On Small Universality of Spiking Neural P System with Multiple Channels

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Outline

- **Motivation**
- **SN P Systems with Multiple Channels**
- **Small Universal Computing with Standard Spiking Rules**
- **Small Universal Computing with Extended Spiking Rules**
- **Conclusion and Future Works**

Motivation

- **The assumption is based on such a neurobiological fact: in the chemical synapse transmitting, there are multiple ion channels in a synapse[1].**
- **SN P systems with multiple channels (SNP-MC systems).**

[1] Nicholls, J., Martin, A., Fuchs, P., Brown, D., Diamond, M., & Weisblat, D. (2012). *From neuron to brain*. (5th ed.). Sinuer Assocites.

SN P Systems with Multiple Channels[2]

$$\Pi = (O, L, \sigma_1, \sigma_2, \ldots, \sigma_m, syn, out)$$

- $O = \{a\}$ **is the singleton alphabet;**
- $L = \{1, 2, \ldots, N\}$ **is the alphabet of channel labels;**
- $\sigma_1, \sigma_2, \ldots, \sigma_m$ **are neurons of the form** $\sigma_i = (n_i, R_i)$
  - $n_i \geq 0$ **is the initial number of spikes;**

[2] H. Peng, J. Yang, J. Wang, T. Wang, Z. Sun, X. Song, X. Lou, X. Huang, Spiking neural P systems with multiple channels, *Neural Network*, 95 (2017) 66-71.

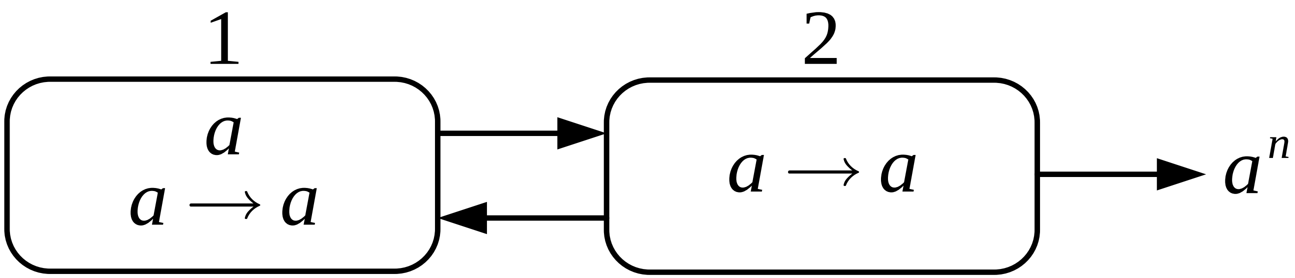
SN P Systems with Multiple Channels

- R_i **is a finite set of rules** $E/a^c \rightarrow a^p(l)$**, where** E **is a regular expression over** O **,** $l \in L_i$ **,** $L_i \subseteq L$ **is a finite set of channel labels used in** σ_i **;**

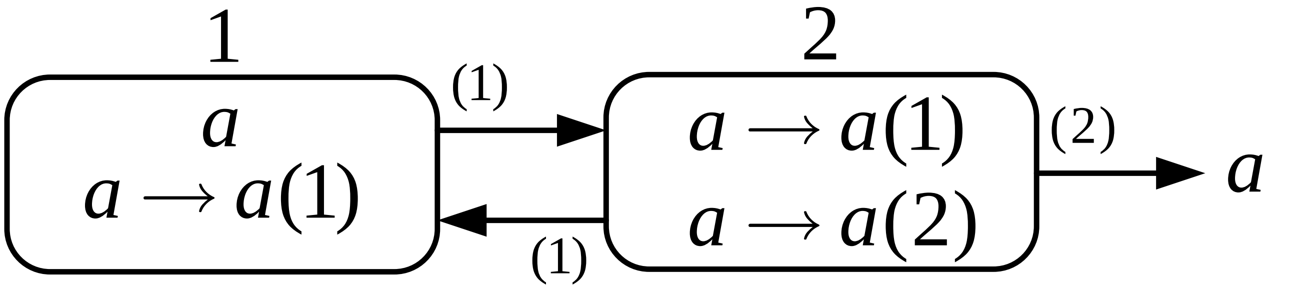
- $syn = \{(i,j,l) \subseteq \{1,2,\ldots,m\} \times \{1,2,\ldots,m\} \times L\}$ **with** $(i,j,l) \notin syn$ **for** $\forall 1 \leq i \leq m$ **and** $\forall l \in L$**;**

