****

**FIRST SEMESTER 2021-2022**

# Course Handout Part II

Date: 20-8-2021

In addition to Part-I (General Handout for all courses appended to the Time Table) this portion gives further specific details regarding the course.

*Course No.* : *CS F214*

## Course Title : Logic in Computer Science

## Instructor-in-Charge : Venkatakrishnan Ramaswamy ([venkat@hyderabad.bits-pilani.ac.in](mailto:venkat@hyderabad.bits-pilani.ac.in)),

*Instructor* : Tathagata Ray ([rayt@hyderabad.bits-pilani.ac.in](mailto:rayt@hyderabad.bits-pilani.ac.in)) ,

Chavali Lalitha (p20190423@hyderabad.bits-pilani.ac.in)

**Scope and Objective of the Course:**

Logic – rigorously applied – plays a key role in several areas of Computer Science. The formal study of Logic is therefore an important component in the computer scientist’s craft. In this course, we will study propositional logic – syntax, semantics, satisfiability and validity, predicate or first-order logic – syntax, semantics, satisfiability and validity, completeness and compactness. We will briefly outline undecidability and incompleteness. We will cover verification by model checking, linear-time temporal logic (LTL) and computational tree logic (CTL). Additionally, program verification using Hoare logic and proofs of correctness will be discussed. We will briefly introduce modal logic and logic programming.

The objectives of the course are to:

* Understand notions of logic that are used in Computer Science
* Understand proof systems, such as propositional and predicate logic and to master the mechanics of proving statements in them.
* Understand model checking and program verification.

**Textbook:**

1. Michael Huth, Mark Ryan, *Logic in Computer Science – Modelling and Reasoning about Systems.* Cambridge University Press. 2nd Edition. 2004.

Errata: <https://www.cs.bham.ac.uk/research/projects/lics/second_edition_errata.pdf>

**Reference books**

1. Mordechai Ben-Ari, *Mathematical Logic for Computer Science, 2e*, Springer, 2003.
2. Herbert B. Enderton, *A Mathematical Introduction to Logic, 2e*, Academic Press, 2001.
3. John Kelly, *The Essence of Logic*, Prentice-Hall India, Eastern Economy Edition, 1997.
4. I. M. Copi, *Symbolic Logic*, Prentice-Hall India, reprint of 1979 edition by Macmillan.
5. Kenneth H. Rosen, *Discrete Mathematics & its applications*, 8th Ed, McGraw Hill, 2018.

**Course Plan:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Lecture No.** | **Learning objectives** | **Topics to be covered** | **Chapter in the Text Book** |
| 1 | Course introduction | Course overview, Introduction to Logic. Barber’s paradox, Russell’s paradox, the historical need for rigour in Mathematics | 1 |
| 2-4 | Learn basic notions of propositional logic and mechanisms of applying proof rules | Propositional Logic: Propositions, logical connectives, natural deduction, rules for natural deduction | 1.1, 1.2 |
| 5-7 | Identify well-formed formulas, state soundness and completeness arguments for propositional logic | Well-formed formulas, parse trees. Semantics of propositional logic, mathematical induction, soundness and completeness of propositional logic | 1.3, 1.4 |
| 8-10 | Recognize/rewrite formulas in CNF & DNF; verify validity/satisfiability of propositions, | Semantic equivalence, satisfiability and validity, conjunctive normal form (CNF), disjunctive normal forms (DNF), Horn clauses and satisfiability | 1.5 |
| 11 | Learn algorithms for solving satisfiability problems | SAT solvers | 1.6 |
| 12-14 | Identify statements not expressible in propositional logic, know basic notions in predicate logic | Predicate logic: Limitations on expressiveness of propositional logic, introduction to predicate logic | 2.1, 2.2 |
| 15-18 | Construct natural deduction proofs in predicate logic | Rules for natural deduction in predicate logic | 2.3 |
| 19-20 | Understand semantic entailment, validity and satisfiability in predicate logic | Semantics of predicate logic | 2.4 |
| 21 | Understand the broad notion of undecidability | Undecidability and expressibility of predicate logic | 2.5, 2.6 |
| 22 | Construct state machines for simple problems | State Machines and Graphs | 2.7 |
| 23-25 | Understand how to write correct LTL formulas | Verification by model checking: Introduction & motivation. Linear-time Temporal logic (LTL) – syntax, semantics, equivalences, connectives. | 3.1, 3.2 |
| 26-27 | Familiarity with model checking | Model checking with examples. | 3.3 |
| 28-29 | Understanding CTL | Branching-time logics. Computation tree logic (CTL) – syntax, semantics, equivalences and connectives | 3.4 |
| 30 | Understand relationship between LTL, CTL and CTL \* | CTL\* and expressive powers of CTL and LTL | 3.5 |
| 31 | Basic understanding of model-checking algorithms | Brief overview of model-checking algorithms | 3.6 |
| 32 | Understand program verification with example scenarios | Program verification: Introduction & Motivation | 4.1 |
| 33-34 | Recognize program variables and logical variables in verification. | A framework for software verification, Hoare logic | 4.2 |
| 35-36 | Construct partial correctness proofs | Proof calculus for partial correctness | 4.3 |
| 37-38 | Construct total correctness proofs | Proof calculus for total correctness | 4.4 |
| 39 | Basic understanding of the role of modal logic | Brief introduction to modal logic and logic programming | 5 |
| 40 | Big picture view of logic and its role in Computer Science | Summary and review of course |  |

**Evaluation Scheme:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Component** | **Duration** | **Weightage (%)** | **Date & Time** | **Nature of Component** |
| Mid-semester Test | 90 minutes | 35% | As announced in the Time Table | Closed book |
| Programming Assignment- 1No. | Take-home | 15% | Submission deadlines to be announced | Open book |
| Assignments (2 Nos.)  (Assignment 1 will be  pre-midsem) | Take-home | 10% | Submission deadlines to be announced | Open book |
| Comprehensive exam | 120 minutes | 40% | 22/12/2021 | Closed book |

**Consultation Hour:** Thu, 9am-9:50am at <https://whereby.com/vramaswamy> or by prior appointment.

**Notices:** Will be posted online on a course management system, the details of which will be announced in class. The system will be linked to BITS Pilani email, which students are expected to check several times a day.

**Make-up Policy:**

No make-ups will be offered, except in case of medical or family emergencies of a severe nature or other unavoidable extenuating circumstances, as judged by the Instructor-in-Charge, for which prior permission must be sought, where feasible. Documented evidence (e.g. a Doctor’s note) will be necessary before consideration of such a request. Additionally, a make-up for the comprehensive exam will require approval from the Dean, AUGSD.

**Academic Honesty and Integrity Policy**: Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

**INSTRUCTOR-IN-CHARGE**

**CS F214**