Tools, methods, and purposes for teaching logic

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Logic is at a crossroads: there have never been so many applications of logic in our lives, but the teaching of logic is pretty much falling into oblivion with logic courses struggling to attract students' interest and be offered regularly. Indeed, logic courses are considered abstract, difficult, and unrelated to modern concerns by many. However, we are surrounded by logic-based applications. For instance, computing devices are pervasive, and logic is at the center of computing theoretically, with Turing machines and computing models (Wigderson, 2019), digitally, with von Neumann architecture and digital circuits (Patterson & Hennessy, 2020), and algorithmically with SAT solving (Biere et al., 2021), model-checking (Clarke et al., 2018), logic (Bratko, 2012) and answer set (Lifschitz, 2019) programming, to name a few. So, while the field is indeed impactful, it struggles to get the attention it deserves.

But logic goes much further than computation. Reasoning is a fundamental cognitive ability that leverages knowledge to make sense of the world and inform our decisions. Modern logic has devised formal languages with unambiguous semantics and reasoning methods, a great achievement that realizes effective calculus of thoughts. It therefore comes as no surprise that logic also plays a significant role in the humanities and mathematics, where reasoning is a central concern. Logicians are therefore present in many academic departments, such as philosophy, mathematics, and computer science, which is a strength for our field. Nevertheless, there is too little logic teaching, regardless of the department, and it is quite challenging to maintain, not to mention develop, regular courses.

While tools and innovative approaches for teaching logic are of paramount importance, logic education cannot be renewed without embracing applications head on, in sharp contrast with tradition.

Indeed, due to its fundamental nature, logic is naturally taught following the mathematical tradition of precisely developing and justifying the theoretical foundations before turning to applications. The obvious drawback of this approach is, however, clearly obvious: one may never get to meaningful applications! Full-fledged applications can rightly be developed in further advanced courses. But this makes things even more difficult, with more logic classes to maintain and justify. Students may hence never see logic in action, jeopardizing the next generation's training.

This has a quite disastrous impact on logic teaching, particularly in our task-oriented society, where outcomes, skillsets, and the ability to achieve objectives is everything. Universities are utterly anxious to avoid the trap of knowledge without skillsets and are blurring the distinction between fundamental and professional degrees. Every year students graduate and enter the workforce where they must demonstrate their abilities and merit. Logic teaching simply cannot ignore this current context.

This teaching tradition has furthermore the unfortunate drawback of grossly downplaying the fundamental challenges of applications, where modeling and effectively inferring meaningful information is of utmost importance. One simply cannot overstate that tailoring theoretical results to a meaningful application is a contribution of immense value. Applications are also a central driving force for notable theoretical developments.

This contributed talk will therefore present an approach to logic teaching where applications and tools take central stage, modeling and inference are leading concerns, and outcomes fall within current concerns in knowledge processing.

In our era of massive production of digital data, making the most of all this knowledge by effective processing is of paramount importance. In order to process data, Machine Learning methods are surely the first to come to mind. Indeed, these methods can take advantage of a high volume of data and accurately predict the correct outcome. However, it is arguable whether cognition can be entirely reduced to function prediction (Darwiche, 2018) and a further type of Data Science, emphasizing structure and relationships, is emerging. As the study of correct reasoning, it comes as no surprise that logic plays a vital role in this approach to structure, link, and leverage knowledge.

This data science is devised around ontologies, as considered by the Sematic Web initiative (Hendler et al., 2020). These ontologies are formal representations of knowledge, and Description Logic (Baader et al., 2017) provides the appropriate theoretical setting to describe and process them. This approach is particularly suited for structured domains such as, for instance, the materials, geospatial, and biomedical fields (Arp et al., 2015). Since these ontologies emphasize structure and relationships, they are often also known as Knowledge Graphs (Fensel et al., 2020).

Technically, Description Logic can be seen as a fragment of first-order logic restricted to unary and binary relations with guarded quantification as encountered in the standard translation for modal logic, or, alternatively, as a multi-modal logic with counting quantifiers. In any case, the predominant inference method used for Description Logic is the tableau method, extending that for first-order logic (Smullyan, 1968). Description Logic therefore allows to present the usual first-order semantics and its completeness theorem.

The objective of this contributed talk is to highlight how Description Logic can be used to teach logic, its semantics and completeness using Protégé (Musen, 2015), an ontology development tool, and the tableau-based inference engine Hermit (Glimm et al., 2014). The talk will also reflect on the author's experience in devising such a course where students develop modeling skills and use the inference engine to assess ontologies and derive implicit knowledge.

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