- $out \in \{1,2,\ldots,m\}$ **indicates the output neuron.**

Examples



A cell-like SN P System



An SNP-MC system

Universality Results of SNP-MC Systems

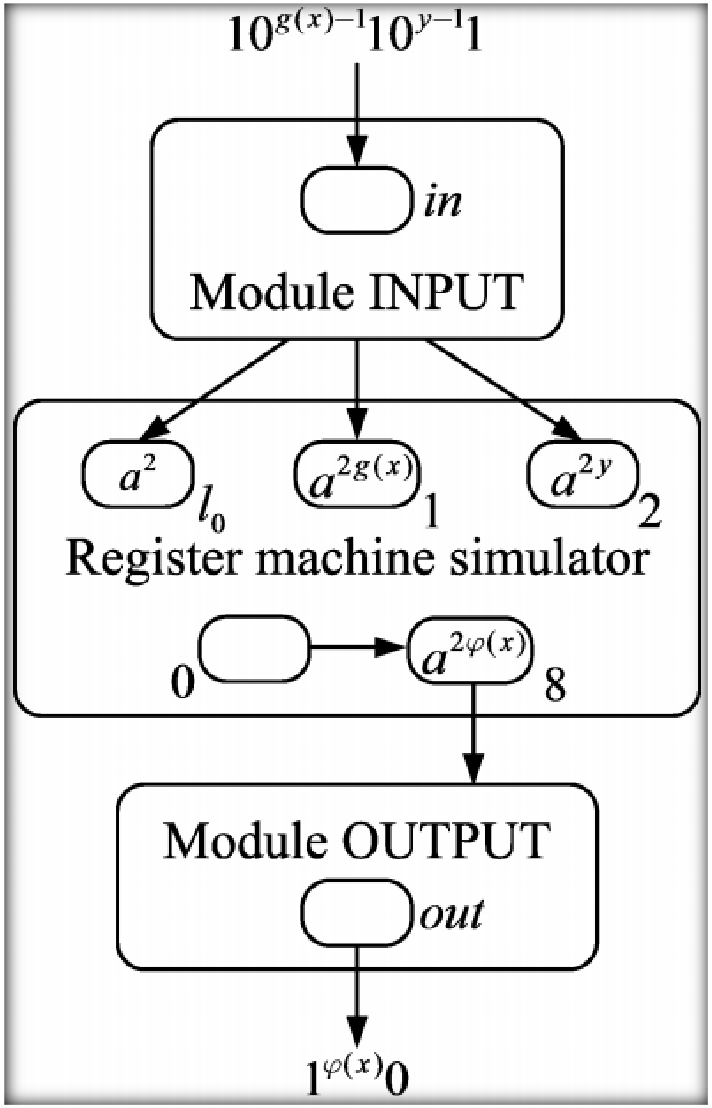
$$N_2 SNP_*^2 = NRE$$

$$N_{acc} SNP_*^2 = NRE$$

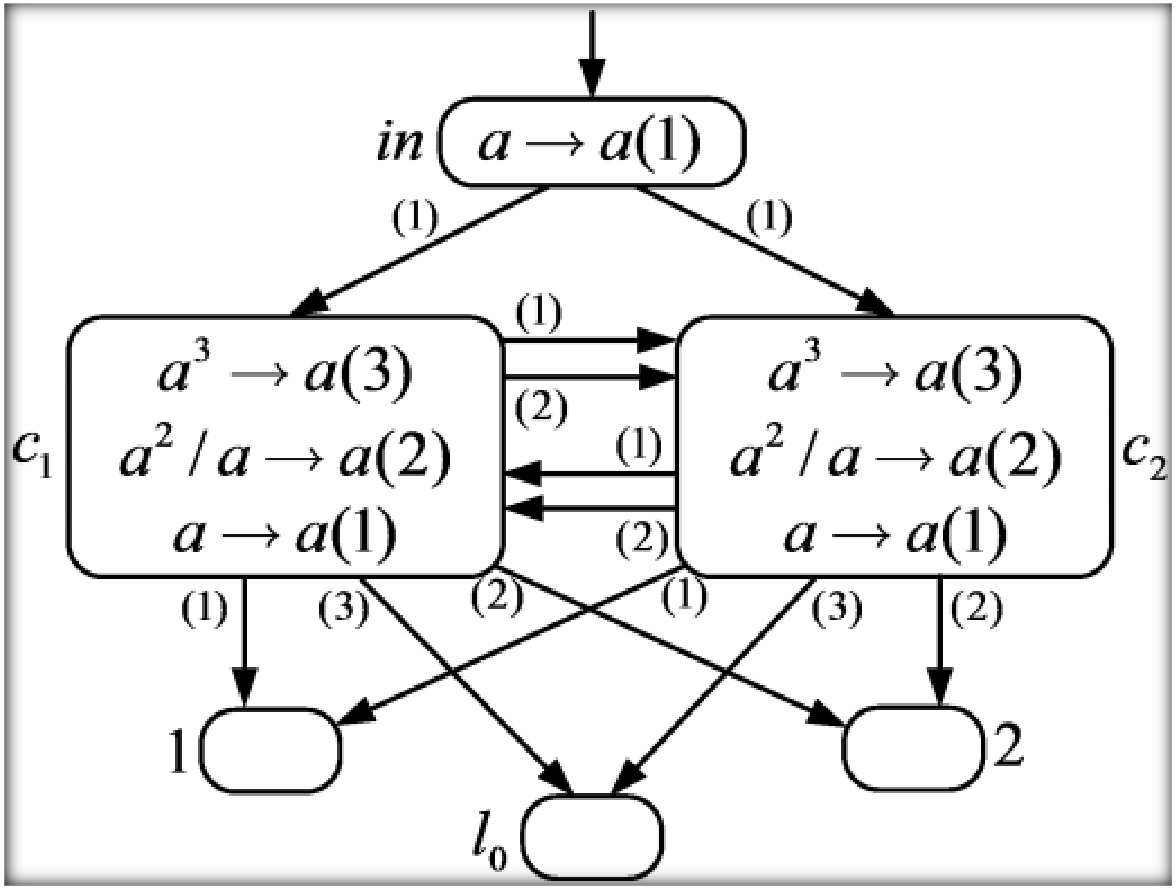
- **It is proved that SNP-MC systems can generate or accept any set of Turing computable numbers.**

