

Impact of Membrane Computing and P Systems in ISI WoS. Celebrating the 65th Birthday of Gheorghe Păun

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*"Congratulations, G. Paun!
Since 2000, you have been cited ... times for your article...
This means that the number of citations your article received
places it in the top 0.5% within its field according to ESI.
Your work is highly influential, and is making a significant im-
pact among your colleagues in your field of study.
Congratulations on your extraordinary career accomplishment!"*
Essential Science Indicators (ESI), ISI Thomson, 2009.



Gheorghe Păun
(b. Dec. 6, 1950)

Abstract: Membrane Computing is a branch of Computer Science initiated by Gheorghe Păun in 1998, in a technical report of Turku Centre for Computer Science published as a journal paper ("Computing with Membranes" in Journal of Computer and System Sciences) in 2000. Membrane systems, as Gheorghe Păun called the models he has introduced, are known nowadays as "P Systems" (with the letter P coming from the initial of the name of this research area "father").

This note is an overview of the impact in ISI WoS of Gheorghe Păun's works, focused on Membrane Computing and P Systems field, on the occasion of his 65th birthday anniversary.

Keywords: Membrane Computing, P Systems, ISI Web of Science(WoS), scientific impact, h-index.

1 Introduction: Brief Bio-Sketch of Gheorghe Păun

"Gheorghe Păun is an example of a person affirming his own existence by writing. He is a prolific writer with a huge number of papers: tens of scientific books, hundreds of articles, several novels, poems, and books on games." (G. Ciobanu, [1]).

Gheorghe Păun (b. December 6, 1950, Romania) is a Romanian mathematician and theoretical computer scientist. He is also a writer and promoter of culture (editor-in-chief of a monthly cultural magazine "Curtea de La Argeş") [9].

G. Păun graduated the Faculty of Mathematics of the Bucharest University in 1974 and got his PhD at the same faculty in 1977 (under the supervision of Solomon Marcus). He has won many scholarships, in Germany, Finland, The Netherlands, Spain, etc.

Presently he is a senior researcher at the Institute of Mathematics of the Romanian Academy, Bucharest, and visiting researcher at Sevilla University, Spain.

Since 1997 he is a Corresponding Member, and since 2012 is a Full Member of the Romanian Academy. Since 2006 he is a member of Academia Europaea.

His main research fields are formal language theory (regulated rewriting, contextual grammars, grammar systems), automata theory, combinatorics on words, computational linguistics, DNA computing, membrane computing. He has (co)authored and (co)edited more than 60 books in these areas, and he has (co)authored more than 500 research papers.

In the last two decades he has visited many universities from Europe, USA, Canada, Japan, China, also participating to many international conferences, several times as an invited/keynote speaker. He is a member of the editorial board of numerous computer science journals and professional associations.

2 G. Păun and Membrane Computing

Gheorghe Păun is the founder of the Membrane Computing area of Computer Science, a research field inspired from the bio-chemistry of the cell (a more suitable name can be "Cell Computing"). The membrane systems, introduced in 1998 in [3] and disseminated in 2000 in [4], are usually called "P Systems". Most cited of all G. Păun's works is "Computing with Membranes" published in 2000, [4], having more than 850 citations (the second position of all cited papers of Journal of Computer and System Sciences). These 850 citing papers have also in turn over 4,900 citations, [7].

In February 2003, Gheorghe Păun answered a few questions on the occasion of ISI nomination of [4] as a fast breaking paper in the field of Computer Science, [8]:

"ST: Why do you think your paper is highly cited?"

It is both based on several "classic" theoretical computer science tools/techniques (grammars, automata, Lindenmayer systems, regulated rewriting, grammar systems), and related to rather "modern" branches of computer science (molecular computing in general, DNA computing in particular); it is highly interdisciplinary (it proposes computation models based on the structure and the functioning of the living cell). The model is very versatile; many variants were proposed, biologically or mathematically motivated. Most of these variants have attractive computer science features: universality and/or computational efficiency; they also promise to have relevance from a biological point of view, as algorithmic models of the cell as a whole (or of other cell-like systems).

