Undergraduate Logic Teaching in Computing: Why, What, How?

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Logic in Computer Science

- Logic is with Mathematics and Engineering a founding discipline of Computing.
- Methods and concepts from logic are found in many computing fields: compiler design, artificial intelligence, programming languages, computer organization and architecture, theoretical computer science, ...
- However, the significance of logic in computing is somewhat fading away!

Logic in Computer Science

- Logic in CS consistently produces new results and methods.
- The computing logic community has grown tremendously, shifting the center of gravity toward applications.
- But there is too little awareness of these striking logic-based applications in the general computing community,
- and the distinct lack of logic teaching at the CS undergraduate level strongly limits opportunities to make these advances more broadly known.

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CS Teaching at UQAM[1]

- Strong emphasis on software engineering and professional skills.
- Logic content scarce.
- Our degree is representative of those following the *Curriculum Guidelines for Undergraduate Degree Programs in Computer Science* from ACM-IEEE,
- and should therefore be similar to many other CS degrees.

[1] Bachelor's degree in Computer Science and Software Engineering
https://etudier.uqam.ca/programme?code=7617

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Logic Teaching at UQAM

- Compulsory
  - Propositional calculus and first-order logic (truth-tables, properties on specific structures).
  - Entity-relationship, relational algebra, and SQL.
  - Unified Modeling Language (UML) and Object Constraint Language (OCL)
  - Rules, Horn clauses, resolution, and some constraint processing.
  - Very briefly introduction to Turing machines and NP-completeness.
- Optional AI course
  - *Conjunctive Normal Form (CNF)*, unification and resolution.
  - Constraint processing, constraint propagation and backtracking search.

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CS Teaching

- Computing professionals are in high demand and computing impacts every sector of society.
- CS teaching is therefore very professionally oriented.
- Logic teaching must take this into account.

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This paper's position

- Too little logic is actually covered in a typical undergraduate computing degree and more logic teaching is essential.
- In order to renew logic teaching, one must:
  - step back and reflect on logic's nature,
  - put modeling and applications at the forefront.

What is logic?

- A tool to formally represent thoughts:
  - in a systematic way from basic building blocks,
  - in order to convey a point of view, a conception of some situation.
- An approach that allows formal processing:
  - that yields an unequivocal, unambiguous semantics that settles conflicting interpretations,
  - and infers new, implicit, knowledge.

Modeling

- Logic is all about modeling, which is
  - a representation of *some aspect* of reality
  - that is useful to communicate and reason about that specific aspect.
- Modeling is ubiquitous is CS since systems are complex, and expensive to design, build, and debug.
- Logic is a *principled* modeling approach.

Logic is about applications

- Many interactions of logic with other computing fields.
- Logic presents many meaningful applications that shows that it is an integral part of computing.
- It is of paramount importance that students acquire logical skills that they can show and use.

A tentative undergraduate first course in logic

- A course content along these lines:
  - propositional logic, and
  - Description Logic, which is
    - a first-order logic fragment with unary and binary relations,
    - with nice decidability properties.

Propositional logic content

- Tool: *SAT-solver* or more conveniently a *Satisfiability Modulo Theories (SMT)* solver.
- Modeling and applications: graph, game problems and more generally finite domain CSP.
- Mentioned Reachouts: CSP, knowledge representation, games, and planning (in AI) and formal verification of hardware and software systems.
- Principles:
  - univocal recursive semantics solves ambiguities,
  - multiple non-equivalent but possibly relevant models,
  - *unit propagation* and *chronological backtracking*.

Description logic content

- Tool: Protégé[2] with the Hermit[3] reasoner.
  - modeling reminiscent of UML class (and object) diagrams.
- Modeling and applications: could be similar to those of UML class diagrams in Software engineering classes.
- Mentioned Reachouts: UML class and object diagrams, Ontologies (semantic web and W3C), relational model in databases.
- Principles:
  - modeling is about eliciting the crucial facts,
  - use of the reasoner to experiment on the limitations and shortcomings of the model,
  - Tableaux algorithm for propositional and first-order logics, mention extensions to description logic.

[2] https://protege.stanford.edu/

[3] http://www.hermit-reasoner.com/

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Conclusion

- Truly too little logic teaching in current computing degrees.
- Maturity of many logic-based methods offer a major opportunity to greatly extend logic teaching in modern professionally-oriented computing degrees.
- An undergraduate logic course that put modeling to the fore and develop hands-on skills with tools appropriate beyond the classroom is totally achievable.
- Establishing such a course is possibly an ambitious endeavor, but this is a challenge that can, and should, be met by the logic in CS community!