

# Sequential P Systems with Active Membranes Working on Sets

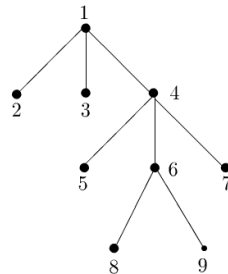
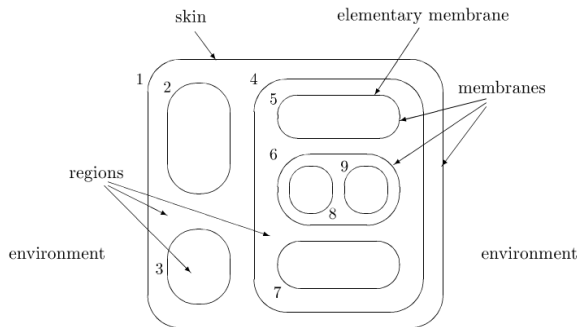
**Michal Kováč**, Damas Gruska

Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava,  
Slovakia

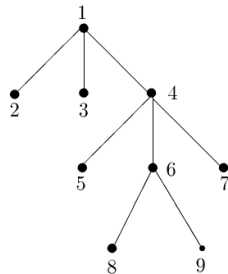
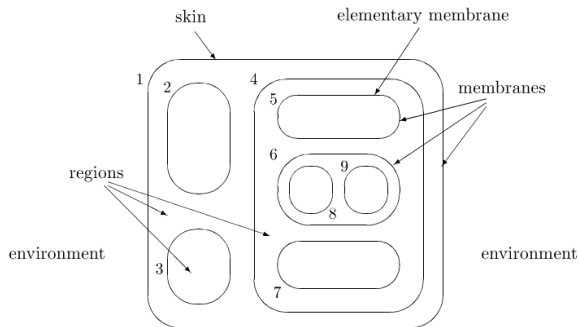
30.9.2015

- 1 Overview of formal models
  - P systems
  - Using sets instead of multisets
- 2 Sequential active set membrane systems
  - Original semantics
  - Modified membrane creation semantics

# Membrane structure

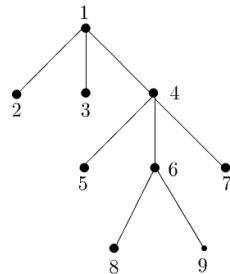
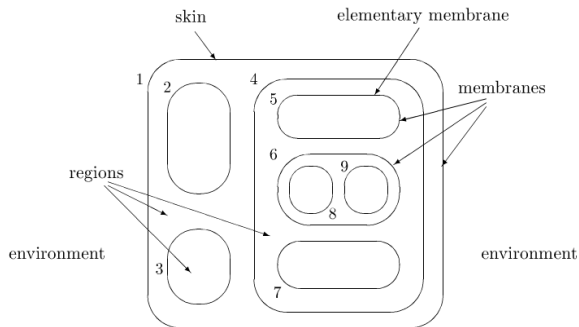


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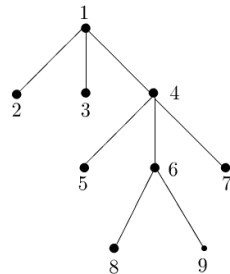
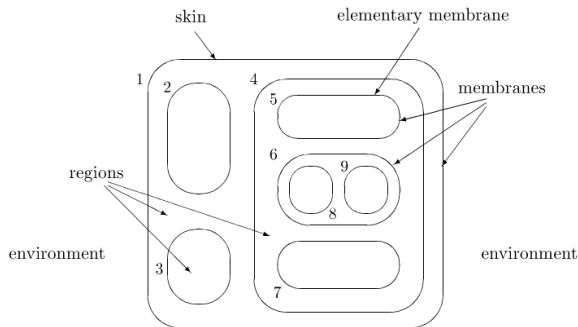
- Multisets

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- Multisets
- Rewriting rules
- Passive vs. Active

# Computation

- Maximal parallel vs. sequential

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- Language
  - Generating mode: language of sequences of objects sent out from the skin membrane
  - Accepting mode: accept the given configuration if the system can halt



# Using sets instead of multisets

- How realistic is the counting?
- Effectiveness of verification techniques

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- Properties:
  - No conflict (objects can participate as reactants in as many rules as they want).
  - If an object is used as a reactant for at least one rule, it is consumed.



