# Using Inhibitors to Achieve Universality of Sequential P Systems

Michal Kováč

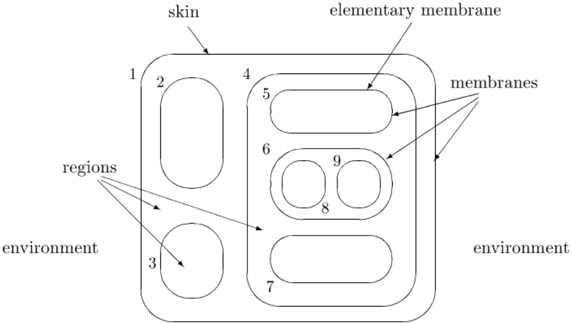
FMFI UK

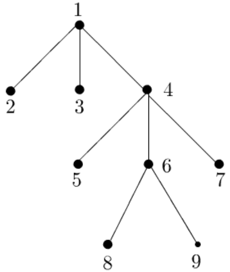
24.6.2014

1. Overview of P systems
   - P systems
   - Variants

2. Sequential P systems with inhibitors
   - Accepting case
   - Generating case

# Membrane structure



# Contents of the membrane

- multiset of objects
  - $a \mid b \mid b$
- rewriting rules
  - $a \mid b \mid b \rightarrow a \mid a_{out} \mid b_{in_6}$
  - $b \rightarrow a \mid \delta$

# P system

We define a P system as
$\Pi = (V, \mu, w_1, w_2, \ldots, w_m, R_1, R_2, \ldots, R_m)$, where:

- $V$ is an alphabet of objects
- $\mu$ is a membrane structure
- $w_1, w_2, \ldots w_m$ are initial multisets of objects in membranes $1 \ldots m$, $w_i \subseteq \mathbb{N}^V$
- $R_1, R_2, \ldots, R_m$ are sets of rewriting rules in membranes $1 \ldots m$, where

$$R_i \subseteq (\mathbb{N}^V \setminus 0^V) \times \mathbb{N}^{V \times (\{here, out\} \cup \{in_1, \ldots in_m\})}$$

.

# Configuration and computational step

- configuration = membrane structure + contents
- computational step: maximal parallelism

# Configuration and computational step

- configuration = membrane structure + contents
- computational step: maximal parallelism

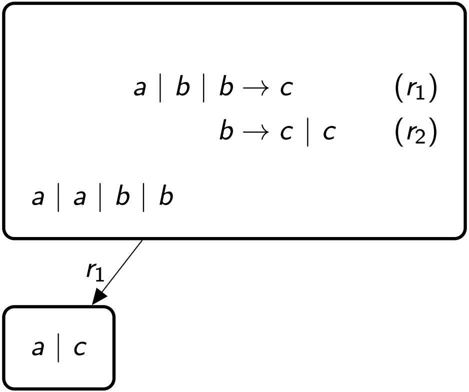
$$a \mid b \mid b \rightarrow c \qquad (r_1)$$

$$b \rightarrow c \mid c \qquad (r_2)$$

$$a \mid a \mid b \mid b$$

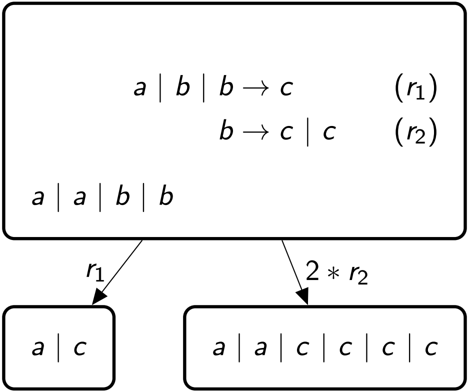
# Configuration and computational step

- configuration = membrane structure + contents
- computational step: maximal parallelism



# Configuration and computational step

- configuration = membrane structure + contents
- computational step: maximal parallelism



# Language

- result of the computation is a multiset of objects, which:
  - have passed the outer membrane
  - is present in a specific membrane at the end

# Language

- result of the computation is a multiset of objects, which:
  - have passed the outer membrane
  - is present in a specific membrane at the end
- generating vs. accepting mode

# Language

- result of the computation is a multiset of objects, which:
  - have passed the outer membrane
  - is present in a specific membrane at the end
- generating vs. accepting mode
- Parikh mapping: PsRE

# Variants of rules

- context (PsRE)

# Variants of rules

- context (PsRE)
- cooperative (PsRE) [Păun, 1998]

# Variants of rules

- context (PsRE)
- cooperative (PsRE) [Păun, 1998]
- catalytic
  - with 2 catalysts (PsRE) [Freund et al., 2005]
  - with 1 catalyst (open problem)
  - with 1 catalyst and inhibitors (PsRE) [Ionescu and Sburlan, 2004]

# Variants of rules

- context (PsRE)
- cooperative (PsRE) [Păun, 1998]
- catalytic
  - with 2 catalysts (PsRE) [Freund et al., 2005]
  - with 1 catalyst (open problem)
  - with 1 catalyst and inhibitors (PsRE) [Ionescu and Sburlan, 2004]
- context-free (PsCF) [Sburlan, 2005]

# Variants of rules

- context (PsRE)
- cooperative (PsRE) [Păun, 1998]
- catalytic
  - with 2 catalysts (PsRE) [Freund et al., 2005]
  - with 1 catalyst (open problem)
  - with 1 catalyst and inhibitors (PsRE) [Ionescu and Sburlan, 2004]
- context-free (PsCF) [Sburlan, 2005]
- context-free with inhibitors (PsET0L) [Ionescu and Sburlan, 2004]

