Asynchronous Spiking Neural P Systems with Structural Plasticity

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SNP systems with structural plasticity

- In short, SNPSP systems;
- Dynamism is only applied for synapses: can create and delete synapses;
- Introduced in Asian CMC 2013 (Chengdu, China), then improved and extended;[1]
- Sequential SNPSP systems;[2]

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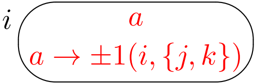
SNP systems with structural plasticity

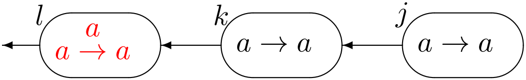
A spiking neural P system with structural plasticity (SNPSP system) of degree $m \geq 1$ is a construct of the form $\Pi = (O, \sigma_1, \ldots, \sigma_m, syn, out)$, where:

- $O = \{a\}$ is the singleton alphabet (a is called spike);
- $\sigma_1, \ldots, \sigma_m$ are neurons of the form $(n_i, R_i), 1 \leq i \leq m$; $n_i \geq 0$ indicates the initial number of spikes in σ_i; R_i is a finite rule set of σ_i with two forms:
  1. Spiking rule: $E/a^c \to a$, where E is a regular expression over O, $c \geq 1$;
  2. Plasticity rule: $E/a^c \to \alpha k(i, N)$, where E is a regular expression over O, $c \geq 1$, $\alpha \in \{+, -, \pm, \mp\}$, $k \geq 1$, and $N \subseteq \{1, \ldots, m\} - \{i\}$;
- $syn \subseteq \{1, \ldots, m\} \times \{1, \ldots, m\}$, with $(i, i) \notin syn$ for $1 \leq i \leq m$ (synapses between neurons);
- $out \in \{1, \ldots, m\}$ indicate the output neuron.

SNPSP systems example

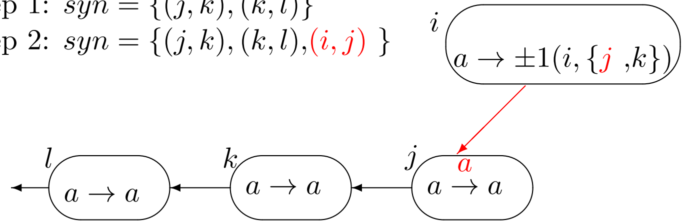
step 1: $syn = \{(j,k),(k,l)\}$





SNPSP systems example

step 1: $syn = \{(j,k),(k,l)\}$
step 2: $syn = \{(j,k),(k,l),(i,j)\ \}$



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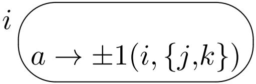
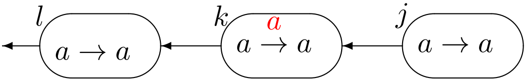
step 3: $syn = \{(j,k),(k,l)\}$





SNPSP systems example

step 1: $syn = \{(j,k),(k,l)\}$

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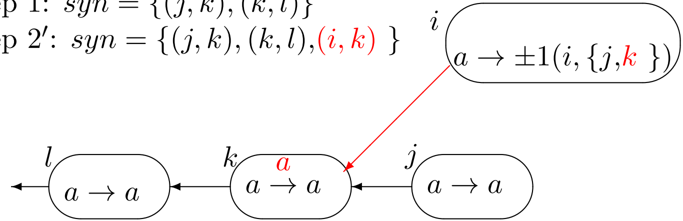

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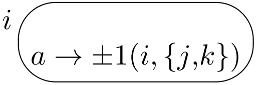

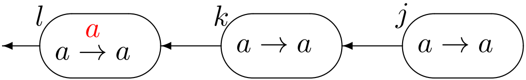

In this work

- Asynchronous SNPSP systems:
  - Show $SLIN = N_{tot}SNPSP^{asyn}(bound_p), p \geq 1$, by:
    - $N_{tot}SNPSP^{asyn}(bound_p) \subseteq SLIN, p \geq 1$.
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  - $NRE = N_{tot}WSNPSP^{asyn}$
    - Under a normal form.

