Writing Membrane Systems in P-Lingua 5

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19th Brainstorming Week on Membrane Computing

Seville, January 24–27, 2023

Outline

Membrane computing

Simulators in membrane computing

How to define the input of the simulator?

The problem with new P system variants

Solving the problem

Conclusions, future/present work and references

Membrane computing

Simulators in membrane computing

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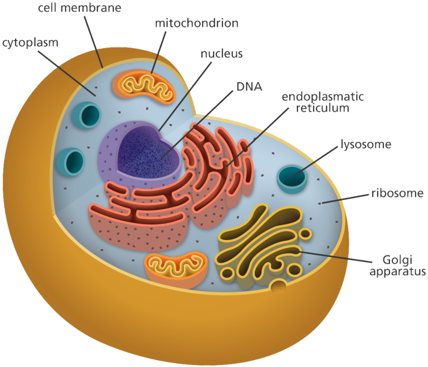
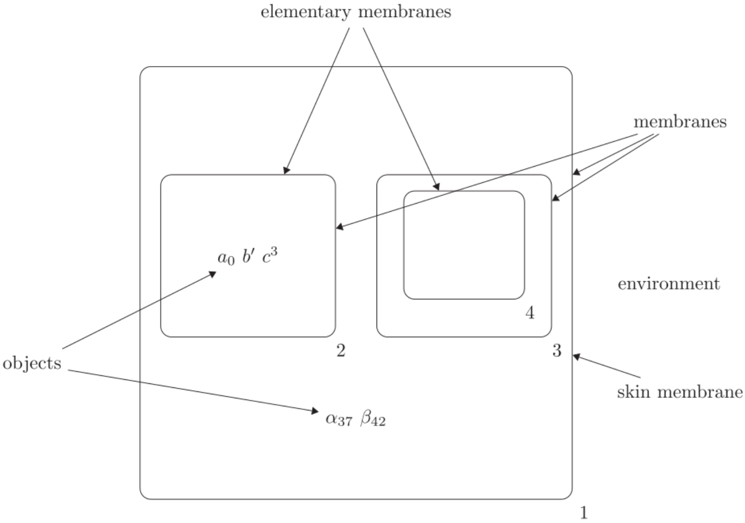
Membrane computing

- Branch of natural computing
- Inspired in the structure and functions of the living cells



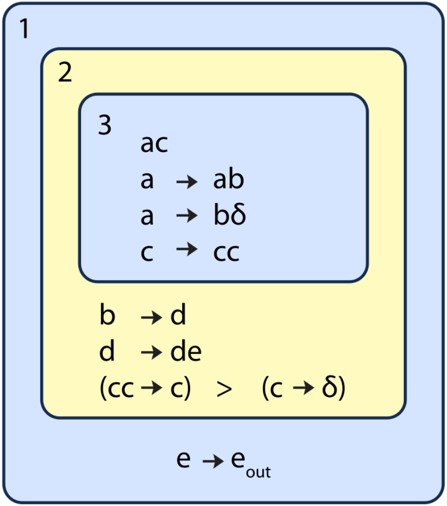
Computational devices in membrane computing

Membrane systems or P systems



Example

Computing squared numbers



1

2

3

ac

$a \rightarrow ab$

$a \rightarrow b\delta$

$c \rightarrow cc$

$b \rightarrow d$

$d \rightarrow de$

$(cc \rightarrow c) > (c \rightarrow \delta)$

$e \rightarrow e_{out}$

Syntax and semantics of membrane systems

- Syntax
  - Definition of the initial structure
  - Definition of initial multisets
  - Definition of rules

- Semantics
  - How rules are selected and executed
  - Described by derivation modes

- A P system *variant* includes the permitted syntactic ingredients for a type of P systems together with the definition of its semantics

Membrane computing

Simulators in membrane computing

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Simulators in membrane computing

Motivation

Simulation vs Implementation

- Membrane systems have not been implemented yet[1]
- We need software (or hardware) to simulate computations

Applications of simulators

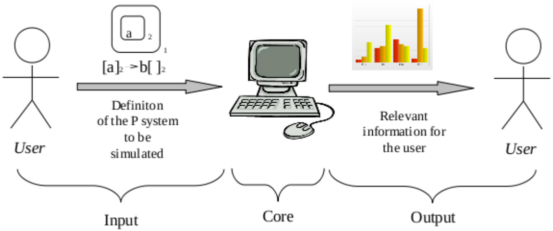
- Pedagogic tools
- Tools to assist researchers in membrane computing
- Simulation, validation and virtual experimentation of models based of membrane computing

[1] Maybe this is a controversial affirmation, but this is a provocative speak!

