Lecture Notes in Computer Science 8961

Commenced Publication in 1973
Founding and Former Series Editors:
Gerhard Goos, Juris Hartmanis, and Jan van Leeuwen

More information about this series at http://www.springer.com/series/7407

Marian Gheorghe · Grzegorz Rozenberg
Arto Salomaa · Petr Sosík · Claudio Zandron (Eds.)

Membrane Computing

15th International Conference, CMC 2014
Prague, Czech Republic, August 20–22, 2014
Revised Selected Papers

Springer

Editors
Marian Gheorghe
Department of Computer Science
University of Sheffield
Sheffield
United Kingdom

Petr Sosík
Dept. Mathematics & Computer Science
Silesian University
Opava
Czech Republic

Grzegorz Rozenberg
Leiden Inst. Advanced Computer Science
Leiden University
Leiden
The Netherlands

Claudio Zandron
DISCO
University of Milan-Bicocca
Milan
Italy

Arto Salomaa
Turku Center for Computer Science
Turku
Finland

ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-319-14369-9 ISBN 978-3-319-14370-5 (eBook)
DOI 10.1007/978-3-319-14370-5

Library of Congress Control Number: 2014958974

LNCS Sublibrary: SL1 – Theoretical Computer Science and General Issues

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media
(www.springer.com)

Preface

This volume contains a selection of papers presented at the 15th International Conference on Membrane Computing (CMC 15), held in Prague, Czech Republic, during August 20–22, 2014 (*http://cmc15.slu.cz/*).

The CMC series was initiated by Gheorghe Păun as the Workshop on Multiset Processing in the year 2000. Then two workshops on Membrane Computing were organized in Curtea de Argeş, Romania, in 2001 and 2002. A selection of papers from each of these three meetings was published as volume 2235 of the Lecture Notes in Computer Science series, as a special issue of Fundamenta Informaticae (volume 49, numbers 1–3, 2002), and as volume 2597 of Lecture Notes in Computer Science, respectively. The next six workshops took place in Tarragona, Spain (in July 2003), Milan, Italy (in June 2004), Vienna, Austria (in July 2005), Leiden, The Netherlands (in July 2006), Thessaloniki, Greece (in June 2007), and Edinburgh, UK (in July 2008), with the proceedings published in Lecture Notes in Computer Science as volumes 2933, 3365, 3850, 4361, 4860, and 5391, respectively. The 10th workshop returned to Curtea de Argeş in August 2009 (LNCS volume 5957).

From the year 2010, the series of meetings on membrane computing continued as the Conference on Membrane Computing with the 2010, 2011, 2012, and 2013 editions held in Jena, Germany (LNCS volume 6501), Fontainebleau, France (LNCS volume 7184), Budapest, Hungary (LNCS volume 7762), and Chişinău, Republic of Moldova (LNCS volume 8340), respectively. Nowadays a Steering Committee takes care of the continuation of the CMC series which is organized under the auspices of the European Molecular Computing Consortium (EMCC). A regional version of CMC, the Asian Conference on Membrane Computing, ACMC, started with 2012 edition in Wuhan, China and continued with 2013 and 2014 editions held in Chengdu, China and Coimbatore, India.

CMC 15 was organized by the Institute of Computer Science of the Faculty of Philosophy and Science, Silesian University in Opava, in collaboration with the Action M Agency, Prague. A special session was dedicated to the memory of Prof. Yurii Rogozhin, the main organizer of the CMC 14, a world-class mathematician and computer scientist and, last but not least, a dear friend of many participants of the CMC series.

Invited lectures were given by Luděk Cienciala (Czech Republic), Erzsébet Csuhaj-Varjú (Hungary), Mario J. Pérez Jiménez (Spain), Jiří Wiedermann (Czech Republic), and Claudio Zandron (Italy). Based on the votes of the CMC 15 participants, the Best Paper Award for this year's CMC Conference was given to Alberto Leporati, Luca Manzoni, Giancarlo Mauri, Antonio E. Porreca, and Claudio Zandron for their paper "Simulating Elementary Active Membranes with an Application to the P Conjecture."