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Construct a right-linear grammar G, such that Π generates the length set of the regular language $L(G)$. Let us denote by $\mathcal{C}$ the set of all possible configurations of Π, with C_0 being the initial configuration. The right-linear grammar $G = (\mathcal{C}, \{a\}, C_0, P)$, where the production rules in P are as follows:

(1) $C \rightarrow C'$, for $C, C' \in \mathcal{C}$ where Π has a transition $C \Rightarrow C'$ in which the output neuron does not spike;

(2) $C \rightarrow aC'$, for $C, C' \in \mathcal{C}$ where Π has a transition $C \Rightarrow C'$ in which the output neuron spikes;

(3) $C \rightarrow \lambda$, for any $C \in \mathcal{C}$ in which Π halts.

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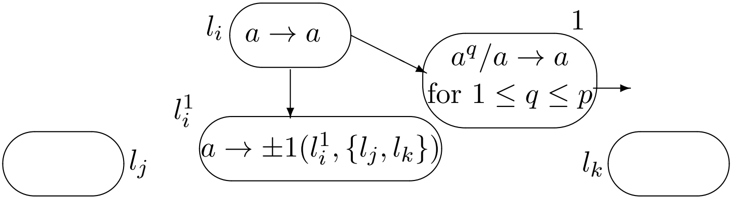
ADD module simulating l_i : $(\mathtt{ADD}(1) : l_j, l_k)$ of a strongly monotonic register machine.



Achieving universality

- Additional ingredient: weighted synapses[3]
- Synapse set is now of the form $syn \subseteq \{1, 2, \ldots, m\} \times \{1, 2, \ldots, m\} \times \mathbb{N}$.
- If σ_i applies a rule $E/a^c \to a^p$, and the synapse (i, j, r) exists (i.e. the weight of synapse (i, j) is r) then σ_j receives $p \times r$ spikes.
- Normal form: if σ_i has standard rule, then σ_i is simple, i.e. $|R_i| = 1$;

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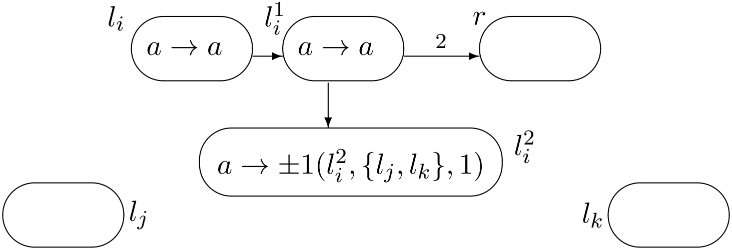

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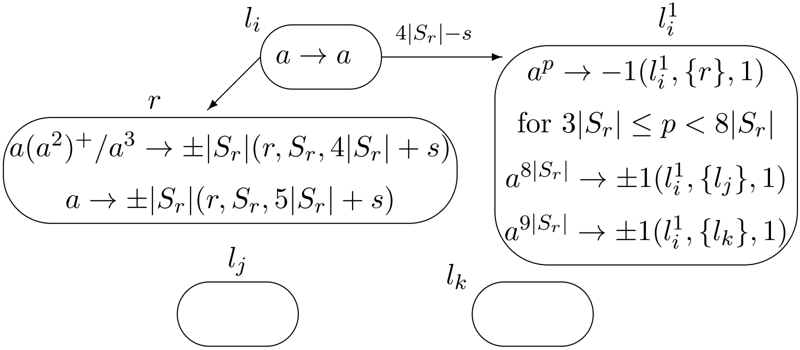

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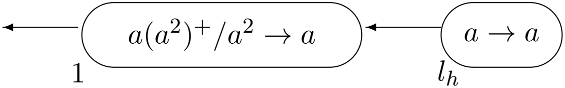

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Final remarks

- Asynchronous SNP systems using extended rules are universal;
- Open question:[4] Asynchronous SNP systems using standard rules only are universal?
  - Their conjecture: No.
- Plasticity rules can produce at most one spike each step;
- Plasticity rules with weighted synapses can produce more than one spike each step;
- Our (non)universality results provide some hint to support their conjecture
- $\alpha \in \{\pm, \mp\}$ can be another form of synchronization: what if we remove this?
- A uniform construction? i.e. SUB module construction is independent on a given M.

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End!

Thank you for your attention!