AN INTRODUCTORY ADAPTIVE SYSTEMS COURSE FOR UNDERGRADUATE COMPUTER SCIENCE MAJORS

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Introduction

This paper describes the development and implementation of an introductory survey course spanning topics in automata theory, biological information processing, and artificial intelligence. The course, Computing Science 464, is designed (and required) for undergraduate honors students in the University of Alberta Computing Science Department. Normally taken in the third year of undergraduate study, the course has the following catalog description:

> CMPUT 464. Introduction to Adaptive Systems. *3
> Finite and infinite automata and their relation to formal languages; brain models and genetic systems; introduction to artificial intelligence. Prerequisite: Computing Science 314.

In the above description, *3 means that the course meets 3 hours each week for one academic term (about 13 weeks). The prerequisite is a discrete structures course which all Computing Science students take in the second year.

The following sections describe the factors leading to the development of this course, outline the subject matter in some detail, and attempt to evaluate the first year's experience with the course (as taught by the author).

Rationale

The development of 464 was motivated by factors particular to the Computing Science curriculum at the University of Alberta. As described by Tartar and Penny [7], the undergraduate program is organized around three principal areas of concentration or "streams": Numerical Mathematics (stream A), Systems and Languages (stream B), and Formal and Adaptive Systems (stream C). Despite possible appearances to the contrary, stream C is not just a "default" area to cover everything not included in streams A and B. Rather, the organization of stream C reflects an integrated view of the subject matter embraced by the fields of (a) switching, automata, and computability theory, (b) biological information processing and modelling of biological systems, and (c) artificial intelligence. The author assumes primary responsibility for this view, which is also reflected in the combination of subjects in 464.

Another feature of the curriculum requiring some explanation is the peculiar status of courses with 500-level numbers at the University of Alberta. Such courses function simultaneously as advanced undergraduate courses (taken by fourth year students with adequate preparation) and as beginning graduate courses. Thus 500-level courses have a mix of undergraduate and graduate students, often in nearly equal proportions. This arrangement has both advantages and disadvantages, but creates special problems when the course is a department's first offering in a subject area. Prior to the introduction of 464, the department's first courses in stream C were at the 500 level (with the exception of some material in a switching theory course). It was felt that the undergraduates, with their heavier course loads and lesser academic maturity, were at a disadvantage and tended to dilute the courses for graduate students.

Approximately two years ago, a task force of the departmental curriculum committee produced a revision of the stream C curriculum designed to cope with the above problem, as well as with other difficulties associated with a recent rapid growth of stream C course offerings. The introduction of 464 as part of this revision served two goals: (a) mandatory exposure to stream C subject matter for students contemplating graduate study (most of whom are honors students); (b) prerequisite preparation in stream C subjects for students taking 500-level stream C courses in the fourth year.

Figure 1 is a diagram of the current organization of the undergraduate stream C curriculum (connecting arrows are prerequisites). University of Alberta course titles are shown with Curriculum 68 [1] numbers in parentheses for equivalent courses. Obviously there is no Curriculum 68 equivalent for 464, which is not particularly surprising since the report recommends no stream C material for undergraduates (with the exception of the sequential machines course (I7) for students specializing in computer organization and design). Such an omission does not shake the author's conviction that exposure to stream C material is an integral part of proper preparation for graduate study in almost any area of computer science.

Early exposure to stream C material is also of special value to the student contemplating graduate work within stream C. Too often a student enters graduate study "interested" in automata theory or artificial intelligence but with little idea of what the subject matter of these fields really is. In both fourth year and graduate study, a student who has taken 464 can make a knowledgeable selection among the 500-level courses shown in Figure 1 (or their equivalents at other institutions). It becomes possible for such a student to complete advanced (600-level) courses in his area of specialization, even in the course of a short Master's degree program.

Organization

This section describes the course content and student workload in 464 as it was taught for the first time in the academic year 1972-3. If the course had a single unifying theme, it was the commonality of approach to machines, be they artificial or natural, found in the various disciplines comprising stream C. Each of the subject headings listed below consumed approximately one week (three 1-hour lectures).

1. FINITE AUTOMATA: McCulloch-Pitts neurons; logical nets; state transition functions; regular expression.

2. TURING MACHINES: languages and machines; Turing and Wang formulations; universal Turing machine; halting problem; recursive functions.

3. CELLULAR AUTOMATA: definitions and examples; computer simulation; von Neumann and Arbib formulations; biological modelling.

