Integrating Logic

in

the Computer Science Curriculum

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Logic in the undergraduate CS curriculum

Ideally, every CS department should have an

- upper-division *Logic in CS* course

for CS/CE juniors and seniors.

The reality, however, is different:

- few CS departments have or can afford to have such a course.

Moreover,

- even if they have such a course, it is an *elective* course, typically with low enrollment.

Nonetheless,

- topics in logic can be integrated in numerous courses in the mainstream computer science curriculum; moreover,
- this can be done in a way that showcases the uses and applications of logic to CS.

Claim: There are many opportunities to do this:

- Introduction to CS for pre-majors/non-majors
- Introduction to Computer Architecture
- Discrete Mathematics
- Principles of Database Systems
- Artificial Intelligence
- Computability & Complexity
- Semantics of Programming Languages
- Software Engineering

Introduction to CS for pre-majors/non-majors

A very good opportunity to teach the basics of Boolean logic, including:

- Connectives and Truth Tables
- Conjunctive and Disjunctive Normal Form
- Boolean formulas and computer circuits.

Time: 1–2 weeks

Textbook: *An Invitation to Computer Science*, by G.M. Schneider and G.L. Gersting

Introduction to Computer Architecture

Boolean logic is covered in more detail and is related to computer architecture

- Connectives and gates
- Circuit design:
  sum-of-products algorithm
- Complete sets of connectives:
  two types of gates suffice to build all circuits
- Circuit equivalence and minimization.

Time: 2 weeks

Textbook: *Structured Computer Organization*, by A.S. Tanenbaum

Discrete Mathematics

- Boolean Logic
  - Connectives
  - Logical equivalence, tautologies, negation, contrapositive
  - Rules of inference: *modus ponens*
- Introduction to First-Order Logic
  - Universal and Existential Quantifiers
  - Syntax and Semantics of First-Order Logic
  - Manipulation of quantifiers
  - Valid first-order formulas
- Elementary Set Theory

Time: 2–3 weeks

Textbook: *Discrete Mathematics with Applications*, by S.S. Epp

Database Systems

Relational Algebra, *Relational Calculus*, and SQL provide an excellent opportunity to

- Teach syntax and semantics of first-order logic
- Demonstrate the use of first-order logic as a database query language

Compare first-order logic to features/limitations of SQL:

- First-order *variables* vs. *aliases* in SQL
- First-order quantifiers vs. `EXISTS`, `NOT EXISTS`
- Neither first-order logic nor SQL can express *Transitive Closure*

Time: 2–3 weeks

Textbook: *Database Systems Concepts*, by A. Silberschatz, H.F. Korth, S. Sudarshan

Artificial Intelligence

Increasing coverage of logic in AI courses

- Logic is used as a tool for *representation* and *reasoning.*
- Logic and automated reasoning
  - Completeness Theorem
  - Unification and Resolution
  - Logic Programming
- Higher-Order Logics and Commonsense Reasoning

Time: 3–4 weeks

Textbook: *Artificial Intelligence: A Modern Approach*, by S.J. Russell and P. Norvig

Computability and Complexity

The unity of logic and computation is manifested throughout such a course:

- formal languages and finite automata
- computability and undecidability results
- logic and computational complexity
  - Boolean SAT is NP-complete
  - Horn Boolean SAT is P-complete
  - Quantified Boolean SAT is PSPACE-complete

Textbook: *Elements of the Theory of Computation*, by H. Lewis and C.H. Papadimitriou

Concluding Remarks

- A wide spectrum of topics in logic can be covered in different computer science courses
- Diverse uses of logic in computer science:
  - To model computer hardware
  - As a database query language
  - As a tool for representation and reasoning
  - As a tool for specification and verification
  - To produce problems that are complete for complexity classes
- Logic permeates through computer science much more than it does through mathematics.

Arnold Schwarzenegger, in **Twins**, to a thug:

> You have **no** respect for logic;
> I have **no** respect for people
> who have **no** respect for logic.

[Arnold proceeds to beat up the thug.]

This slide is stolen from a talk by Ian Barland