In addition to the texts of the invited talks, this volume contains 19 papers out of the 24 presented at the Conference and two papers selected from the 22 presented at the

ACMC 2014. Each paper was subject to at least two referee reports for the Conferences and of an additional one for this volume.

The editors warmly thank the Program Committee, the invited speakers, the authors of the papers, the reviewers, and all the participants for their contributions to the success of CMC 15.

November 2014

Marian Gheorghe
Grzegorz Rozenberg
Arto Salomaa
Petr Sosík
Claudio Zandron

Organization

Steering Committee

Gabriel Ciobanu	Iaşi, Romania
Erzsébet Csuhaj-Varjú	Budapest, Hungary
Rudolf Freund	Vienna, Austria
Marian Gheorghe (Chair)	Sheffield, UK
Vincenzo Manca	Verona, Italy
Maurice Margenstern	Metz, France
Giancarlo Mauri	Milan, Italy
Linqiang Pan	Wuhan, China
Gheorghe Păun	Bucharest, Romania/Seville, Spain
Mario J. Pérez-Jiménez	Seville, Spain
Petr Sosík	Opava, Czech Republic
Sergey Verlan	Paris, France

Organizing Committee

Petr Sosík (Co-chair)	Opava, Czech Republic
Petr Čermák (Co-chair)	Opava, Czech Republic
Luděk Cienciala	Opava, Czech Republic
Miroslav Langer	Opava, Czech Republic
Šárka Vavrečková	Opava, Czech Republic
Štěpánka Tůmová	Opava, Czech Republic
Hana Černíková	Opava, Czech Republic

Program Committee

Artiom Alhazov	Chişinău, Moldova
Luděk Cienciala	Opava, Czech Republic
Gabriel Ciobanu	Iaşi, Romania
Erzsébet Csuhaj-Varjú	Budapest, Hungary
Giuditta Franco	Verona, Italy
Rudolf Freund	Vienna, Austria
Marian Gheorghe (Co-chair)	Sheffield, UK
Thomas Hinze	Cottbus, Germany
Florentin Ipate	Bucharest, Romania
Shankara Narayanan Krishna	Bombay, India
Alberto Leporati	Milan, Italy
Vincenzo Manca	Verona, Italy
Maurice Margenstern	Metz, France
Giancarlo Mauri	Milan, Italy

Radu Nicolescu	Auckland, New Zealand
Linqiang Pan	Wuhan, China
Gheorghe Păun	Bucharest, Romania/Seville, Spain
Dario Pescini	Milan, Italy
Agustín Riscos-Núñez	Seville, Spain
Petr Sosík (Co-chair)	Opava, Czech Republic
György Vaszil	Debrecen, Hungary
Sergey Verlan	Paris, France
Claudio Zandron	Milan, Italy
Gexiang Zhang	Chengdu, Sichuan, China

P Systems: A Formal Approach to Social Networks (Abstract)

Erzsébet Csuhaj-Varjú[1], Marian Gheorghe[2], and György Vaszil[3]

[1] Department of Algorithms and Their Applications, Faculty of Informatics
Eötvös Loránd University, Pázmány Péter sétány 1/c, 1117 Budapest, Hungary
csuhaj@inf.elte.hu

[2] Department of Computer Science, University of Sheffield
Regent Court, 211 Portobello, Sheffield S1 4DP, United Kingdom
m.gheorghe@sheffield.ac.uk

[3] Department of Computer Science, Faculty of Informatics
University of Debrecen, PO Box 12, 4010 Debrecen, Hungary
vaszil.gyorgy@inf.unideb.hu

One of the major challenges for membrane computing is to find applications of the obtained theoretical results in different scientific areas. Concepts and methods in P systems theory have been so far successfully employed in some other areas of computer science and in modeling several biological phenomena, but except applications in linguistics and natural language processing, only a limited amount of attention has been paid to using membrane systems as formal tools in social sciences.

One of the few steps in this direction was made in [12] where P systems were proposed to model social networks, an area of contemporary computer science and practice which is rapidly growing, involving methods and approaches from a multitude of research areas.

