Self-Explaining Agents

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2. On the Meaning of Terms
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Agents

- *agents* and *multi-agent systems* (MAS) play the role of the sources of abstractions for the design and development of intelligent systems
- the notion of agent is typically adopted to frame every single AI technique within a coherent *architecture*
- MAS provide the conceptual and technical ground for *assembling* agents within working *intelligent systems*
  - this includes recent AI advancements, including deep learning (DL), large-language models (LLM), and generative AI in general
- so that *agent-oriented software engineering* (AOSE) represent the only viable foundation of any current and future discipline for intelligent systems engineering

Humans

- with respect to traditional software engineering (SE), intelligent systems often need humans to play an *active part* in the systems, rather than merely be a client to be served
  - so, humans are still expected to bring their own *goals* to the table, as usual
  - but they are now supposed to also bring their own knowledge, skills, understanding of the world, ...
  - which the overall system relies upon for its intelligent behaviour
- as a result, nowadays humans work as legitimate *components* of intelligent systems in the same way as software and physical agents do
  - intelligent socio-technical systems (STS)
- *agent-oriented software engineering* perfectly fits the scope of intelligent STS
  - where the *agent abstraction* accounts for activity, knowledge, intelligence, goals, learning...
  - from *both* human and artificial agents

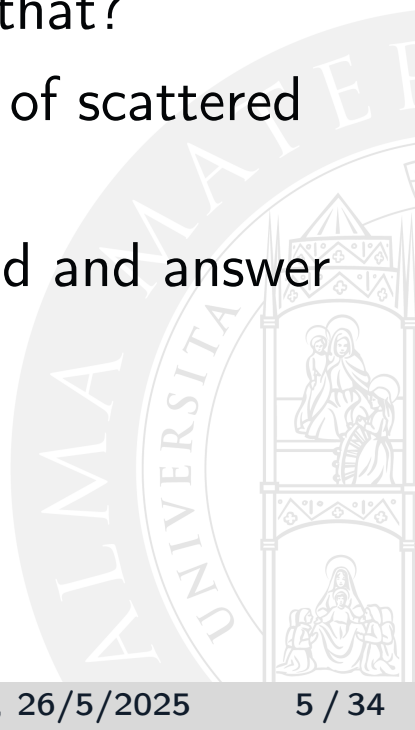
Current State of AI Systems

- intelligent STS as the general *model* for AI systems
- AOSE as the general discipline for AI *engineering*

? general question: how do we shape agents according to that?

! currently, a lot of confused ideas around, and a plethora of scattered AI technologies emerging worldwide

... maybe we need some *further questions* before we proceed and answer



The Raise of XAI

People need to understand

- humans rely more and more on intelligent systems for their everyday activities, as well as for critical aspects such as health and money
- in the context of intelligent STS where both humans and intelligent agents work together to generate *intelligent behaviour*
  - e.g. *decision support systems* exploit intelligent systems in order to promote rational human decisions—in health care, urban traffic management, legal procedure, ...

! information and actions by intelligent agents need to be understandable by humans to be accepted and *trusted*

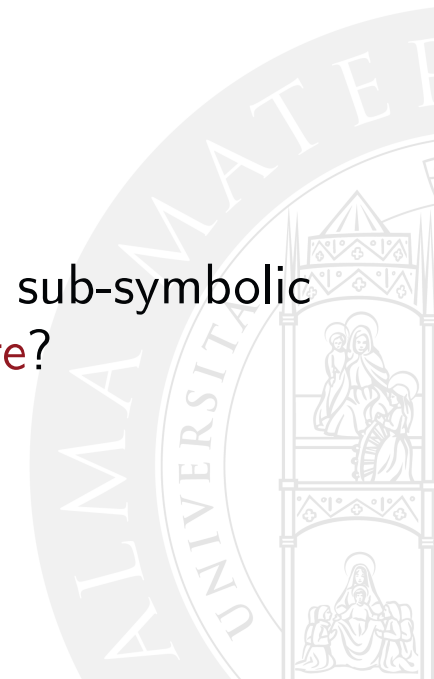
- as well as for *responsibility* and *accountability* reasons

→ humans need *explanations*

- which is where explainable artificial intelligence (XAI) comes from[Gunning, 2016]

Why Don't Humans Understand Intelligent Systems?