ST: Does it describe a new discovery or a new methodology that's useful to others?

It proposes a new branch of natural computing: a distributed, parallel, and nondeterministic computing model, processing multisets in a cell-like or tissue-like compartmental structure, thus extending the field of molecular computing. Topics such as communication, synchronization, (maximal) parallelism, space-time trade-off, complexity, localization, etc. can find a natural framework to be dealt with. This is also a (reductionistic) global algorithmic model of the living cell, a kind of model the biologists are waiting for in the near future.

ST: What were some of the circumstances that led you to do this research?

The research was done in the prolongation of several years of work in DNA computing, which, in their turn, have continued many years of work in formal language theory. Very specifically, the paper was written in the framework of a project supported by The Academy of Finland, during a stage in Turku Centre for Computer Science, in the scientifically very "hot" group of Arto Salomaa.

ST: Could you summarize the significance of your paper in layman's terms?

The goal is to abstract a computability model from the structure and the functioning of the living cell. In short, in the compartments determined by a "membrane structure" (a cell-like hierarchical arrangement of membranes) one places multisets of "objects" (corresponding to the chemicals swimming in solutions) and "evolution rules" (corresponding to chemical reactions). The rules are applied in a maximally parallel (each object which can evolve by a rule from the same compartment should evolve) nondeterministic (the objects and the rules are randomly chosen) manner. The objects can also pass through membranes (one can say that they are "communicated" from one compartment to another one), the membranes can be dissolved, divided, created. The application of rules and the communication of objects can be controlled in various ways, either biologically or computer science motivated. A sequence of "transitions" from a configuration of the system to another configuration is called a "computation" and with a halting computation one associates a result, e.g., in the form of the multiset of objects present in a specified output membrane at the end of the computation. Several variants were considered. Most of them are computationally universal (they can compute all Turing computable vectors of natural numbers); this holds true even in certain cases where the computation is done by communication only (no object evolves, but only changes the compartments where it is placed). When an enhanced parallelism is available (e.g., via membrane division) polynomial solutions to NP-complete problems can be obtained by a space-time trade-off. No biological implementation was reported, but there are several software implementations, as well as several (preliminary) applications, mainly in simulating biological phenomena. Details can be found at the web address <http://ppage.psystems.eu>, as well as in the monograph Gheorghe Păun, *Membrane Computing. An Introduction*, Springer-Verlag, Berlin, 2002."

3 Collaborators and Followers of Gheorghe Păun

Publications of G. Păun have been cited in more than 15,000 international works (co)authored by more than 1700 computer scientists as: Y. Matyiasevich, A. Salomaa, G. Rozenberg, A. Ehrenfeucht, M. Hagiya, J. Kral, J. Berstel, J. Beauquier, B. Rozoy, J. Dassow, M. Novotny, R. Freund, P.R.J. Asveld, I.M. Havel, R. Siromoney, K.G. Subramanian, F. Urbanek, E. Csuhaj-Varju, J. Kelemen, A. Kelemenova, J. Hromkovic, M. Latteux, M. Clerbout, E. Makinen, N. Nirmal, H.C.M. Kleijn, Al. Meduna, CC. Squier, Z. Tuza, X.M. Nguyen, F.J. Brandenburg, J. Kari, V. Niemi, H. Fernau, J. Shallit, D. Watjen, A. Lepisto, A. Carpi, T. Harju, M. Jantzen, H. Bordihn, D. Raz, J. Honkala, T. Yokomori, G. Mauri, M. Katsura, V. Manca, K. Krithivasan, J. Reif, M. Margenstern, J. Goldstine, Y. Rogozhin, H. Tanaka, M. Conrad, S. Crespi Reghizzi, M.J. Pérez-Jiménez, D. Wotschke, A. Obtulowicz, M. Holcombe, O. Ibarra, O. Ecegioglu, C. Teuscher, J. Karhumaki, L. Cardelli, E. Shapiro, J. Wiedermann, E. Moriya, C. Rossello, K. Ueda, S.G. Akl etc.

