Spiking Neural P Systems Research at Algorithms and Complexity Laboratory of the University of the Philippines Diliman

Francis George C. Cabarle, Jym Paul Carandang, Ren Tristan dela Cruz, Kelvin C. Buño, John Matthew Villaflores, Miguel Ángel Martínez-del-Amor*, Nestine Hope Hernandez, Richelle Ann B. Juayong, Henry N. Adorna

Algorithms & Complexity
Department of Computer Science
University of the Philippines Diliman
Diliman 1101 Quezon City, Philippines
Main contact: `hnadorna@up.edu.ph`

1 Introduction

The Algorithms and Complexity laboratory (in short, ACLab) of Department of Computer Science, University of the Philippines Diliman consists of a subgroup of nine members, listed as authors in this report, working mainly on membrane computing. The website for AClab is at `http://aclab.dcs.upd.edu.ph/` while the website of the subgroup for membrane computing is at `https://sites.google.com/site/aclabmcgroup/`. The membrane computing subgroup of AClab consists of professor Henry N. Adorna, three assistant professors: Francis George C. Cabarle, Kelvin C. Buño, and Nestine Hope Hernandez (working on other P system models), with Richelle Ann Juayong having recently finished her PhD dissertation on P systems with energy.

Since 2009, AClab has produced research on SN P systems (more details below). At present time, Kelvin Buño is in part working on dP Scheme which include distributed variants of P systems, which includes SN dP systems for his PhD work; for masters work, Jym Paul Carandang and John Matthew Villaflores are working on GPU simulators for SN P systems and their variants, while Ren Tristan dela Cruz is working on SN P systems with plasticity. Francis George C. Cabarle is doing postdoctoral research with Xiangxiang Zeng at Xiamen University (Xiamen, China). Henry N. Adorna is visting Linqiang Pan at Huazhong University of Science and Technology (Wuhan, China).

* M.Á Martínez-del-Amor is mainly with the Research Group on Natural Computing, Department of Computer Science and Artificial Intelligence, Universidad de Sevilla, Avda. Reina Mercedes s/n, 41012 Sevilla, Spain

Some of main the research directions of ACLab for SN P systems (and their variants) include: their syntax and semantics for computing, applications, or modelling; their representations as vectors and matrices, in order to perform linear algebra operations in describing the system evolution; their simulation algorithms and software simulators (both sequential and parallel); their computing power and efficiency with respect to other P systems and models of computation.

2 Works on spiking neural P systems

2.1 Matrix representations and algorithms for GPU simulations

The work on representing SN P systems as vectors and matrices started at BWMC2010 in [1], followed by a publication at CMC2010 in [2]. The earliest version of an SN P system simulator for graphics processing units (or GPUs) is in PCSC2011 in [3], followed by a journal version in [4]. Succeeding investigations by improving the simulation algorithm, software simulator, and GPUs include [5, 6]. Note that so far, these GPU simulators run on the CUDA hardware manufactured by NVIDIA corporation. The first and preliminary SN P system simulator using the open-standard software known as OpenCL is in [7].

Further improvements of the simulation and GPU simulator on NVIDIA CUDA hardware were afterwards referred to as CuSNP (short for CUDA for SN P systems) published as a preliminary work in [8], with following improvements reported at BWMC2016 in [9, 10, 11] with the most recent in [12]. Lastly, since SN P systems in general are sparse graphs, we have started to work on simulators that make better use of GPUs with sparse matrix representations in [13].

2.2 Variants of SN P systems

Since SN P systems and most of their variants are static and directed graphs[2] some variants inspired by dynamic graphs focusing on edge-centric evolution (hence, synapse-centric evolution for SN P systems) were introduced. The first variant are SN P systems with structural plasticity introduced in [14] allowed neurons to use only the standard spiking rules while making use of a second type of rule known as a plasticity rule. Plasticity rules allowed neurons to create or delete their own synapses, with further works in [15, 16, 17, 18, 19] including a quick survey in [20]. The second variant for edge-centric dynamism are SN P systems with scheduled synapses introduced [21], where in synapses can also (dis)appear in the system depending on a given schedule or duration.

Lastly, works on SN dP systems where the entire input is divided in parts, so that the parts enter into different components of the system (each component is an SN P system) are given in [22, 23].

[2] A few variants have dynamism, e.g. neuron division and budding following dynamic graphs, but such variants are mainly focused on evolving the neurons instead of the synapse only.

2.3 More on SN P systems and their computations, formal methods

Works comparing the structure and behaviour of SN P systems to other well-known models for concurrency such as Petri nets and process algebra are given in [22, 24, 25, 26].

Other works on describing the computation of SN P systems with respect to their ingredients (e.g. rule types, delays), other invariant properties include [1, 2, 27, 28, 29], and their lower bound simulation of finite automata in [30, 31].

A quick survey of SN P systems including work from AClab is in [20], as well as in a bibliography of SN P systems literature as of February 2016 in `http://membranecomputing.net/IMCSBulletin/index.php?page=bibSNPsystemF`.