- the technical XAI problem
  - *symbolic* approaches are *transparent* yet slow
  - *sub-symbolic* approaches are *fast* yet opaque
- so, symbolic / sub-symbolic *integration* is the most promising way out
  - and, everyone is already doing that[Calegari et al., 2020]
- yet: what about agents?
  - integration how?
  - and, mostly, based on what integration model?
  - which *conceptual foundation* for integrating symbolic / sub-symbolic techniques within a coherent agent model / architecture?



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The Problem of Pervasive CS

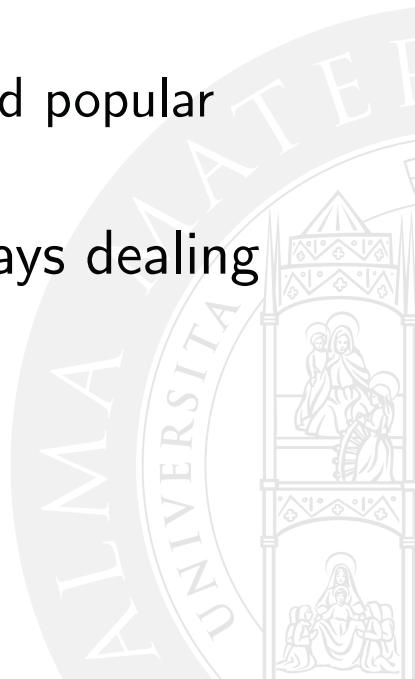
- *computer science* (CS) has possibly gone so far that (also) belong within the social sciences[Connolly, 2020]
  - yet, its basic foundations still lay in the ground of *hard sciences*
  - possibly on the edge of classic disciplines such as logics and mathematics

→ if "All science is computer science",[Johnson, 2001] the use of basic terms becomes problematic

- since many terms and ideas from human sciences have (also) a consolidated "commonsense" meaning
- clashing with the need for precise and non-ambiguous definitions of concepts and notions required by hard sciences

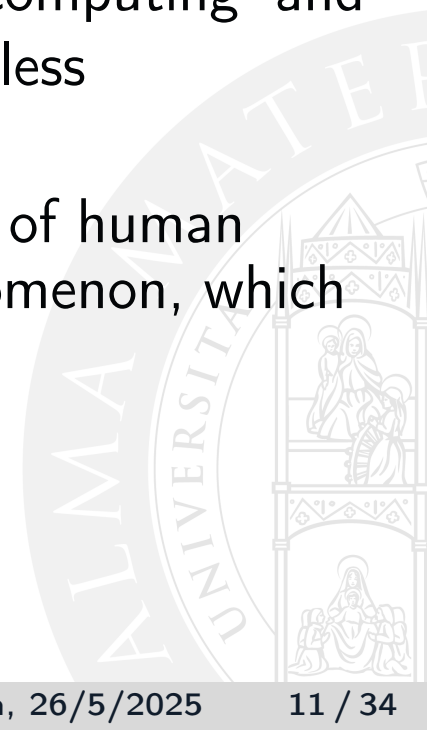
The Problem of Pervasive AI

- the pervasive emergence of AI techniques in human activity and social organisations has made the problem of "commonsense acceptations of terms" an issue for AI, too
- terms such as, e.g., 'learning', 'understanding', 'explaining' have become both central in AI and *ill-defined*
  - as they are widely used in both the scientific context and popular discourse
- as one may expect, a flow of specific literature is nowadays dealing with that issue



The Problem of Terms in AI vs. CS

- in the XAI area, the term and the very notion of explanation represent one of the main subject of scientific debate[Ciatto et al., 2020]
- more generally, the very notion of what intelligence is have always been a cause of conflict in the AI field
- not the same in the CS field, where the issues 'what is computing' and 'what is computer science' are the subject of a more or less conventional epistemic debate[Denning, 2010]—why?
- *computation* is mostly perceived as an artificial product of human invention, whereas *intelligence* is a sort of natural phenomenon, which
  - we observe around us, and mostly within us
  - we use to understand the world and *make science*



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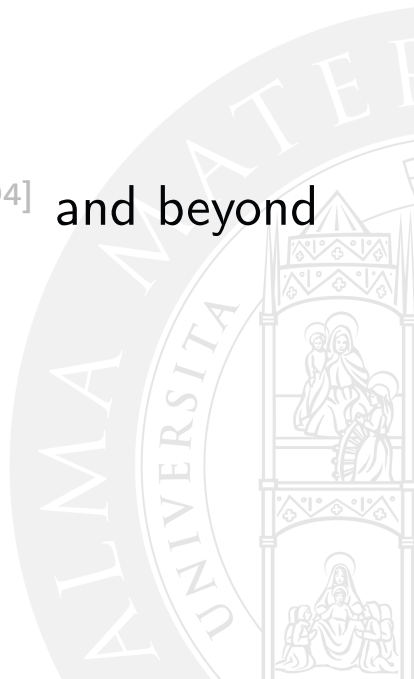
Not Just a Scientific Issue