Simulators in membrane computing

General structure

- There is a wide variety of simulation tools [2]
- They (usually) have a general structure


a
2
1
[a]2 -> b[ ]2
Definiton of the P system to be simulated
User
Relevant information for the user
User
Input
Core
Output

[2] L. Valencia-Cabrera et al. An interactive timeline of simulators in membrane computing. *Journal of Membrane Computing* **1**, 209–222 (2019)

Membrane computing

Simulators in membrane computing

How to define the input of the simulator?

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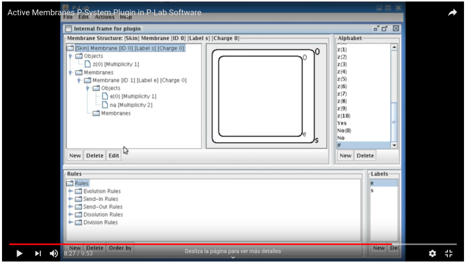
Let's begin by the beginning

How to define the input of the simulator?

- Definition of the p system to be simulated
  - Initial membrane structure
  - Initial multisets
  - Set of rules
- Our first approach was a GUI called P-Lab[3]



Active Membranes P-System Plugin in P-Lab Software

Internal frame for plugin

Membrane Structure: [Skin] Membrane [ID 0] [Label s] [Charge 0]

```
[Skin] Membrane [ID 0] [Label s] [Charge 0]
  Objects
    z(0) [Multiplicity 1]
  Membranes
    Membrane [ID 1] [Label e] [Charge 0]
      Objects
        e(0) [Multiplicity 1]
        na [Multiplicity 2]
      Membranes
```

Alphabet: z(1), z(2), z(3), z(4), z(5), z(6), z(7), z(8), z(9), z(10), Yes, No(0), No, #

```
Rules
  Evolution Rules
  Send-In Rules
  Send-Out Rules
  Disolution Rules
  Division Rules
```

Labels: e, s

[3] https://www.youtube.com/watch?v=LFHxSPD9Y5M&t=315s

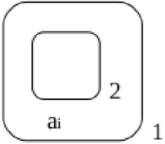
How to define the input of the simulator?

- P-Lab fails since (in our opinion) a GUI to define P systems:
  - could be too rigid
  - could be difficult to extend
  - could be obsolete
- So, why not to move to a definition language?

P-Lingua: A language to define P systems

- Language close to scientific notation
- Standard, modular and parametric
- Decoupled from its applications
- Several supported variants of P systems
- Extensible
- Website: `http://www.p-lingua.org`
- It was presented in the 6th BWMC (2008)

An example: Transition P systems



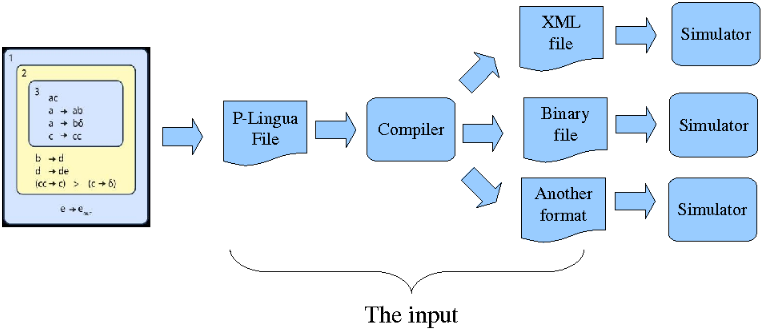
$$[a_i\ [\ ]_2]_1 \longrightarrow [a_{i+1}\ [b_i]_2]_1\ 1 \leq i \leq 10$$

```
@model<transition>
def main()
{
 @mu = [[]'2]'1;
 @ms(1) = a{1};
 [a{i} []'2]'1 --> [a{i+1} [b{i}]'2]'1 : 1<=i<=10;
}
```

pLinguaCore

- Java library for compilers and simulators
- Free software (GNU GPL license)
- It reads P-Lingua files
- It generates P system definitions in other formats
- It implements several simulation algorithms

pLinguaCore



The history

- P-Lingua + pLinguaCore 1.0 (2008)
  - Active membranes P systems with division rules
- P-Lingua + pLinguaCore 2.0 (2010)
  - Several cell-like P system variants
  - Built-in simulators
- P-Lingua + pLinguaCore 2.1 (2010)
  - Tissue-like P systems with division rules
- P-Lingua + pLinguaCore 3.0 (2013)
  - PDP systems
  - Several simulators for PDP systems
- P-Lingua + pLinguaCore 4.0 (2014)
  - Spiking Neural P systems
  - Tissue-like P systems with cell-separation rules

Some related tools

- PMCGPU project
  - Moving to efficiency
  - Parallel simulators for MC on the GPU
  - The input is generated with P-Lingua
- MeCoSim: Membrane Computing Simulator
  - A software to design end-user applications based on membrane computing
  - It includes a custom version of pLinguaCore
  - It has been used for simulation of real ecosystems
- And more!

