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An Improved Modeling Method Based on Colored Petri Net

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Abstract

A kind of method named multi-grade colored Petri net had been proposed in order to analyze the complex system. For the first time, this new method was used to analyze a training simulator system. This model can reflect the complex environments of the system accurately and avoid the difficulty when use classical research approach to develop accurate mathematics model.

Keywords: colored Petri net, optimization, modeling

1. Introduction

With the science and technology development, the system scale is more and more large, and relation is more and more complicated, and interactive information is more and more frequent, and needs added parameter and dimension to describe. There would be a series of difficulty in the establishment of system model, analysis and optimization of operation. So far optimization calculation of complicated system has not got universal application in the industry, as well has no mature of general calculation.

For a large-scale actual system, it is impossible to use the target function of mathematics to describe system accurately, because there will be more than one factor to measure the system in the actual engineering problem. Setting up the simulator system of complicated system and carrying on optimization need a great deal of manpower and material resources, and need certain of time, but the actual engineering usually has deadline strictly. Now, optimization mainly aims at the system which has certain outside condition and appearance parameter. Actually, the process always meets various interference of outside factor and experiences various influence of indetermination factor. And all those could lower the use value of optimization. In the mid 60's of last century, Aris and someone others firstly put forward that big system can resolve into many sub-systems and carried on the calculation to the sub-system on the different grade in order to solute the optimization problem of big system[1].

2. Theory of Petri Net

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In 1962, a German named Carl Adam Petri put forward Petri net firstly in his doctor dissertation--"Communication with Automata"[2].The Petri net is a kind of mathematics and chart tool to describe and analyze[3], and is one of the useful tools to describe and model information processing system. It has the similar visual description function with flow chart, frame diagram and net diagram, and also can simulate the dynamic behavior of system by flow of token[4].To develop the information processing system which is parallel, asynchronous, distributed, intercurrent, indetermination and (or) randomicity, can make full use of this kind of tool to construct a Petri model, and then analyze. We can get the information of system structure and dynamic state immediately, and evaluate and reform the system according to the information.

Colored Petri net is a kind of mature Petri net compared with the basic Petri net, and it is more abstract. Colored Petri net defines a token color set for each place, and define an action color set for each transition in the net. With the token color set, a place can mean various resources, but the original place only means a kind of resource, extending the content of token. Simultaneously, the action color set of transition can mean combined condition when complicated event take place, and reduce the nodes, and the model is much simpler and clearer [5].

The system which has continuous and discrete event dynamic behavior and both interact each other is named farraginous dynamic system. Taking certain kind of training simulator system for example, equipments of the system obey physical regulation generally, and can be described by the differential equation and algebraic equation because of continuous dynamic state. But there also has interactive information in the system, which is discrete behavior driven by the event. These discrete dynamic behaviors usually rely on continuous dynamic behaviors and base on the logic rule.

The interactive information of the training simulator system is a typical discrete event process, and the occurrence of the event is parallel, asynchronous and random etc.. The traditional method of modeling, description and analysis, such as decision tree and queuing theory, seem to lack the ability to describe this kind of problem. The discrete time system is even more complicated. It has not only the state transition that the internal event triggers, but also the state transition that the external event triggers; has not only the state transition that the event drives, but also the state transition that the time drives. According to these characters, Petri net and colored Petri net have shortage and can not satisfy the need completely. Therefore we improve the colored Petri net. We combine the optimization theory of large-scale system with colored Petri net to adapt to the model analysis of complicated system.

3. Multi-grade colored Petri net

According to the definition of the colored Petri net, we can define:

Multi-grade colored Petri net can be a set including nine elements,

$MCPN = (P, T, \mathrm{Pr}e, Post, A, C, R, E, M_0)$,

1、 P is a finite set of places;

2、 T is a finite set of transitions. $T \supseteq \{T_i, T_u\}$, among them, T_i is a set including independent transition and T_u is a set including dependent transition ;

3、 $P \cup T \neq \Phi, P \cap T = \Phi$;

4、 C is set of color and assigns color set for transition and place in the net ;

5、 Pre and $Post$ are functions about triggering color ;

6、 A is a set of directed arcs and satisfies $P \cap T = P \cap A = \Phi$;

7、 E is matrix and the element is state of external event. We can define $e_i = 0$ to show that event i does not occur and we can define $e_i = 1$ to show that event i does occur ;

8、R is matrix and the element show the relation between dependent transition T_u and external event. We can define the numerical value of the element as the following: when external event must occur, transition can fire then the value is "1" ; when external event must not occur, transition can fire, then the value is "-1" ; when the fire of transition is not influenced by the external event, the value is "0" ;

9、M_0 is the original marking and shows the original distribution of token in the place.

