

Genomic Object Net: Petri Net Enhancement for Multi-Cellular Processes

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1 Introduction

Recent study of cell lineage of multi-cellular organism such as *C. elegans* shows us that cell-cell interaction and localization of gene products take very important role in the development of early embryo [3]. In order to describe such multi-cellular processes, we extend the software tool Genomic Object Net [2, 4] in which we enhanced the hybrid parametrized functional Petri net (HPFPN) model to extend the parameter space of elements of Petri net and carry out the dynamical change of Petri net.

2 Hybrid Parametrized Functional Petri Net

A place P of a *hybrid parameterized functional Petri net* (HPFPN) holds a vector $(d_1, \dots, d_{r_P}, c_1, \dots, c_{s_T})$ of nonnegative integers d_1, \dots, d_{r_P} called the discrete components and nonnegative real numbers c_1, \dots, c_{s_T} called the continuous components as its contents. A transition T of a HPFPN is specified with input arcs a_1, \dots, a_p coming from places P_1, \dots, P_r and output arcs b_1, \dots, b_q going to places Q_1, \dots, Q_q (Fig. 1). Each input arc a_i specifies how the contents of P_i is consumed through the arc a_i with a function $A_i([P_1], \dots, [P_p], [Q_1], \dots, [Q_q])$, where $[P_i]$ and $[Q_j]$ denote the contents of P_i and Q_j , respectively. For a discrete component d_k , A_i defines the amount which is removed from d_k through a_i by firing. For a continuous component c_l of P_i , A_i defines the speed of consumption from c_l through a_i . Each output arc b_j specifies how the contents of Q_j is increased through the arc b_j with a function $B_j([P_1], \dots, [P_p], [Q_1], \dots, [Q_q])$.

With the components of a place in HPFPN, we can represent, for example, the concentration, localization, phosphorylation, etc. of some protein.

In order to describe dynamical changes of Petri net, we employ the following rules (R1-R12) (Table 1) of synthesis and reduction which have been introduced for Petri net [1]. A rewriting procedure is defined as a program which specifies how these rules are applied by using the parameter values of a HPFPN which is being rewritten (e.g. Fig. 2-5).

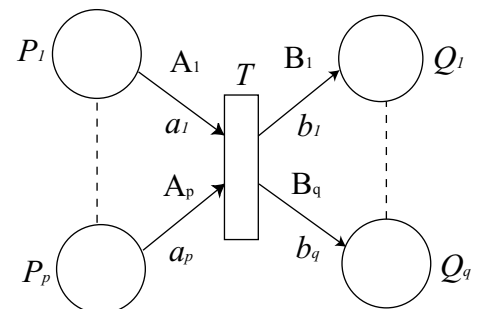


Figure 1: Transition of hybrid parametrized functional Petri net.

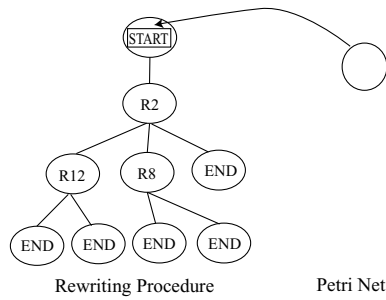


Figure 2: Dynamics1

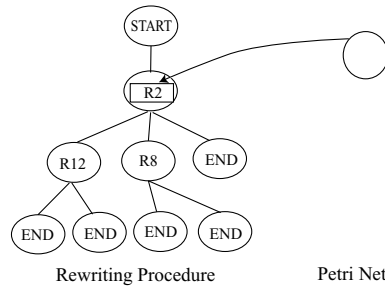


Figure 3: Dynamics2

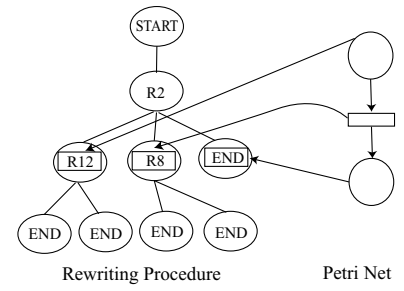


Figure 4: Dynamics3

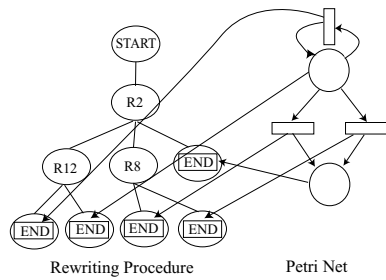


Figure 5: Dynamics4

Table 1: Petri net rewriting rules.

R1	(Fusion of Series Places)
R2	(Division of Place into Series Places)
R3	(Fusion of Series Transitions)
R4	(Division of Transition into Series Transitions)
R5	(Fusion of Parallel Places)
R6	(Division of Place into Parallel Places)
R7	(Fusion of Parallel Transitions)
R8	(Division of Transition into Parallel Transitions)
R9	(Elimination of Self-loop Place)
R10	(Creation of Self-loop Place)
R11	(Elimination of Self-loop Transition)
R12	(Creation of Self-loop Transition)

3 Discussions and Future Works

By using HPFPN, place can hold both continuous and discrete parameters. This gives us much flexibility for describing biological objects and their networks. This enables us to simulate the dynamical changes of Petri net as shown in Fig. 2-5. In Fig. 2 the Petri net has only one place and START operation is executed. In Fig. 3, after R2 rule is executed, then the place is divided into series places as shown in Fig. 4. Finally, R12 rule is executed for the place and self-loop transition is created. R8 rule is also executed for the transition and it is divided into parallel transitions in Fig. 5. Here, END operation stops the evolution of element. With this method of rewriting, we can describe the developmental process of Petri net deductively. We are planning to simulate a realistic multi-cellular process such as the development of *C. elegans* embryo with this framework of HPFPN.

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