Course Proposal

Computability and Complexity

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KFUPM

May 2008

The Chairman
Department of Mathematics and Statistics
King Fahd University of Petroleum and Minerals

May 20 2008

Dear Chairman,

Please give your consideration to to enclosed course proposal. The title of the course is *Computability and Complexity* and is intended to run for the first time in the 082 semester. The course will cover the basics of computability theory from a mathematical perspective, and will include modules on Kolmogorov complexity and resource-bounded computation.

The students will be introduced to the the fundamental mathematical work of Alan Turing and Kurt Gödel amongst others, and will be shown some of the most interesting theorems of mathematical logic in the 20^{th} century. They will also learn about the famous unsolved problem P=NP? and obtain a appreciation for some of the issues involved in polynomial time computation. We will also touch on the concept of randomness and Komolgorov complexity - a research area in which I am both interested and active.

This course is intended to prepare students for further study in the area of mathematical computability theory, but for those students who do not continue in this direction of study, the course will provide an appreciation of some of the academic issues behind modern computing.

At first I am asking that this course be accepted for the degree of Bachelor of Science in Mathematics, but if we manage to attract enough computer science students, I will apply for it also to be counted as a core course for computer science degrees. I hope that this course will go some way to convincing students interested in computer science, that the study of pure mathematics is also an option for them.

Sincerely,

Stephen Binns
Assistant Professor
Department of Mathematics and Statistics
KFUPM

Proposed Course Specification: *Computability and Complexity*

0. Department	Department of Mathematics and Statistics

A. Course Identification and General Information

1. Course title	Computability and Complexity
2. Credit hours	3
3. Program	BS Mathematics
4. Faculty	Dr Stephen Binns
5. Level	4th semester and above
6. Prerequisites	MATH 232 or ICS 254
7. Corequisites	Nil
8. Location	Main campus

B. Aims and Objectives

1. Summary of main learning outcomes	An introduction to the modern mathematical theory behind computabilty and algorithmic complexity. The students will be exposed to the basic concepts and techniques needed to continue with study of theoretical computer science and mathematical computability theory. For students who will not continue further in this area, it is intended to give an appreciation of the theory and issues underlying contemporary computing and information technology.
2. Course development plans	The course will be initially offered to those students taking a BS in mathematics, however we intend to attract computer science students as well. It is expected that a variety of web-based material will be used including Java applets simulating Turing machines. Some use of actual computer coding may be appropriate depending on the students' capabilities in these areas. A WebCT page will be set up if the class size warrants it. The chosen textbook lends itself to self-study and, again depending on class size, some project work, including class presentations, is possible.

C. Course Description

Proposed Bulletin description: The course will consist of the basics of mathematical computability theory including Turing machines, computable sets and languages, computable enumerability and decidability. Fundamental theorems such as the Recursion Theorem will be proved. The decidability of logical theories will be addressed and the proof of Gödel's famous Incompleteness Theorem will be sketched. The second half of the course will cover Algorithmic complexity theory and the major open problem P=NP? will be dealt with in detail.

1. Topics to be covered	See attached syllabus.
2. Course Components	The course will consist of 3 lectures per week, two major exams and a final exam.
3. Additional private study or learning hours	The students will be expected to spend an average of 3 hours per week on homework. In addition there will be two projects to be completed in the semester. Approximately 5 hours to be spent on each project.
4. Development of Learning Outcomes in Domains of Learning	
a. Knowledge	
(i) Knowledge to be acquired	Basics of computability Theory, Complexity Theory and Randomness. Open problems especially P=NP? will be explained. An understanding will be obtained of the similarity between certain types of algorithms with respect to computational feasibility.
(ii) Teaching strategies	Lectures will be the primary method of instruction. Each new topic will be motivated at first asking an open-ended question. The students will propose answers which will be critiqued by the instructor and the class. An introduction will then be given to the standard mathematical analysis of the question. More details will be added in subsequent lectures and questions arising from the analysis will be raised and dealt with. Along the way students will be expected to answer basic questions based on the mathematical analysis
(iii) Methods of assessment	The assessment will be based on exams, projects and quizzes. The projects will aim to evaluate students' understanding as well as give them an opportunity to investigate more thoroughly issues arising from the material presented in lectures. Quizzes will test that students' current knowledge of the material, and exams will test the students' overall understanding of the material. All evaluation methods will test both understanding and problem-solving ability.

C. Course Description cont.

b. Cognitive skills	
(i) Cognitive skills to be developed	The ability to reason logically and precisely about a well-defined mathematical subject. The ability to express arguments in the language of mathematics and computer science. The ability to argue cogently with mathematical symbolism. The development of the ability to think informally but accurately about the fundamental intuitive concepts of computability and complexity
(ii) Teaching strategies	The students will be expected to produce formal mathematical proofs. These will be corrected and returned to the student for improvement if necessary. It is important that the student learns to internalise the requirements of a correct mathematical argument, and feedback will be given through homework correction and review of quizzes and exams. Opportunity will be given for students to improve their homework grades by reviewing and correcting their own work.
(iii) Methods of assessment	Quizzes and exams will contain a mixture of questions designed to assess both general understanding and problem solving ability. True/false questions and short explanation questions will be used to evaluate a student's intuition and understanding. More detailed questions will be used to evaluate accuracy and logical argument.
c. Interpersonal skills and responsibility	Some group work may be assigned but in general the students will work individually.
(i) Skills to be developed	
(ii) Teaching strategies	
(iii) Methods of assessment	
(d) Communication Information technology and numerical skills	
(i) Skills to be developed	Professional communication of ideas and arguments.
(ii) Teaching strategies	A WEBCT page will be created with a chat-room to discuss homework and Projects
(iii) Methods of assessment	No direct assessment of these skills
(e) Psychomotor skills	Not Applicable
(i) Skills to be developed	
(ii) Teaching strategies	
(iii) Methods of assessment	
6. Schedule of assessment tasks	