G. Păun is an very influential author, a founder of several research groups in membrane computing. Many researchers were attracted to investigate molecular computation models by G. Păun, from countries as: Romania, Republic of Moldova, Hungary, Austria, Spain, The Netherlands, Finland, China etc.

Many well know researchers were involved in studying open problems proposed G. Păun: J. Berstel, L. Boasson, J. Beauquier, B. Rozoy, P.R.J. Asveld, F. Urbanek, J. Dassow, M. Latteux, M. Clerbout, C.C. Squier, Z. Tuza, J. Cassaigne, S. Schwer, P. Seebold, E. Makinen, F.J. Brandenburg, A. Lepisto, A. Carpi, J. Kari, V. Niemi, D. Hauschildt, M. Jantzen, D. Raz, D. Pixton, M.J. Pérez-Jiménez, G. Mauri, Cl. Ferretti, K. Khrithivasan, R. Freund, M. Margenstern, Y. Rogozhin, H. J. Hoogeboom, A. Obtulowicz, etc.

Books (co)authored by Gheorghe Păun:

1. Grammars for Economic Processes, The Technical Publ. House, Bucharest, 1980 (in Romanian).
2. Matrix Grammars, The Scientific and Enciclopaedic Publ. House, Bucharest, 1981 (in Romanian).
3. Contextual Grammars, The Publ. House of the Romanian Academy, Bucharest, 1982 (in Romanian).
4. Recent Results and Problems in Formal Language Theory, The Scientific and Enciclopaedic Publ. House, Bucharest, 1984 (in Romanian).
5. The Paradoxes of Hierarchies, The Scientific and Enciclopaedic Publ. House, Bucharest, 1987 (in Romanian).
6. (in collaboration with J. Dassow, Germany) Regulated Rewriting in Formal Language Theory, Akademie-Verlag, Berlin, 1989, Springer-Verlag, Berlin, 1989 (nr. 18 in series Monograph on Theoretical Computer Science).
7. (in collaboration with E. Csuhaj-Varju, Hungary; J. Dassow, Germany; J. Kelemen, Czechoslovakia) Grammar Systems. A Grammatical Approach to Distribution and Cooperation, Gordon and Breach, series Topics in Computer Mathematics, London, 1994.
8. Marcus Contextual Grammars, Kluwer Academic Publ., Dordrecht, Boston, London, 1997.
9. (in collaboration with G. Rozenberg, A. Salomaa) DNA Computing. New Computing Paradigms, Springer-Verlag, Heidelberg, 1998 (translated in Japanese, in 1999, in Chinese and Russian in 2004).
10. (in collaboration with C. Calude) Computing with Cells and Atoms, Taylor and Francis, London, 2000.
11. Membrane Computing. An Introduction, Springer-Verlag, Berlin, 2002 (translated in Chinese, in 2012).

Collective volumes (co)edited by Gheorghe Păun:

1. Mathematical Aspects of Natural and Formal Languages, World Scientific Publishing, Singapore, 1994.
2. Mathematical Linguistics and Related Topics, Editura Academiei Romane, Bucharest, 1995.
3. Artificial Life: Grammatical Models, The Black Sea University Press, Bucharest, 1995.

