Overview

In last 50 years Information and Communication Technology (ICT) has had a great impact on our society. The most profound and accelerated impact of ICT can be seen in the last decade in the form of cell phones, connected computers and Internet. We even have a virtual currency. ICT is an interdisciplinary discipline combining IT (Information Technology) and CT (Communication Technology). IT has its root in computer science and CT has its root in theory of communication. Both the fields now can be seen as two sides of the same coin. Both deals with information, in IT we store (send information from now to then) and manipulate the information and in CT we send information from here to there (communicate). The mathematical principles of ICT lie in theoretical computer science (Turing machine) and information and coding theory (work of Shannon and Hamming). Realization of ICT is via logic gates and circuits in the area of Electronics and VLSI. If you look around the Nature around you many times you feel: What are the principles of Natural ICT? Can we use these principles to create Natural ICT engineering?

We are fortunate enough that due to advancement of many fields we are now in a position to talk about Natural ICT. There are three main areas of Natural ICT:

1. ICT inspired by Nature
2. ICT by Natural objects
3. Nature as ICT (natural information processing)

Natural ICT includes the following new and emerging areas:

Mathematics of Natural Information Processing
Natural Computing
Natural Engineering (Synthetic Biology)
Natural Algorithms
Natural Communication
Natural Signal Processing
Naturotronics- Natural Logic Gates and Circuits
Natural Programming Languages (Molecular Programming)
Natural Networks (Nano-scale Networks, Complex Networks, Bi-Fi)
Natural Storage
Natural Logic
Natural Robotics (Molecular)
Natural Security and Cryptography
Natural Coding and Information Theory

Thus, Natural computing is a recent branch of computer science where we are learning from the nature on how to compute with natural living things such as DNA, protein, bacteria, etc. We want to solve complex problems with the help of DNA computer or bacterial computer or chemical computer. We want to store our data on such living things. So we require molecular/natural algorithms and natural error control. We can also divide principles of computing based on physics. On one side we have computing systems based on classical physics and on the other hand we have another emerging model of quantum computing based on quantum physics. Quantum computing and Biomolecular computing are also considered as a part of natural computing.

It turns out that nature itself is a computer, computing many things from billions of years. In 1994 a cryptographer Adleman did the first (breakthrough) engineering experiment by showing how to solve Hamiltonian path problem using DNA computer. Since then many more experiments have been done and many new natural computing models have been discovered. One of the potential applications of DNA computer is Doctor in a cell by 2050. In 2004, Shapiro demonstrated a DNA computer capable of diagnosing the cancer and releasing the drug. In July 2009, scientists have shown that a bacterial computer can also solve simple Hamiltonian path problem. In June 2011, Erik Winfree has built the largest DNA computer for finding square root. In July 2012, Martin Fussenegger’s group has built single cell mammalian biocomputers. Now we also have Monkey computing, Elephant computing and so on…

This course is useful for computer science students and to anyone who want to learn about natural ICT.

**Tentative Course Content**

The course provides basic overview of natural ICT and it covers basic notation of biochemistry and molecular biology that are needed to learn about DNA computing. Basic models of computing such as finite automata (FA), push-down automata (PDA), linear bounded automata (LBA) and Turing machine (TM) with corresponding languages and their relationships, Quantum Turing machine (QTM) and quantum languages, computation by circuits, thermodynamics of computation, post systems, rewriting systems, L-systems, algorithmic botany, cellular automata, block cellular automata, Adleman experiment with DNA computer, different models of DNA computation (Lipton model, Sticker model, DNA splicing model, DNA self assembly, hair pin model) and complexity problems such as integer factorization, basic arithmetic etc. Overview of algorithmic self assembly (ASA), algorithms for natural security and cryptography, Experiments in self-assembly, DNA origami (2D and 3D), Error-correction in self-

**Expected Outcome**

The students after completing the course will get a basic overview of the emerging area of Natural ICT and other natural computing models such as DNA computing, bacterial computing, Membrane computing and Chemical computing. They will get an insight on how to visualize various natural processes as a part of natural computing and they will learn the engineering aspects of natural computing. It exposes them the natural algorithms for solving various problems using natural objects such as DNA, protein, bacteria etc and they will learn about the various available tools such as Xgrow, Xtile, CadNano, Sarse, Tiamat. They will also learn about the natural error correction schemes. Projects in the course provide first hand research opportunities in niche and hot area to the students. There are many universities offering Master degree in Natural computing.

**Text Book**

There is no specific text book but the following books will be helpful. We will provide many additional materials such as videos, handouts etc during the course. There is no need to purchase any book.

3. Sudheer Sahu and John H. Reif, DNA based self assembly and Nan robotics, 2008

11. Rozenberg, Grzegorz; BÃock, Thomas; Kok, Joost N. (Eds.), Handbook of Natural Computation, Springer, 2010
17. Computation in Cells and Tissues: Perspectives and Tools of Thought R. Paton (Editor), Hamid Bolouri (Editor), W. Michael L. Holcombe (Editor), J. Howard Parish(Editor), Richard Tateson (Editor)
18. Self-organizing Software: From Natural to Artificial Adaptation Giovanna di Marzo Serugendo (Editor), Marie-Pierre Gleizes (Editor), Anthony Karageorgos (Editor)
19. Computability of the DNA and Cells: Splicing and Membrane Computing [Hardcover] Andrei Paun (Author)
20. Natural Computing in Computational Finance, Brabazon, Anthony; O'Neill, Michael; Maringer, Dietmar G. (Eds.) 1st Edition., 2010, 241

Mark Distribution (Tentative) / Grading Policy
Assignments - 20%
Mid Term -30%
Attendance -10%
Project or Final Exam -40 % (one of them is optional)

Project Policy
Project has to be done in 3 parts.
Part-1 (5%): Submission of 1 page abstract via Moodle consisting of problem formulation. It is due in approximately 4 weeks after the start of the course.
Part-2 (5%): Mid progress report (of 1 page) in another 4 weeks after part-1.
Part-3 (30%): Final user manual and demo of the s/w towards the 18th week. Submission date of software to Moodle will be announced later. If you are not doing project then you can appear for final exam.

**Tutorials:** None  
**Lab:** None  
**Capacity:** 20 students will be admitted.  