**Introduction**

Since the second part of the last century, attempts have been made to mimic biological functions to build effective models to solve complex problems in the daily life [1]. Evolution computing, such as genetic computing, neural computing and molecular computing, belongs to nature computing. With the developing of the computer science, the nature computing algorithm shows excellent power and great potential to complete the computational tasks.

As the youngest branch of nature computing, membrane computing is inspired by living cells [2]. Cell, who is the smallest biological molecular unit, is worth for us to further studying in the real life. In the structure and function of the cell, the membrane plays a vital role to separate it from interior. A plasma membrane can depart the outer environment and protect the material in it from outer environment. Generally, a cell contains other functioning organs and can be divided into several regions by the inner membranes internally. Membrane computing found this phenomenon and formalizes this essential feature of the living cell. Therefore, an important component, membrane structure, is extracted for membrane computing. Similarly, kinds of organs distributed in the membrane is regarded as membrane objects and all membrane objects obey the membrane information exchange manner in which they are located, constituting the third major ingredient of membrane computing, named membrane evolutionary rules.

**Classical P system**

Membrane computing is first proposed by Gheorghe Păun in 1998, so it is also known as P system [3]. As mentioned before, a P system is formed by a unique membrane structure, which contains some hierarchically arranged membranes, who delimits some regions to place the corresponding objects naturally. In this section, we introduced a classical P system through three aspects, membrane structure, objects and membrane evolutionary rules comprehensively.

**Membrane structure** Membrane structure plays a key role to P system. Here we prepared a classical membrane structure in Fig. 1.



**Fig. 1** A classical membrane structure

As shown in Fig. 1, the prepared membrane structure consists of 8 membranes totally. There are three kinds of membranes contained in a classical membrane structure. Generally, the plasma membrane is regraded as skin membrane placed in the outermost layer to keep the proposed P system from external environment. And the membranes lied in a cell, around the nucleus can be divided two series membranes: elementary membranes, membranes without any other membrane inside, and nonelementary membranes, which are placed inside the skin membrane whereas contain other elementary membranes simultaneously. In addition, each membrane uniquely determines a compartment that is region. As shown in Fig. 1, a classical membrane structure contains many regions, which are the regions in a unique membrane and the regions between membranes and the adjacent membranes totally.

**Membrane objects** Membrane objects are abstracted from the chemicals swimming in a water solution in a cell region. The simulated chemicals are unstructured and usually expressed as symbols from alphabet. In classical P system, membrane objects are the substance that are used to express a vector or a solution for a specific mathematical problem. Overall, the objects are relevant to the regions of the membrane structure and evolve by means of membrane evolutionary manners.

**Membrane evolutionary rules** Membranes for different organs or cells always have different functions. As we all known, another important function of various biological membranes is to control the movement of the substances out and in. In a cell, the possible chemical reactions are analogized to the membrane evolutionary rules in a P system.

A typical evolutionary rule is defined as, where alpha  represent the objects originally existing in the P system. It is worth noting that the substances in the left side of the arrow represent the substance who occurs chemical reaction in the corresponding membrane and the substances in the right arrow means the substances produced by the given evolutionary rules. And the specifically evolutionary rule can be interpreted as the following meaning:

Two objectsand one objectwould react and produce new objects consisting of oneand three new objects,. And the produced objects indicate different status in the corresponding membrane. Taking the producedas example, it would stay in the original region constantly. Moreover, as for three new objects, the one who marked bywould leave the membrane who produced it to the hierarchically outer layer of membrane who contains the original membrane. Meanwhile, the other two objects,enter orderly to the inner membrane who are surrounded by the original membrane.

In fact, a membrane evolutionary rule can be seen as information exchange manner to achieve the communication between membranes. Each membrane can be defined in different characteristic to control the communication with other surrounding membranes successfully. Especially, for the skin membrane, the objects would not belong to the P system since it leaves out to outer environment. In addition, the objects who remain in the elementary membrane is not able to be marked by ”in” operation because there is no membrane contained in the elementary membranes yet.