4. (with A. Salomaa) *New Trends in Formal Languages: Control, Cooperation, Combinatorics.*, Lecture Notes in Computer Science 1218, Springer-Verlag, Berlin, 1997.
5. *Computing with Bio-Molecules. Theory and Experiments*, Springer-Verlag, Singapore, 1998.
6. (with A. Salomaa) *Grammatical Models of Multi-Agent Systems*, Gordon and Breach, London, 1999.
7. (with J. Karhumäki, H.A. Maurer, G. Rozenberg) *Jewels are Forever*, Springer-Verlag, Berlin, 1999.
8. (with G. Ciobanu) *Foundamentals of Computing Theory '99*, Proceedings of the FCT Conf., Iasi, 1999, Lecture Notes in Computer Science, 1684, Springer-Verlag, Berlin, 1999.
9. (with C. Calude) *Finite versus Infinite. Contributions to an Eternal Dilemma*, Springer-Verlag, London, 2000.
10. (with C. Calude, M.J. Dinneen) *Pre-proceedings of Workshop on Multiset Processing*, Curtea de Argeş, Romania, August 2000, TR 140, CDMTCS, Univ. Auckland, New Zealand, 2000.
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15. (with M. Ito, S. Yu) *Words, Semigroups, Transductions (Festschrift in Honour of Gabriel Thierrin)*, World Scientific, Singapore, 2001.
16. (with D. Dascalu, E. Pincovski, Vl. Topa, V. Voicu) *Micro and Nanostructures*, Ed. Academiei, Bucharest, 2001.
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22. (with N. Jonoska, G. Rozenberg) Aspects of Molecular Computing. Essays Dedicated to Tom Head on the Occasion of His 70th Birthday, LNCS 2950, Springer-Verlag, Berlin, 2004.
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24. (with C. Martin-Vide, G. Mauri, G. Rozenberg, A. Salomaa) Membrane Computing, International Workshop, WMC 2003, Tarragona, July 2003, Selected Papers, LNCS 2933, Springer-Verlag, Berlin, 2004.
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33. (with C.S. Calude, M.J. Dinneen, M.J. Perez-Jimenez, G. Rozenberg) Unconventional Computation. 4th International Conference, UC2005, Sevilla, Spain, October 2005. Proceedings, LNCS 3699, Springer-Verlag, Berlin, 2005.
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56. (with L. Valencia-Cabrera et al.) Proceedings of the Eleventh Brainstorming Week on Membrane Computing, Fenix Editora, Sevilla, 2013.
57. (with L. Pan, M.J.Pérez-Jiménez, T. Song) Proceedings of the 9th International Symposium BIC-TA 2014, Wuhan, China, Comm. in Computer and Information Sciences, vol. 472, Springer, 2014.
58. (with G. Rozenberg, A. Salomaa) Discrete Mathematics and Computer Science, Ed. Academiei, București, 2014. v (cu L.F. Macias-Ramos et al.) Proceedings of the Twelfth Brainstorming Week on Membrane Computing, Fenix Editora, Sevilla, 2014.
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4 Impact of G. Păun's Works

The publications of G. Păun have been cited in more than 15,000 international works, (co)authored by more than 1700 computer scientists.

More than 200 papers (co)authored by G. Păun are indexed/abstracted in ISI WoS, having over 3,000 citations and $h\text{-index} = 28$ [7]. The most cited paper is "Computing with membranes", [4], published in 2000, having more than 850 citations (the second position of all cited papers from Journal of Computer and System Sciences. [7]).

In 2009, G. Păun was included by ISI (Thompson-Reuters) in the Highly Cited Researchers category, which means he was at that time among the most cited 0.5% computer scientists in the world.

The most cited paper published in International Journal of Computers Communications & Control (IJCCC) is "Spiking Neural P Systems with Anti-Spikes", coauthored by G. Păun (with L. Pan), [2], [7]. Also the papers [6] and [5] are in top 10 of IJCCC.

Nowadays there exist over 2500 works and over 60 PhD thesis in the field of Membrane Computing and P Systems (and about 50 collective volumes), with over 500 (co)authors from Romania, Austria, The Netherlands, Germany, Finland, Japan, UK, Canada, Hungary, India, Italy, Spain, Czech Republic, USA, Poland, France, Republic of Moldova, China, Switzerland, Australia, New Zealand, Filipine, Malaesia, Slovakia etc.

A webpage dedicated to P Systems is hosted in Vienna [10]. Every year three meetings dedicated to P Systems are organized: Conference of Membrane Computing (former Workshop on Membrane Computing, initiated in 2000), Brainstorming Week on Membrane Computing (since

2003), and Asian Conference on Membrane Computing (since 2012). Several conferences in natural computing or unconventional computing explicitly have Membrane Computing in their scopes.

