Mechanism of Fuzzy *ARMS* on Chemical Reaction

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Abstract A new computing model Fuzzy abstract rewriting system on multisets is designed that is closer to reality by introducing fuzziness on computation. The mechanism of Artificial Cell System with hierarchically structurable membrane on chemical reaction is developed with fuzzy multiset evolution rules and fuzzy data. Significance of a parameter on the Fuzzy Artificial Cell System which describes the behaviour of the membrane structure is studied.

Keywords Membrane structure · Multiset · Abstract rewriting system · Artificial Cell System · Chemical reaction · Fuzzy data · Fuzzy abstract rewriting rules

1 Introduction

Uncertainty is an inherent property of all living systems. Fuzzy set was introduced by Zadeh and it has application in many fields [12]. Formal languages are precise while natural languages are quite imprecise. To reduce a gap between these two constructs [3], it becomes advantageous to introduce fuzziness into the structures of formal languages [8]. Since rigid mathematical models employed in life sciences are not

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completely adequate for the interpretation of biological information, there have been various proposals to use fuzzy sets in the modeling of biological systems. Thus, studies have been made on the use of the theory of fuzzy sets in P system, which is a computing model proposed in the area of membrane computing [7].

The last years have witnessed an increasing interest in the development of uncertain mathematical approaches to membrane computing. The reasons have been, among others, to keep close to the development of new formal computational paradigms dealing with fuzzy information, and the possibility of applying P systems to model real biological processes where handling with uncertainty, are necessary. A first contribution to this line of research was given by Obtulowicz and Paun [4], by extending the classical model to several probabilistic ones. Obtulowicz [5] also discussed several possible rough set based mathematical models of uncertainty that could be used in membrane computing. In a similar vein, several fuzzy approaches have been introduced. In one of them, fuzzy mathematics are used to handle the uncertainty in the number of copies of the reactives in the membranes [6]. An orthogonal approach to the fuzzification of both multisets and hybrid sets is presented by Apostolos Syropoulos [11]. Y. Suzuki and H. Tanaka have introduced the multiset rewriting system, "Abstract rewriting System on multisets" (*ARMS*). Based on this system, they have developed a molecular computing model called Artificial Cell System which consists of a multiset of symbols, a set of rewriting rules and membranes [9, 10]. These correspond to a class of P systems which is a parallel molecular computing model proposed by Gh. Paun and is based on the processing of multisets of objects in cell-like membrane structures [7].

In [2], the authors consider the phenomenon of Iron(III)salen complexes catalyzing the H_2O_2 oxidation of aryl methyl sulfides and sulfoxides and propose the possible mechanisms based on the kinetic and spectral studies. Recently, in [1], based on membrane computing, a computational study of the work in [2] is done and a model, called *Kinetic ARMS* in Artificial Cell System with hierarchically structurable membrane (*KACSH*), is developed.

In this present study we introduce a new mechanism of computing system called as *FACSH* with fuzzy multiset evolution rules and fuzzy data. i.e., *Fuzzy ARMS* in Artificial Cell System with hierarchically structurable membrane to study significantly the biochemical reactions to understand the nature of interaction between the synthesised complexes and biomolecules. We also have analysed a parameter on the system which describe the behaviour of the membrane structure.

2 Preliminaries

We first recall the basic structural ingredients of the computing device.

2.1 P System with Fuzzy Data [11]

A P system with fuzzy data is a construct $\Pi_{FD} = (O, \mu, w^{(1)}, \ldots, w^{(m)}, R_1, \ldots, R_m, i_0, \lambda)$ where O is an alphabet (i.e., a set of distinct entities) whose elements are called objects; μ is the membrane structure of degree $m \geq 1$; membranes are injectivelly labeled with succeeding natural numbers starting with one; $w^{(i)} : O \to N_0 \times I, 1 \leq i \leq m$, are functions that represent multi-fuzzy sets over O associated with each region i; N_0 is the set of all natural numbers including 0, $I = [0, 1]$; $R_i, 1 \leq i \leq m$, are finite sets of multiset rewriting rules (called evolution rules) over O. An evolution rule is of the form $u \to v, u \in O^*$ and $v \in O^*_{TAR}$, where $O_{TAR} = O \times TAR, TAR = \{here, out\} \cup \{in_j | 1 \leq j \leq m\}$. The effect of each rule is the removal of the elements of the left-hand side of each rule from the current compartment and the introduction of the elements of right-hand side to the designated compartments; $i_0 \in \{1, 2, \ldots, m\}$ is the label of an elementary membrane (i.e., a membrane that does not contain any other membrane), called the output membrane; and $\lambda \in [0, 1]$ is a threshold parameter, which is used in the final estimation of the computational result.