References

1. X. Zeng, H. N. Adorna, M. Á. Martínez del Amor, and L. Pan, "When matrices meet brains," *Proceedings of the Eighth Brainstorming Week on Membrane Computing, 311-320. Sevilla, ETS de Ingeniería Informática, 1-5 de Febrero, 2010*, 2010.
2. X. Zeng, H. Adorna, M. Á. Martínez-del Amor, L. Pan, and M. J. Pérez-Jiménez, "Matrix Representation of Spiking Neural P Systems," in *Membrane Computing: 11th International Conference, CMC 2010, Jena, Germany, August 24-27, 2010* (M. Gheorghe, T. Hinze, G. Păun, G. Rozenberg, and A. Salomaa, eds.), pp. 377–391, Berlin, Heidelberg: Springer Berlin Heidelberg, 2011.
3. F. Cabarle, H. Adorna, and M. Martínez-del Amor, "Spiking neural P system without delay simulator implementation using GPGPUs," in *Proc. 11th Philippine Computing Science Congress, Naga city, Philippines*, pp. 35–43, 2011.
4. F. Cabarle, H. Adorna, and M. A. Martinez-del Amor, "Simulating Spiking Neural P systems without delays using GPUs," in *Natural Computing for Simulation and Knowledge Discovery*, pp. 109–121, IGI Global, 2014.
5. F. G. C. Cabarle, H. Adorna, and M. Martnez, "A spiking neural P system simulator based on CUDA," *Lecture Notes in Computer Science*, vol. 7184 LNCS, pp. 87–103, 2012.
6. F. G. C. Cabarle, H. Adorna, M. Martinez-Del-Amor, and M. Perez-Jimenez, "Improving GPU simulations of spiking neural P systems," *Romanian Journal of Information Science and Technology*, vol. 15, no. 1, pp. 5–20, 2012.
7. A. R. Lagunda, G. I. Palaganas, F. G. C. Cabarle, and H. Adorna, "Spiking Neural P Systems GPU Simulation using OpenCL," Proc. 16th Philippine Computing Science Congress, 16-18 March 2016, Puerto Princesa, Palawan, Philippines, pp. 215–221, 2016.
8. J. Carandang, J. Villaflores, F. G. C. Cabarle, and H. Adorna, "CuSNP: Improvements on GPU Simulations of Spiking Neural P Systems in CUDA," *Proc. 16th Philippine Computing Science Congress, 16–18 March, 2016, Puerto Princesa, Palawan, Philippines*, pp. 77–84, 2016.
9. J. P. Carandang, J. M. Villaflores, F. G. C. Cabarle, H. N. Adorna, and M. Á. Martínez del Amor, "Improving Simulations of Spiking Neural P Systems in NVIDIA CUDA GPUs: CuSNP," *Proc. 14th Brainstorming Week on Membrane Computing (BWMC2016), Sevilla, Spain*, vol. 14, pp. 135–150, 2016.