Roughly speaking, social networks are communities of individuals connected through a communication network and interested in some common social phenomena or activities. When formalizing these networks, their special features, as interpersonal relationships between individuals, are expected to appear in the syntactic model. In various formalisms related to the study of social phenomena, these relationships are defined as information-carrying connections. Two basic types of them are *strong* and *weak ties*. Weak ties are responsible for the embeddedness and structure of social networks and for the communication within these systems [16]. There are other measures that characterize connections between nodes (agents). *Centrality* gives an indication of the social power of a node and the strength of its connections. It relies on other measures, *betweenness* or *closeness degrees*. Betweenness is the degree of connectivity between a node and the nodes that have a significant number of neighbors (direct connections). Closeness measures the distance between a node and all the other nodes in the network, degree counts the number of connections. For more details on these concepts and for some other measures of connections existing in social networks the reader is advised to consult [25].

Research supported in part by the Hungarian Scientific Research Fund, “OTKA”, project K75952.

To describe communities of agents interacting with each other and with their dynamically changing environment, purely syntactic models have already been used. Examples from formal language theory are the framework of eco-grammar systems, launched in [10] and networks of (parallel) language processors describing populations of agents by rewriting systems in [8,14]. Multi-agent systems in terms of formal language theory and membrane computing were discussed in [5], [6], [4], and [17].

P systems, especially tissue P systems, can also be considered as collections of agents (individuals) communicating with each other: the compartments or nodes with the multisets of objects represent the individuals and the rules of the system describe the communication/interaction between the components. In the case of population P systems, see [7], the established communication links may dynamically change. Notice that the objects can also be considered as information pieces. In this case a node represents a loosely organized community of agents.

In [12] new classes of P systems capturing communication aspects in social networks were introduced and various research topics related to connections between P systems theory and the theory of social interactions and networks were initiated. They are called *population P systems governed by communication* (pgcP systems, for short). In this case, in addition to the multisets of standard objects which are called cellular objects, so-called communication objects are present in the network. The transition takes place by rewriting and communication of the cellular objects and recording the performed communication. The transitions are governed by communication, i.e., rules can be performed only if some predicates on the multisets of communication symbols associated to the links are satisfied. Whenever communication takes place, the number of communication symbols associated to the link increases.

It is easy to see that the model provides various possibilities to study the behavior of the nodes: *ordinary* or *popular* nodes - those that host individuals and allow communication between them; *new-born* nodes - those that are dynamically created and linked to the existing network; *non-visible* or *extinct* nodes - the nodes that are no longer connected to the network or have disappeared; nodes with one way communication, only allowing information to go into, *blackholes* or allowing only to exit from, *whiteholes*. Some of these aspects have been already discussed in membrane computing: for example, population P systems allow nodes to be dynamically connected and disconnected [7]. We can also take into account connections between nodes and look at the *volume of communication* - the amount of (new) information generated or sent-received by various nodes or groups of nodes; *frequency of communicated messages* - the number of communication steps related to the evolution (computation) steps; *communication motifs* - patterns of communication identified throughout the network evolution.

In [12] we have focused on communication in these networks. In order to characterize it, and the fact that the strength of connections might evolve in time by either increasing or decreasing the frequency of communication, we introduced some sort of symbols that act in this respect, called complementary communication symbols. The customary (or positive) symbols strengthen a connection, whereas the complementary (negative) ones weaken it.

The idea of complementary alphabets is not new in the field of natural computing. It is a core idea of *DNA computing*, and the concept of related notions have been discussed in membrane computing as well [1], [2], [3], [20], [19].

In [12] some further concepts regarding some specific types of pgcP systems have also been defined, and some preliminary results for *deterministic* and *non-cooperative* pgcP systems, based on tools of Lindenmayer systems (D0L systems), have been presented. Among others, we described the growth of the communication volume, the frequency, and the intensity of communication on the links.

In our talk we discussed pgcP systems and presented a preview of open problems and possible research directions. For example, important questions are how the different types of predicates for communication affect the volume and the intensity of communication and the types of communication motifs in the network. Description of other *concepts and measures* from social networks like *leaders and clusters emergence* in terms of pgcP systems would also be of interest.

