To (Possibly) Know Thyself : Logic in (Artificial) Intelligence

The concept of Artificial Intelligence arose with the dawn of computer science, a field in which mathematical logic was of great importance. In the context of AI, logic helps mechanize reasoning systems. However, while parts of a working system are inspired by ideas from logic, other parts seem logically problematic. These challenging features may suggest improvements to logical theory. The domain of AI provides many examples of such interactions.

Part of the problem with defining AI is the challenge of defining "Intelligence". John McCarthy, The Father of Artificial Intelligence, who first coined the term AI, suggested "Intelligence is the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines... We cannot yet characterize in general what kinds of computational procedures we want to call intelligent. We understand some of the mechanisms of intelligence and not others."[1]. This leads to the process of deriving intelligent programs being quite difficult as program designers lack understanding of the intellectual mechanisms required to do the task at hand efficiently [1]. The attempt to formalize "Intelligence" requires multifaceted developments in many areas of Logic. One of which is developing a logical notion of common sense reasoning.

Commonsense reasoning is the pre-scientific reasoning that engages human thinking about everyday problems [2]. A method in which to achieve common sense reasoning is via modelling using a non-monotonic logic [3]. Consider that in a normal or a complete mathematical proof there is no ambiguity, one covers all possibilities in which the proof shall hold. This contrasts with non-mathematical common sense reasoning where one does not consider remote options. For instance, consider a plan to get to the airport. It could be impeded by an earthquake, a meteor strike, or a highway accident. Now it would seem fair for us to reasonably ignore the first two factors, and often even the third. This demonstrates that acceptance of a plan, unlike acceptance of a proof (which could be the certification of a result due to a plan), is risky. Risk and the possibility of unpleasant surprises are features of sound commonsense reasoning. This means that this reasoning is non-monotonic [3]. More formally, classical logics were designed with mathematics in mind and their consequence relations are monotonic. That is, if a set T of formulas implies a consequence B then a larger set $T \cup \{A\}$ will also imply B. A logic is non-monotonic if its consequence relation lacks this property. *Preferred models* provide a general way to induce a non-monotonic consequence relation. Invoke a function that for each T produces a subset M_T of the models of T; in general, we will expect M_T to be a proper subset of these models. We then say that T implies B if B is satisfied by every model in M_T. As long as we do not suppose that $M_T \subseteq M_S$ if $S \subseteq T$, the implication relation will be non-monotonic [3]. McCarthy advocated non-monotonic logic as a language to describe reasoning in the common sense world. However, we must note that given that there is no agreed-upon understanding of intelligence, non-monotonicity is not a magic path to efficient reasoning. It can be useful in reasoning about uncertainty. But so can probabilities, which much of the present-day advancements in AI depend on [3].

The current developments in AI depend on mimicking biology via probabilistic models as opposed to formalized reasoning [4]. These techniques were pioneered and largely used in the work of Geoffrey Hinton [A1] who takes a more Connectionist [A2] approach to model reasoning. To him memory is just weighted connections in the brain, learning is the updating of these weights, and reasoning arises from these weightings. The more this is scaled the better the reasoning is [5]. While purely logical AI has plateaued in popularity, this approach to AI still has merits. For instance, a recent AI program (AlphaGeometry) was able to solve difficult IMO problems utilizing both a probabilistic neural network model for guiding "Intuition" and a symbolic reasoning engine that was used to provide deductive arguments. Hence, AlphaGeometry demonstrates AI's growing ability to reason logically and to discover and verify new knowledge [6].

To conclude, logic deals with reasoning, but not all reasoning an Intelligence engages in is mathematical. Even in our development of mathematical logic, when reasoning about logic we repeatedly employ imaginative constructs which hardly have a formal basis other than what we call "Intuition". But once we have pinned down our intuitions in logical prose, we readily extract truths in a deductive manner.

Appendix

[A1] The so called “Godfather of AI”, a cognitive scientist and a pioneer of the field of computational neuroscience

[A2] An approach to the study of human mental processes and cognition that utilizes mathematical models known as connectionist networks

References

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