10. J. Carandang, J. Villaflores, F. G. C. Cabarle, H. Adorna, and M. Á. Martínez-del Amor, “CuSNP: Spiking Neural P Systems Simulators in CUDA,” *5th Asian Conference on Membrane Computing 2016*, 2016.
11. J. P. Carandang, J. M. Villaflores, F. G. C. Cabarle, H. Adorna, and M. Á. Martínez-del Amor, “CuSNP: Spiking Neural P Systems Simulators in CUDA,” *Romanian Journal of Information Science and Technology*, vol. 20, no. 1, pp. 57–70, 2017.
12. J. P. A. Carandang, F. G. C. Cabarle, H. N. Adorna, N. H. S. Hernandez, , and M. A. Martinez-del Amor, “Nondeterminism in Spiking Neural P Systems: Algorithms and Simulations,” Pre-proc. 6th Asian Conference on Membrane Computing (ACMC2017), 21 to 25 September 2017, Xihua University, Chengdu, China, 2017.
13. M. Á. M. del Amor, D. Orellana-Martín, F. G. C. Cabarle, M. J. Pérez-Jiménez, and H. N. Adorna, “Sparse-matrix Representation of Spiking Neural P Systems for GPU,” *Fifteenth Brainstorming Week on Membrane Computing (BWMC2017)*, pp. 161–170, 2017.
14. F. G. C. Cabarle, H. N. Adorna, M. J. Pérez-Jiménez, and T. Song, “Spiking neural p systems with structural plasticity,” *Neural Computing and Applications*, vol. 26, no. 8, pp. 1905–1917, 2015.
15. F. G. C. Cabarle, N. H. S. Hernandez, and M. Á. Martínez-del Amor, “Spiking Neural P Systems with Structural Plasticity: Attacking the Subset Sum Problem,” in *Membrane Computing: 16th International Conference, CMC 2015, Valencia, Spain, August 17-21, 2015* (G. Rozenberg, A. Salomaa, J. M. Sempere, and C. Zandron, eds.), pp. 106–116, Springer International Publishing, 2015.
16. F. G. C. Cabarle, H. N. Adorna, and M. J. Pérez-Jiménez, “Sequential spiking neural P systems with structural plasticity based on max/min spike number,” *Neural Computing and Applications*, vol. 27, no. 5, pp. 1337–1347, 2016.
17. F. G. C. Cabarle, H. N. Adorna, and M. J. Pérez-Jiménez, “Asynchronous Spiking Neural P Systems with Structural Plasticity,” in *Unconventional Computation and Natural Computation* (C. S. Calude and M. J. Dinneen, eds.), vol. 9252 of *LNCS*, pp. 132–143, Springer International Publishing, 2015.
18. R. T. A. de la Cruz, F. G. C. Cabarle, and X. Zeng, “On Languages Generated by Spiking Neural P System with Structural Plasticity,” Pre-proc. 18th International Conference on Membrane Computing (CMC18), 24 to 28 July 2017, University of Bradford, U.K., pp. 115–132, 2017.
19. R. T. A. dela Cruz, F. G. C. Cabarle, and X. Zeng, “Arithmetic and Memory Module using Spiking Neural P Systems with Structural Plasticity,” Pre-proc. 6th Asian Conference on Membrane Computing (ACMC2017), 21 to 25 September 2017, Xihua University, Chengdu, China, 2017.
20. H. N. Adorna, F. G. C. Cabarle, L. F. Macías-Ramos, L. Pan, M. J. Pérez-Jiménez, B. Song, T. Song, and L. Valencia-Cabrera, “Taking the Pulse of SN P Systems: a Quick Survey,” in *Multidisciplinary Creativity: Homage to Gheorghe Păun on His 65th Birthday* (M. Gheorghe, I. Petre, M. J. Perez-Jimenez, G. Rozenberg, and A. Salomaa, eds.), pp. 3–16, Spandugino, 2015.
21. F. G. C. Cabarle, H. N. Adorna, M. Jiang, and X. Zeng, “Spiking Neural P systems with Scheduled Synapses,” *IEEE Transactions on NanoBioscience (to appear)*, 2017.
22. F. G. C. Cabarle and H. N. Adorna, *Theory and Practice of Computation: Workshop on Computation: Theory and Practice Quezon City, Philippines, September 2011 Proceedings*, ch. Some Notes on Spiking Neural dP Systems and Petri Nets, pp. 62–77. Springer Japan, 2012.

23. J. G. Q. Torres, K. C. Buño, and F. G. C. Cabarle, "Some Notes on Spiking Neural dP Systems," Pre-proc. 6th Asian Conference on Membrane Computing (ACMC2017), 21 to 25 September 2017, Xihua University, Chengdu, China, 2017.
24. F. G. C. Cabarle and H. N. Adorna, "On Structures and Behaviors of Spiking Neural P Systems and Petri Nets," in *Membrane Computing: 13th International Conference, CMC 2012, Budapest, Hungary, August 28-31, 2012* (E. Csuhaj-Varjú, M. Gheorghe, G. Rozenberg, A. Salomaa, and G. Vaszil, eds.), pp. 145–160, Springer Berlin Heidelberg, 2013.
25. R. A. B. Juayong, N. H. S. Hernandez, F. G. C. Cabarle, and H. N. Adorna, "A Simulation of Transition P Systems in Weighted Spiking Neural P Systems," Proceedings of Workshop on Computation: Theory and Practice WCTP2013, ch. 2, pp. 62–78, World Scientific, 2014.
26. H. N. Adorna, K. C. Buño, and F. G. C. Cabarle, "Notes in Delays and Bisimulations of spiking neural P systems using SNP Algebra," Proceedings of Workshop on Computation: Theory and Practice WCTP2013, ch. 2, pp. 15–34, World Scientific, 2014.
27. G. N. Ibo and H. N. Adorna, "Characterizing Periodicity as a Dynamical Aspect of Generative SN P Systems," *Pre-proc. 12th International Conference on Membrane Computing 23–26 August, 2016, Fontainebleau, Paris, France*, pp. 115–132, 2017.
28. F. G. C. Cabarle, K. C. Buño, and H. N. Adorna, *Proceedings of Theory and Practice of Computation: 2nd Workshop on Computation: Theory and Practice*, ch. Time after Time: Notes on Delays in Spiking Neural P Systems, pp. 82–92. Springer Japan, 2013.
29. F. G. C. Cabarle, K. C. Buño, and H. N. Adorna, "On the Delays in Spiking Neural P Systems," *Philippine Computing Journal*, vol. 7, no. 2, pp. 12–17, 2013.
30. F. G. C. Cabarle, H. N. Adorna, and M. J. Pérez-Jiménez, "Notes on spiking neural p systems and finite automata," *Thirteenth Brainstorming Week on Membrane Computing*, pp. 77–89, 02/2015 2015.
31. F. G. C. Cabarle, H. N. Adorna, and M. J. Pérez-Jiménez, "Notes on spiking neural P systems and finite automata," *Natural Computing*, vol. 15, no. 4, pp. 533–539, 2016.