Multidimensional Sevilla Carpets Associated with P Systems

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Summary. In this paper we address the problem of describing the complexity of the evolution of a P system. This is especially difficult in the case of P systems where the number of membranes increases along the computation, via division or creation of membranes. In these cases the number of steps of a computation is not sufficient to evaluate the complexity. Sevilla Carpets were introduced in [1], and they describe the space-time complexity of P systems. Based on them, we define a four-dimensional manifold which can be used to compare evolutions of P systems.

1 Introduction

The evolution of a P system is a complex process where (eventually) a large number of symbol-objects, membranes and rules are involved. In the case of P systems where the number of membranes increases along the computation, via creation or division of membranes, the problem of describing the complexity of the computational process becomes especially difficult. In these cases, due to the parallelism intrinsic to P systems, an exponential number of membranes can be obtained in polynomial time. This feature makes these models of P systems a powerful tool to attack **NP**-complete problems and, indeed, several efficient solutions to these types of problems have been presented both in the model of P systems with *active membranes* (see, e.g., the Partition [2], Subset Sum [12], Knapsack [13], Bin Packing [14], SAT [15] or Validity [16]) and P systems with *membrane creation* (see, e.g., SAT [4], QSAT [5] or Subset Sum [6]).

These solutions are proposed in the framework of *Recognizer P systems with external output* [13]. The basic idea in these solutions is the construction of an exponential number of membranes (*workspace*) in polynomial time and the use of each membrane as an independent computational device. All membranes evolve *in parallel* and the computation has a polynomial cost in time. The process ends with a final stage (with a polynomial cost) that checks the answers of these devices and sends an answer to the environment.

The cost in *time* (number of cellular steps) of these solutions is polynomial, but it is clear that the time is not the unique variable that we need to consider in order to evaluate the "complexity" of the process. G. Ciobanu, Gh. Păun and Gh. Ştefănescu presented in [1] a new way to describe the complexity of a computation in a P system. The so-called *Sevilla Carpet* is an extension of the notion of Szilard language from grammars to the case when several rules are used at the same time.

In [3], new parameters for the study of the descriptive complexity of P systems were introduced and several examples of a graphical representation of Sevilla carpets and of the usefulness of these parameters for comparing different solutions for a given problem were provided.

In this paper we extend the definition of Sevilla Carpets to describe the computations of P systems. We present a four dimensional manifold which can be used for a better understanding of the complexity of a P system. The graphical representation of this four-dimensional manifold is carried out via projections on three-dimensional spaces.

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