The University of Western Ontario

Computer Science 881b, Winter 2001

UNCONVENTIONAL COMPUTING (I): 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 [3], 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 [2]. Moreover, computing with DNA provides enormous parallelism. In Adleman's first DNA computing experiment ([1] 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 [2]. 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 [2].

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/881b01.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 (tentative): Thursdays, 1:00-3:00pm, MC 320.

Topics

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

Student evaluation
Each student will give a lecture on a topic agreed on with the instructor and submit a term paper on the same topic. The marks will be calculated as 50% for the paper, 40% for the presentation and 10% for class participation.

Remark
Depending on the number of participants, the way of conducting the course may have to be modified.

References

[1] L.Adleman. Molecular computation of solutions to combinatorial problems. *Science* v.266, Nov.1994, 1021–1024.

[2] L.Adleman. Computing with DNA. *Scientific American*, August 1998, 54–61.

[3] L.Kari. DNA computing - arrival of biological mathematics. *The Mathematical Intelligencer*, vol.19, 2(1997), 9-22.