Formal language aspects of natural computing

Ramanujan Mathematical Society
Lectures Notes Series

Ramanujan Mathematical Society

Lecture Notes Series

Volume 3

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Proceedings of a research-level group
discussion held at the Indian Institute of
Technology, Chennai, November 2005

Volume editors

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International Press

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PREFACE

Computing with molecules has been a fascinating area of research for long since Nobel laureate Richard Feynman gave his visionary idea in late 1950's. The field of biologically inspired computing has coexisted with main stream computing since the 1930's and the pioneers in this area include McCulloch W. Pitts, R. Rosen, A.M. Turing, J. Von Neumann. These ideas were however first realized only in 1994 when L. Adleman took an instance of a Hamiltonian path problem and solved the problem in a biological laboratory using operations on DNA strands. Since then lot of progress has been made in the area of Natural Computing. DNA computing, membrane computing, peptide computing, computing with ciliates are some of the approaches in Natural Computing. Various theoretical models have also been constructed based on these concepts of Natural Computing. The area is just in an embryonic stage. There is a lot of potential for this area to grow. As Leonard Adleman said "They were built by 3 billion years of evolution and we are just beginning to tap their potential to serve non-biological purposes. Nature has given us an incredible toolbox, and we are starting to explore what we might build." A good amount of work in this area is being carried out in Europe, USA, Canada, etc.

To elaborate further, 'natural computing' is computing inspired by nature. This field of research tries to imitate nature in the way it computes and designs new models and paradigms of computing used by nature. Research in this field includes theoretical and empirical understanding of these paradigms. Thus while evolutionary algorithms use the concepts of mutation, recombination and natural selection in biology, neural networks are inspired by the highly interconnected neural structures in the brain and the nervous system. Another aspect of natural computing is molecular computing which includes DNA computing and peptide computing.

Molecular computing is concerned with the use of biomolecules for the purpose of computing. It has the potential to resolve two well recognized obstacles of conventional computers, miniaturization and massive parallelism. Through molecular computing one descends to the nano-scale computing which solves the miniaturization problem. Since for example, a single drop of solution can contain trillions of DNA molecules, and when an operation is performed on a tube containing DNA molecules, it is performed on every molecule in the tube, massive parallelism is obtained. The well known field of molecular computing, viz DNA computing started with Adleman's paper. A lot of research on this is being done in USA, Israel and Europe. Even though the initial enthusiasm about replacing a silicon computer by this model has come down, it is perceived that DNA computing will be very useful for solving hard problems such as breaking a cryptocode or in DNA to DNA computations. Peptide computing is another model of molecular computing which is still at the conceptual level only.

The idea that molecular system can perform computation is not new and was started with Van Neumann's discussions of self-reproducing automata (Cellular automata) in the 1940's. Molecular computing has opened up new formal models of computations like splicing systems, Watson Crick automata and Sticker systems.

Observing the reactions taking place in a cell, the concept of cellular computing has been developed. It is concerned with the use of membranes, biomolecules and biochemical processes for the purpose of computing. DNA computing can give unbounded parallelism but the concept of membrane computing has been developed to have a distributed and parallel model of computing inspired from the structure and functioning of living cells. At

present, it is basically a theoretical model only. Implementation using biomedia or silicon media is being explored.

To popularize this emerging field of natural computing among the Indian research community and attract the young potential researchers to this dynamic field, "A Research level group discussion on Natural Computing" under the sponsorship of CARDMATH (Centre for Advancement of Research in Discrete Mathematics), Department of Science and Technology, India was organized from November 21-27, 2005 at Indian Institute of Technology Madras, Chennai.

This group discussion stressed much on DNA computing, membrane computing, peptide computing and was attended by almost all the leading peer researchers of the Natural Computing area in India which includes Prof. K.G. Subramanian (MCC, Chennai), Dr. Dersanambika (Kerala), Dr. S.N. Krishna (IIT Bombay) Dr. K. Lakshmanan (TIFR, Bombay), Prof. T.S. Chandra (Biotechnology, IITM).

The group discussion had a pack of lectures in the morning session and lab visits and discussion in the afternoon. Some of the existing theoretical results were presented. Students (Ph.D and B.Tech.) from IIT Madras presented some new ideas and were thrown open for discussion.

Research material which highly motivate young researchers were distributed to the participants. As a continuation of our efforts to make this field known, we have attempted to bring out a complied volume in the form of lecture notes. Since the areas that were discussed are not much known to researchers all over India, we have included 11 survey articles, 7 research papers to show further direction of research and three short notes on molecular computing algorithms for specific problems designed by the B.Tech. students motivated by this group discussion.

The volume has two sections followed by a "Students column". The first section contains 11 survey articles covering P systems, DNA computing, network of evolutionary processors, cellular automata, evolutionary algorithms, peptide computing, splicing systems. The second section has 7 research articles in the area of Natural Computing. "Students column" deals with designing algorithms in molecular computing models to solve some NP complete problems on the lines of Adleman's work.

We wish to place on record our sincere thanks to the international academicians who have contributed to the discussion meeting and also to the current volume. Especially we thank Tom Head, Gheorghe Păun, Erzsébet Csuhaj-Varjú, György Vaszil, Helmut Jürgensen, Pierluigi Frisco, Wim Hordijk for their contribution to this volume.

Our thanks to CARDMATH DST, India for sponsoring the programme. Our sincere thanks to the Indian Institute of Technology Madras for having permitted us to host this programme. Our thanks also are due to the Heads of the Department of Mathematics and Computer Science and Engineering for their constant support and encouragement. We also thank our research scholars H. Ramesh, L. Jeganathan, Rita Brata Sen Gupta, Masilamani for their cooperation in organizing this programme. We acknowledge the kind services of Mr. E. Boopal for the compilation work.

March 2006 **Kamala Krithivasan**
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