2.2 P System with Fuzzy Multiset Rewriting Rules [11]

A P system with fuzzy multiset rewriting rules and crisp data is just an ordinary P system that has, in addition, a corresponding fuzzy set for each set R_i of multiset rewriting. A P system with multiset fuzzy rewriting rules will compute a number to some degree. Clearly, such systems must also obey the so called maximal parallelism principle, that is the rules should be selected in such a way that only optimal output will be yielded. Thus, P systems with fuzzy data differ fundamental from P systems with probabilistic rewriting rules in that there is no bias in the selection of the rules. When a P system with fuzzy multiset rewriting rules halts, the result of the computation up to some degree is equal to the cardinality of the multiset contained in the output compartment. Clearly, it is also necessary to know how to compute the truth degree that is associated with the computational result.

2.3 ARMS *(Abstract Rewriting System on Multisets) [9]*

ARMS is like a chemical solution in which molecules floating on it can interact with each other according to reaction rules. Technically, a chemical solution is a finite multiset of elements denoted by $A^k = \{a, b, .., \}$; these elements correspond to molecules. Reaction rules that act on the molecules are specified in *ARMS* by rewriting rules. In fact, this system can be thought of as an underling algorithmic chemistry [1].

Let A be an alphabet whose elements are called objects; the alphabet itself is called a set of objects. A multiset over a set of objects A is a mapping $M : A \to N_0$. The number $M(a)$, for $a \in A$, is the multiplicity of object a in the multiset M. We do not accept here an infinite multiplicity. We denote by $A^{\#}$ the set of all multisets over A including the empty multiset ϕ defined by $\phi(a) = 0$ for all $a \in A$. A multiset rewriting rule (evolution rule) over a set A of objects is a pair (M_1, M_2) of elements in $A^{\#}$(which can be represented as a rewriting rule $w_1 \to w_2$, for two strings $w_1, w_2 \in A^{\#}$ such that $M_{w_1} = M_1$ and $M_{w_2} = M_2$). We use to represent such a rule in the form $M_1 \to M_2$.

An abstract rewriting system on multisets (*ARMS*) is a pair $\Gamma = (A, (R, \rho))$ where A is a set of objects; R is a finite set of multiset evolution rules over A; ρ is a partial order relation over R, specifying a priority relation among rules of R.

With respect to an *ARMS* Γ, we can define over $A^{\#}$ a relation ($\Rightarrow$): for $M, M' \in A^{\#}$ we write $M \Rightarrow M'$ iff $M' = (M - (M_1 \cup \cdots \cup M_k)) \cup (M'_1 \cup \cdots \cup M'_k)$, for some $M_i \to M'_i \in R, 1 \leq i \leq k, k \geq 1$, and there is no rule $M_s \to M'_s \in R$ such that $M_s \subseteq (M - (M_1 \cup \cdots \cup M_k))$; atmost one of the multisets M_i, $1 \leq i \leq k$, may be empty. A multiset $M \in A^{\#}$ is dead if there is no $M' \in A^{\#}$ such that $M \Rightarrow M'$. This is equivalent to the fact that there is no rule $M_1 \to M_2 \in R$ such that $M_1 \subseteq M$. A multiset $M \in A^{\#}$ is initial if there is no $M' \in A^{\#}$ such that $M' \Rightarrow M$.

In *ARMS*, all the reaction rules are applied in parallel. In every step, all the rules are applied to all objects in every membrane that can be applied. If there are more than one applicable rule that can be applied to an object then one rule is selected randomly.

