Chapter 29
Introduction to Molecular Computation:
Theory and Applications – DNA and Membrane Computing

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ABSTRACT

The present chapter deals with the topic Molecular Computation. The chapter first defines the basic terminologies associated with the processes. The chapter discusses the basic molecular biology and DNA and membranes. Emphases are given on the structural arrangements of DNA and the molecular architecture of biological membranes. The chapter also focuses on the molecular logic behind the applications of DNA and bimolecular membranes in computations. There are discussions on the current researches that are going on in the field of DNA and membrane computations. There are comparative analyses of the existing computational techniques with molecular computations. There are very few reports that deal with the underlying basics of molecular computation techniques. Thus the chapter may be a first hand guide for researchers interested in the field. The chapter is written for the benefits of both the biologists as well as computer scientists.

INTRODUCTION

It is a well-known fact that for, the last 40 years or so silicon microprocessors have been ruling the hardware industries. With the passage of time, hardware manufacturers have kept on putting more and more electronic devices onto their microprocessors. However, Gordon Moore, the founder of the company Intel, predicted way back in 1965 that microprocessors would double in complexity every two years. This is known as the Moore's law. However, the physical speed and miniaturization limitation of silicon microprocessors are constantly restricting the further advancements of silicon microprocessors. To avoid the use of Silicon chips alternative approaches have been proposed and that is to use the cellular DNA in place of silicon chips. The use of DNA in computing can revolutionize the field of computation to

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new levels. It is picking up where Moore's Law leaves off. The bio-molecule DNA has in many different ways more flexible than silicon chips. This is the main reason of the popularity associated with DNA computation. DNA computing may therefore be considered as a branch of study that deals with DNA biochemistry and computer hardware.

DNA computation is a type of parallel computation technique. The beauty of the process lies in the fact that various DNA molecules have their capabilities to combine among each other in various different ways to perform a particular task. DNA computers perform in a better way than any other computer built so far to solve some specialized problems. A couple of mathematical problems can be solved in a better way by DNA computer. It is known that the DNA molecules were utilized to handle the assignment problem. Researchers from CALTECH made a circuit made up of as many as 130 unique DNA strands and this DNA computer can calculate the square root of numbers up to 15. In short, the basic aim of the DNA computation technique is to use the information processing capabilities of the specific bio-organic molecules (DNAs) to replace the digital switching primitives.

However, DNA computing techniques are in their infancy as such that their implications are only beginning to be explored. But scientists believe that the technique has immense potential to transform the future of computers. DNA computing would revolutionize the pharmaceutical and biomedical applications.

Another mode of biological computations is the membrane computing technique. Membrane computing (MC) is a very specialized field in computer science. The basic principle of the process is to abstract computing ideas and models from the structure and the functioning of living cells. The technique relies upon the way the cells are organized in tissues or higher order structures. In other words, MC deals with distributed and parallel computing models. It processes multiple sets of symbolic objects in a localized manner just like living cells perform several different biological tasks in parallel inside different cellular compartments which are encapsulated by membranes. However, this does not reflect the entire picture of a membrane system in the realm of computer science. The different types of membrane systems are referred to as the P system, as per the name of the inventor Gheorghe Păun.

The membrane is basically a three-dimensional vesicle from biological world. However the concept of using biological membranes as computing tools is more general. A membrane is considered as a separator of two regions. The membrane helps in the passage of signal flow in and out and provides a selective link of communications between two regions. This is where the theory of computing comes in. However, till date the P-systems are still a theoretical concept and no practical applications of the process have been implemented.

The uses of biological materials like DNA and membrane for the purpose of computation seem a very promising field. Since the subject is still very young, researches are going on to come up with a plausible way of using these biomaterials in computations. In the present scenario, the present aim of the chapter is to give a fair idea about the basics of the process. There are very few articles available that deal with the DNA and membrane computing techniques. In the present chapter, emphasis will be given on the elucidation of the existing knowledge about the biological computations using the two important biological components, viz, the DNA and membranes. The chapter is intended for both the computer scientists and molecular biologists as it will encompass the biological aspects of computations. The basics of molecular biology will be discussed. The DNA structure and membrane architecture will be presented and these will be linked to the theory of computations. The chapter may be used a first hand guide for the researchers interested in the field of Molecular computations.