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                           465: Threshold
                           Logic and        <-┐
                           Learning machines  |
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                           462: Switching     |
                        ┌-> Theory and Logical--|
                        |  Design (I6)        |
                        |                     |
                        |                     |
                        |                     └-> 571: Sequential
314: Introduction       |                     ┌-> Machines (I7)
to Discrete           --|                     |
Structures (B3)         |                     |
                        |                     |-> 572: Automata and
                        |                     |   Computability (A7)
                        |  464: Introduction  |
                        └-> to Adaptive      --|
                           Systems            |
                                              |-> 551: Artificial
                                              |   Intelligence (A9)
                                              |
                                              └-> 555: Computing in
                                                  Biological Systems
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Figure 1. Undergraduate Stream C Curriculum

4. BIOCHEMICAL INFORMATICN PROCESSING: structure and components of living cell; genetic code and protein synthesis; genetic control processes (enzyme induction); genetic information transmission.

5. NEURAL INFORMATION PROCESSING: architecture of central nervous system; information transmission by neurons; information processing in visual system.

6. COMPUTERS AND INTELLIGENCE: neural network simulation; introduction to artificial intelligence; overview of artificial intelligence research.

7. GAME PLAYING: game trees and heuristic search; Samuel checker player; chess-playing programs.

8. PROBLEM SOLVING AND THEOREM PROVING: propositional and predicate calculi; Logic Theorist and General Problem Solver; resolution theorem proving.

9. NATURAL LANGUAGE PROCESSING: basic linguistic concepts; survey of computer models; Quillian's TLC; Winograd system.

Class time not accounted for in the above outline was consumed by review sessions, examinations, discussion of homework assignments, and a few guest lectures. The instructor's absence for a week forced the deletion of an anticipated week on pattern recognition. Also, with so many topics to be surveyed, a compromise had to be effected between superficial remarks on some subjects (e.g., recursive functions) and more detailed treatment of selected research projects (e.g., Samuel's checker player, Winograd's system).

In addition to assigned readings (see discussion of textbooks below), students wrote two examinations, after topics 5 and 9 in the outline. Major homework assignments required completion of problem sets in automata theory and artificial intelligence and short essays on biological information processing and artificial intelligence. It should be noted that the course was "computer independent" in the sense that no programming assignments were given. The desirability of this feature is perhaps debatable, although an almost entirely theoretical course of this nature seems to provide good balance for students who are doing extensive programming in most of their other third-year courses.

<u>Textbooks</u>

The author is not aware of any single text which adequately introduces the wide ranging subject matter of 464. For the first year, several books were selected in an attempt to cover as much of the material as possible at minimum cost to the student. The books were supplemented with handouts containing photocopied excerpts of essential material not found in the texts. To cover the section on cellular automata, descriptions of von Neumann's model (as summarized by Burks [4]) and Arbib's model (in Chapter 10 of [3]) were distributed. To supplement the section on natural language processing, students received the introductory portion of Winograd's article [8].

Perhaps the most useful textbook is Arbib's delightful and inexpensive <u>Brains, Machines, and Mathematics</u>, [2]. Though out of date in some respects, this book provides a concise, integrated introduction to topics in automata theory, neural information processing, and cybernetics. Students in 464 were required to read most of this book. A good comprehensive introduction to automata theory is Minsky's <u>Computation: Finite and Infinite Machines</u> [5]. Unfortunately this book not only is expensive but also contains much more material than can comfortably be accomodated in 464. Students were encouraged to read selected chapters (see Discussion). Wooldridge's paperback <u>Mechanical Man: The Physical Basis of Intelligent Life</u> [9] provides a good highly readable introduction to biological information processing (both biochemical and neural), followed by a fair treatment of selected artificial intelligence topics, all from the point of view of an information scientist. Students read most of this book. Despite its rather high price, Slagle's <u>Artificial Intelligence: The Heuristic Programming Approach</u> [6] remains the best concise introduction to a broad range of topics in mainstream artificial intelligence. Students read over half of this book during the last few weeks of the course.

Discussion

The first experience with 464 seems to have been largely successful. Almost all of the initial enrolment of around 60 students completed the course with a passing grade. Another group of about the same size has pre-registered for this year. Since the third year honors class contains approximately 40 students, the course appears to attract some students for which it is not required. Almost all of the enrolment is from Computing Science however.

Student assessment of the course, through the University of Alberta Course Guide, was generally favorable, but included a few comments about the course being a "waste of time" or "too easy." The distribution of grades did not suggest that there were many students to whom these remarks might apply. The instructor heard no objection to the absence of programming assignments, although the students obviously enjoyed live demonstrations of graphics programs for simulating Turing machines and simple cellular automata. The author's expectation that the students' penchant for programming is satisfied by other third year courses seems correct.

The greatest difficulties in the first offering of 464 were related to reading materials. The mixed bag of texts and handouts described above did not help to confirm the unified approach to the varied subject matter that the instructor wished to project. Because of its scarcity and cost, most students did not buy the Minsky book [5] and many did not read it. This deficiency was partially compensated by a brief introduction to sequential machines which a majority of students had received in their switching theory course (462) the previous term. Nevertheless, the author hopes this year to supplement the reading material, and replace some of it, with an extensive set of course notes (which could eventually develop into a textbook if there were sufficient demand).

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References

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