3 Fuzzy ARMS

Now we propose a new computing device that based on Abstract Rewriting systems on multisets which is closely related to P system with fuzzy multiset rewriting rules and fuzzy data which is called as *FARMS*.

3.1 Definition

A *Fuzzy ARMS* (*FARMS*) is a quintuple $\Gamma = \{A, (R, \rho), J, \mu\}$ where A is a set of objects, R is a finite set of multiset rewriting rules over A, ρ is a partial order relation over R, specifying a priority relation among the rules of R, $J = \{r_j / j = 1 \text{ to } n, n =$ cardinality of $R\}$ i.e. the number of multiset rewriting rules over A, $\mu : J \to [0, 1]$ is the membership function in R such that $\mu(r_j) = i, i \in [0, 1]$.

In *FARMS*, reaction rules are applied in parallel. When there are more than one applicable-rules then one rule is selected randomly.

A *Fuzzy ARMS* generates a *Fuzzy ARMS language L(FARMS)* as follows. An object $x \in A^*$ is said to be in *L(FARMS)* iff it is derivable from any object $S \in A$ and the grade of membership $\mu_{(L(FARMS))}(x)$ is greater than 0, where

$$\mu_{L(FARMS)}(x) = \left(\begin{array}{c} max \\ 1 \leq k \leq n \end{array}\right) \left[\left(\begin{array}{c} min \\ 1 \leq i \leq l_k \end{array}\right) \mu(r_i^k) \right], x \in A^*$$

where n is the number of different derivatives that x has in *FARMS*; l_k is the length of the kth derivative chain; r_i^k denotes the label of the ith multiset rewriting rule used in the kth derivative chain, $i = 1, 2, \ldots, l_k$.

Clearly, $\mu_{L(FARMS)}(x)$ = Strength of the strongest derivative chain for S to x for all $x \in A^*$.

3.2 Example

Consider the *Fuzzy ARMS*

$$\Gamma = \{A, (R, \rho), J, \mu\}$$

where $A = \{a, b, c, d, f\}$

$$R = \left\{ \begin{array}{l} r_1 : a^m, f \rightarrow b^m, c^m \; with \; \mu(r_1) = 0.8 \\ r_2 : c^m, d \rightarrow a^m, c^m \; with \; \mu(r_2) = 0.5 \end{array} \right\},$$

$J = \{r_j \in R/j = 1 \text{ to } 2\}$, $\mu : J \rightarrow I$ is the membership function s.t $\mu(r_j) = i, i \in [0, 1]$ and $\rho = \phi$.

The set of the rewriting rules, R is $\{r_1, r_2\}$. We do not assume priority among these rules. In *FARMS*, reaction rules are applied in parallel. When there are more than one applicable rule, then one rule is selected randomly. Let us take $\{a^m, f, d : m \geq 1\}$ as an initial state.

If $m = 1$, the rule r_1 is applied in parallel and $\{a, f, d\}$ is transformed into $\{b, c, d\}$ with $\mu(r_1) = 0.8$. Since r_1 cannot be applied on this multiset, r_2 is applied, resulting into the multiset $\{a, b, c\}$ with $\mu(r_2) = 0.5$. As there are no rules that can transform the multiset further, the system is in a dead state. Thus the grade of membership value is

$$\mu_{L(FARMS)}(a, b, c) = \left(\begin{array}{c} max \\ 1 \leq k \leq n \end{array}\right) \left[\left(\begin{array}{c} min \\ 1 \leq i \leq l_k \end{array}\right) \{0.8, 0.5\} \right] = 0.5$$

If $m = 2$, the rule r_1 is applied in parallel and $\{a, a, f, d\}$ is transformed into $\{b, b, c, c, d\}$ with $\mu(r_1) = 0.8$. Since r_1 cannot be applied on this multiset, r_2 is applied, resulting into the multiset $\{a, a, b, b, c, c\}$ with $\mu(r_2) = 0.5$. As before, there are no rules that can transform the multiset further. So, the system is in a dead state.

