

Reactivity to change

- Reactivity to (environment) change is a different notion
- This mainly comes from early AI failures, and from robotics
- It stems from agency, rather than from autonomy—as discussed in the previous slide
- However, this issue will be even clearer when facing the issue of artifacts and environment design
(Autonomous) Agents Change the World

Action, change & environment

- Whatever the model, any model for action brings along the notion of *change*
  - an agent acts to change something around in the MAS
- Two admissible targets for change by agent action
  - **agent** an agent could act to change the state of another agent
    - since agents are autonomous, and only data flow among them, the only way another agent can change their state is by providing them with some information
    - change to other agents essentially involves *communication actions*
  - **environment** an agent could act to change the state of the environment
    - change to the environment requires *pragmatical actions*
    - which could be either physical or virtual depending on the nature of the environment
Autonomous Agents are Social

From autonomy to society

- From a philosophical viewpoint, autonomy only makes sense when an individual is immersed in a society.
  - autonomy does not make sense for an individual in isolation
  - no individual alone could be properly said to be autonomous
- This also straightforwardly explains why any program in any sequential programming language is not an autonomous agent *per se* [Graesser, 1996, Odell, 2002]

Autonomous agents live in a MAS

- Single-agent systems do not exist in principle
- Autonomous agents live and interact within agent societies & MAS
- Roughly speaking, MAS are the only “legitimate containers” of autonomous agents
Autonomous Agents are Interactive

Interactivity follows, too

- Since agents are subsystems of a MAS, they interact within the global system
  - by essence of systems in general, rather than of MAS
- Since agents are autonomous, only data (knowledge, information) crosses agent boundaries
- Information & knowledge is exchanged between agents
  - leading to more complex patterns than message passing between objects
Autonomous Agents Do not Need *Exactly* a Goal

Agents govern MAS computation

- By encapsulating control, agents are the main forces governing and pushing computation, and determining behaviour in a MAS
- Along with control, agent should then encapsulate the *criterion* for regulating the thread(s) of control

Autonomy as self-regulation

- The term “autonomy”, at its very roots, means self-government, self-regulation, self-determination
  - “internal unit invocation” [Odell, 2002]
- This does *not* imply in any way that agents *needs* to have a goal, or a task, to be such—to be an agent, then
- However, this *does* imply that autonomy captures the cases of goal-oriented and task-oriented agents
  - where goals and tasks play the role of the criteria for governing control
Goal-/Task-Orientedness is not a Definitory Feature for Agents

Example: finite-state automaton with encapsulated control

- An agent might be a finite-state automaton
- Encapsulating control as an independent thread
- Equipped with state transition rules
- The criteria for the govern of control would there be embodied in terms of (finite) states and state transition rules

Goal-orientedness and task-orientedness are just possible features for agents

- They are not definitory features anyway
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“Weak” Notion of Agent

Four key qualities [Wooldridge and Jennings, 1995]

Weak agents are
- Autonomous
- Proactive
- Reactive (to change)
- Social
Are Autonomous Agents Intelligent?

Intelligence helps autonomy

- Autonomous agents have to self-determine, self-govern, ...
- Intelligence makes it easy for an agent to govern itself
- While intelligence is not mandatory for an agent to be autonomous
  - however, *intelligent autonomous agents* clearly make sense
Are Autonomous Agents Mobile?

**Mobility is an extreme form of autonomy**

- Autonomous agents encapsulate control
- At the end of the story, control might be independent of the environment where an agent lives—say, the virtual machine on which it runs
- *Mobile autonomous agents* clearly make sense
  - mobility, however, is *not* required for an agent to be autonomous
Do Autonomous Agents Learn?

Learning may improve agent autonomy

- By learning, autonomous agents may acquire new skills, improve their practical reasoning, etc.
- In short, an autonomous agent could learn how to make a better use out of its autonomy
- Learning autonomous agents clearly make sense
  - learning, however, is not required for an agent to be autonomous
“Strong” Notion of Agent

Mentalistic notion [Wooldridge and Jennings, 1995]

Strong agents have mental components such as

- Belief
- Desire
- Intention
- Knowledge
- ...

Intelligent agents and mental components

Intelligent autonomous agents are naturally (and quite typically) conceived as strong agents
Summing Up

**Definition (Agent)**

Agents are *autonomous computational entities*

- **genus** agents are computational entities
- **differentia** agents are autonomous, in that they encapsulate control along with a criterion to govern it

**Agents are autonomous**

- From autonomy, many other features stem
  - autonomous agents *are* interactive, social, proactive, and situated;
  - they *might* have goals or tasks, or be reactive, intelligent, mobile
  - they live within MAS, and *interact* with other agents through *communication actions*, and with the environment with *pragmatical actions*
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Bibliography


Agents: From Premises to Definition

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