On Small Universality of SNP-MC Systems

The framework of the small universal SNP-MC system

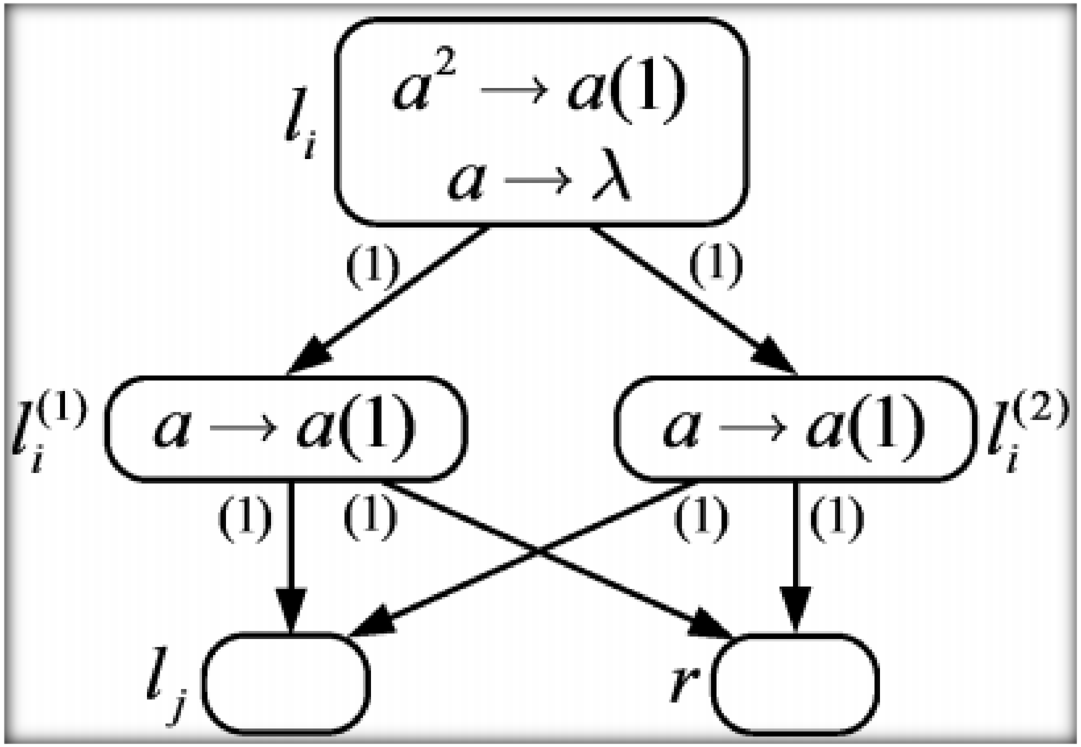


Small Universal Computing with Standard Spiking Rules



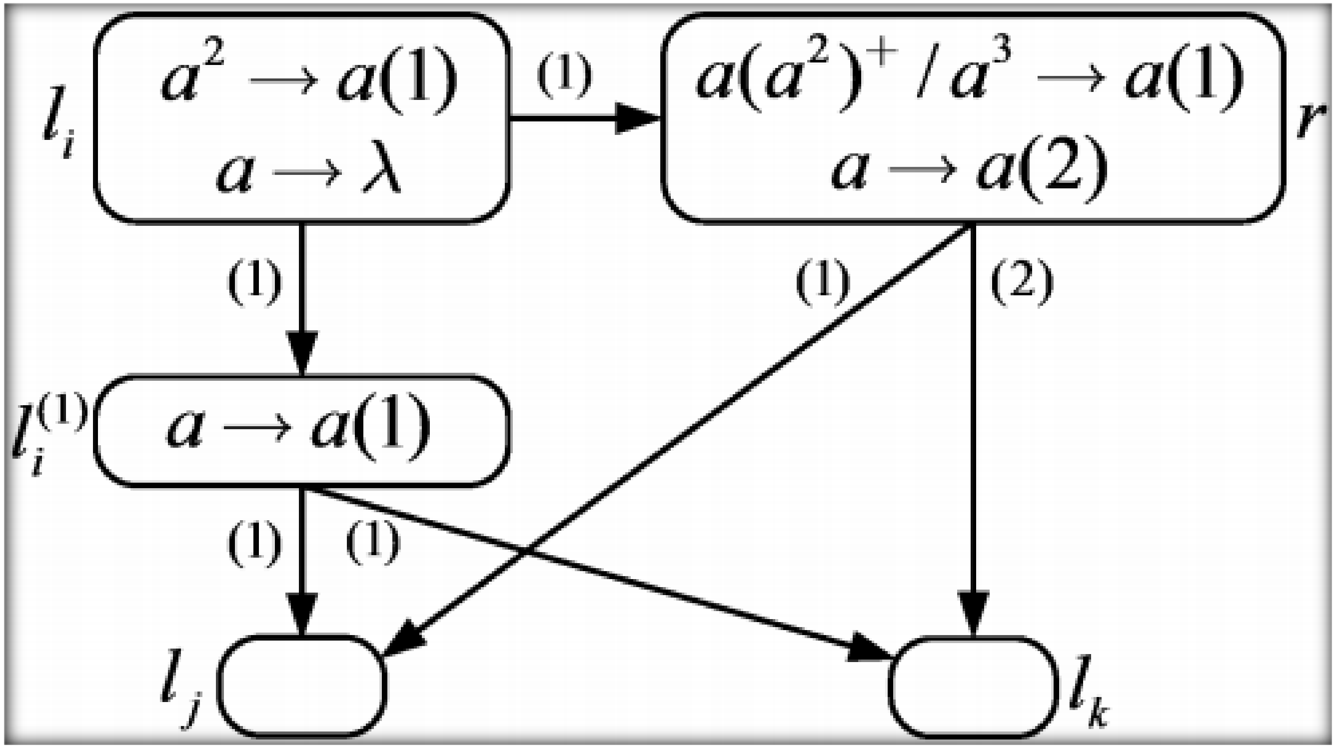
INPUT

Small Universal Computing with Standard Spiking Rules