Thus the grade of membership value is

$$\mu_{L(FARMS)}(a,a,b,b,c,c) = \left(\begin{array}{c} max \\ 1 \leq k \leq n \end{array}\right) \left[\left(\begin{array}{c} min \\ 1 \leq i \leq l_k \end{array}\right)\{0.8, 0.5\}\right] = 0.5$$

proceeding like this, we obtain the language as

$$L(FARMS) = \{a^n, b^n, c^n / n \geqq 1\} \quad with \quad \mu_{L(FARMS)}(a^n, b^n, c^n) = 0.5$$

4 *FARMS* in *ACS* with Hierarchically Structurable Membrane

We now introduce *FACSH*, a mechanism of Artificial Cell System with hierarchically structurable membrane with fuzzy multiset evolution rules and fuzzy data.

4.1 Definition

A *Fuzzy ACSH* (*FACSH*) is a construct

$$\Gamma = \{A, \mu, M_1, M_2, M_3, ., M_m, (R_p, \rho), i_0, J, \omega\}$$

where A is the set of objects; μ is the membrane structure; M_i are the multisets associated with the regions $1, 2, \ldots, m$ of μ, where $i = 1$ to m; R_p is a set of Fuzzy multiset evolution rules over$A, p = 1$ to m of μ; ρ is the partial order relation over R_p, $i_0 \in \{1, 2, \ldots, m\}$ is the elementary membrane (output); $J = \{R_{pq} \in R_p / p = 1, \ldots, m, q \geq 1\}, q =$ cardinality of R_p; $\omega : J \rightarrow [0, 1]$ is the membership function s.t. $\omega(R_{pq}) = i, i \in [0, 1]$.

Reaction rules are applied in the following manner:
The same rules are applied to every membrane. There are no rules specific to a membrane. All the rules are applied in parallel. In every step all the rules are applied to all objects in every membrane that can be applied. If there are more than one applicable rules that can be applied to an object then one rule is selected randomly. If a membrane dissolves then all the objects in its region are left free in the region immediately above it. All objects and membranes not specified in a rule and which do not evolve are passed unchanged to the next step.

A *Fuzzy ACS* generates a language *L*(*FACSH*) as follows: An object $x \in A^*$ is said to be in *L*(*FACSH*) iff it is derivable from any object $S \in A$ and the grade of membership$\omega_{L(FARMS)}(x)$ is greater than 0, where

$$\omega_{L(FACSH)}(x) = \left(\begin{array}{c} max \\ 1 \leq k \leq n \end{array}\right) \left[\left(\begin{array}{c} min \\ 1 \leq i \leq l_k \end{array}\right)\omega(R_i^k)\right], x\ inA^*$$

where n is the number of different derivatives that x has in $FACSH$, l_k is the length of the kth derivative chain, R_i^k denotes the label of the ith multiset evolution rule used in the kth derivative chain, $i = 1, 2, \ldots, l_k$.

Clearly, $\omega_{L(FACSH)}(x)$ = Strength of the strongest derivative chain for S to x for all $x \in A^*$.

4.2 *Mechanism for Sulfides Oxidation in* FACSH

4.2.1 Process A

First we describe the complex formation between the oxidant and the substrate.

$(a)\, Z + X(F3)X \rightarrow X(F4O)X;$
$X(F4O)X + RSR' \rightarrow X(F3)X + RSOR'$

A simple abstract reaction scheme is followed. Following convention is used to do the computation. When $X = H = L, X = Cl = M, X = Br = N, X = CH_3 = P$ and $X = OCH_3 = Q$, (a) will have the following reaction rules

1. $Z + L(F3)L \rightarrow L(F4O)L;\quad L(F4O)L + RSR' \rightarrow L(F3)L + RSOR'$
2. $M(F3)M + Z \rightarrow M(F4O)M;\quad M(F4O)M + RSR' \rightarrow M(F3)M + RSOR'$
3. $N(F3)N + Z \rightarrow N(F4O)N;\quad N(F4O)N + RSR' \rightarrow N(F3)N + RSOR'$
4. $P(F3)P + Z \rightarrow P(F4O)P;\quad P(F4O)P + RSR' \rightarrow P(F3)P + RSOR'$
5. $Q(F3)Q + Z \rightarrow Q(F4O)Q;\quad Q(F4O)Q + RSR' \rightarrow Q(F3)Q + RSOR'$