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- $C = (T, l, c)$ 
  - $l : V(T) \rightarrow \{0, \dots, m-1\}$
  - $c : V(T) \rightarrow 2^\Sigma$
- Rewriting rules
  - $u \rightarrow w$
  - $u \rightarrow w\delta$
  - $u \rightarrow [{}_j v_1]_j v_2,$   
 where  $u \subseteq \Sigma, |u| \geq 1, v_1, v_2 \subseteq \Sigma$  and  $w \subseteq (\Sigma \times \{\cdot, \uparrow, \downarrow\})$

# Register machine

- Registers with non-negative values  $r_1, r_2, \dots$
- Labeled instructions  $i : op$ , where  $op$  is:
  - $add(j, k)$
  - $sub(j, k, l)$
  - $halt$
- State = (instruction pointer, values of registers)
- Step: modify the register value, move the instruction pointer

# Simulation of a register machine

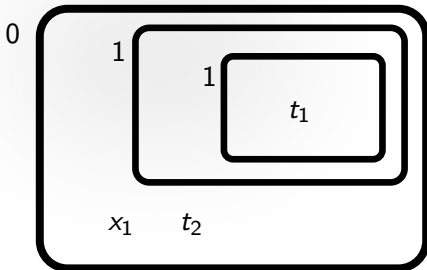
Simulation of a register machine (2 registers, 3 instructions):

- 1 : *sub*(1, 2, 3)
- 2 : *add*(2, 1)
- 3 : *halt*

# Example simulation

Skin membrane (6 rules):