According to the composition of the training simulator system and multi-grade colored Petri net which we define above, the system can be seemed to three layers: the top layer includes information that simulator interacts with other external systems, and can seem to be a management layer; all the subsystems of the simulator system belong to the bottom layer, and it describes the information of each subsystem how to switch in different states, and is the foundation of the whole system; then the training simulator system can seem to a middle layer and completes the communication and harmony of the whole system. It goes without saying that each grade of the multi-grade colored Petri net may have one or many subnets. Some transition can be influenced by external event and is under control. The net which exist this kind of transition can be defined as dependent Petri net, otherwise it can be defined as independent Petri net.

4. Application and analysis

We take the testing and control subsystem for example, and it mainly simulate the operation training and complete the training task of related battle station, and simulate equipment to complete task under different condition, such as parameter and monitor etc..

Analyzing the design elucidation, the subsystems receive (and return) the order and parameter from (to) the superior, and receive the parameter that other subsystems transmit. It interacts with other subsystems and receives "instruction", and transmits "information" to other subsystems. In order to carry on the test of the subsystem, it needs "chief instruction", and "sub instruction".

According to the analysis above, we can apply multi-grade colored Petri net in the subsystem as following Fig.1:

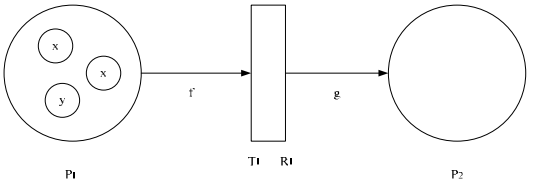

Figure 1 Example for multi-grade colored Petri net in a subsystem

There are two places (P_1 and P_2), and one transition (T_1), and two connections (f and g) in the diagram. The place P_1 has two $< x >$ tokens and one $< y >$ token. R_1 means that external event influences transition T_1 and T_1 belongs to dependent transition. According to the definition, we can describe the subsystem as follows:

1、$P = \{P_1, P_2\}$

2、$T = \{T_1\}$, and $T_1 \in T_u$

3、$C = \{< y >, < x >\}$

4、$A = \{P_1 to T_1, T_1 to P_2\}$

5、$\Pr e(P_1, T_1 / < y >) = f(< y >) = < x >$

$\Pr e(P_1, T_1 / < x >) = f(< x >) = 2 < y > + < x >$

$\Pr e(P_2, T_1 / < y >) = \Phi$

$\Pr e(P_2, T_1 / < x >) = \Phi$

$Post(P_1, T_1 / < y >) = \Phi$

$Post(P_1, T_1 / < x >) = \Phi$

$Post(P_2, T_1 / < y >) = g(< y >) = < y >$

$Post(P_2, T_1 / < x >) = g(< x >) = 2 < x >$

6、 $E = [e_1 \quad e_2]^T$

7、 $R = [1 \quad 0]$

8、 $M_0 = \begin{bmatrix} M_0(P_1) \\ M_0(P_1) \end{bmatrix} = \begin{bmatrix} 2 < x > + < y > \\ \phi \end{bmatrix}$

Based on the description, color token $< y >$ fires transition T_1, because $M_0(P_1) = (2 < x > + < y >) \geq \Pr e(P_1, T_1 / < y >)$. There is not enough token $< y >$ in the input place of T_1 (according to $\Pr e(P_1, T_1 / < x >) = f(< x >) = 2 < y > + < x >$, it needs two tokens $< y >$ and one token $< x >$ to make transition T_1 be fired by token $< x >$), so transition T_1 is not fired by token $< x >$. We suppose transition T_1 has something to do with two external event, and when $E = [1 \quad 1]^T$ (the two external event take place together), transition T_1 is fired. After the transition,

$$M_1(P_1) = M_0(P_1) + Post(P_1, T_1 / < y >) - \Pr e(P_1, T_1 / < y >) = < y > + < x >$$
$$M_1(P_2) = M_0(P_2) + Post(P_2, T_1 / < y >) - \Pr e(P_2, T_1 / < y >) = < y >,$$

Namely,

$M_1 = \begin{bmatrix} < y > + < x > \\ < y > \end{bmatrix}$

The process can be described by $M_0[(T_1 / < y >) > M_1$, and be called "M_1 is the reachable state of M_0".

According to the operation process of the subsystem, we know how the external event ("chief instruction" and "sub instruction") influence the multi-grade colored Petri net. If the necessary event does not occur, dependent transition can be fired. Similarly, when lacking of inner condition, dependent transition also can not be fired even if external event occurs.

5. Conclusion

The color token can represent not only simple variable, but also arbitrarily complicated type in the training simulator system. For the whole system, we can apply multi-grade colored Petri net according to the above step, and acquire optimization model, and enhance efficiency.

According to the analysis and modeling process, multi-grade colored Petri net has favorable potential to solve similar optimization problem which has complicated restriction. Simultaneity, it inherits the general characteristics of Petri net and has the intuitionistic chart to show the system. So it is easy for us to comprehend the complicated system clear.

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