Abstracts of Doctor Habilitatus Thesis

Title: Small Abstract Computers
Author: Artiom Alhazov
Institute: Institute of Mathematics and Computer Science of the A.S.M.
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Keywords: Theoretical computer science and unconventional computing, Models of computation and Turing computability, Descriptional complexity and small universal systems, P systems as parallel distributed multiset and string processing, Promoters/inhibitors and priorities, Active membranes and polarizations, Symport and antiport, Determinism and reversibility, Insertion-deletion-substitution and [hybrid] networks of evolutionary processors, Maximal and minimal parallelism and asynchronous mode.

Structure of the thesis:[1] The thesis is written in English and consists of Introduction, 6 chapters, general conclusions and recommendations, bibliography of 291 titles, 8 appendices and 219 pages of main text. The thesis includes certain numbered material: 25 figures, 9 tables, 22 definitions, 19 lemmas, 77 theorems, 47 corollaries, 9 remarks, 24 examples and 54 formulas.

Publications on the thesis topic: 120, see the author's publication webpage[2] for the list of scientific papers and links.

The concept of the unconventional computing has caught the attention of many minds, and many researchers consider it a breakthrough in theory of information processing. This is a recent and very dynamic domain of research.

The most popular motivations for the unconventional computing are those of miniaturization (as a starting point for massive parallelism or vast storage), and those of the Moore's law. We can imagine, however, other arguments to focus on the unconventional computing, without having direct applications in mind. For instance, 1) developing new algorithmic design methods for the conventional computers, 2) new perspective insights into the fundamental Physics laws, e.g., determinism, reversibility, conservation, 3) new measures of information, since this field often uses unconventional data structures, e.g., multisets, 4) new encoding methods, due to different methods of representing the information, 5) interdisciplinary research on the crossroads of Classical computing, Information theory, Number theory, Biology, Physics, etc. Unconventional computing is already a successful domain of fundamental research.

[1] `http://www.cnaa.md/en/thesis/24558/`
[2] `http://aartiom.50webs.com/`

One can consider numerous variants of models, looking for adequacy with respect to the biochemical origins of the ideas, elegance of the definitions, powerful results, or similarity with other domains of theoretical computer science.

Area of studies reflected in this habilitation thesis consists of (symbol-objects/string-objects) membrane computing and other formal computing models, mainly *distributed parallel systems rewriting multisets or strings* (e.g., networks of evolutionary processors, reversible logical elements with memory, number-conservative cellular automata, circular Post systems, insertion-deletion systems, splicing systems and ciliate gene assembly. Most of these models permit (or naturally have) parallelism and biologically inspired features. We stress, however, that the scope of the thesis is limited to studying these models as *formal computational models*, i.e., mathematical structures. The thesis consists of analysis of the corresponding domains and original research of the author. The membrane systems models considered here are: maximally parallel multiset rewriting, with/without cooperation, without or with promoters/inhibitors/priorities, deterministic or not, reversible or not; P systems with symport/antiport, with active membranes, with insertion-deletion, with ciliate operations, with energy, etc.

The main goal of the research consists in determining the computational power of restricted models. This contributes to the potential subsequent applications, answering questions about suitability of these models for the needs or possibilities of the applications.

Scientific problems solved in this thesis include: 1) Finding the computational power of a) transitional P systems with membrane creation and division, b) P systems with active membranes without polarizations, c) deterministic controlled non-cooperative P systems, d) P systems with energy. 2) Characterizing a) the class of problems polynomial-time solvable by P systems with active membranes without polarizations, b) exact power of hybrid networks of evolutionary processors with 1 node.

Theoretical significance. A number of fundamental problems of distributed parallel multiset/string processing were addressed, and the best known bounds have been proved, e.g., for the membrane systems language family and for the number of rules in maximally parallel multiset rewriting systems.

The best known results for the optimization problems considered by different authors have been established, e.g., the power of symport-3 in one membrane, the number of nodes in the hybrid networks of evolutionary processors, the number of polarizations of efficient P systems with minimal parallelism, and synchronization time of P systems.