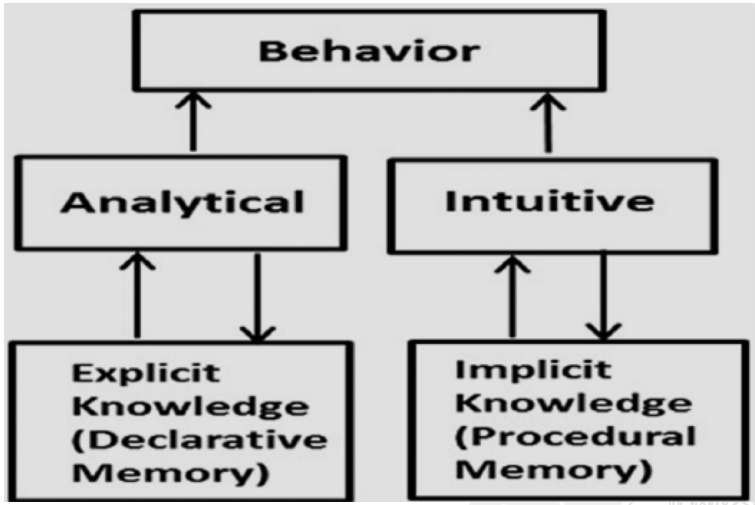
- understanding intelligence is not (just) an issue for AI
- instead, it is first of all an *issue for humans* in general
- and, all things considered, it always has been
- e.g.
  - human rationality vs. the rationality of the world
  - *logic* from Aristotle[De Rijk, 2002] to Tarski[Tarski and Tarski, 1994] and beyond



Rationality vs. Intuition

! human cognition processes are our main reference for modelling and shaping intelligent processes

- two sorts of cognitive processes in humans
  - *esprit de finesse* vs. *esprit de géométrie*—rationality has limits[Pascal, 1669]
  - *cognitivism* against *behaviourism* in psychology[Skinner, 1985]
  - *fast* vs. *slow thinking*[Kahneman, 2011]



- generally speaking, cognitive processes in humans are widely recognised to be either rational or intuitive
  - and, of course, human cognition can be mostly understood as a basically non-linear combination of the two

Social Intelligence: Humans Share Knowledge

! human cognition is *not* just an individual process[Kirsh, 1999]

- it is not brain size (or whatever like that) that separates humans from other intelligent animals like primates
  - instead, it is mostly our will to *share knowledge*[Dean et al., 2012]
- in general, knowledge sharing is a peculiar trait of humanity
  - it is how we do understand each other
  - it is how we learn
  - it is the foundation of human society
  - where human culture is a *cumulative* one

e.g. human science is a shared *social construct*

- scientific artefacts are required to be *understandable* for the community
- so as to enable *reproducibility* and *refutability* in the scientific process[Popper, 2002]

Sharing is Rational

- we already know that there is *intelligence without representation*[Brooks, 1991b] and *without reason*[Brooks, 1991a]
  - yet, human cumulative culture is based on *representation* tools—language, writing, books, the Web
- *repeatable*, *systematic* sharing requires rational representation
  - even when we are sharing *intuitive, implicit knowledge*
- and, sharing implicit knowledge typically calls for *rational* explanation

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Explanation Everywhere

- the notion of *explanation* is the core of many research efforts
  - along with accessory notions such as *interpretation* and *understandability*
- and undergone a constant flow of diverse and (sometimes) even extravagant definitions
  - e.g., even GDPR[Voigt and von dem Bussche, 2017] recognises "the citizens' right to explanation"[Goodman and Flaxman, 2017]
- most of them encompassing both the explanator's and the explainee's acts in the same acceptation of the term 'explanation'
  - the *dialogical* acceptation of explanation

Explanation as an Explanator's Act

- however, if we adopt the dialectical notion of explanation, how can we understand explanation in the most abstract way?
- e.g., the same explanation could be given by an expert to a single friend, to a class of listeners in a physical room, to an undetermined audience on a social platform...
  - how can we model that independently of the explainees?
  - and possibly measure its effectiveness in some way?

