Logic and Computation

CS 245 / Fall 2012

Dr. Igor Ivkovic

iivkovic@uwaterloo.ca

Motivational Quotes

- A fear of heights is illogical. A fear of falling, on the other hand, is prudent and evolutionary.
- I would if I could, but I can't so I shan't.
  – Dr. Sheldon Cooper, The Big Bang Theory

- The problems of language here are really serious. We wish to speak in some way about the structure of the atoms. But we cannot speak about atoms in ordinary language. – Werner Heisenberg
- Logic will get you from A to B. Imagination will take you everywhere. – Albert Einstein

[BrainyQuote. Online, 2012. http://www.brainyquote.com]

Syllabus /1

- Logic and Computation
  CS 245 (Section 002) – Fall 2012
- **Instructor:** **Dr. Igor Ivkovic**
- **Email:** **iivkovic@uwaterloo.ca**
- Office hours: By appointment in DC 2555E
- Lectures:
  (Section 002) 11:30-12:50TTh in MC 2054

My CARE™ Approach

- **What can you expect from me as your instructor?**

  Clear and Technical Lectures

  Approachable and Helpful

  Resources and Material for Studying

  Engaging Theory and Practical Applications

Syllabus /2

- Course Description:
  - Propositional and predicate logic. Soundness and completeness and their implications.
  - Unprovability of formulae in certain systems. Undecidability of problems in computation, including the halting problem.
  - Reasoning about programs. Correctness proofs for both recursive and iterative program constructions.
  - Prerequisites: (CS 136, 145 taken in Fall 2010 or earlier, or CS 146), MATH 135; Honours Mathematics students only.
  - Antirequisites: PMATH 330, SE 112/212.

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- Course Objectives:
  - Formalize English sentences into properly formed formulae in the propositional and predicate logics, and to interpret such formulae in English.
  - Prove the correctness (or incorrectness) of simple formulae in the propositional and predicate logic, and find errors in purported proofs.
  - Demonstrate a basic understanding of transformational (algebraic) proof for proving statements in the propositional and predicate logic.
  - Explain the concepts of partial decidability and of undecidability, giving examples of each; apply reductions to demonstrate certain problems have these difficulties.
  - Prove the correctness of simple functional and/or imperative programs.

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- Announcements, Assignments, and Grades:
  - http://www.student.cs.uwaterloo.ca/~cs245/
- Lecture Notes for Section 002 on LEARN:
  - **https://learn.uwaterloo.ca/**
- Attendance:
  - **You are highly encouraged to attend all lectures and keep detailed class notes.**
- Course Textbooks (both are optional):
  - Zhongwan: "Mathematical Logic for Computer Science", 2nd Edition, World Scientific, ISBN 9810230915.
  - Nissanke: "Introductory Logic and Sets for Computer Scientists", 1st Edition, Addison Wesley, ISBN 0201179571.

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- Grading Scheme:
  - Assignments — 25% (five assignments)
  - Midterm Exam — 30% (held on Nov 1st, 04:30-06:20Th)
  - Final Exam — 45% (scheduled by the Registrar)
- Exam Policy:
  - Students are required to obtain a passing grade for the weighted grade of the midterm and the final exam. **If the weighted grade for the midterm and the final exam is less than 50%, the assignments grade will not be counted.**
  - A missed midterm exam will receive a mark of 0, unless there is a valid documented reason. If a documented reason is provided for missing the midterm, its weight is applied to the final exam.

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- Final Exam Policy:
  - If a documented reason is provided for missing the final exam, a grade of incomplete (INC) is given, and the final exam must be written at the end of the next term the course is offered.
  - **A copy of the documented reason must be given to the instructor.** For a missed final exam, upon the receipt of a valid doctor's note, the student's term work is evaluated to determine if a grade of INC is suitable.
  - If an INC is granted, the student's grade will be calculated using the weightings of the course components from the term the student was registered, the student's term marks from the registered term, and the mark from the final exam when it is written. The final exam should be written with the scheduled exam in the following semester.
  - **A copy of the documented reason must also be given to the Instructional Support Coordinator (ISC) for the course.**

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- Assignments:
  - There will be five course assignments. The assignments will be due throughout the term, and will be typically due on Mondays by 23:55pm. Assignments must be submitted in the assignment drop boxes in the MC building.
  - **No late submissions will be accepted.**
  - An assignment not handed in receives a mark of 0, unless there is a documented reason. If a documented reason is supplied, the weight of the missing assignment is distributed across the other assignments. A copy of the documented reason must be given to and approved by the instructor.

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- Assignments/Midterms Delivery:
  - Marked assignments will be returned in the student's tutorial section, unless the student requests otherwise to the instructor.
  - Papers not claimed before the submission of final grades will be destroyed in compliance with the UW's confidential shredding procedures.
- Group Work Policy:
  - **All assignments and exams must be done individually and no group work is permitted.**

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- Assignment Remarking:
  - Attach a sheet of paper to your assignment clearly stating the questions that you want remarked. Include any supporting evidence for your case.
  - No more than two weeks after the assignment is handed back, return your assignment with the remarking page to the tutor during a tutorial or an office hour.
  - **Note that the entire assignment is examined when remarking, so the assignment could receive a grade lower than the one originally assigned.**

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- In-Class Discipline:
  - **Students are encouraged to attend all lectures, but are required not to be disruptive during lectures out of respect for their classmates and for the instructor.**
  - Disruptive behaviour includes talking with people next to them, playing YouTube videos, Facebook and Twitter updates, etc. Also note that comments and feedback about the course are welcome, but outside of lecture time.
  - A student who is found to be disruptive during lectures will be given only one verbal warning for the term.
  - At the instructor's discretion, if the same student continues to be disruptive, for each incident of disruption, they will be penalized 3% of their final mark for the course, and may be asked to leave the lecture during which the disruption incident occurred. They would also be liable for any missed milestones during the lecture.