Membrane computing

Simulators in membrane computing

How to define the input of the simulator?

The problem with new P system variants

Solving the problem

Conclusions, future/present work and references

The problem with new P system variants

- Extending pLinguaCore for a new P system variant:
  - Decide a new name to identify the variant.
  - Implement code to extend the parser in pLinguaCore.
  - Implement code to generate custom output formats.
  - Implement one or more simulation algorithms.
- All is hard-coded!
- How to use a variant not supported in pLinguaCore?

Membrane computing

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Extend P-Lingua to write P system variants

- P-Lingua 5 includes an extension of the language to define P system variants
- It has retro-compatibility with P-Lingua 4
- pLinguaCore is not longer required
- A new toolkit developed from scratch in C/C++ [4]
    - A parser for the command-line:
        - Input: P-Lingua 5 files
        - Output: P system definition in XML, JSON or binary format
    - A C++ generic simulator for the command-line

[4] I-Pérez-Hurtado et al. A new P-Lingua toolkit for agile development in membrane computing, *Information Sciences* (2022), **587**, 1–22

P-Lingua 5

Example: Cell-Like P systems with membrane division rules

```
!dam_evolution {
   ?[a -> v]’h;
   ?[a ->  ]’h;
}
!dam_send_in {
   a ?[ ]’h -> ?[b]’h;
}
!dam_send_out {
   ?[a]’h -> b ?[ ]’h;
}
!dam_dissolution {
   ?[a]’h -> b;
   ?[a]’h ->  ;
}
```

P-Lingua 5

Example: Cell-Like P systems with membrane division rules

```
!dam_division {
   ?[a]’h -> ?[ ]’h ?[ ]’h;
   ?[a]’h -> ?[b]’h ?[ ]’h;
   ?[a]’h -> ?[ ]’h ?[b]’h;
   ?[a]’h -> ?[b]’h ?[c]’h;
}

@model(membrane_division) =
       dam_evolution,
       // evolution rules are maximally parallel
       @1{dam_send_in, dam_send_out, dam_dissolution, dam_division};
       // upper-bound for send_in, send_out, dissolution, division is 1
```

P-Lingua 5

Example: Cell-Like P systems with membrane division rules

```
@model<membrane_division>
@include "membrane_division_model.pli"
def Sat(m,n)
{
 /* Initial configuration */
 @mu = [[]’2]’1;

 /* Initial multisets */
 @ms(2) = d{1};

 /* Set of rules */
 [d{k}]’2 --> +[d{k}]-[d{k}] : 1 <= k <= n;
```

P-Lingua 5

Example: Transition P systems

```
!transition_evolution /* Limited to rules with 3 inner membranes */
{
       [a -> v]’h;
       [a -> v, @d]’h;
   (?) [a -> v]’h;
   (?) [a -> v, @d]’h;
       [a [ ]’h1 --> v [w]’h1]’h;
       [a [ ]’h1 --> v [w]’h1]’h;
   (?) [a [ ]’h1 --> v [w]’h1]’h;
   (?) [a [ ]’h1 --> v [w]’h1]’h;
       [a [ ]’h1 [ ]’h2 --> v [w1]’h1 [w2]’h2]’h;
       [a [ ]’h1 [ ]’h2 --> v [w1]’h1 [w2]’h2]’h;
   (?) [a [ ]’h1 [ ]’h2 --> v [w1]’h1 [w2]’h2]’h;
   (?) [a [ ]’h1 [ ]’h2 --> v [w1]’h1 [w2]’h2]’h;
       [a [ ]’h1 [ ]’h2 [ ]’h3 --> v [w1]’h1 [w2]’h2 [w3]’h3]’h;
       [a [ ]’h1 [ ]’h2 [ ]’h3 --> v [w1]’h1 [w2]’h2 [w3]’h3]’h;
   (?) [a [ ]’h1 [ ]’h2 [ ]’h3 --> v [w1]’h1 [w2]’h2 [w3]’h3]’h;
   (?) [a [ ]’h1 [ ]’h2 [ ]’h3 --> v [w1]’h1 [w2]’h2 [w3]’h3]’h;
} @model(transition) = transition_evolution;
```

