



**Universiteit
Leiden**
The Netherlands

Spiking Neural P Systems

Wang, J.

Citation

Wang, J. (2011, December 20). *Spiking Neural P Systems*. IPA Dissertation Series. Retrieved from <https://hdl.handle.net/1887/18261>

Version: Corrected Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/18261>

Note: To cite this publication please use the final published version (if applicable).

Spiking Neural P Systems

Jun Wang



The work in this thesis has been carried out under the auspices of the research school IPA (Institute for Programming research and Algorithmics).

Spiking Neural P Systems

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van de Rector Magnificus prof. mr. P.F. van der Heijden,
volgens besluit van het College voor Promoties
te verdedigen op dinsdag 20 December 2011
klokke 12.30 uur

door

Jun Wang
geboren te Wuhan, China,
in 1981

Promotiecommissie

Promotor: Prof. Dr. J.N. Kok
Co-promotor: Dr. H.J. Hoogeboom
Overige leden: Prof. Dr. T.H.W. Bäck
Prof. Dr. J. Kleijn
Prof. Dr. G. Mauri
Prof. Dr. L. Pan

Universiteit van Milaan
Huazhong University of Science and Technology

Contents

1	Introduction	1
1.1	Membrane Computing	1
1.2	Spiking Neural P Systems	2
1.3	Several Other SN P Systems	4
1.4	Other Variants	5
1.5	A Simple Example	6
1.6	Overview of the Thesis	8
2	Limited Asynchronous Spiking Neural P Systems	13
2.1	Introduction	13
2.2	Prerequisites	15
2.3	Limited Asynchronous Spiking Neural P Systems	16
2.4	An Example	19
2.5	Universality of Limited Asynchronous SN P Systems	21
2.6	Limited Asynchronous SN P Systems with an Observer	32
2.7	Finite Limited Asynchronous SN P Systems	35
2.8	Conclusions and Remarks	37
3	Solving NP-complete Problems by Spiking Neural P Systems with Budding Rules	39
3.1	Introduction	39
3.2	SN P Systems with Budding Rules	42
3.3	SN P Systems Solving SAT	45
3.4	A Uniform Solution to SAT by SN P Systems with Budding Rules	48
3.5	Conclusions and Directions for Future Research	55
4	Spiking Neural P Systems with Neuron Division	59
4.1	Introduction	59
4.2	SN P Systems with Neuron Division	60
4.3	Solving SAT	62
4.4	Conclusions and Remarks	74

5	A Note on the Generative Power of Axon P Systems	77
5.1	Introduction	77
5.2	Formal Language Theory Prerequisites	78
5.3	Axon P Systems	79
5.4	Axon P Systems as Number Generators	81
5.4.1	A Characterization of <i>NFIN</i>	81
5.4.2	Relationships with Semilinear Sets of Numbers	81
5.5	Axon P Systems as Language Generators	85
5.6	Conclusions and Remarks	86
6	Spiking Neural P Systems with Weights	87
6.1	Introduction	87
6.2	Prerequisites	90
6.3	Spiking Neural P Systems with Weights	91
6.4	An Example of WSN P System	93
6.5	Preliminary Results	95
6.6	Universality of WSN P Systems with Integers	95
6.6.1	The Generative Case	96
6.6.2	The Accepting Case	101
6.7	Systems with Natural Numbers as Weights	103
6.8	Efficiency of WSN P Systems	108
6.8.1	Time Complexity for Non-deterministic SN P Systems	108
6.8.2	Semi-uniform Solution to Subset Sum	110
6.8.3	Uniform Solution to SAT	112
6.9	Final Remarks	115
7	Spiking Neural P Systems with Astrocytes	117
7.1	Introduction	117
7.2	Prerequisites	120
7.3	Spiking Neural P Systems with Astrocytes	121
7.4	An Example of SNPA System	124
7.5	Universality of SNPA Systems	126
7.5.1	SNPA Systems Working in the Generative Mode	126
7.5.2	SNPA Systems Working in the Accepting Mode	131
7.6	Finite SNPA Systems	133
7.7	Conclusions and Remarks	135
8	Asynchronous Extended Spiking Neural P Systems with Astrocytes	137
8.1	Introduction	137
8.2	Prerequisites	139
8.3	Spiking Neural P Systems with Astrocytes	140
8.4	Universality of ASNPA Systems	142
8.5	Conclusions and Remarks	150

Bibliography	153
Samenvatting	157
Curriculum Vitae	159