References

1. A. Alhazov, B. Aman, R. Freund, Gh. Păun. Matter and Anti-Matter in Membrane Systems. In: *BWMC12* (L.F. Macías, M.A. Martínez-del-Amor, Gh. Păun, A. Riscos-Núñez, L. Valencia-Cabrera, eds.), Fénix Editora, 1–26, 2014.
2. B. Aman, G. Ciobanu. Turing completeness using three mobile membranes. In *Unconventional Computing 2009*, Lecture Notes in Computer Science, 5715, 42–55, 2009.
3. B. Aman, G. Ciobanu. Mutual mobile membranes systems with surface objects. In *7-th Brainstorming Week of Membrane Computing*, 29–39, 2009.
4. G. Bel-Enguix. A Multi-agent Model for Simulating the Impact of Social Structure in Linguistic Convergence. In *ICAART(2)* (J. Filipe et. al, Eds.), INSTICC Press, 367–372, 2009.
5. G. Bel-Enguix, M. A. Grando, M. D. Jiménez López. A Grammatical Framework for Modelling Multi-Agent Dialogues. In *PRIMA 2006* (Z.-Z. Shi, R. Sadananda, Eds.), LNAI 4088, Springer Verlag, Berlin Heidelberg, 10–21, 2009.
6. G. Bel-Enguix, M. D. Jiménez López. Membranes as Multi-agent Systems: an Application for Dialogue Modelling. In *IFIP PPAI 2006* (J.K. Debenham, Ed.), Springer, 31–40, 2006.
7. F. Bernardini, M. Gheorghe. Population P systems. *Intern J of Universal Comp Sci*, 10, 509–539, 2004.
8. E. Csuhaj-Varjú. Networks of Language Processors. *EATCS Bulletin* 63, 120–134, 1997.
9. E. Csuhaj-Varjú. Computing by networks of Watson-Crick $D0L$ systems. In *Proc. Algebraic Systems, Formal Languages and Computation* (M. Ito, Ed.) RIMS Kokyuroku 1166, August 2000, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, 43–51, 2000.
10. E. Csuhaj-Varjú, J. Kelemen, A. Kelemenová, Gh. Păun. Eco-Grammar Systems: A Grammatical Framework for Studying Lifelike Interactions. *Artificial Life*, 3(3), 1–28, 1997.
11. E. Csuhaj-Varjú, V. Mitrana. Evolutionary systems: a language generating device inspired by evolving communities of cells. *Acta Informatica*, 36(11), 913–926, 2000.
12. E. Csuhaj-Varjú, M. Gheorghe, M. Oswald, Gy. Vaszil. P systems for Social Networks. In *BWMC9* (M.A. Martínez-del-Amor, Gh. Păun, I. Pérez-Hurtado, F.J. Romero-Campero, L. Valencia-Cabrera, eds.), Fénix Editora, 113–124, 2011.
13. E. Csuhaj-Varjú, A. Salomaa. Networks of Watson-Crick $D0L$ systems. In *Words, Languages & Combinatorics III. Proceedings of the International Colloquium, Kyoto, Japan, March 14-21, 2000.* (M. Ito, T. Imaoka, Eds.), World Scientific Publishing Co., Singapore, 134–149, 2003.
14. E. Csuhaj-Varjú, A. Salomaa. Networks of Parallel Language Processors. In *New Trends in Formal Languages. Control, Cooperation, and Combinatorics* (Gh. Păun, A. Salomaa, Eds.), LNCS 1218, Springer Verlag, Berlin Heidelberg, 299-318, 1997.