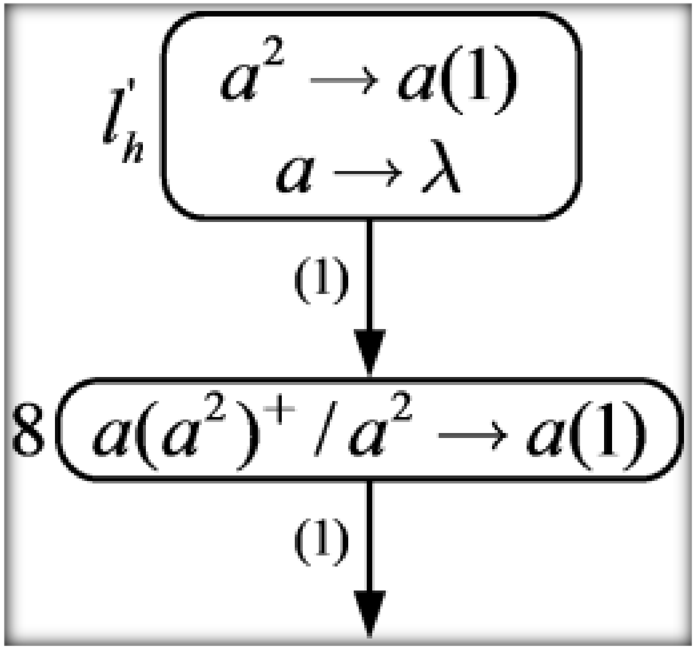
$$l_i{:}(ADD(r), l_j)$$

Small Universal Computing with Standard Spiking Rules



$$l_i:(SUB(r),l_j,l_k)$$

Small Universal Computing with Standard Spiking Rules



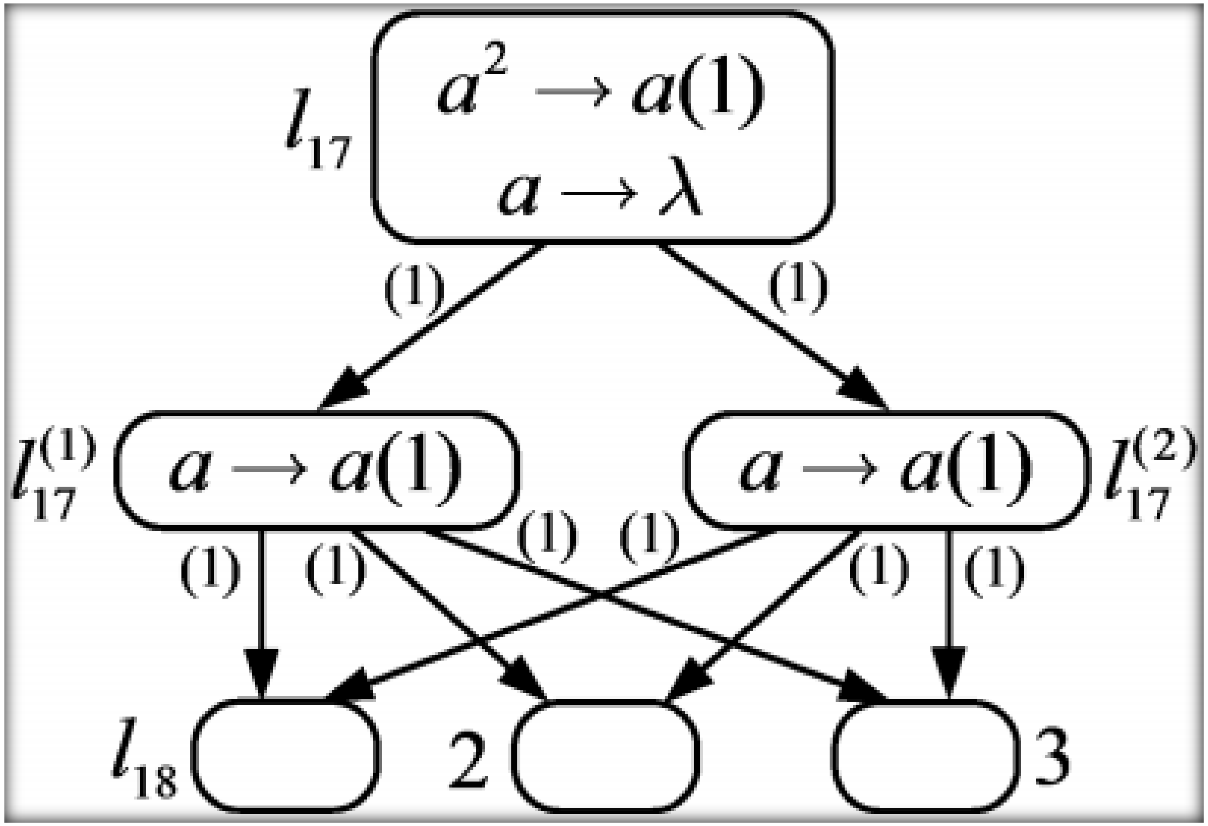
OUTPUT

Small Universal Computing with Standard Spiking Rules

- **9 neurons for 9 registers**
- **25 neurons for 25 labels**
- **2 auxiliary neurons in each ADD module, 20 in total**
- **1 auxiliary neurons in each SUB module, 14 in total**
- **3 neurons in INPUT module**