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- Academic Integrity:
  - In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Check the Office of Academic Integrity's website for more information,
  - http://uwaterloo.ca/academic-integrity/
- Grievance:
  - A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4,
  - http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm
  - When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

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- Academic Discipline:
  - A student is expected to know what constitutes academic integrity to avoid committing academic offenses and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) or about “rules” for group work/collaboration should seek guidance from the course professor, academic advisor, or the undergraduate associate dean. For information on categories of offenses and types of penalties, students should refer to Policy 71, Student Discipline,
  - http://www.adm.uwaterloo.ca/infosec/Policies/policy71.htm
  - For typical penalties check Guidelines for the Assessment of Penalties,
  - http://www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm

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- Avoiding Academic Offenses:
  - Most students are unaware of the line between acceptable and unacceptable academic behaviour, especially when discussing assignments with classmates and using the work of other students. For information on commonly misunderstood academic offenses and how to avoid them, students should refer to the Faculty of Mathematics Cheating and Student Academic Discipline Policy,
  - http://www.math.uwaterloo.ca/navigation/Current/cheating_policy.shtml
- Appeals:
  - A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72, Student Appeals,
  - http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm

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- Note for Students with Disabilities:
  - The Office for Persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.

Commonly Used Notation /1

- For a set S = {0, 2, 4, 6, 8, 10, …}
  - The **extension** of the set are its members, (i.e., 0, 2, 4…)
  - The **intension** of the set is the common property of its members (i.e., non-negative integers divisible by 2)
- Common properties of sets:
  - $S \subseteq T$ if for $\forall x \in S \Rightarrow x \in T$
  - $S = T \Leftrightarrow S \subseteq T \wedge T \subseteq S$ ($\wedge$ is the logical AND)
  - $S \subseteq T$ is a proper subset of T if $S \neq T$ (i.e., if $T \subseteq S$ is not true)
  - $\{\alpha\} = \{\alpha, \alpha\} = \{\alpha, \alpha, \alpha\} = \{\alpha, \alpha, \alpha, \ldots\}$
  - $\{\alpha, \beta\} = \{\beta, \alpha\} = \{\beta, \beta, \alpha\} = \{\alpha, \alpha, \beta, \beta\}$

    (I.e., the order and duplication is irrelevant in unordered sets)
  - $\emptyset$ = (has no members) and $\emptyset \subseteq S$ for every set S
  - $S \cup T = \{x \mid x \in S \vee x \in T\}$ ($\vee$ is the logical OR)

Commonly Used Notation /2

- Additional properties of sets:
  - $\langle \alpha, \beta \rangle = \langle \gamma, \delta \rangle$ only if $\alpha = \gamma \wedge \beta = \delta$

    (I.e., the order is important in ordered sets)
  - $S_1 \times S_2 \times \ldots S_n = \{\langle x_1, x_2, \ldots x_n \rangle \mid x_1 \in S_1, \ldots x_n \in S_n\}$
  - $S^2 = \{\langle x_1, x_2 \rangle \mid x_1, x_2 \in S\}$
  - $S^3 = \{\langle x_1, x_2 , x_3 \rangle \mid x_1, x_2, x_3 \in S\}$

    …
  - $S^n = \{\langle x_1, x_2, x_3, \ldots x_n \rangle \mid x_1, \ldots x_n \in S\}$
- Function **f** is a set of ordered pairs | if $\langle x, y \rangle \in$ **f** $\wedge$ $\langle x, z \rangle \in$ **f** then y = z
  - The **domain** of **f** is the set of all x | $\langle x, y \rangle \in$ **f** for some y
  - The **range** of **f** is the set of all y | $\langle x, y \rangle \in$ **f** for some x

Commonly Used Notation /3

- Additional properties of function **f**
  - If domain(**f**) = S and range(**f**) $\subseteq$ T then **f** maps S into T
  - If f(x) = f(y) implies x = y then **f** is called an **injection**
  - range(**f**) = T then f is called a **surjection**
- For a binary relation R such that xRy
  - R is **reflexive** on S $\Leftrightarrow$ for any x $\in$ S, xRx
  - R is **symmetric** on S $\Leftrightarrow$ for any x, y $\in$ S, when xRy then yRx
  - R is **associative** on S $\Leftrightarrow$ for any x, y, z $\in$ S, when both xRy and yRz then xRz
  - R is called an **equivalence relation** on S $\Leftrightarrow$ R is reflexive, symmetric, and associative on S
  - **For any x $\in$ S, the set {y $\in$ S | xRy, where R is equivalence relation} is called the R-equivalence class of x**

Food for Thought

- Read
  - **Chapter 1 (Introduction) from Zhongwan's textbook**