# The Distributed Autonomy

## Software Abstractions and Technologies for Autonomous Systems

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CCW Meeting of Experts on Lethal Autonomous Weapons Systems

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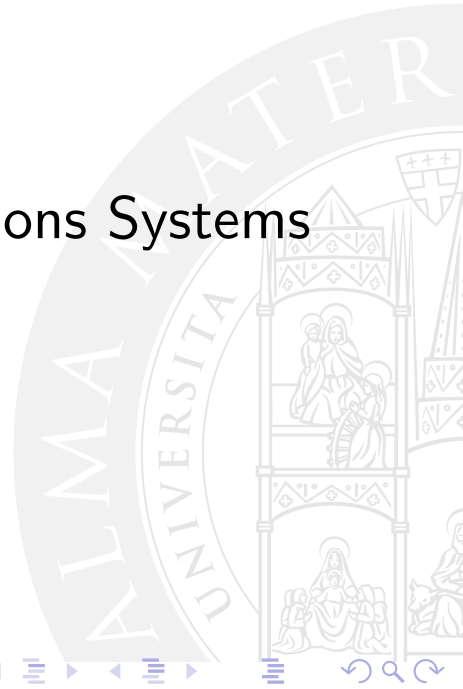


# Autonomous Systems as Software Systems

- 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

# Complex Software Systems as Multi-Agent Systems [ZO04]

- 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

# Socio-Technical Systems as MAS

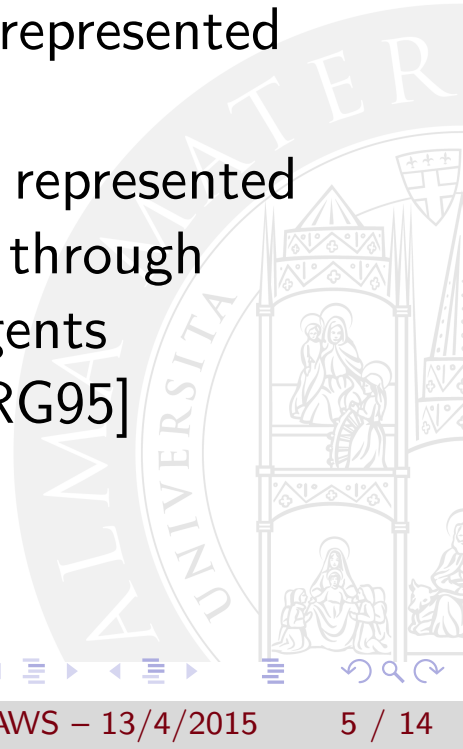
- Most of the relevant systems nowadays are socio-technical systems—that is, systems where components are human and software agents altogether
  - as AWS typically are
- When modelling and engineering socio-technical systems, the agent abstraction typically accounts for *both* human and software agents

# 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 & Coordination

- 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

# Distributed Autonomy

- 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

# Critical Issues I

## 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

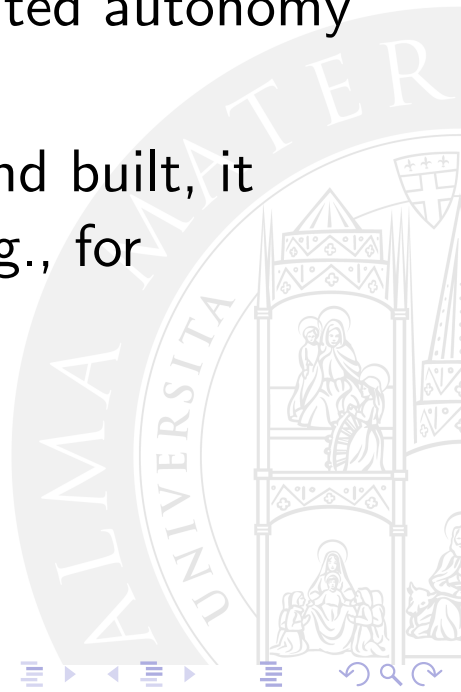
# Critical Issues II

## 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



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