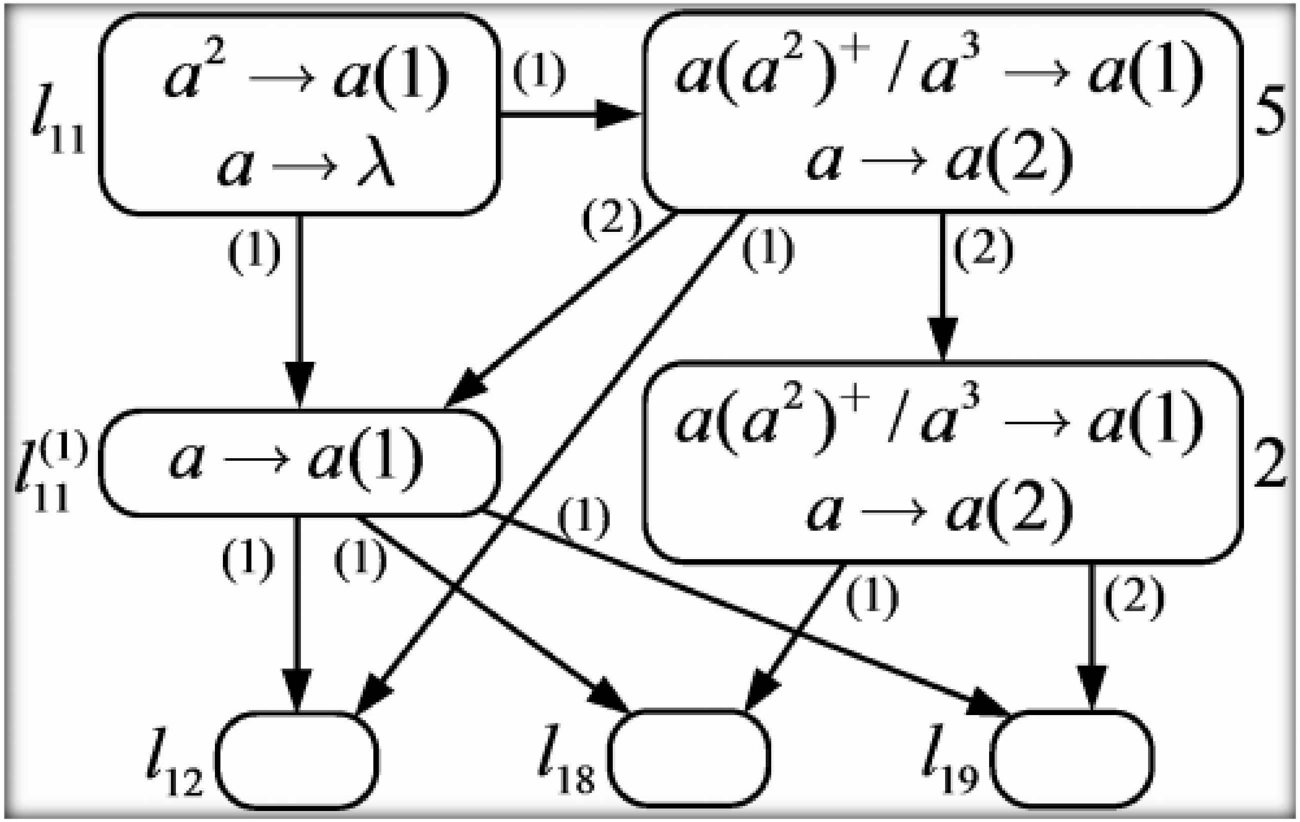
- **The constructed SNP-MC system using standard spiking rules uses 71 neurons.**