**Character and application**

A P system means a new computing device that can delimit a unique membrane structure and solve the computational problem by which objects evolve in the corresponding regions. Since the theory of membrane computing have been proposed, it has rapidly become a hot topic of research and attracted a lot of attention [4]. P system have been developed in three types, such as cell-like P systems, tissue-like P systems and neural-like P systems [5]. Like the classical P system mentioned in last section, it can be fundamentally seen as a cell-like P system. The tissue-like P system and neural-like P system consider a directed graph structure and neuron network structure respectively.

P system is a parallel and distributed computation device [6]. In a P system, the membrane contained in it can work independently. With the membrane computing developing, there are many P system designed before [7]. Membrane computing theory have been successfully applicated to many complicated tasks, such as NP-complete problem [8], HIV infection [9], modelling of avascular tumor growth [10], modelling of epidermal growth factor receptor signaling network [11], quorum sensing in bacteria [12] and optimization problems especially [13] et al. Employing membrane computing theory properly can address the gene selection tasks in high-dimensional microarray datasets successfully [14].

**Reference**

[1] Păun G. Introduction: Membrane computing—what it is and what it is not//Membrane Computing. Springer, Berlin, Heidelberg, pp. 1-6, 2002. DOI: <https://doi.org/10.1007/978-3-642-56196-2_1>

[2] Paun G. Membrane computing: an introduction. Springer Science & Business Media, 2002.

[3] Păun G. Computing with membranes. Journal of Computer and System Sciences, vol. 61, no. 1, pp. 108-143, 2000.

[4] Zhang G, Gheorghe M, Pan L, et al. Evolutionary membrane computing: a comprehensive survey and new results. Information Sciences, no. 279, pp. 528-551, 2014. DOI: <https://doi.org/10.1016/j.ins.2014.04.007>

[5] G. Pa˘un, G. Rozenberg, A. Salomaa, The Oxford Handbook of Membrane Computing, Oxford University Press, Inc., New York, NY, USA, 2010.

[6] García-Victoria P, Cavaliere M, Gutiérrez-Naranjo M A, et al. Evolutionary game theory in a cell: A membrane computing approach. Information Sciences, vol. 589, pp. 580-594, 2022. DOI: <https://doi.org/10.1016/j.ins.2021.12.109>

[7] Gheorghe M, Ipate F, Dragomir C, et al. Kernel P systems-version I. Eleventh Brainstorming Week on Membrane Computing (11BWMC), pp. 97-124, 2013.

[8] T.Y. Nishida, T. Shiotani, Y. Takahashi, Membrane algorithm solving job-shop scheduling problems, in: Proceedings of the 9th International Workshop on Membrane Computing, 2008, pp. 363–370.

[9] Frisco P, Corne D W. Modeling the dynamics of HIV infection with conformon-P systems and cellular automata[C]//International Workshop on Membrane Computing. Springer, Berlin, Heidelberg, PP: 21-31, 2007.

[10] Gutiérrez Naranjo M Á, Pérez Jiménez M J, Romero Campero F J. Simulating avascular tumors with membrane systems. Proceedings of the Third Brainstorming Week on Membrane Computing, 185-195. Sevilla, ETS de Ingeniería Informática, 31 de Enero-4 de Febrero, 2005, 2005.

[11] Pérez-Jiménez M J, Romero-Campero F J. A study of the robustness of the EGFR signalling cascade using continuous membrane systems[C]//International Work-Conference on the Interplay Between Natural and Artificial Computation. Springer, Berlin, Heidelberg, pp: 268-278, 2005.

[12] Chan K G, Chin P S, Tee K K, et al. Draft genome sequence of Aeromonas caviae strain L12, a quorum-sensing strain isolated from a freshwater lake in Malaysia. Genome announcements, vol. 3, no. 2, pp: e00079-15, 2005.

[13] Zhang G, Rong H, Neri F, et al. An optimization spiking neural P system for approximately solving combinatorial optimization problems. International Journal of Neural Systems, vol. 24, no. 5, pp: 1440006, 2014.

[14] Elkhani N, Muniyandi R C. Membrane computing to model feature selection of microarray cancer data[M]//Proceedings of the ASE BigData & SocialInformatics 2015, pp: 1-9, 2015.