International recognition of G. Păun consist in:

- Invitations as visiting researcher received from many universities and research institutes from Hungary, Czech Republic, Slovakia, Germany, Finland, France, Japan, Holland, Austria, Spain, USA, Canada, Poland, Italy, New Zealand, Greece, China, Singapore, etc., and finished with many collaborations with local researchers.
- Over 100 invited lectures to universities from Germany (Magdeburg, Frankfurt, Hamburg, Tübingen), Hungary (Budapest, Győr), Czech Republic (Brno, Prague, Olomouc), Slovakia (Bratislava), Spain (Tarragona, Barcelona, Madrid, Sevilla), Finland (Turku, Laapeenranta), Holland (Leiden), Japan (Kyoto, Tokyo-Chiba, Tokyo-Waseda, Tokyo-Dendai, Hiroshima), France (Paris, Lille), UK (London), Canada (Ontario), Poland (Warsaw), US (Greenville NC, Binghamton), Italy (Milano, Roma, Brescia, Pisa, L'Aquila, Siena, Palermo, Verona), Greece (Xanthi), China (Beijing, Wuhan), etc;
- Visiting professor at Technical University of Vienna (Austria), Turku Centre for Computer Science (Finland), Rovira i Virgili University of Tarragona (Spain) and Politecnica University of Madrid (Spain), Banach Center of Poland Academy of Sciences (Poland), University of Singapore, University of Malaysia, Hungarian Academy etc.
- Humboldt scholarship in Germany at University of Magdeburg (May 1, 1992 - July 31, 1993; July-August 1999); many scholarships in France, Finland, Spain, The Netherlands;
- Research scholarship "Ramon y Cajal" in Spain (Tarragona and Sevilla) for five years (2001-2006) and leader of a project of excellency in Spain (Sevilla, 2009-2014).
- Member of the program committees of more than 120 international conferences, organizer of the symposiums Artificial Life: Grammatical Models (Mangalia - Romania, 1994), Molecular Computing (Mangalia - Romania, 1997), Multiset Processing (Curtea de Argeş - Romania, 2000), Membrane Computing (Curtea de Argeş 2001, 2002, 2009, Tarragona 2003, Milano 2004, Viena 2005, Leiden 2006, Salonic 2007, Edinburgh 2008, Jena 2010, Fontainebleau 2011, Budapest 2012, Chisinau 2013, Praga 2014, Valencia 2015);
- Founder and main organizer of series "Brainstorming Week on Membrane Computing" (Tarragona 2003, Sevilla 2004-2015); member of steering committee of Conferences Developments in Language Theory, Universal Machines and Computations and DNA Based Computing, and of workshops Grammar Systems and Descriptive Complexity in Formal Systems.

G. Păun is/was member in Editorial Board of many journals, as: Journal of Universal Computer Science (Springer-Verlag), Journal of Computing and Informatics (Computers and Artificial Intelligence), Acta Cybernetica, Journal of Automata, Languages, and Combinatorics, Grammars, Fundamenta Informaticae, Romanian Journal of Information Science and Technology, Computer Science Journal of Moldova, International Journal of Foundations of Computer Science (World Scientific), International Journal of Computer Mathematics, Natural Computing: An International Journal, Soft Computing (Springer)- Area editor (DNA and membrane computing), BioSystems (Elsevier); Theoretical Computer Science. Natural Computing Series (Elsevier); International Journal of Unconventional Computing; New Generation Computing (Springer and Omsa-Japonia), Progress in Natural Science (Elsevier and Science in China Press), Economic

Computation and Economic Cybernetics Studies and Research, International Journal of Computers Communication & Control, etc.

He also received several scientific honors and awards, in Romania and abroad, among others, the Doctor Honoris Causa title from:

1. University of Opava – The Czech Republic (2008),
2. University of Pitești - Romania (2010) and
3. Agora University of Oradea - Romania (2015).

5 Summary

A quick overview of Gheorghe Păun computer science activity and, especially, of the impact of his activity is provided, focusing on the data from ISI WoS and on the developments in Membrane Computing, a branch of Natural Computing initiated by him in 1998.

Acknowledgment

Celebrating Gheorghe Păun's 65th birthday, we wish him a good health, long life, and new scientific achievements!

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