D. Student Support	
1. Availability of faculty for consultation and advice	The lecturer will be available for office hours on Sundays and Tuesdays, and on Saturdays, Mondays, and Wednesdays by appointment. After-hours help can be given via WebCT.
E. Learning Resources	
1. Required texts	Introduction to the Theory of Computation (2nd Ed.) *by Michael Sipser,* Course Technology (2005)
2. Essential references	
3. Recommended books and reference material	A variety of extra books and material exist in the main library. Minimal use of these will be required as the proposed textbook is very comprehensive.
4. Electronic materials	
5. Other materials	
F. Facilities required	
1. Accommodation	One lecture room
2. Computing resources	Projection facilities for electronic slides
3. Other resources	
G. Course evaluation and Improvement Processes	
1. Strategies for obtaining student feedback on quality of teaching.	Standard course evaluation form. Anonymous feedback form on WebCT. Detailed course evaluation by students.
2. Other strategies for evaluation of teaching	Review by the lecturer of the amount and nature of the material covered.
3. Processes for improvement of teaching	Attending advanced WebCT seminar to improve knowledge and delivery of on-line teaching possibilities.
4. Processes for verifying standards of student achievement	Comparison of grades with similar level mathematics courses.
5. Action planning for improvement	Examination of on-line student feedback will lead to a review of the amount of material covered and a resulting adjustment in future offerings of this course. In particular, the section on Kolmogorov complexity can either be expanded or eliminated if required by time constraints.

Proposed Syllabus - Computability and Complexity
Section numbers refer to the proposed textbook:
Introduction to the theory of Computation 2nd edition by Michael Sipser.
PWS Publishing Company 2005.

Week	Topic	Section	Topic	Hours
1	Computability	3.1	Turing Machines	3
		3.2	Variants of Turing machines	
2	Decidability	3.3	Algorithms and the Church-Turing Thesis	3
		4.1	Decidable Sets	
		4.2	Universal Turing Machines	
3	Undecidable Problems	4.2	The Halting Problem	3
		5.2	Reducibility	
		5.2	Post Correspondence Problem	
4	Turing Recognisable Languages	5.3	Mapping reducibility	3
			Computably enumerable sets	
			Turing Completeness	
5	Fundamental theorems of Computability Theory		The Enumeration Theorem	3
			The Parameter Theorem	
		6.1	The Recursion Theorem	
		First exam		
6	Logical theories and Decidability	6.2	Formulas and Proofs	3
		6.2	Decidable Theories	
		6.2	Gödel's Incompleteness Theorem	
7	Information and Kolmogorov Complexity	6.3	Descriptions	3
		6.3	Kolmogorov complexity	
		6.3	Compressibility and Randomness	
8	Complexity Theory	7.1	Bounded Resources	3
		7.1	Big-O and Little-O notation	
		7.2	Polynomial-time computation	
9	Nondeterministic Computation	3.2	Nondeterministic Turing machines	3
		7.3	The Class NP	
		7.3	$P \neq NP$?	
		Second exam		
10	NP completeness	7.4	Polynomial time reducibility	
		7.4	NP complete problems	
		7.4	SAT	
11	Cook-Levin Theorem	7.4	SAT	3
		7.4	SAT NP Complete	
		7.5	3-SAT	
12	Other NP-complete problems	7.5	CLIQUE	3
		7.5	HAMPATH	
		7.5	VERTEX-COVER	
13	Space complexity	8.1	Space complexity classes	3
		8.1	Savitch's Theorem	
		8.2	PSPACE	
14	PSPACE problems	8.3	TQBF	3
		8.3	PSPACE completeness	
		8.3	Games and PSPACE	

List of American Schools Using the Proposed Textbook:

San Jose State Univ
California State Univ
California State Univ
Univ of Nevada
U of Alaska - Anchorage
Washington State Univ
University Washington
Lewis-Clark State College
Montana Tech
Brigham Young Univ
Idaho State University
California State Univ
California State Univ
Community College Of Denver
Univ of Texas at Dallas
University Of Texas
El Paso CC
Univ of New Mexico
University Of Houston
Univ of Arizona
Louisiana State Univ
Southern Univ A&M Coll
Univ of New Orleans
Univ of Arkansas
Arkansas State Univ
Univ of Missouri
Univ of Missouri
Wichita State Univ
Univ of Nebraska
Metropolitan State Univ
California State Poly Univ
Univ of California
Dixie Jr Coll
Portland State Univ
Univ of Oregon
University Of Washington
Boise State Univ
Montana State University
Washington State University
BYU IDAHO
Utah Valley State College
Univ of Nevada
Texas A&M University
University Of Wyoming
Baylor Univ
Univ of Texas - Pan American
New Mexico State University
University Of Texas
Arizona State Univ
LA Tech College
McNeese State Univ
Univ of Louisiana
OK State Univ
Univ of Central Oklahoma
Columbia College
Washington Univ in St Louis
Avila College
Creighton University
Univ of Minnesota
Univ of Iowa