The Distributed Autonomy
Software Abstractions and Technologies for Autonomous Systems

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Artificial systems in general feature nowadays an ever-growing relevance of ICT components and models.

When *autonomy* is concerned, issues like deliberation, planning, knowledge representation, and the like, emphasise the role of computational/software component/subsystems.

In perspective, talking about forthcoming *autonomous systems* mostly means talking about *software systems* / components.
Nowadays, most of the complex computational systems of interest can be thought, modelled, and built as multi-agent systems (MAS). MAS are not necessarily autonomous; however:

- they are built out of many autonomous components, called agents.
- they are the reference computational paradigm for building autonomous (software) systems.
Most of the relevant systems nowadays are socio-technical systems—that is, systems where components are human and software agents altogether.

- as AWS typically are

When modelling and engineering socio-technical systems, the agent abstraction typically accounts for both human and software agents.
Agents & Goals

- **Agents** are computational entities whose defining feature is *autonomy* [Woo02]

- Agents are *goal-driven*, since *goals* determine and explain the agent’s course of actions [CC95]

  - **teleonomic** (goal-oriented) agents feature implicitly represented goals (*weak agency*)
  - **teleologic** (goal-governed) agents feature explicitly represented goals (*strong agency*), typically handled through *mentalistic abstractions* by intelligent agents [WJ95]—e.g. BDI agent architectures [RG95]
Agent societies rule collective MAS behaviours towards the overall system goals, by governing mutual agent dependencies [MC94].

Agent societies are built around coordination media [GC92], encapsulating social (coordination) laws.

There, social goals may be either implicitly or explicitly represented: so, in turn, societies (and MAS in general) could be either teleonomic or teleologic, respectively, as wholes.
When a complex socio-technical system (such as an AWS) is built as a MAS
- a number of autonomous components (either humans or software agents) and structures (societies) are in place
- each one capable to pursue its own goals either teleonomically or teleologically

So, autonomy could be conceived as a *distributed property* of socio-technical systems
- distributed autonomy
Who is in charge, really?

- Distributed autonomy means that *decisions* are actually *distributed*
  - possibly with components featuring different *sorts of autonomy* in the same system
  - possibly distributed among both human and software agents in an articulated way
  - possibly in a dynamic way, at run time
- Autonomy, deliberation, decision: it is no longer like pulling a trigger
- *It is much more complex than that*
- Autonomy is distributed
  - and so are responsibility and liability
Further sources of complexity

- Teleonomic / teleologic agents / societies typically coexist in the same MAS
- In critical socio-technical systems, any sort of deliberation (human included) typically depend on huge amounts of data and information elaborated by (possibly autonomous) software components
- Agents may depend on each others, *interfere*, exchange goals
- Any agent may belong to more than one MAS, and make different systems interfere with each other
- *Self-organising MAS* make it possible to build autonomous systems — including LAWS — which are not just teleonomic, but also has no single place for system goals—goals are nowhere *visible* when observing the system
Norms for LAWS?

- Understanding who/what is actually taking a decision – and, based on what – is no longer a trivial issue when distributed autonomy is in place.
- Without a well-founded engineering discipline, distributed autonomy may lead to *uncertain responsibility* / liability.
- Without norms on how LAWS are actually designed and built, it unclear whether LAWS could be actually regulated, e.g., for compliancy with IHL principles.


BDI agents: From theory to practice.  

Michael J. Wooldridge and Nicholas R. Jennings.  
Intelligent agents: Theory and practice.  

Michael J. Wooldridge.  
*An Introduction to MultiAgent Systems*.  
John Wiley & Sons Ltd., Chichester, UK, March 2002.
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