15. E. Csuhaj-Varjú, Gy. Vaszil. P automata or purely communicating accepting P systems. In *Membrane Computing*, LNCS 2579, Springer Verlag, Berlin Heidelberg, 219–233, 2003.
16. M.D. Granovetter. The Impact of Social Structures on Economic Development. Journal of Economic Perspectives, 19, 33–50, 2004.
17. M. D. Jiménez López. Agents in Formal Language Theory: An Overview. In *Highlights in Practical Applications of Agents and Multiagent Systems. 9th International Conference on Practical Applications of Agents and Multiagent Systems* (J. Bajo Pérez et. al, Eds.) Advances in Intelligent and Soft Computing 89, Springer, 283–290, 2011.
18. M. Minsky. *Finite and Infinite Machines.* Prentice Hall, Englewood Cliffs, New Jersey, 1967.
19. Gh. Păun. *Membrane computing. An Introduction*. Springer, 2002.
20. L. Pan, Gh. Păun. Spiking neural P systems with anti-spikes, *Int J Computers Comms Control*, 4, 273–282, 2009.
21. Gh. Păun. Computing with Membranes. *J. of Comput. Syst. Sci.*, 61, 108–143, 2000.
22. Gh. Păun, G. Rozenberg, A. Salomaa. *DNA Computing - New Computing Paradigms*. Springer Verlag, 1998.
23. G. Rozenberg, A. Salomaa. (Eds). *Handbook of Formal Languages I-III*. Springer, 1997.
24. Gh. Păun, G. Rozenberg, A. Salomaa. (Eds). *The Handbook of Membrane Computing*. Oxford University Press, 2009.
25. S. Wasserman, K. Faust. *Social Networks Analysis: Methods and Applications*. Cambridge University Press, 1994.

Inconspicuous Appeal of Amorphous Computing Systems (Invited Talk)

Jiří Wiedermann

Institute of Computer Science, Academy of Sciences of the Czech Republic,
Pod Vodárenskou věží 2, 182 07 Prague 8, Czech Republic
jiri.wiedermann@cs.cas.cz

Abstract. Amorphous computing systems typically consist of myriads of tiny simple processors that are randomly distributed at fixed positions or move randomly in a confined volume. The processors are "embodied" meaning that each of them has its own source of energy, has a "body" equipped with various sensors and communication means and has a computational control part. Initially, the processors have no identifiers and from the technological reasons, in the interest of their maximal simplicity, their computational, communication, sensory and locomotion (if any) parts are reduced to an absolute minimum. The processors communicate wirelessly, e.g., in an airborne medium they communicate via a short-range radio, acoustically or optically and in a waterborne medium via molecular communication. In the extreme cases the computational part of the processors can be simplified down to probabilistic finite state automata or even combinatorial circuits and the system as a whole can still be made universally programmable. From the theoretical point of view the structure and the properties of the amorphous systems qualify them among the simplest (non-uniform) universal computational devices. From the practical viewpoint, once technology will enable a mass production of the required processors a host of new applications so far inaccessible to classical approaches to computing will follow.

Extended Abstract: The history of amorphous computing systems began by the end of the twentieth century, mainly as an engineering endeavor (cf. [1], [2], [4], [5], [6], or [13]). Namely, in those days the progress in constructing the micro-electro-mechanical systems (MEMS) has enabled to think of devices integrating a central data processing unit (the microprocessor) and several components that interact with the surroundings such as micro-sensors, wireless communication unit, and the energy source in a small unit. These parts can possibly be complemented by micro-actuators and locomotive means. The resulting device can be viewed as an embodied computational unit. Note that such a unit possesses all the necessary parts characterizing autonomous embodied robots.

MEMS devices generally range in size from 20 micrometres (20×10^{-6} m) to a millimetre (i.e. 0.02 to 1.0 mm). Current ideas about nano-electro-mechanical systems (NEMS) and nano-technology consider such systems at a nano-scale (10^{-9} m).

The driving force behind the respective development has mainly been a vision of huge amounts of the respective "micro-robots" engaged in various application tasks

This work was partially supported by RVO 67985807 and the GA ČR grant No. P202/10/1333.

requiring local computation, local sensing, local actions and wireless communication among the randomly distributed units of the system. The joint idea has been that using local communication, the respective devices could self–organize in order to perform a coordinated action none of the elements alone was able to realize.

It is obvious that the resulting system of locally communicating units has no fixed architecture what is reflected by the term "amorphous computing systems".

