Mind &/v Logic

3. Knowledge representation

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knowledge & knowledge representation (KR)

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Knowledge

- Where shall we begin? ...

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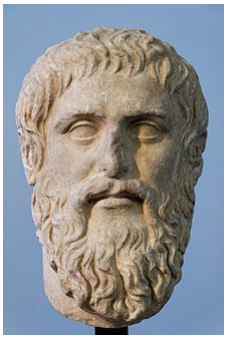
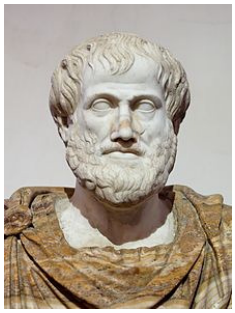


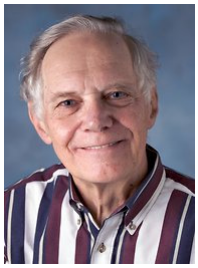
Plato



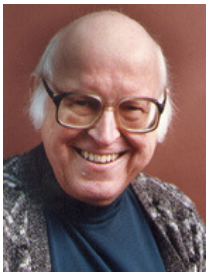
Aristotle

Ancient Philosophy

Cognitive psychology & AI



U. Neisser



A. Newell

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Knowledge & intentionality

Imagine, for example, playing a game of chess against a complex chess-playing program. In looking at one of its moves, we might say to ourselves something like this: "It moved this way because it believed its queen was vulnerable, but still wanted to attack the rook." In terms of how the chess-playing program is actually constructed, we might have said something more like, "It moved this way because evaluation procedure P using static evaluation function Q returned a value of +7 after an alpha-beta minimax search to depth d." The problem is that this second description, although perhaps quite accurate, is at the wrong level of detail, and does not help us determine what chess move we should make in response. Much more useful is to understand the behaviour of the program in terms of the immediate goals being pursued, relative to its beliefs, long-term intentions, and so on. This is what the philosopher Daniel Dennett calls taking an *intentional stance* towards the chess-playing system.

Brachman & Levesque (2003), p. 5

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Knowledge representation

- **KR hypothesis:** Any mechanically embodied intelligent process will be comprised of structural ingredients that a) we as external observers naturally take to represent a propositional account of the knowledge that the overall process exhibits, and b) independent of such external semantical attribution, play a formal but causal and essential role in engendering the behavior that manifests that knowledge. (Smith, 1982)
- Knowledge representation ... can be thought of as the study of what options are available in the use of a representation scheme to ensure the computational tractability of reasoning. (Levesque, 1986, p. 256)

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(mind
& knowledge)
&/v logic

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A calculus of thought?

- The basic assumption underlying KR (and much of AI) is that thinking can be usefully understood as mechanical operations over symbolic representations. This hypothesis is, in fact, quite old, much older than computers, and seems to have originated with the philosopher Leibniz ... Just as there is a calculus of arithmetic, where numerical expressions are formally manipulated in a value-preserving way, so might there be a calculus of thought, where propositional expressions could be formally manipulated in a truth-preserving way. (Levesque, 1986, p. 257)

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Logicism vs. Anti-logicism

The central tenet of logicist AI -- that knowledge is best represented using formal logic – has been debated as long as the field of knowledge representation has existed. ... The crux of the debate is simply this: Logicists believe that first-order logic, along with its modifications, is a language particularly well suited to capture reasoning, due to its expressivity, its model-theoretic semantics, and its inferential power. Note that it is not a particular syntax for which logicists argue; it is the notion of a formal, declarative semantics and methods of inference that are important. ... Anti-logicists have argued that the program, outside of textbook examples, is undesirable and infeasible.

Lifschitz et al (2008), p. 67

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Anti-logicist arguments

- Deductive reasoning is not enough.
- Deductive reasoning is too expensive.
- Writing down all the knowledge (the right way) is infeasible.
- Other approaches do it better and/or cheaper.

Lifschitz et al. (2008), p. 67

+ If we use epistemic logic to represent knowledge, closure under implication leads into an intractible problem: Logical omniscience!

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epistemic
Logic →
Logical
Omniscience

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Epistemic logic: the basics

- Syntactically, the language of propositional epistemic logic is simply a matter of augmenting the language of propositional logic with a unary epistemic operator K_c such that
  - K_cA reads "Agent *c* knows *A*"
    and similarly for belief
  - B_cA reads "Agent *c* believes *A*" for some arbitrary proposition *A*.
- Hintikka provided a semantic interpretation of epistemic and doxastic operators which we can present in terms of standard possible world semantics along the following lines (Hintikka 1962):
  - K_cA: *in all possible worlds compatible with what c knows, it is the case that A*
  - B_cA: *in all possible worlds compatible with what c believes, it is the case that A*

Hendricks & Symons (2009)

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Logical consequence

- In epistemic logic, we typically abstract away from some practical computational limitations of real epistemic agents. ... What matters is that if some propositions do in fact follow from the agent's theory (from what the agent knows, or believes), then so too do all their logical consequences. ... In a recursively axiomatizable epistemic logic, logical omniscience amounts to closure under a recursively axiomatizable system of inferences. Thus all the inferences in question can in principle be carried out by a single Turing machine, an idealized computer.

  Williamson (2009), p. 437-8

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Logical omniscience (some forms)

- If $\vdash p$ then $\vdash Kp$. Closure under theoremhood
- If $\vdash p \rightarrow q$ then $Kp \rightarrow Kq$. Closure under logical implication
- $\vdash K(p \rightarrow q) \rightarrow (Kp \rightarrow Kq)$. Closure under material implication

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More trouble...

- Are the following valid?

$$\bullet\ Kp \rightarrow KKp$$

$$\bullet\ \neg Kp \rightarrow K\neg Kp$$

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References

- Brachman, R. & Levesque, H. (2003). *Knowledge representation and reasoning*. Amsterdam, etc.: Elsevier / Morgan Kaufmann.
- Hendricks, V. & Symons, J. (2009). Epistemic logic. *The Stanford Encyclopedia of Philosophy (Spring 2009 Edition)*, Edward N. Zalta (ed.), URL = <http://plato.stanford.edu/archives/spr2009/entries/logic-epistemic/>.
- Hintikka, J. (1962). *Knowledge and belief: An introduction to the logic of the two notions*. Cornell: Cornell University Press.
- Levesque, H. (1986). Knowledge representation and reasoning. *Annual Review of Computer Science*, *1*, 255-287.
- Lifschitz, V., Morgenstern, L. & Plaisted, D. (2008). Knowledge representation and classical logic. In F. van Harmelen, V. Lifschitz, & B. Porter (eds.), *Handbook of knowledge representation* (pp. 3-88). Amsterdam, etc.: Elsevier.
- Smith, B. (1982). *Reflection and Semantics in a Procedural Language.* PHD Thesis. MIT Laboratory for Computer Science.
- Williamson, T. (2009). Some computational constraints in epistemic logic. In S. Rahman, J. Symons, D. M. Gabbay, & J. P. van Bendegem (eds.), *Logic, epistemology, and the unity of science*, vol. 1 (pp. 437-456). Dordrecht: Springer.

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