! even though the dialectical notion of explanation is perfectly legitimate, here we stick to the notion of *explanation as an explanator's act*, so that

  - we can model it in the most abstract way, and
  - we can focus on the (individual) *cognitive process* of the *explanator*

Explanation in Math Teaching I

- contribution from *math teaching* [D'Amore, 2005]
  - being math the most difficult subject to explain & teach, math teaching is likely the best source of inspiration possible
- a semiotic representation is required whenever the object of an explanation is inaccessible to perception

  semiotics — acquisition of a *representation built out of signs*

  noetics — *conceptual acquisition* of an object
  - e.g., a rectangle is an abstract geometrical concept, yet teachers draw some random rectangle on the blackboard when they try to make pupils grasp the abstract notion of rectangle
- how do they *explain* abstract concepts, promoting learning as a noetic process out of some semiotic representation?

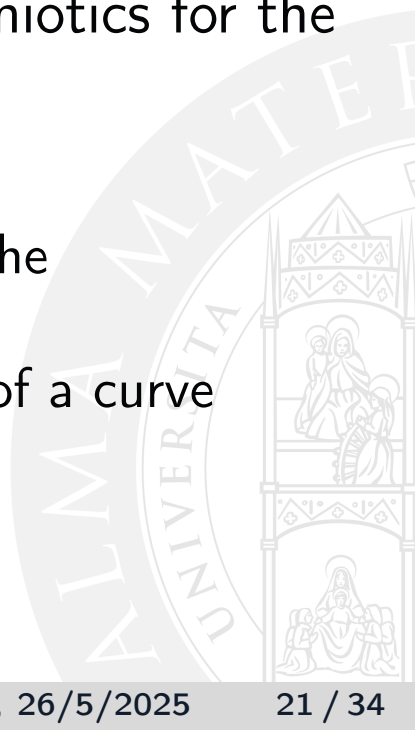
Explanation in Math Teaching II

- explanation as *transformation*
  - explaining a concept by providing different *semiotic representations* of the same concept

transformation of treatment — changing representation within the same register of semiotics

transformation of conversion — changing register of semiotics for the representation

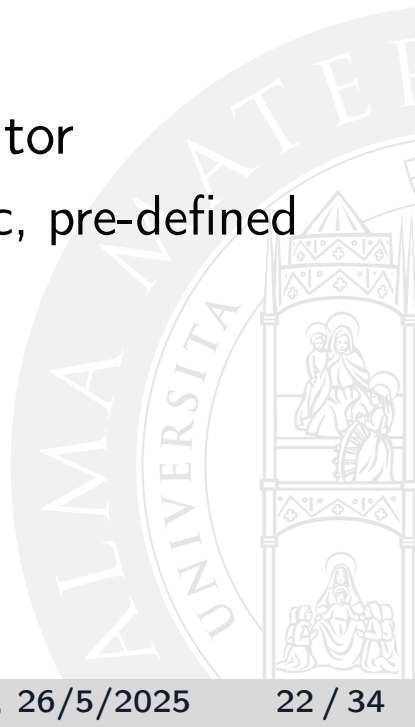
e.g.
- converting between polar and Cartesian coordinates in the representation of a curve (*transformation of treatment*)
- switching from the analytic to the geometric definition of a curve (*transformation of conversion*)



Explanation in Math Teaching III

- ! *explanation* as
  - first, *generation of semiotic representation*
  - then, transformation of semiotic register
- by the explanator

- ! explanation is first of all an *individual act* of the explanator
  - which may or may not be directed explicitly to a specific, pre-defined explainee



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Rationality vs. Intuition in Agents

- the notion of rational vs. intuitive cognition is *not* born in the CS / AI fields
  - surely not in the agent community
- yet, they roughly match the two main families of AI techniques
  - symbolic vs. sub-/non-symbolic
  - informally, *classic AI* vs. *ML-based AI*
- and, the two sides of today agent models and technologies

Is XAI Just Intelligent Systems Explaining to Humans?

- most of the research on explainability aims at making *intelligent systems understandable to humans*
  - explainers are *software components*—e.g., the agents
  - explainees are *humans* [Rosenfeld and Richardson, 2019, Anjomshoae et al., 2019, Guidotti et al., 2019]
- looking at STS, this means that at least one dimension is missing
  - we know about humans explaining to humans—e.g., teachers with pupils at schools
  - we know that humans try to be understood by software agents everyday—e.g., by Alexa & Siri, by ChatGPT & Gemini
  - ? what about *agents explaining to agents*?

