Report about the research stay of Gheorghe Păun

at MTA SZTAKI, Budapest in the frame of the Centre of Excellence project (June 24 – August 05, 2004)

The main topic of research during this period was membrane computing in relation with grammar systems.

Both these areas of research are well established branches of theoretical computer science.

Grammar systems investigate sets of grammars which cooperate according to specified protocols in generating a unique language; there are two main classes of systems, the cooperating-distributed (CD) grammar systems (introduced by E. Csuhaj-Varjú and J. Dassow, in 1998) and the parallel-communicating (PC) grammar systems (introduced by Gh. Păun and L. Sântean, in 1989). Colonies (J. Kelemen and A. Kelemenova, 1992) and eco-grammar systems (E. Csuhaj-Varjú, J. Kelemen, A. Kelemenova, and Gh. Păun, 1994) are other two important types of grammar systems. All these (together with distributed models from DNA computing, such as test tube systems) were generalized (E. Csuhaj-Varjú and A. Salomaa, 1996) to networks of language processors.

Membrane computing is a branch of natural computing (initiated by Gh. Păun, in 1998) which aims at abstracting a computing model from the structure and the functioning of the living cell (and from the organization of cells in tissues). The domain is rather active in the last years - and also in this area the SZTAKI group led by E. Csuhaj-Varjú has remarkable contributions.

Although the two areas, grammar systems and membrane computing, deal with related topics (distributed and parallel computing), up to now no attempt was done to bridge them, to borrow ideas from one domain to another one. The investigations carried during my stage in Budapest had a central goal such a bridge, and this turned out to be a very fruitful idea (taking advantage also of the common scientific preoccupations with E. Csuhaj-Varjú and Gy. Vaszil).

Thus, the following papers were (totally or partially) written during this period (general descriptions of these papers are also given):

1. Gh. Păun, Grammar systems vs. membrane computing: A preliminary approach, *Pre-Proc. Workshop on Grammar Systems*, MTA SZTAKI, Budapest, 2004, 225–245.

   This paper starts the a systematic study of the relationships between grammar systems and membrane computing, trying to import features of (mathematical or computational) interest from one area to another one. One considers in some detail the case of cooperating distributed (CD) and parallel communicating (PC) grammar systems: the t-mode of cooperation from CD grammar systems can be used instead of the target indications from cell-like P systems, while the use of multisets of strings in PC grammar systems leads to a sort of tissue-like P systems (able to solve `SAT` in linear time). The paper has a preliminary character; many open problems and research topics are formulated.

2. E. Csuhaj-Varjú, Gh. Păun, Gy. Vaszil, Grammar systems vs. membrane computing: The case of CD grammar systems. Manuscript, to be submitted.

   This paper considers the possibility to extend from CD grammar systems to P systems (with string-objects) one of the most interesting communication protocol, the so-called t mode: a string is moved from a component/region to another one when no further rule can be applied to it in the component/region where it is processed. We use this idea for moving objects in a P system either *in* or *out*, or in both directions. The power of the obtained classes of P systems is investigated, in comparison with families of languages generated by grammars in the Chomsky hierarchy or by CD grammar systems.

3. E. Csuhaj-Varjú, Gh. Păun, Gy. Vaszil, Grammar systems vs. membrane computing: The case of PC grammar systems. Manuscript, to be submitted.

   This paper continues the investigation of the relationships between grammar systems and membrane systems, addressing the case of parallel communicating (PC) grammar systems. Specifically, we introduce a class of computing devices which can be considered at the same time as a variant of PC grammar systems (using multisets of strings) and as a variant of tissue-like P systems (using string-objects and communicating by request). We first investigate the power of these devices (proving their universality), then we show that these devices are also computationally efficient, in the sense that **NP**-complete problems can be solved in this framework in a polynomial time (we illustrate this by solving `SAT`).

4. Gh. Păun, Membrane computing after five years (Section added to the Russian translation of the book *Computing with Cells and Atoms*, by C. Calude, Gh. Păun – first published in 2001 by Taylor and Francis, London).

   One briefly discusses the main directions of research considered in the period which passed from the writing of the English version of the book until now, in order to offer to the reader of the Russian edition of the book a glimpse about the current state-of-the-art of membrane computing, as well as bibliographical information about current developments in the area (starting with the web page from `http://psystems.disco.unimib.it`, where, among others, a complete bibliography of membrane computing can be found).