$(b)\, Z + XY(F3)XY \rightarrow XY(F4O)XY;$
$XY(F4O)XY + RSR' \rightarrow XY(F3)XY + RSOR'$

Following convention is used to do the computation. When $X = Y = Cl = M$ and $X = Y = t - Butyl = T$, (b) will have the following reaction rules

6. $Z + MM(F3)MM \rightarrow MM(F4O)MM;$
   $MM(F4O)MM + RSR' \rightarrow MM(F3)MM + RSOR'$
7. $Z + TT(F3)TT \rightarrow TT(F4O)TT;$
   $TT(F4O)TT + RSR' \rightarrow TT(F3)TT + RSOR'$

4.2.2 Behaviour of *FACSH − A*

Consider the *FACSH*

$$\Gamma = (A, \mu, M_1, M_2, M_3, (R_p, \rho), i_0, J, \omega)$$

where $A = \{Z, S, A_i, B_i, P_i, i = 1, \ldots, 7\}$. $\mu = [_1[_2[_3\,]_3]_2]_1$,
M_1, M_2, M_3 are the multisets associated with the regions 1, 2, 3 of μ,
$M_1 = \{Z, A_i, i = 1, \ldots, 7\}, M_2 = \{S\}, M_3 = \{\phi\}$,
$i_0 = 3$ is the output membrane and $\rho = \phi$,
R_p is a set of Fuzzy multiset evolution rules over $A; p = 1$ to 3
$J = \{R_{pq} \in R_p / p = 1 \text{ to } 3, q = 1 \text{ to } 7\}, q =$ cardinality of R_p,
$\omega : J \to [0, 1]$ is the membership function s.t. $\omega(R_{pq}) = i, i \in [0, 1]$, where

$$\omega_{L(FACSH)}(x) = \begin{pmatrix} max \\ 1 \le k \le n \end{pmatrix} \left[\begin{pmatrix} min \\ 1 \le i \le l_k \end{pmatrix} \omega(R_i^k) \right], x \in A^*$$

$R_p = \{R_1, R_2, R_3\}$ consists the following evolution rules.

$$R_1 = \left\{ \begin{array}{lll} R_{11} : Z + A_1 \to B_{1in} & with & \omega(R_{11}) = 0.005 \\ R_{12} : Z + A_2 \to B_{2in} & with & \omega(R_{12}) = 0.006 \\ R_{13} : Z + A_3 \to B_{3in} & with & \omega(R_{13}) = 0.001 \\ R_{14} : Z + A_4 \to B_{4in} & with & \omega(R_{14}) = 0.0009 \\ R_{15} : Z + A_5 \to B_{5in} & with & \omega(R_{15}) = 0.001 \\ R_{16} : Z + A_6 \to B_{6in} & with & \omega(R_{16}) = 0.006 \\ R_{17} : Z + A_7 \to B_{7in} & with & \omega(R_{17}) = 0.001 \end{array} \right\}$$

$$R_2 = \left\{ \begin{array}{lll} R_{21} : B_1 + S \to A_{1out}, + P_{1in} & with & \omega(R_{21}) = 0.0009 \\ R_{22} : B_2 + S \to A_{2out} + P_{2in} & with & \omega(R_{22}) = 0.003 \\ R_{23} : B_3 + S \to A_{3ou}t + P_{3in} & with & \omega(R_{23}) = 0.02 \\ R_{24} : B_4 + S \to A_{4out} + P_{4in} & with & \omega(R_{24}) = 0.03 \\ R_{25} : B_5 + S \to A_{5out} + P_{5in} & with & \omega(R_{25}) = 0.02 \\ R_{26} : B_6 + S \to A_{6out} + P_{6in} & with & \omega(R_{26}) = 0.003 \\ R_{27} : B_7 + S \to A_{7out} + P_{7in} & with & \omega(R_{27}) = 0.0009 \end{array} \right\}$$