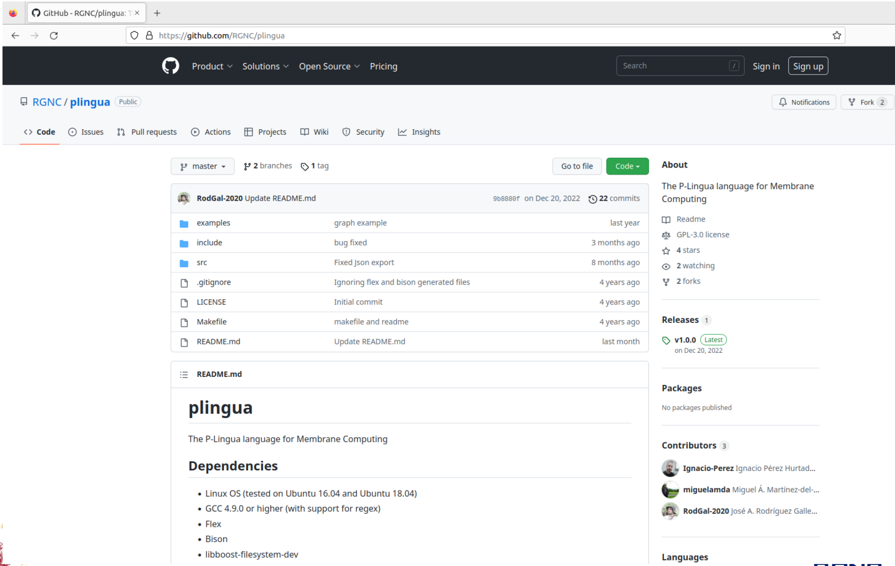
P-Lingua 5

The command-line simulator

- A command-line simulator has been written in C++
- It reads the output generated by the P-Lingua compiler (XML/Json/binary file defining the P system)
- It optionally reads a file with the initial configuration
- It simulates the P system following the defined semantics in the file
- It outputs one computation until a halting state or a number of simulation steps
- It can be run in a non-randomized mode, where it outputs always the same computation for a given P system
- The final configuration is written to a file, the simulation can be re-started

P-Lingua 5

https://github.com/RGNC/plingua



RodGal-2020 Update README.md 9b8880f on Dec 20, 2022 22 commits

examples	graph example	last year
include	bug fixed	3 months ago
src	Fixed Json export	8 months ago
.gitignore	Ignoring flex and bison generated files	4 years ago
LICENSE	Initial commit	4 years ago
Makefile	makefile and readme	4 years ago
README.md	Update README.md	last month

README.md

plingua

The P-Lingua language for Membrane Computing

Dependencies

- Linux OS (tested on Ubuntu 16.04 and Ubuntu 18.04)
- GCC 4.9.0 or higher (with support for regex)
- Flex
- Bison
- libboost-filesystem-dev

About

The P-Lingua language for Membrane Computing

Readme
GPL-3.0 license
4 stars
2 watching
2 forks

Releases 1

v1.0.0 Latest
on Dec 20, 2022

Packages

No packages published

Contributors 3

Ignacio-Perez Ignacio Pérez Hurtad...
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RodGal-2020 José A. Rodríguez Galle...

Languages

Membrane computing

Simulators in membrane computing

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Conclusions

- A new version of P-Lingua has been designed including rule patterns and semantic definitions
- a command-line compiler has been written from scratch in C/C++
- a command-line simulator tool is also provided
- hard-coding the definition of the P system variants is not longer necessary
- this tool allows the designers to "play" with experimental variants of P systems

Future/present work

- To debug the code and complete the documentation
- To write simulators for parallel architectures, such as multi-core processors, pthreads, GPUs, FPGAs...
- To design optimized simulation tools for interesting case studies
- And more...

References

- I. Pérez-Hurtado et al. A new P-Lingua toolkit for agile development in membrane computing, *Information Sciences* (2022), **587**, 1–22
- M. del-Amor et al. Adaptative parallel simulators for bioinspired computing models, *Future Generation Computer Systems* (2020), **107**, 469–484
- I. Pérez-Hurtado et al. P-Lingua in two steps: flexibility and efficiency, *Journal of Membrane Computing* (2019), **1**, 93–102

Thanks for your attention!

P-Lingua