5. E. Csuhaj-Varjú, J. Dassow, Gh. Păun, Gy. Vaszil, Dynamically hybrid and time-varying hybrid CD grammar systems. Manuscript, to be submitted.

   We consider CD grammar systems where the mode of using a component is either determined by the string itself to be rewritten (regular languages are given such that, if the string belongs to one of these languages, then the string has to be processed in a mode associated with that language, irrespective which is the component which processes it), or the mode is one from a periodic sequence of modes given in advance. Interesting enough, in both cases we obtain characterizations of recursively enumerable languages, a result which is not very frequent in the CD grammar systems area.

6. E. Csuhaj-Varjú, J. Kelemen, A. Kelemenová, Gh. Păun, Gy. Vaszil, Cells in environment: P colonies. Paper in preparation.

   The paper proposes and briefly investigates a class of abstract computing devices composed from as simple as possible agents acting and evolving in a shared environment. The device is of a type similar to the so-called tissue P systems known in the field of membrane computing, but with the cell components being of a very simple form. Moreover, we suppose no direct communication among cells, while the environment is completely uniform (only one kind of symbols is present in the beginning). Still, in this extremely weak framework we prove that our computing device is able to compute whatever a Turing machine can do; several different universality results are given, obtained by varying the size and the number of the cells.

7. E. Csuhaj-Varjú, A. Di Nola, Gh. Păun, M.J. Pérez-Jiménez, Gy. Vaszil, Editing configurations of P systems. Paper in preparation.

This paper proposes and preliminarily investigates the possibility of transforming a configuration (membrane structure and multisets of symbol-objects present in the compartments of this membrane structure) of a P system into another configuration, by means of a given set of rules acting both on the membranes and on the multisets of objects. Although such a transformation can be obtained during a computation of a P system, we consider it as a goal *per se*, as a pre-computation phase, when the system itself is build. In this framework, several important topics appear, such as the edit-distance between configurations (with respect to a given set of editing rules), normal forms, reachability, existence of single configurations from which a given family of configurations can be constructed, etc. We investigate here only a few of these questions; the paper is mainly devoted to formulating problems in the new framework, calling attention to the possible extensions and usefulness of the present approach.

The collaboration with Erzsébet Csuhaj-Varjú and György Vaszil was really intensive, with daily discussions, based on the strong previous cooperation and, as said before, on the identity of research interests; exciting discussions with Prof. Tamás Roska about cellular neural networks and related topics were also organized.

During the stay in Budapest, I have also participated in the following scientific events:

1. Attending the conference of prof. S. Marcus (Romanian Academy), "In the Palindromic World", held on June 28 in the Eötvös Loránd University.

2. Delivering the conference "Membrane Computing. An Introduction", at MTA SZTAKI, on July 1, 2004.

3. Attending the Workshop on Grammar Systems, organized in MTA SZTAKI from July 5 to July 9, where I have delivered the invited talk "Grammar Systems versus Membrane Computing. A Preliminary Approach". Discussions during the workshop with R. Freund, J. Dassow, J. Kelemen, M. Holzer, M.A. Grando, G. Bel Enguix, M.D. Jimenez-Lopez, and other participants, about various papers and possible collaborations.

4. Attending the Formal Languages Colloquium in Honour of Arto Salomaa, Turku, Finland, July 11, 2004, where I have delivered the invited talk "Membrane Computing. Back to Turku After Six Years"

5. Attending the ICALP (International Colloquium on Automata, Languages and Programming), Turku, Finland, July 12–16.

Other scientific activities held during this period:

1. Work as editorial committee member of *Fundamenta Informaticae, Natural Computing, BioSystems, International Journal of Foundations of Computer Science* (papers evaluated for publication in all of these journals).

2. Work as program committee member of the Conference on Developments in Language Theory, Auckland, New Zealand, 2004.

3. Editorial work on the volume *Application of Membrane Computing*, in preparation for Springer-Verlag.

Definitely, my stay in MTA SZTAKI was very useful. The interaction with the local people was always pleasant, fruitful, scientifically beneficial, the working conditions were excellent.

Last but not least, I would like to mention the efficient and pleasant collaboration with dr. Géza Haidegger, in managing the administrative issues related to my stage.

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