$R_3 = \phi$

Initially the value of k is 1. In *FACSH*, all the rules are applied to all objects in every membrane that can be applied. If there are more than one applicable rule that can be applied to an object then one rule is selected randomly. In the initial state, we have 7 objects ($A_i, i = 1$ to 7) and an object Z in membrane 1. Any one of the 7 objects and Z are processed by the rule R_1. Let the object A_1 and the object Z are processed by the rule $R_{11} : Z + A_1 \to B_{1in}$ *with* $\omega(R_{11}) = 0.005$. It evolves the object B_1 to membrane 2. Objects in membrane 2 cannot be processed by the rules in membrane 2. There is no rule and object in membrane 3. In the next state, the object B_1 and the object S are processed only by the rule $R_{21} : B_1 + S \to A_{1out}, + P_{1in}$ *with* $\omega(R_{21}) = 0.0009$ in membrane 2. It evolves the object P_1 to membrane 3 and the object A_1 to membrane 1. Objects in membrane 1 cannot be processed by the rules in membrane 1. There is no object in membrane 2. Since there is no rule that can transform the object in membrane 3 further, the process halts. The resulting object in the output membrane 3 is P_1 (Fig. 1).

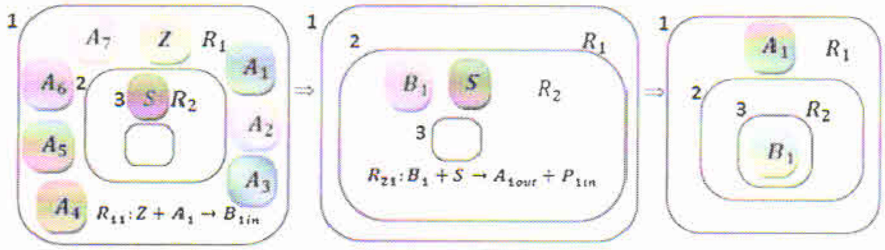

Fig. 1 *FACSH -A*

$$\underset{1 \le k \le n}{max}\left[\underset{1 \le i \le l_1}{min}(0.005, 0.0009)\right] = 0.0009; \quad \mu_{L(FACSH)}(P_1) = 0.0009$$

Similarly, we have the possible seven transformations and the rules that can be applied in parallel to transform the objects to the desired one. As a result, we have

$$\mu_{L(FACSH)}P_i = \left\{\begin{matrix} 0.0009 \; if \; i = 1, 4, 7 \\ 0.001 \; if \; i = 3, 5 \\ 0.003 \; if \; i = 2, 6 \end{matrix}\right\}; \quad L(FACSH) = \{P_i/i = 1, 2, \ldots, 7\}$$

4.3 Mechanism for Sulfoxides Oxidation in FACSH

4.3.1 Process B

First we describe the complex formation between the oxidant and the substrate.

$(a)\, Z + X(F3)X \rightarrow X(F4O)X;$
$X(F4O)X + RSOR' \rightarrow X(F3)X + RSO_2R'$

$(b)\, Z + XY(F3)XY \rightarrow XY(F4O)XY;$
$XY(F4O)XY + RSOR' \rightarrow XY(F3)XY + RSO_2R'$

A simple convention is used to do the computation on reactions in Process B as in process A.

4.4 FARMS *in* ACS *with Hierarchically Structurable Membrane (FACSH − B)*

Next we present the Fuzzy Abstract Rewriting System on multisets based on Artificial Cell System with Hierarchically structurable membrane to describe the complex formation between the oxidant and the substrate. Shortly we call the system as *FACSH − B*.