Small Universal Computing with Standard Spiking Rules



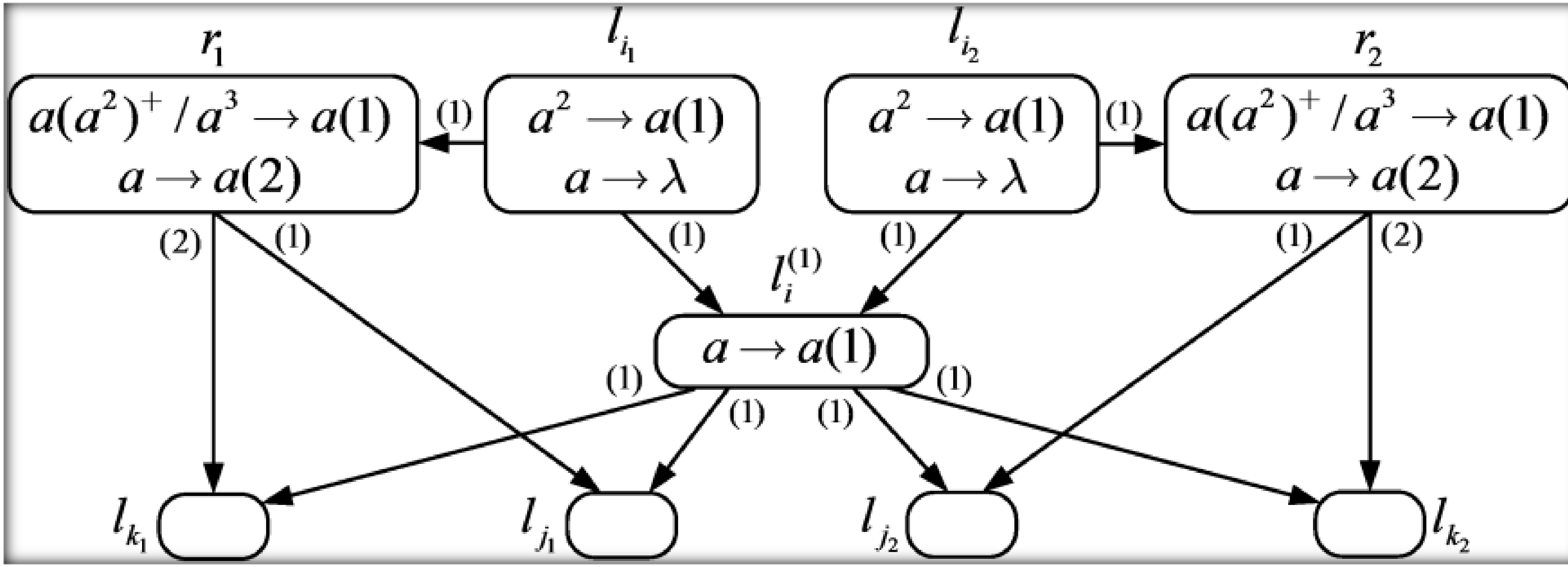
$$l_{17}:(ADD(2),l_{21}),\ \ l_{21}(ADD(3),l_{18})$$

Small Universal Computing with Standard Spiking Rules



$$l_{11}:(SUB(5),l_{12},l_{13}),\ \ l_{13}(SUB(2),l_{18},l_{19})$$

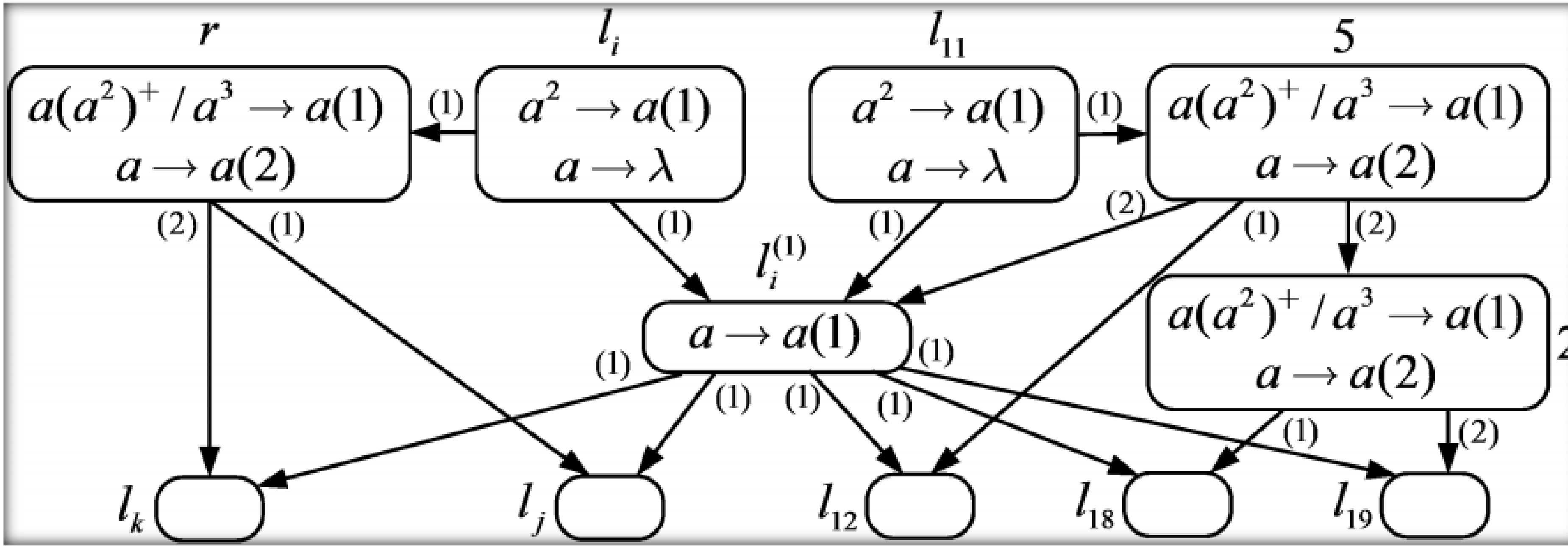
Small Universal Computing with Standard Spiking Rules