An important characterization of rewriting systems has been obtained for

the deterministic controlled non-cooperative multiset rewriting systems.

A landscape of results was produced for the fundamental properties of multiset rewriting, such as variants of determinism, reversibility, and self-stabilizations, for multiset processing with different features (e.g., kinds of cooperation and control) working in different modes.

The computational completeness was shown for systems with very weak forms of cooperation between the elements of these systems, e.g., non-cooperative transitional P systems with membrane creation and dissolution, and P systems with polarizationless active membranes.

The optimal results were obtained for some well-studied problems, e.g., different problems for P systems with symport/antiport, different problems for P systems with polarizationless active membranes, the number of nodes in the computationally complete networks of evolutionary processors.

Impact. We only mention a few cases where further investigation by other authors emerges from the publications reflected here. A perspective research direction has been introduced, that of obligatory hybrid networks of evolutionary processors. Out of the results reflected here, those on insertion-deletion systems, have been further developed answering the original open problem. The research for P systems with active membranes computing the permanent has lead to a few subsequent breakthroughs in complexity theory of P systems.

By the completion of this thesis, DBLP[3] has shown 37 journal papers and 37 conference ones, and Google Scholar[4] has reported the authors *h-index* of 16 and *i10-index* of 30, having registered over 880 citations. His publications were presented at over 35 scientific conferences, including participation at over 20 international conferences.

Applied value of the work. One of the applications is polymorphic P systems. Its use is providing a framework where rules can dynamically change during the computation, which is important for problems of symbolic computation and computer algebra. Other applications deal with linguistics. An efficient implementation of dictionaries by membrane systems has been proposed, using membrane (tree) structure to represent the prefix tree of the dictionary. P systems were found suitable for performing inflections of words in the Romanian language. There was also proposed P systems annotating affixes of the Romanian language, also elaborating a model that accounts for complex derivation steps that may consist of multiple affixes, changing terminations and/or root alternations.

[3] `http://www.informatik.uni-trier.de/~ley/pers/hd/a/Alhazov:Artiom.html`
[4] `http://scholar.google.com/citations?sortby=pubdate&user=M8LdW5kAAAAJ`

Main scientific results. 1) A universal P system with *23 rules* has been presented in Section 3.1. 2) A detailed study of the properties of *determinism and reversibility* is given in Section 2.3. 3) Universality of transitional P systems with *membrane creation and dissolution* is proved in Section 2.5. 4) P systems with *polarizationless active membranes* are computationally complete, as presented in Section 4.2. 5) *PSPACE*-complete problems can be solved by P systems with polarizationless active membranes, as described in Section 4.5. 6) The best known results on the hybrid networks of evolutionary processors (HNEPs) are presented in Section 5.1. Specifically, *HNEPs* are universal with 7 nodes, while HNEPs with 1 node have been exactly characterized by a regular expression. 7) *Deterministic controlled non-cooperative* systems accept only finite sets and their complements; this result is described in Section 2.2. 8) It was proved that P systems with *energy* are computationally complete in the maximally parallel mode; this result is presented in Section 4.8. 9) P systems with *insertion-deletion* of a single symbol without context (with priority of deletion) are computationally complete; this result is presented in Section 5.2. 10) Besides the abovementioned theoretical results, in Chapter 6 there was described a number of *applications*, such as synchronization, polymorphism, dictionary and inflections of words in Romanian language.

Artiom ALHAZOV is a leading researcher in the Institute of Mathematics and Computer Science of the Academy of Sciences of Moldova. He is an author of over 160 scientific publications (about 20 single-authored, also collaborating with over 50 co-authors, from 14 countries). The work of Artiom Alhazov focuses on parallel distributed multiset/string processing as an area of Theoretical Computer Science. In 2001 he graduated from the Faculty of Mathematics and Computer Science, the State University of Moldova. In 2006 he became a Ph.D. in Computer Science, Rovira i Virgili University, Tarragona. In 2013 he defended the Doctor Habilitatus Thesis in Computer Science.