Effective Agent Interaction is Not Just Communication

- MAS can be seen as open, distributed, *heterogeneous* systems, working in *unpredictable environment* to solve *general-purpose* problems
  - with no predefined *best approach* known in advance
- MAS aggregate diverse sorts of intelligence—each agent possibly encapsulating different algorithms, techniques, logics, ...
  - competing / cooperating together to produce the best solution a run-time
  - either by selecting the best one, or integrating some / all

? how could hugely-heterogeneous, intelligent agents interact within a MAS so as to understand each other?

- yet, based on which conceptual ground?
- what if we replace "intelligent agents" with "humans" in the question above?

Agent Sharing in MAS

- *effective interaction amongst intelligent agents* in open and heterogeneous MAS mandates for knowledge sharing among agents
  - in the same way as humans share knowledge and cognition in cooperative contexts
  - so, beyond mere *inter-agent communication*
    - including classical *environment-mediated communication* among agents[Omicini, 2012]
- it is not enough for agent A to know that B believes ϕ
  - in order to accept ϕ, A needs to understand (at least) *why* B believes ϕ
- also dealing with – and possibly focusing on – *knowledge acquired through sub-symbolic techniques*
  - which needs a *symbolic representation* and possibly a *transformation* to be shared rationally among heterogeneous agents

Agent Explaining to Agents

- effective interaction among agents in non-trivial MAS cannot be just based on mere agent communication
  - *complex agent cognitive processes* need to be *shared* not just in terms of their final results

! explanation as the main *tool for sharing knowledge* among agents

- having the potential to work as an actual enabler of full-fledged *agent-to-agent communication*
- so that tools like *agent communication languages* (ACL)[Singh, 1998] and *ontologies*[Huhns and Singh, 1997] are just technical premises
  - the syntactic and semantic premises, respectively
- whereas explanation aims at sharing the *cognitive causes* behind beliefs

! so, first and foremost, agents explaining to agents

Self-explaining Agents

- agent-based intelligent systems made of self-explaining agents[Omicini, 2020]
  - equipped with their own specific *rational explanation* capability, whatever their nature
  - able of providing a rational, *sharable representation* of their own specific cognitive process and results
  - capable of *manipulating* such a representation in order to build one or more explanations
- an *architectural requirement* for intelligent agents of any sort is that they need to be equipped with their own *explanation module*
  - matching the specific agent cognitive process so as to produce a symbolic representation of the process itself as well as of its results
- also, agents should be provided with enough *knowledge* of the *domain of discourse* to make them capable of *symbolic manipulation* of the *representation* in the form of a *transformation of the semiotic register*
  - to make them able to provide *rational explanations* in symbolic form

Case Study: Decision Support System for Legal Process

- MAS with heterogeneous legal agents
  - some legal agents could be *deep-learning agents* trained over diverse sets of existing legal databases
  - others might be *logic-based agents*, rationally elaborating over some symbolic representation of some legal corpus
- each one not just providing its own argument and supporting its suggestions
  - not just directly providing humans with explanations
- instead, cooperatively building a *shared proposal* to be presented to human decision-makers in a potentially-understandable way

! this requires first of all that agents – symbolic vs. sub symbolic vs. hybrid – are capable of explaining themselves through a *rational form* that could be effectively shared not just with humans, but also with other agents

  - possibly exploiting *argumentation* techniques [Billi et al., 2021]

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Overall

1. explanation should be deemed as an *essential tool* for any *intelligent component*
   - in particular, agents in multi-agent systems
2. intelligent agents should be able to able to explicitly represent their cognitive processes and their results
   - independently of their nature—symbolic / sub-symbolic / hybrid
3. and manipulate those representations
   - so that rational explanation would properly complement their ability to *reason* and *communicate*
4. intelligent agents should be able to *explain* themselves first of all to other agents
   - not just be part of a system explaining itself to humans
5. symbolic techniques are to be used for explanations—representing and manipulating cognitive processes and their results
   - so, as *first-class citizens* in both *agent modelling* and *intelligent systems engineering*
   - e.g., argumentation [Calegari et al., 2022]

Thanks...

...for your kind attention!

and, to Prof. Sirbu for inviting me here

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