A module simulating two SUB instructions with $r_1 \neq r_2$

- **Instructions l_0, l_3, l_4, l_6, l_{10}, l_{15} and l_{19}, which address registers *1,5,6,7,4,3* and *0*, can share a common neuron.**

Small Universal Computing with Standard Spiking Rules



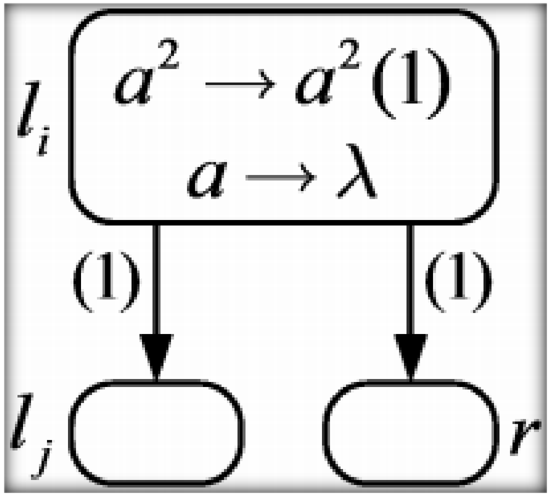
A module simulating instructions l_{11} and l_{13} with other instruction with $r \neq 2$ and $r \neq 5$

- **Instructions l_8, l_{11}, l_{13}, l_{18} *and* l_{22}, which address registers *6,5,2,4 and 0*, can share one common neuron.**

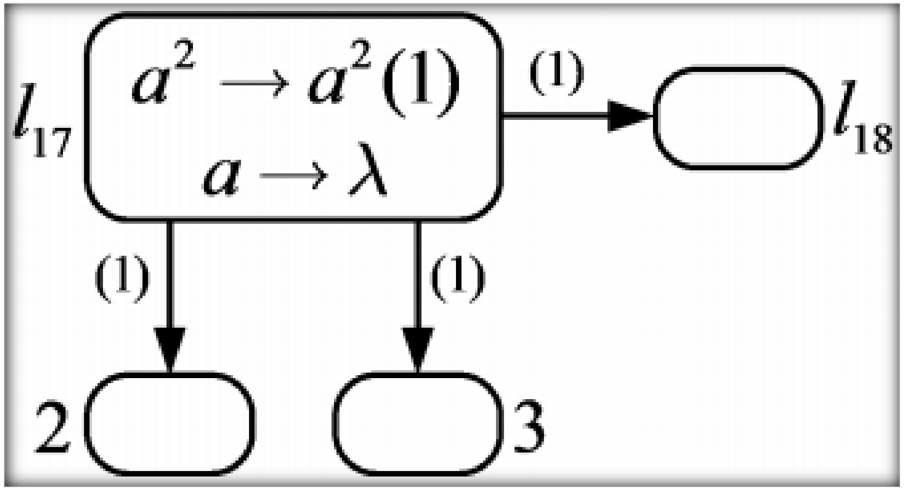
Small Universal Computing with Standard Spiking Rules

- **The constructed SNP-MC system using standard spiking rules is decremented from 71 to 57 neurons.**

Small Universal Computing with Extended Spiking Rules



l_i:(ADD(r),l_j,l_k)



l_{17}:(ADD(2),l_{21}),l_{21}(ADD(3),l_{18})

- **The constructed SNP-MC system using extended spiking rules uses 39 neurons.**

Conclusion and Future Works

- **Investigated the problem of small universality of SNP-MC in computing Turing computable function.**
- **SNP-MC system in computing Turing computable function:**
  - **Standard spiking rules: 57 neurons**
  - **Extended spiking rules: 39 neurons**

Conclusion and Future Works

- **Integrate other strategies and models in SNP-MC systems, such as exhaustive use of rules, white hole neurons, homogeneous neurons, request rules, asynchronous mode, local synchronous mode, sequential mode…**

Thank you for your attention!