

Chapter 8

Local Search with P Systems: A Case Study

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ABSTRACT

Local search is currently one of the most used methods for finding solutions in real-life problems. It is usually considered when the research is interested in the final solution of the problem instead of the how the solution is reached. In this paper, the authors present an implementation of local search with Membrane Computing techniques applied to the N-queens problem as a case study. A CLIPS program inspired in the Membrane Computing design has been implemented and several experiments have been performed. The obtained results show better average times than those obtained with other Membrane Computing implementations that solve the N-queens problem.

1. INTRODUCTION

Searching is the basis of many processes in Artificial Intelligence. The key point is that many real-life problems can be stated as a *space of states*: a *state* is the description of the world at a given instant (expressed in some language) and two states are linked by a *transition* if the second state can be reached from the previous one by applying one *elementary operation*. By using these concepts, a searching tree where the nodes are the states, the root is the starting state and the

edges are the actions considered. Given an initial state, a sequence of transitions to one of the final states is searched.

By using this abstraction, searching methods have been deeply studied by themselves, forgetting the real-world problem which they fit. The studies consider aspects as the completeness (if the searching method is capable of finding a solution if it exists), complexity in time and space, and optimality (if the found solution is *optimal* in some sense). By considering the searching tree, classical search has focused on the order in which

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the nodes should be explored. In this classical search two approaches are possible: the former is *blind search*, where the search is guided only by the topology of the tree and no information is available from the states; the latter is called *informed search* and some information about the features of the nodes is used to define a *heuristics* to decide the next node to explore.

Searching problems have been previously studied in the framework of Membrane Computing. In Gutiérrez-Naranjo and Pérez-Jiménez (2010), a first study on depth-first search in the framework of Membrane Computing was presented. In this paper we go further with the study of searching methods in Membrane Computing by exploring local search. We consider the N-queens problem as a case study and we present a family of P systems which solves it by implementing local search ideas.

The paper is organized as follows: First we recall some basic definitions related to local search. Then, we recall the problem used as a case study: the N-queens problem, previously studied in the framework of Membrane Computing in Gutiérrez-Naranjo, Martínez-del-Amor, Pérez-Hurtado, and Pérez-Jiménez (2009). Next, we provide some guidelines of the implementation of local search in our case study and show some experimental results. The paper finishes with some final remarks.

2. LOCAL SEARCH

Classical search algorithms explore the space of states systematically. This exploration is made by keeping one or more paths in memory and by recording the alternatives in each choice point. When a final state is found, the path, that is, the sequence of *transitions*, is considered as the solution of the problem. Nonetheless, in many problems, we are only interested in the found state, not properly in the path of transitions. For

example, in job-shop scheduling, vehicle routing or telecommunications network optimization, we are only interested in the final state (a concrete disposition of the objects in the world), not in the way in which this state is achieved.

If the sequence of elementary transitions is not important, a good alternative to classical searching algorithms is *local search*. This type of search operates using a single state and its set of neighbors. It is not necessary to keep in memory how the current state has been obtained.

Since these algorithms do not systematically explore the states, they do not guarantee that a final state can be found, i.e., they are not complete. Nonetheless, they have two advantages that make them interesting in many situations:

- Only a little piece of information is stored, so very little memory (usually constant) is used.
- These algorithms can often find a reasonable solution in an extremely large space of states where classical algorithms are unsuitable.

The basic strategy in local search is considering a current state and, if it is not a final one, then it moves to one of its neighbors. This movement is not made randomly. In order to decide where to move, a *measure of goodness* is introduced in local search. In this way, the movement is performed towards the best neighbor or, at least, a neighbor who improves the current measure of goodness. It is usual to visualize the *goodness* of a state as its height in some geometrical space. In this way, we can consider a landscape of states and the target of the searching method is to arrive to the *global maximum*. This metaphor is useful to understand some of the drawbacks of this method: *flat regions*, where the neighbors are as good as the current state, or *local maximum* where the neighbors are worse than the current state, but it is not a *global*

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