Seven Research Suggestions

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After (about) 22 years since the first paper, still many research questions exist.

For the two decades development, see the bibliography and the CMC20 talk of Gexiang Zhang, "Membrane Computing: Developmental Analysis" (to be published in *Journal of Membrane Computing*)

By the way: VERY important – **Journal of Membrane Computing**

Write – read – cite!

Contents in *Bulletin of the IMCS*:

`http://membranecomputing.net/IMCSBulletin/`

Two Very General Ideas

(Q1) *Back to literature!*

M. Gheorghe, Gh. Păun, M.J. Pérez-Jiménez (Eds.) Frontiers of Membrane Computing. Open Problems and Research Topics, *Proc. 10th BWMC*, Sevilla Univ., 2012, vol. 1, 171–249

M. Gheorghe, Gh. Păun, M.J. Pérez-Jiménez, G. Rozenberg (Eds.) Frontiers of Membrane Computing. Open Problems and Research Topics, *Intern. J. Found. Computer Sci.*, 24, 5 (2013), 547–623.

Examine systematically the status of each suggestion made in this "mega-paper"

(Q2) Look to the future (well,... *the future started yesterday...*), namely, to *the Fourth Industrial Revolution*: connectivity, artificial intelligence, machine learning, cyber-systems, robots...

Where can MC contribute?

Three "Hybridization" Suggestions

(Q3) Systematic comparison of "basic" classes of P systems – cell-like, tissue-like, spiking neural, and numerical, with multiset rewriting rules, active membranes, symport/antiport, spiking rules, programs (production-repartition) rules, respectively, with various specific features – catalysts, polarizations, regular expression guarding the (spiking) rules, unique object (the spike), etc.

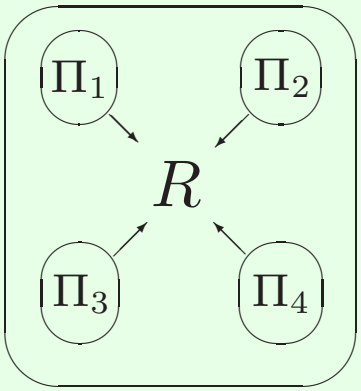
Examples of questions:

1. efficiency of one-object systems
2. numerical P systems with only one variable (in each region)
3. anti-matter in numerical P systems
4. SN P systems with "programs" like in numerical P systems? (can cover the sigmoidal function idea?)

(Q4) Bridging P and R

Borrowing notions investigated in R and investigating them for P (which of them make sense? which of them are decidable?) was suggested many times.

Another "hybridization" idea:



Examine the usual R questions for such a hybrid system; what about computability in this framework? (how to define the result of a computation?); what about the case when the P systems not only send objects to the environment, but they can also bring objects back inside? what about using simple P systems (non-universal), or of various types? in the case of SN P systems, we will have two possibilities: to distinguish between the spikes of various SN P systems or not – in the latter case, the R system is supposed to get only one (type of) object from the environment; how R systems with only one object in their alphabet behave?

(Q5) Bringing to MC further notions from the quantum area

1. To consider P systems with *quobjects*, $(a, \alpha), a \in A, 0 \leq \alpha \leq 1$.

What about rules of the form

$$a \to (b, \beta)(c, \gamma), \ \beta, \gamma \in [-1, 1],$$

$$\begin{aligned} (a, \alpha) \quad &\to \quad (b, \alpha \oplus \beta)(c, \alpha \oplus \gamma), \text{ where} \\ \alpha \oplus \delta \quad &= \quad \begin{cases} 0, & \text{if } \alpha + \delta < 0, \\ \alpha + \delta, & \text{if } 0 \leq \alpha + \delta \leq 1, \\ 1, & \text{if } \alpha + \delta > 1, \end{cases} \end{aligned}$$

A multiplicative operation? How to define a successful computation? By halting? And which could be the result of a computation? (Maybe the distance between two prescribed events, without halting, maybe the string of objects which reach probability 1.) Should the objects of the form $(a, 0)$ be preserved in the system or they should be eliminated?

2. entanglement

How to define it? Hereditary?

Power and efficiency

Combine entanglement with quobjects (a possible new way towards efficiency?)

Two More Precise Proposals

(Q6) Homogeneous P systems (the bio-chemistry is unique everywhere)

Example of questions:

1. efficiency for homogeneous P systems
2. homogeneous numerical P systems
3. various semantics
4. additional restriction: if P is the homogeneous set of rules present in all compartments, choose $P' \subseteq P$ (maximal?) and use it (in the maximally parallel way, etc.) in all compartments. Power and efficiency?

(Q7) SN P systems with astrocytes producing calcium, with calcium directly involved in the spiking activity.

Two types of cells,

$$
\begin{array}{ll}
astrocytes & \alpha_1, \ldots, \alpha_m, \text{ of the form } (c^{p_{i,0}}, A_i), p_{i,0} \geq 0, \\
 & \text{with the rules in } A_i \text{ of the form } E_c/c^s \to c^t, s \geq 1, t \geq 0, \text{ and} \\
neurons & \sigma_1, \ldots, \sigma_n, \text{ of the form } (a^{r_{i,0}}, R_i), r_{i,0} \geq 0, \\
 & \text{with the rules in } R_i \text{ of the form } E_a/a^s c^{s'} \to a^t, s, s' \geq 1, t \geq 0,
\end{array}
$$

Synapses: any but not (σ_i, α_j)

Versions: the regular expressions in neurons also depending on the calcium units (hence over the alphabet $\{a, c\}$), with delay, with or without the possibility of replicating calcium, when an astrocyte sends objects c to several neurons.

Questions: normal forms, universality, small universal systems, plasticity, homogeneity, etc. Are astrocytes of this form improving the results known for usual SN P systems?

Thank you!

...and please do not forget: write, read, cite!

thus promoting JMC