Chapter I

Membrane Computing: Main Ideas, Basic Results, Applications

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ABSTRACT

Membrane computing is a branch of natural computing whose initial goal was to abstract computing models from the structure and the functioning of living cells. The research was initiated about five years ago (at the end of 1998), and since that time the area has been developed significantly from a mathematical point of view. The basic types of results of this research concern the computability power (in comparison with the standard Turing machines and their restrictions) and the efficiency (the possibility to solve computationally hard problems, typically NP-complete problems, in a feasible time and typically polynomial). However, membrane computing has recently become attractive also as a framework for devising models of biological phenomena, with the tendency to provide tools for modelling the cell itself, not only the local processes. This chapter surveys the basic elements of membrane computing, somewhat in its “historical” evolution:
from biology to computer science and mathematics and back to biology. The presentation is informal, without any technical detail, and an invitation to membrane computing intended to acquaint the nonmathematician reader with the main directions of research of the domain, the type of central results, and the possible lines of future development, including the possible interest of the biologist looking for discrete algorithmic tools for modelling cell phenomena.

INTRODUCTION

In some sense, the whole history of computer science is the history of attempts to discover, study, and, if possible, implement computing ideas, models, and paradigms the same way nature — humans included — computes. We do not enter here into the debate whether or not the processes taking place in nature are by themselves “computations”, or whether we, *Homo sapiens*, interpret them as computations. But we do recall that when defining the computing model now known as the Turing machine, which provides the standard — and by now definition — of what is computable, A. Turing (in 1935 and 1936) explicitly wanted to abstract and model what a clerk in a bank is doing when computing with numbers. One decade later, McCullock, Pitts, and Kleene founded the finite automata theory starting from modelling the neuron and the neural nets; still later, this led to the area known now as neural computing. Genetic algorithms and evolutionary computing and programming are now well-established (and frequently applied) areas of computer science. One decade ago, Adleman’s history-making experiment of computing with DNA molecules was reported, proving not only that biology can inspire computer and algorithm design for electronic computers, but also that biological support (a bioware) can be used for computing. In recent years, the search of computing ideas, models, and paradigms in biology, or in nature in general, has become explicit and systematic under the general name of natural computing.

Membrane computing is a part of this intellectual enterprise, starting from two general premises: 1) nature has evolved the living beings from the biochemistry in the compartments of a cell, to tissues, organs, organisms, populations, during billions of years, with goals different from those of computer science but which often turn out to be surprisingly useful for computing and computer science (the best illustration is that of genetic algorithms and evolutionary computing), and 2) The cell is the smallest living thing, and at the same time it is a marvellous, tiny machinery with a complex structure, an
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