CS771 : Foundations of Formal Methods 2021

Lecture 0: Introduction and logistics

Instructor: S. Akshay

IIT Bombay, India

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CS771: Foundations of Verification and Automated Reasoning (FVAR)

Also called Foundations of Formal Methods

This course in a nutshell

1. How to reason

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1. How to reason
   - about human thought

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- Not quite: but as we will see, we can use these techniques to reason about AI too!

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What we need are

1. languages to formalize reasoning: symbolic logic
2. mathematical models of the computing objects: abstractions, automata
3. algorithms and tools to automate this whole process!

What this course is not about and what it is about

The idea of this course is not to...

- ... cover a specific topic in depth
- ... exhaustively cover all logics, automata, models

The idea of this course is to...

- ... provide a breadth-first view of this entire field of formal methods
- ... look at some logics, techniques in detail
- ... prepare students to do advanced courses and R&D/MTP in this area!

Who uses Formal Methods?

Widely used in industry

- Hardware and software verification
- Cyber-physical systems: Avionics, Automobiles, space!
- Hot area: explainability in AI/ML!

Including Amazon, Intel, IBM, Microsoft Research, Google, Samsung, TCS, NASA, Mathworks ...

Widely used in Academia too

- FM groups in all major universities around the world
- An interplay of mathematics and computer science, logic and coding, theory and practice.

For a more colorful video, see
`https://www.youtube.com/watch?v=AM_gwEKjnGY`

Course structure

Topics to be covered in this course:

- Module 1: Logics to formalize reasoning
- Module 2: The problem of satisfiability
- Module 3: Program verification
- Module 4: Automata-based model checking of systems
- Extra Module: Advanced topics on automata and computability

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There are advanced courses in each of these topics! CS433, CS615, CS713, CS735, CS738, CS739 But this course is the ring that binds them all.... :-)


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Mode of instruction

- Combination of: Detailed slides + live lectures (recorded) + some video voiceovers, $\sim$2-3 hrs per week
- Tutorials/Doubt clearance sessions: $\sim$0.5-1 hr per week
- Weekly reading & writing assignments, self study: 3+ hrs per week, compulsory!
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- Moodle progress quizzes : 10%
- Home works and submittable assignments : 20%
- Paper presentation (in lieu of midsem): 25%
- Final exam / Presentation + viva: 35%

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- Other: Class participation, interactions : 0-10%

Module 1: Logic, a language for reasoning

1. Men are mortal
2. Socrates is a man

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Who shaves the barber?

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A language zoo for reasoning: Symbolic logic

- Propositional logic
- Predicate logic
- Temporal logic
- Modal logic

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Theory behind powerful solvers

- SAT solvers
- SMT solvers
- Pseudo-Boolean solvers?

Module 3: Application to reasoning about programs

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int foo(int n) {
    int k, j;
    k = 0; j = 1;
    while (k != n) {
        k = k + 1;
        j = 2*j;
    }
    return(j);
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list * bar(list * i) {
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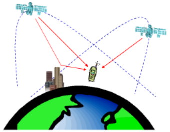
- The “art and science” of proving programs (in)correct – using logic and reasoning!

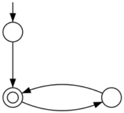
Module 4: Application to Model checking



System $\xrightarrow{\text{satisfy?}}$ specification

System Model $\xrightarrow{\text{model-checking}}$ Spec Model

$\models ?$



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Other linked courses

- CS 433: Automated reasoning: advanced course more practical
- CS 713: Specialized course on Automata & logic connections
- CS 738/739: Model checking, cyber-physical systems
- CS 433: Artificial intelligence (before the NN revolution!?)
- CS 620/xxx: Formal methods and machine learning
- CS 766: Verification of concurrent programs

Links to other domains

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  - Techniques to verify and explain, check robustness of DNNs.
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- Cyber-physical, real-time systems, etc.

In conclusion

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- Formalizing using Logic
- Building efficient algorithms when possible
- Showing undecidability when impossible
- A gateway to the fascinating area of formal methods in CS!

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- Emphasis on home work, reading assigments, presentations
- Honor code will be rigorously imposed
- Visit the course webpage for all details!
  `https://www.cse.iitb.ac.in/~akshayss/courses/cs771`
  - Next class coming Thursday, at 3.30pm on teams.
  - Attend first few classes... to get a taste!
  - If you can't make it due to slot clash, but are interested, mail me!