The application range of amorphous computing systems is tremendous, covering practically all areas of life. For instance, when spread around, they can be used for surveillance of regions, buildings, road traffic, natural environments like oceans, deserts, inaccessible mountains, alien planets, etc. (cf. [3], [5], [6], [12], [13], and [14]). They can monitor various parameters, like temperature, precipitation, movements of persons and/or their life function, traffic density, presence of chemical compounds, seismicity, winds, water flow, life manifestation, etc., etc. The respective measurements are transmitted and collected in a base station for further processing. In medical sciences, nano-sized devices can even enter living bodies in order to monitor their interior organs and suppress undesirable phenomena. In futuristic applications amorphous computing systems can perform genetic manipulations at the cell level to strengthen the immune system, to heal up injuries, to cure heart or brain strokes, etc. (cf. [7]). The latter ideas are inspired by the existing bacteria that represent a template for such systems in nature.

Amorphous computing systems communicating via radio can be seen as an extreme case of wireless sensory networks. From the latter networks they differ in several important aspects. First, they are considered under severe restriction on resources, such as energy, memory and computational speed. Second, in order to simplify their mass production the computational and communication hardware is reduced to a minimum which seems to be necessary to maintain the required functionality and scalability of the network. Among the respective requirements the absence of node identifiers, practical non-existence of embedded communication software and asynchronicity of processors is assumed. Specific probabilistic protocols, entirely differing from those used in the wireless sensory networks, must be developed allowing reliable message delivery among the processors of amorphous computing systems. Last but not least, amorphous computing systems must be much more robust than the wireless sensory networks. This is due to the increased probability of their nodes' loss caused by their (perhaps temporal) inaccessibility, failure or damage, low reliability of a single inter-processor communication and quite general assumptions concerning their placement or movement (cf. [10], [11], [16], [18]).

Waterborn amorphous computing systems usually work on different principles than the radio-driven systems since radio waves do not travel well through good electrical conductors like salt water and similar liquids. Therefore, the former systems communicate with the help of the signal molecules that spread around via Brownian motion [16]. In some cases the decisions of nano-machines are based on so–called quorum sensing [18], i.e., on the density of signal molecules in the environment. This calls for a completely different design of the communication and control mechanisms that has no counterpart in the domain of classical distributed computing.

The inconspicuous appeal of amorphous computing systems consists in their immense variety of forms, in the possibility of their adaptation to particular characteristics of their operational environment, in their extreme simplicity and, last but not least, in their wide applicability to problems that cannot be solved by classical computational means. All these properties are supported by the computational universality of the underlying systems.

So far, the prevailing focus of research in amorphous computing systems has mostly been focused towards engineering or technological aspects of such systems almost completely ignoring theoretical questions related to their computational power and efficiency. Obviously, without knowing their theoretical limits, one cannot have a complete picture of the potential abilities and limitations of such systems. This was the starting point of the project of the present author and his (then) PhD student L. Petrů (cf. his PhD thesis [8]) devoted to studies of theoretical issues in amorphous computing initiated in 2004. Since that time various models of amorphous systems have been investigated.

The aim of the present talk is to give a brief overview of the developments in the corresponding research as performed within our amorphous computing research project. In the talk we present the main design ideas behind the respective models, point to the main problems to be solved, indicate their solution, and present the main results. The models will be approached roughly in the order of their increased generality (cf. [19], [20], [21]).

We start with the simplest model of amorphous cellular automata [8] and will continue with more elaborated asynchronous stationary amorphous computing systems [9], [17]. Then we turn our attention towards the so-called flying amorphous computing systems with mobile processors (cf. [10] and [11]). Finally, we describe molecularly communicating nano-machines that orchestrate their activities either by a molecular analogue of radio broadcast [16] or via quorum sensing [18]. Interestingly, in the latter case the nano-machines must be endowed by the self-reproduction ability.

The main result of our investigations is the proof of the computational universality of the amorphous computing systems considered above. This points to the versatility of such systems in various computational or robotic applications (cf. [15], [17]).

We conclude by stressing that the amorphous computing systems offer a radically new concept in information technology that has the potential to revolutionize the way we communicate and exchange information.

