The University of Western Ontario

Computer Science 9562/4462b, Winter 2009

DNA COMPUTING

Description

Biomolecular (DNA) computing is a new computation paradigm which proposes the use of molecular biology tools to solve mathematical problems. Computing with DNA offers a completely new way of looking at and performing computations: the main idea is that data can be encoded in DNA strands, while molecular biology laboratory techniques (called *bio-operations*) that involve manipulation of DNA strands in test tubes can be used to simulate arithmetical and logical operations.

Besides the novelty of the approach, and in spite of the technical difficulties that arise from the error rates of bio-operations, there are several reasons why computing with DNA might have advantages over electronic computing. These include memory capacity, massive parallelism, and power requirements. Indeed, one gram of DNA, which when dry would occupy a volume of approximately one cubic centimetre, can store as much information as approximately one trillion CDs. Moreover, computing with DNA provides enormous parallelism. In Adleman's first DNA computing experiment solved an instance of the Directed Hamiltonian Path Problem) which was carried out in one fiftieth of a teaspoon of solution, approximately 10^{14} oriented edges were simultaneously concatenated in about one second. It is not clear whether the fastest available supercomputer is capable of such a speed. Finally, as far as energy efficiency is concerned, in principle one joule is sufficient for approximately 2×10^{19} ligation operations, while existing supercomputers operate in the significantly smaller range of 10^9 operations per joule.

These practical incentives and the fascination of being able to perform computations with biological means have inspired many researchers to pursue the challenging topic of DNA computing. It is anticipated that the pioneer research in this field of intersection between computation and biology will have great significance in many aspects of science and technology. Indeed DNA computing sheds new light onto the very nature of computation, and opens vistas for computability models totally different from the classical ones. In an optimistic way, one may think of an analogy between the work of researchers in this area and the work on finding models of computation carried out in the 30s, which has laid the foundation for the design of today's electronic computers.

In this course we explore ways of encoding information in DNA sequences, molecular procedures used for computation, classes of problems that can be solved by DNA computing, and the feasibility and advantages of a DNA computer.

Course webpage: http://www.csd.uwo.ca/~lila/cs662.html

Prerequisites
The course has no *formal* prerequisites. However, students with backgrounds other than computer science should contact the instructor.

Instructor
Lila Kari, 385 Middlesex College, Tel. 661 2111 ext. 86894, lila@csd.uwo.ca, http://www.csd.uwo.ca/~ lila,

Class meetings: Wednesdays, 9:30am-10:30am, Fridays 9:30am-11:30am, MC320

Office hours: Wednesdays 10:30-11:30, MC 385.

Textbook: "Theoretical and Experimental DNA Computation", Martyn Amos, published by Springer, 2005.

Topics
• Introduction to DNA computing • Encoding information in DNA • Bio-operations • DNA models of computation • DNA algorithms • Error rates in DNA computing

Student evaluation

There will be five short assignments, worth 2% each, for a total of 10% of the final grade. They will be scheduled roughly every two weeks. In addition, each student will give a lecture on a topic agreed on with the instructor and submit a term paper on the same topic. For the graduate students, the lecture will be worth 30% and the term paper worth 60% of the final grade. For the undergraduate students, the lecture will be worth 45% and the term paper will be worth 45% of the final grade. In addition, the lecture and term paper will be evaluated differently for the undergraduate and graduate students: For the graduate students the emphasis will be on in-depth research of the topic and both analysis and synthesis of the researched material, while for the undergraduate students the emphasis will be on understanding and structured analysis of the topic. (Depending on the number of participants, the way of conducting the course may have to be modified.)

Assigment and Final Paper schedule (tentative)
Assignment 1 due date: Wednesday, Jan. 21, 1:30PM (summary of weeks of Jan 5 and Jan.12)
Assignment 2 due date: Wednesday, Feb. 4, 1:30PM (summary of weeks of Jan 19 and Jan 26)
Assignment 3 due date: Wednesday, Feb. 25, 1:30PM (summary of weeks of Feb 2 and Feb 9)

Assignment 4 due date: Wednesday, March 18, 1:30PM (summary of weeks of Feb 23, Mar 2, Mar 9)
Assignment 5 due date: Wednesday, April 8, 1:30PM (summary of weeks of Mar 16, Mar 23, Mar 30)

Student Presentations start after the Conference Week (Feb 16- Feb 20) and the exact date will depend on the class size and chosen topic.

Final Paper due date: Wednesday, April 8, 2009, 10:30am.

Assignments

Submission of Assignments: Please use the *Assignment Submission Form*, available at http://www.csd.uwo.ca/faculty/submission_form.html and submit your assignment in the CS4462 locker (TBA).

Late Assignment Policy:

Late assigments cost 10% of the assignment per day late unless an extension has been granted. After a week has passed from the due-date no assignments will be accepted for marking.

If for any reason the assignment a schedule cannot be adhered to, the marks will be pro-rated. (For example, the 5 assignments are worth 10% of the overall mark for the course. If an assignment has to be cancelled for any reason, the remaining assignment weights will be pro-rated to add up to 10%.)

Every effort will be made to have assignments marked and handed back within 3 weeks of the hand-in date, preferably sooner.

Extensions: Extensions may be granted only by the course instructor. If you have serious medical or compassionate grounds for an extension, you should follow the procedure for Academic Accommodation for Medical Illness.

Ethical Conduct

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:

http://www.uwo.ca/univsec/handbook/appeals/scholoff.pdf

Plagiarism: Students must write their essays and assignments in their own words. Whenever students take an idea, or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. Plagiarism is a major academic offence.

All assignments are individual assignments. You may discuss approaches to problems among yourselves; however, the actual details of the work (assignment writing, answers to concept questions, etc.) must be an individual effort.

The standard departmental penalty for assignments that are judged to be the result of academic dishonesty is, for the student's first offence, a mark of zero for the assignment, with an additional penalty equal to the weight of the assignment also being applied. You are responsible for reading and respecting

the Computer Science Department's policy on Scholastic Offences and Rules of Ethical Conduct.

The University of Western Ontario uses software for plagiarism checking. Students may be required to submit their written work and programs in electronic form for plagiarism checking.

Academic Accommodation for Medical Illness

If you are unable to meet a course requirement due to illness or other serious circumstances, you must provide valid medical or other supporting documentation to your Dean's office as soon as possible and contact your instructor immediately. It is the student's responsibility to make alternative arrangements with their instructor once the accommodation has been approved and the instructor has been informed. In the event of a missed final exam, a "Recommendation of Special Examination" form must be obtained from the Dean's Office immediately. For further information please see:

http://www.uwo.ca/univsec/handbook/appeals/medical.pdf

A student requiring academic accommodation due to illness should use the Student Medical Certificate when visiting an off-campus medical facility or request a Record's Release Form (located in the Dean's Office) for visits to Student Health Services. The form can be found at:

https://studentservices.uwo.ca/secure/medical_document.pdf