- $x_1 \rightarrow x_1 \downarrow_1$  ,  $x_2 \rightarrow x_2 \downarrow_2$
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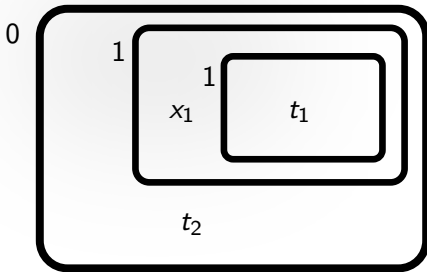
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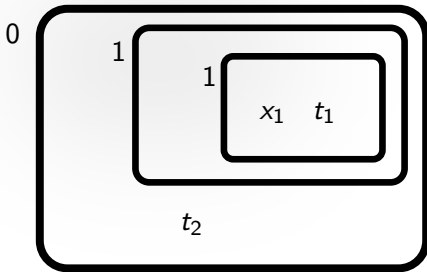
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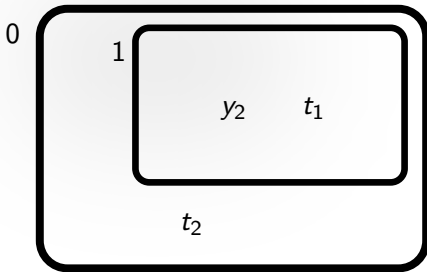
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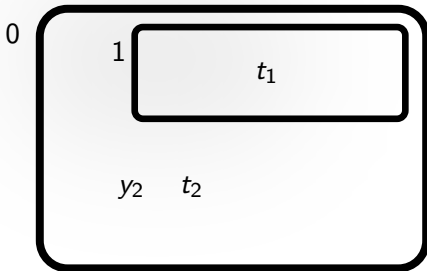
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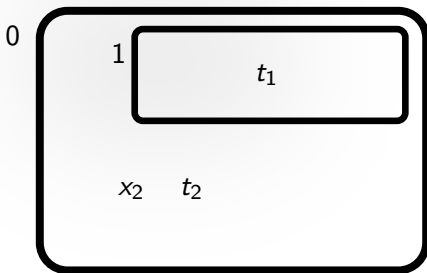
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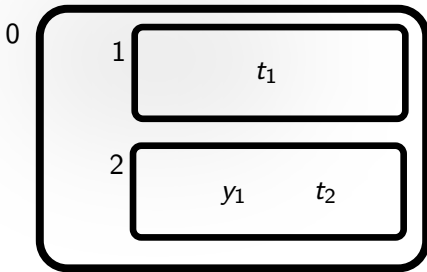
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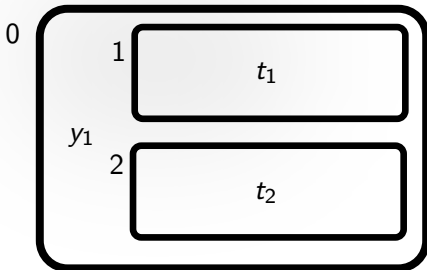
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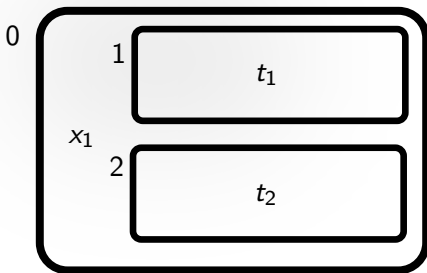
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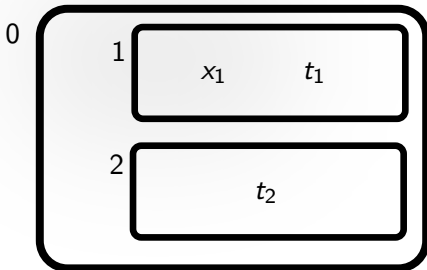
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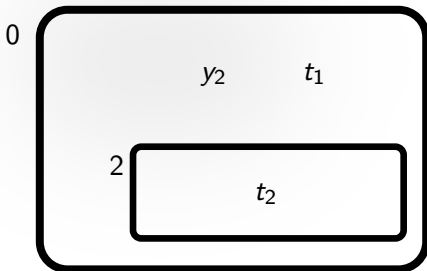
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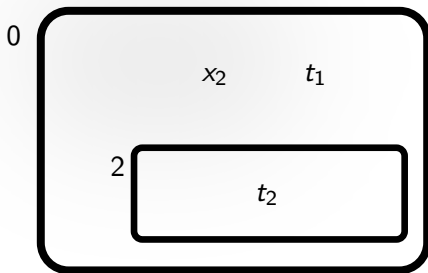
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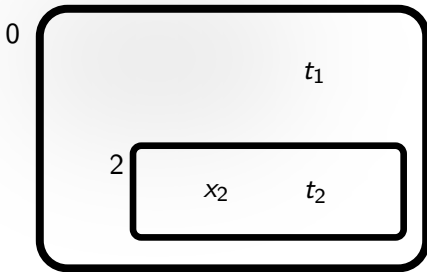
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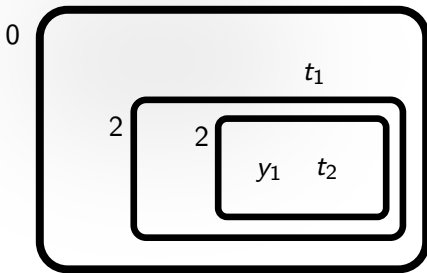
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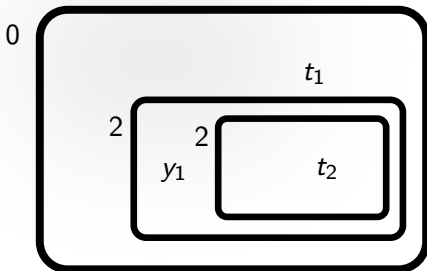
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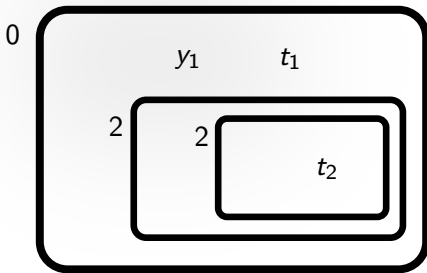
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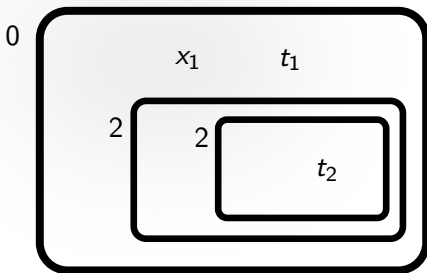
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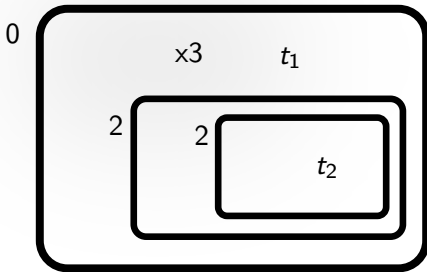
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- $x_1 t_1 \rightarrow y_2 t_1 \delta$
- $y_1 \rightarrow y_1 \uparrow$  ,  $y_2 \rightarrow y_2 \uparrow$