4.5 Behaviour of $FACSH - B$

Consider the *FACSH*

$$\Gamma = (A, \mu, M_1, M_2, M_3, (R_p, \rho), i_0, J, \omega)$$

where $A = \{Z, SO, A_i, B_i, P_i, i = 1, \dots, 7\}$, $\mu = [_1[_2[_3]_3]_2]_1$,
M_1, M_2, M_3 are the multisets associated with the regions $1, 2, 3$ of μ,
$M_1 = \{Z, A_i, i = 1, \dots, 7\}, M_2 = \{SO\}, M_3 = \{\phi\}$,
$i_0 = 3$ is the output membrane and $\rho = \phi$,
$R_p = \{R_1, R_2, R_3\}$ consists the set of Fuzzy multiset evolution rules over A,

$$R_1 = \begin{Bmatrix} R_{11} : Z + A_1 \to B_{1in} & with & \omega(R_{11}) = 0.2 \\ R_{12} : Z + A_2 \to B_{2in} & with & \omega(R_{12}) = 0.01 \\ R_{13} : Z + A_3 \to B_{3in} & with & \omega(R_{13}) = 0.006 \\ R_{14} : Z + A_4 \to B_{4in} & with & \omega(R_{14}) = 0.005 \\ R_{15} : Z + A_5 \to B_{5in} & with & \omega(R_{15}) = 0.006 \\ R_{16} : Z + A_6 \to B_{6in} & with & \omega(R_{16}) = 0.01 \\ R_{17} : Z + A_7 \to B_{7in} & with & \omega(R_{17}) = 0.006 \end{Bmatrix}$$

$$R_2 = \begin{Bmatrix} R_{21} : B_1 + SO \to A_{1out}, +P_{1in} & with & \omega(R_{21}) = 0.0002 \\ R_{22} : B_2 + SO \to A_{2out} + P_{2in} & with & \omega(R_{22}) = 0.0007 \\ R_{23} : B_3 + SO \to A_{3ou}t + P_{3in} & with & \omega(R_{23}) = 0.0008 \\ R_{24} : B_4 + SO \to A_{4out} + P_{4in} & with & \omega(R_{24}) = 0.0009 \\ R_{25} : B_5 + SO \to A_{5out} + P_{5in} & with & \omega(R_{25}) = 0.0008 \\ R_{26} : B_6 + SO \to A_{6out} + P_{6in} & with & \omega(R_{26}) = 0.0007 \\ R_{27} : B_7 + SO \to A_{7out} + P_{7in} & with & \omega(R_{27}) = 0.0002 \end{Bmatrix}$$

$R_3 = \phi$

$J = \{R_{pq} \in R_p / p = 1 \text{ to } 3, q = 1 \text{ to } 7\}, q =$ cardinality of R_p,
$\omega : J \to [0, 1]$ is the membership function s.t. $\omega(R_{pq}) = i, i \in [0, 1]$, where

$$\omega_{L(FACSH)}(x) = \begin{pmatrix} max \\ 1 \leq k \leq n \end{pmatrix} \left[\begin{pmatrix} min \\ 1 \leq i \leq l_k \end{pmatrix} \omega(R_i^k) \right], x \in A^*$$

As we have done in $FACSH - A$ the computation is done. We have the possible 7 transformations and the rules that can be applied in parallel to transform the objects to the desired one. As a result,

$$\mu_{L(FACSH)}(P_i) = \begin{Bmatrix} 0.0002 \; if \; i = 1, 7 \\ 0.0007 \; if \; i = 2, 6 \\ 0.0008 \; if \; i = 3, 5 \\ 0.0009 \; if \; i = 4 \end{Bmatrix}; \quad L(FACSH) = \{P_i / i = 1, 2, \dots, 7\}$$

5 Conclusion

A new membrane computing model on *Fuzzy ARMS* is introduced and the mechanism on Artificial Cell system is proposed. We have studied the significance of a parameter on the Fuzzy Artificial Cell system with hierarchically structurable membrane. It is decided to extend the work to investigate the correlation between *ACS* and *P* System. It is a preliminary research work on the study of binding of metal complexes with protein which may pave the way for drug designing further to design a computing system. As an application, it is worth to find out the power of this computing system and the characteristics of the concentration of chemical compounds. Further application and properties of the proposed system could be studied. We believe that the new system would be of use in the modeling of living organisms.

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