References

1. H. Abelson, et al. Amorphous Computing. MIT Artificial Intelligence Laboratory Memo No. 1665, Aug. 1999
2. H. Abelson, D. Allen, D. Coore, Ch. Hanson, G. Homsy, T. F. Knight, Jr., R. Nagpal, E. Rauch, G. J. Sussman, R. Weiss. Amorphous Computing. Communications of the ACM, Volume 43, No. 5, pp. 74–82, May 2000
3. D. K. Arvind, K. J. Wong: Speckled Computing Ű A Disruptive Technology for Network Information Appliances. Proc. IEEE International Symposium on Consumer Electronics (ISCE'04), 2004, pp. 219-223
4. D. Coore: Introduction to Amorphous Computing. Unconventional Programming Paradigms: International Workshop 2004, LNCS Volume 3566, pp. 99–109, Aug. 2005
5. J. M. Kahn, R. H. Katz, K. S. J. Pister. Next century challenges: mobile networking for "Smart Dust". In: Proceedings of the 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking, MobiCom '99, ACM, pp. 271–278, Aug. 1999

6. J. M. Kahn, R. H. Katz, K. S. J. Pister. Emerging Challenges: Mobile Networking for Smart Dust. Journal of Communications and Networks, Volume 2, pp. 188–196, 2000
7. Kurzweil, R.: The Singularity is Near. Viking Books, 652 pages, 2005
8. L. Petrů: Universality in Amorphous Computing. PhD Disseration Thesis. Dept. of Math. and Physics, Charles University, Prague, 2009
9. L. Petrů, J. Wiedermann: A Model of an Amorphous Computer and Its Communication Protocol. In: Proc SOFSEM 2007: Theory and Practice of Computer Science. LNCS Volume 4362, Springer, pp. 446–455, July 2007
10. L. Petrů, J. Wiedermann: A Universal Flying Amorphous Computer. In: Proc. Unconventional Computation, 10th International Conference, UC'2011, LNCS, Vol. 6714, 2011, pp. 189-200
11. L. Petrů, J. Wiedermann: A Robust Universal Flying Amorphous Computer. In: C. Calude, R. Freivalds, K. Iwama (Eds.), Jozef Gruska Festschrift, LNCS, 2014, to appear
12. M. J. Sailor, J. R. Link: Smart dust: nanostructured devices in a grain of sand, Chemical Communications, Vol. 11, p. 1375, 2005
13. S. C. Shah, F. H. Chandio, M. Park: Speckled Computing: Evolution and Challenges. Proc. IEEE International Conference on Future Networks, 2009, pp. 181-185
14. B. Warneke, M. Last, B. Liebowitz, K. S. J. Pister: Smart Dust: Ccommunicating with a Cubic-Millimeter Computer. Computer, Volume: 34, Issue: 1, pp. 44–51, Jan. 2001
15. J. Wiedermann, L. Petrů: Computability in Amorphous Structures. In: Proc. CiE 2007, Computation and Logic in the Real World. LNCS Volume 4497, Springer, pp. 781–790, July 2007
16. J. Wiedermann, L. Petrů: Communicating Mobile Nano-Machines and Their Computational Power. In: Third International ICST Conference, NanoNet 2008, Boston, MA, USA, September 14-16, 2008, Revised Selected Papers, LNICST Vol. 3, Part 2, Springer, pp. 123-130, 2009.
17. J. Wiedermann, L. Petrů: On the Universal Computing Power of Amorphous Computing Systems. Theory of Computing Systems 46:4 (2009), 995-1010, www.springerlink.com/content/k2x6266k78274m05/fulltext.pdf
18. Wiedermann, J.: Nanomachine Computing by Quorum Sensing. In: J. Kelemen and A. Kelemenová (Eds.): Paun Festschrift, LNCS 6610, p. 203-215, 2011
19. Wiedermann, J.: Amorphous Computing: A Research Agenda for the Near Future. Natural Computing, 2012, Vol. 11, No. 1, p. 59-63.
20. Wiedermann, J.: Computability and Non-computability Issues in Amorphous Computing. In Baeten, J.C.M., Ball, T., de Boer, F.S. (ed.). Theoretical Computer Science. Berlin: Springer, 2012, p. 1-9.
21. Wiedermann, J.: The many forms of amorphous computational systems. In: H. Zenil (Ed.): A Computable Universe. Understanding Computation and Exploring Nature As Computation, p. 243-256, Singapore: World Scientific, 2013

Contents

Invited Papers

Regular Papers