Membrane 2 (4 rules):

- $x_2 \rightarrow x_2 \downarrow_2$
- $x_2 t_2 \rightarrow [{}_2 y_1 t_2]_2$
- $y_1 \rightarrow y_1 \uparrow$  ,  $y_2 \rightarrow y_2 \uparrow$

# Issues with original semantics

- Two issues:
  - 1 Explicit membrane creation rule



# Issues with original semantics

- Two issues:
  - 1 Explicit membrane creation rule
  - 2 Sending an object to a child membrane

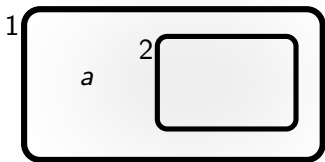
# Issues with original semantics

- Two issues:
  - 1 Explicit membrane creation rule
  - 2 Sending an object to a child membrane
- Alternatives:
  - 1 Inject-or-create (no explicit membrane creation rule)

# Issues with original semantics

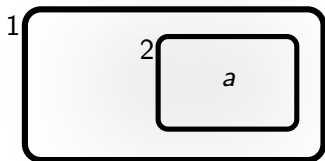
- Two issues:
  - 1 Explicit membrane creation rule
  - 2 Sending an object to a child membrane
- Alternatives:
  - 1 Inject-or-create (no explicit membrane creation rule)
  - 2 Wrap-or-create

# Inject-or-create semantics

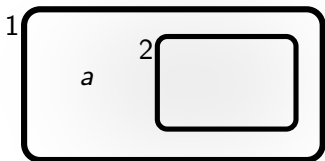


# Inject-or-create semantics

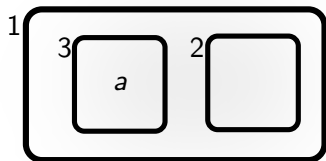
$$a \rightarrow a \downarrow_2$$



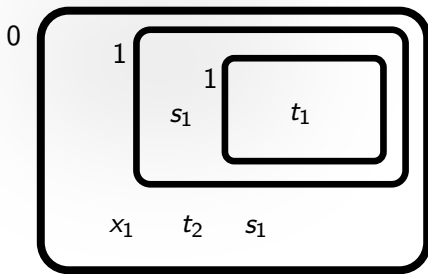
# Inject-or-create semantics



$a \rightarrow a \downarrow_3$



# Wrap-or-create semantics



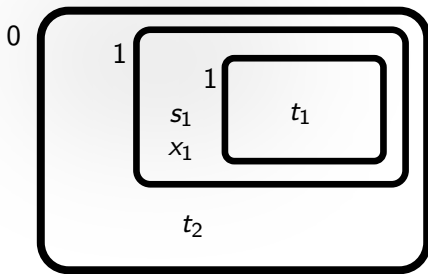
Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

# Wrap-or-create semantics



Skin membrane:

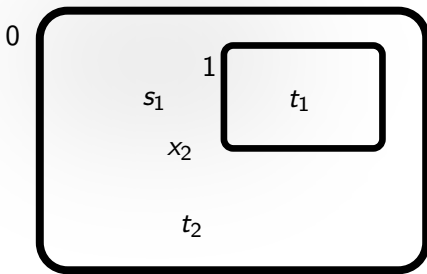
- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow 1$
- $x_2 s_2 \rightarrow [2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$



# Wrap-or-create semantics



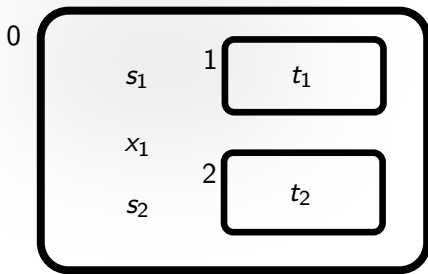
Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [{}_2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [{}_2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

# Wrap-or-create semantics



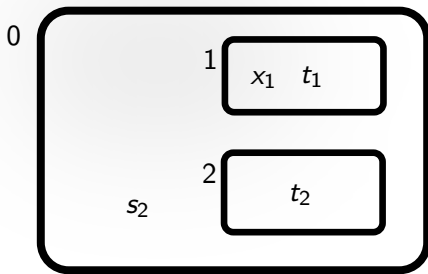
Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [{}_2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [{}_2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

# Wrap-or-create semantics



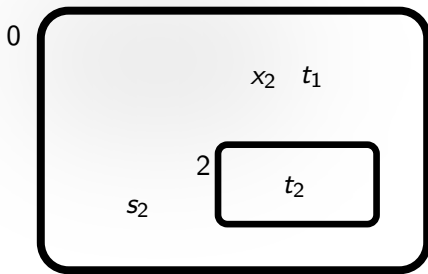
Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [{}_2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [{}_2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

# Wrap-or-create semantics



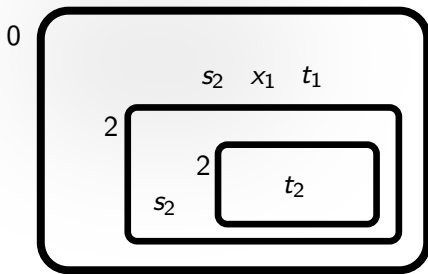
Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [{}_2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [{}_2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

# Wrap-or-create semantics



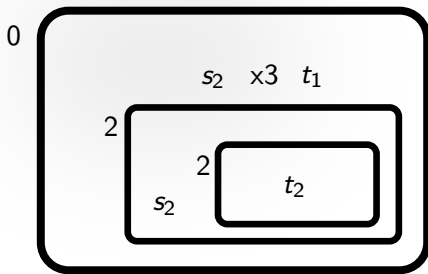
Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [{}_2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [{}_2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

# Wrap-or-create semantics



Skin membrane:

- $x_1 t_1 \rightarrow x_3 t_1$
- $x_1 s_1 \rightarrow x_1 \downarrow_1$
- $x_2 s_2 \rightarrow [2 s_2]_2 s_2 x_1$
- $x_2 t_2 \rightarrow [2 t_2]_2 s_2 x_1$

Membrane 1:

- $x_1 \rightarrow x_2 \delta$

# Comparison of membrane creation semantics

semantics	membranes	time	alphabet
original	$O(n)$	$O(n)$	$2 * \#instr. + \#reg.$
original	$O(\log(n))$	$O(\log(n))$	$3 * \#instr. + 5$
inject-or-create	$O(\log(n))$	$O(\log(n))$	$3 * \#instr. + 5$
wrap-or-create	$O(n)$	$O(1)$	$\#instr. + 2 * \#reg.$



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P systems without multiplicities of symbol-objects.  
*Information Processing Letters*, 100(3):124–129.



Kleijn, J. and Koutny, M. (2011).

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*Fundam. Inf.*, 110(1-4):217–230.



Thanks for your attention!