# Variants of computational step

- maximal parallelism (PsRE)

# Variants of computational step

- maximal parallelism (PsRE)
- sequential (equals to VASS, [Ibarra et al., 2005])

# Variants of computational step

- maximal parallelism (PsRE)
- sequential (equals to VASS, [Ibarra et al., 2005])
- asynchronous ($\sim$ sequential in most cases) [Freund, 2005]

# Variants of computational step

- maximal parallelism (PsRE)
- sequential (equals to VASS, [Ibarra et al., 2005])
- asynchronous ($\sim$ sequential in most cases) [Freund, 2005]
- minimal parallelism (PsRE) [Ciobanu et al., 2007]

# Extensions of sequential P systems

- priorities [Ibarra et al., 2005]
- unbounded membrane creation [Ibarra et al., 2005]

# Extensions of sequential P systems

- priorities [Ibarra et al., 2005]
- unbounded membrane creation [Ibarra et al., 2005]
- **inhibitors [Kováč, 2014, submitted]**

# Extensions of sequential P systems

- priorities [Ibarra et al., 2005]
- unbounded membrane creation [Ibarra et al., 2005]
- **inhibitors [Kováč, 2014, submitted]**
- further study (rules with emptyness detection, . . . )

# Register machine

Minsky register machine is $M = (n, P, i, h)$, where:

- $n$ is the number of registers
- $P$ is a set of labeled instructions of type:
    - $(add(r), k, l)$
    - $(sub(r), k, l)$
    - $halt$
- $i$ is the initial instruction
- $h$ is the final instruction

# Simulation of register machine

- Contents of register $j$ is represented by the multiplicity of the object $a_j$
- For an instruction $(add(r), k, l)$ there is a rule $e \to a_j | f$
- For an instruction $(sub(r), k, l)$ there are rules
  - $e | a_j \to f$
  - $e \to z | \not{a}_j$
- Halting rules
  - $h | a_j \to h | \#$ for all $a \leq j \leq n$
  - $\# \to \#$

# Overview of the simulation for the generating case

- Simulation of a maximal parallel step
- Phases of membranes: *RUN* and *SYNCHRONIZE*, represented by objects

# Major difficulties

- Preventing the rule application on already rewritten objects in the same maximal parallel step

# Major difficulties

- Preventing the rule application on already rewritten objects in the same maximal parallel step
  - replace objects on the right side $a$ with $a'$
  - add *RESTORE* phase

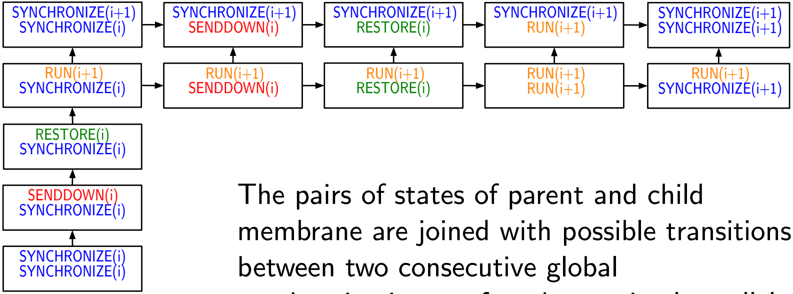
# Major difficulties

- Preventing the rule application on already rewritten objects in the same maximal parallel step
  - replace objects on the right side $a$ with $a'$
  - add *RESTORE* phase
- Sending objects via membranes

# Major difficulties

- Preventing the rule application on already rewritten objects in the same maximal parallel step
  - replace objects on the right side $a$ with $a'$
  - add *RESTORE* phase
- Sending objects via membranes
  - add *SENDDOWN* phase

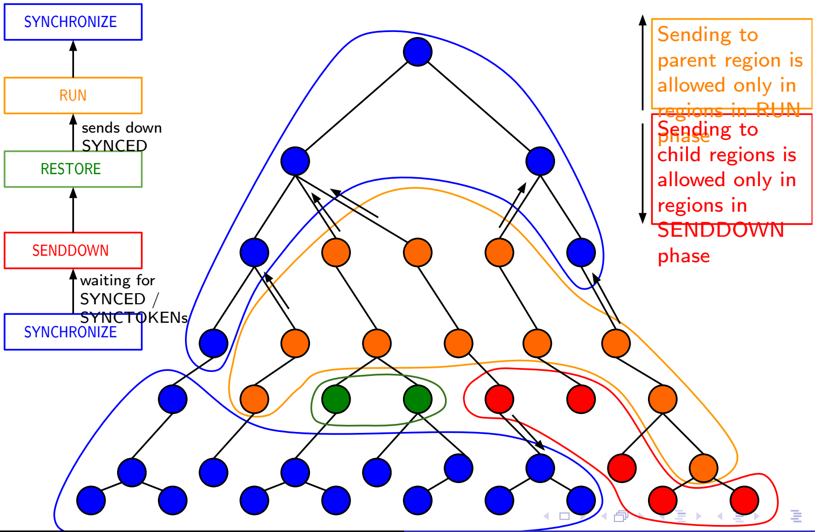
# Parent and child membrane phases




The pairs of states of parent and child membrane are joined with possible transitions between two consecutive global synchronizations - after the maximal parallel steps i and i+1

Obr. : Possible pairs of states of parent and child membrane

# Snapshot of all membrane states



Thanks for your attention