On Descriptive Complexity of P Systems

M. A. Gutiérrez-Naranjo; M.J. Pérez-Jiménez; A. Riscos-Núñez

Research Group on Natural Computing
Department of Computer Science and Artificial Intelligence
University of Sevilla
Avda. Reina Mercedes s/n, 41012 Sevilla, Spain
E-mail: {magutier,marper,ariscosn}@us.es

Abstract. In this paper we address the problem of describing the complexity of the evolution of a P system. It is specially hard in the case of P systems with active membranes, where the number of steps of a computation is not sufficient to show the complexity. Sevilla Carpets were introduced in [1], and they describe the space-time complexity of P systems. Based on them, we define some new parameters which can be used to compare evolutions of P systems. To illustrate this, we also include two solutions to the Subset Sum problems and compare them via these new parameters.

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 with active membranes, the problem of describing the complexity of the computational process becomes specially hard. In this case, elementary membranes can divide into two new membranes and, due to the parallelism intrinsic to P systems, an exponential number of membranes can be obtained in polynomial time. This feature makes P systems with active membranes a powerful tool to attack NP-complete problems and several efficient solutions to these type of problems have been proposed (see, e.g. [2, 7–9] or [10]).

All these solutions are proposed in the framework of *Recognizer P systems with external output*, and they present significant similarities among them. The basic idea in these designs is the creation 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 polynomial cost) that checks the answers of these devices and sends an output to the environment.

The complexity in *time* 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. Ciobanu, Păun and Stefănescu 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 the Szilard language from grammars to the case when several rules are used at the same time.

In this paper we use *Sevilla Carpets* to describe the computation of P systems that solve the Subset Sum problem. Two families of recognizer P systems have been designed that need a polynomial time to send an output to the environment. We present their corresponding *Sevilla Carpets* in order to compare them, and some ideas to improve the design of P systems to solve other new problems are proposed.

The paper is organized as follows. In Sections 2 we first give some preliminary notions on *recognizer P systems* and a polynomial complexity class on P systems is defined. Section 3 presentes the Sevilla Carpets and some new parameters related with them are presented in Section 4. Finally, we use these parameters to compare two solutions of the Subset Sum problem and some final remarks are provided.

References

1. Ciobanu, G.; Păun, Gh.; Stefănescu, Gh. Sevilla Carpets Associated with P Systems, in A. Alhazov, C. Martín–Vide and Gh. Păun (eds.), *Proceedings of the Brainstorming Week on Membrane Computing*, Report 26/03 Rovira i Virgili University, Tarragona, 2003, 135-140.
2. Gutiérrez-Naranjo, M.A.; Pérez-Jiménez, M.J.; Riscos Núñez, A. A Fast P System for Finding a Balanced 2-Partition, *Soft Computing*. Springer. To appear.
3. Mäkinen, E. A Bibliography on Szilard Languages, Dept. of Computer and Information Sciences, University of Tampere, `http://www.cs.uta.fi/reports/pdf/Szilard.pdf`
4. Mateescu, A. and Salomaa, A. Aspects of Classical Language Theory, in G. Rozenberg and A. Salomaa (eds.), *Handbook of Formal Languages* (vol. 1), Springer-Verlag, Berlin Heidelberg, 1997.
5. Păun, Gh. P Systems with Active Membranes: Attacking NP Complete Problems, *Journal of Automata, Languages and Combinatorics*, **6**(1), 2001, 75–90.
6. Păun, Gh. *Membrane Computing. An Introduction*, Springer-Verlag, Berlin, 2002.
7. Pérez-Jiménez, M.J.; Riscos-Núñez, A. Solving the Subset Sum Problem by Active Membranes, *New Generation Computing*, to appear.
8. Pérez-Jiménez, M.J.; Riscos-Núñez, A. A Linear Solution for the Knapsack Problem Using Active Membranes, in C. Martín-Vide, G. Mauri, Gh. Păun, G. Rozenberg and A. Salomaa (eds.),*Membrane Computing*. Lecture Notes in Computer Science, **2933**, 2004, 250–268.
9. Pérez-Jiménez, M.J.; Romero-Jiménez, A.; Sancho-Caparrini, F. A Polynomial Complexity Class in P systems Using Membrane Division, in E. Csuhaj–Varj, C. Kintala, D. Wotschke, and Gy. Vaszyl (eds.), *Proceedings of the 5th Workshop on Descriptional Complexity of Formal Systems*, Budapest, Hungary, 2003, 284–294.
10. Pérez-Jiménez, M.J.; Romero-Jiménez, A.; Sancho-Caparrini, F. Solving VALIDITY Problem by Active Membranes with Input, in M. Cavalieri, C. Martín-Vide, Gh. Paun (eds), *Proceedings of the Brainstorming Week on Membrane Computing*, Report GRLMC 26/03, 2003, 279–290.
11. Salomaa, A. *Formal Languages*, Academic Press, New York, 1973.
12. Zandron, C. *A Model for Molecular Computing: Membrane Systems*. Ph.D. Thesis, Università degli Studi di Milano, 2001.