APPLICATION OF COLORED PETRI NET IN MODELING OF AN AGRICULTURAL ENTERPRISE INFORMATION MANAGEMENT SYSTEM

Fangtian Zhang [1], Kaiyi Wang [1,2,*], Jin Sui [1], Chang Liu [1], Zhongqiang Liu [1]

[1] *National Engineering Research Center for Information Technology in Agriculture, Beijing , China 100097*

[2] *Beijing University of Technology, Beijing, China 100022*

[*] *Corresponding author, Address: P.O.Box 2449-26, Beijing, 100097, China, Tel: +86-10-51503427, Fax: +86-10-51503750, Email: wangky@nercita.org.cn*

Abstract: Business system modeling of an agricultural enterprise is one of the difficulties in developing and researching an agricultural enterprise management information system. Given the inadequate description of concurrent and synchronal events in the traditional modeling methods, this paper presents a modeling method, which uses Colored Petri Net. The paper discusses the application of Colored Petri Net in system modeling with the example of an agricultural enterprise production management system model, and analyzes the feasibility and effectiveness of that model.

Keywords: Colored Petri net, CPN, Agricultural Enterprise Information Management, modeling, simulation

1. INTRODUCTION

Agriculture is the foundation of the national economy in our country. But at present the agricultural power of production still has a great disparity compared with some developed countries: the backward level of production technology, low high-tech content, weak market competitiveness, and the dominant traditional manual management during the process of agricultural production and management, etc. Therefore, accelerating agricultural information and modernization process, improving agricultural production management level, enhancing agricultural market competitiveness and achieving the sustainable development in agriculture have been a most pressing task before us.

An agricultural enterprise information management system is a very important tool adopted during the process of agricultural enterprises IT application. It has better function such as production plan management, marketing management, purchasing management, store control, distribution and delivery and DSS and so on. It is well known that a good business system needs a good model to support it. Establishing a model and analyzing it have two advantages (Chen et al., 2006). One is to check whether a model correctly reflects the features of the system modeled. The other is that it is of advantage to find some potential problems in designing a new system. Tools that could model business systems are more. Colored Petri net (CPN or CP-net) is one of them and it could describe concurrent and synchronal events better compared with other tools. A system model based on CPN could not only mask many details within the system but also clearly display many behavior properties. Business system modeling of an agricultural enterprise is one of the difficulties in developing and researching agricultural enterprises management information system. The paper discusses the application of CPN in system modeling with the example of an agricultural enterprise production management system model, and analyzes the feasibility and effectiveness of that model.

The rest of this paper is organized as follows. Section 2 gives the analysis of the features of an agricultural enterprise information management system. Section 3 is devoted to the relevant definitions of Petri net and colored Petri net. The method about how to model a business system is introduced in Section 4. And analysis and simulation of the model are presented in Section 5. Finally, in Section 6 we briefly evaluate the model based on CPN.

2. ANALYSIS OF FEATURES OF AN AGRICULTURAL ENTERPRISES INFORMATION MANAGEMENT SYSTEM

Generally the business process of an agricultural enterprise includes some links such as purchasing management, store management, production management, marketing management, cost control and so on. It is found from the process that the management information system to be modeled is very complex. And it is also discovered that flexibility, concurrency and hierarchic structure are the most content after researching the structure and behavior properties of this system. At the same time these are also the keys to study in modeling.

Here system flexibility refers to the variety of products of an agricultural enterprise, this is to say, the products managed by the system to be modeled have great varieties. So an effective way is needed to model these varieties. It is interesting that the colored sets of CP-nets could be just used to describe those varieties. System concurrency is the property about the concurrent process of production management. For example, the production order and supply order of a type of product enter into the workshop and warehouse respectively at some time. This property could bring into many synchronal problems which happen dynamically. When it is coming to system hierarchic structure, it means that all the links of business process of an agricultural enterprise are very complicated, this is to say, it is made up of interactive sub modules or sub systems.

Above all, the system model using CPN could effectively describe the properties of flexibility, concurrency and hierarchic structure.

3. RELATION DEFINITIONS OF COLORED PETRI NET

Petri net targets researching organization structure and dynamic behavior, and aims at the state changes, which may happen in the system, and the relation among these changes. It could accurately describe concurrent and distributed systems (Liu et al., 2006). Relevant definitions of CPN are shown below.

Definition 1 (Petri net) (Wu et al., 2006, Yuan et al., 1998, Brauer, 1980): In a formal way, a Petri net is a 3-tuple: $PN = (P, T, F)$. Where:

(1) P is a finite set of Places;

(2) T is a finite set of Transitions;

(3) F is a finite set of Arcs such that: $P \bigcap T = P \bigcap F = T \bigcap F = \varnothing$.

A colored Petri net extends a general Petri net, with adding colored sets and declarations. It could be more flexibly suitable to model the application of system business.

Definition 2 (Colored Petri net t) (Wu et al., 2006, Yuan et al., 1998, Jensen, 1997, Jensen, 1998): In a formal way, a colored Petri net is a 9-tuple: $CPN = (\sum, P, T, F, N, C, G, E, I)$

(1) $\sum$ is a finite set of non-empty types, also called colored sets;

(2) P is a finite set of Places;

(3) T is a finite set of Transitions;

(4) F is a finite set of Arcs such that: $P \cap T = P \cap F = T \cap F = \varnothing$;
(5) N is a node function. It is defined from F into colored over arcs $P \times T \cup T \times P$;
(6) C is a color function. It is defined from P into $\sum$ token;
(7) G is a guard function. It is defined from T into expressions such that: "Boolean function with probability"

$$\forall t \in T : \left[Type\left(G\left(t\right)\right) = B \wedge Type\left(\text{var}\left(G\left(t\right)\right)\right) \in \Sigma \right];$$

(8) E is an arc expression function. It is defined from F into expressions such that:

$$\forall a \in F : \left[Type\left(E\left(a\right)\right) = C\left(p\right)MS \wedge Type\left(\text{var}\left(E\left(a\right)\right)\right) \in \Sigma \right]$$

Where p is the place of $N\left(a\right)$

(9) I is an initialization function. It is defined from P into closed expression such that

$$\forall p \in P : \left[Type\left(I\left(p\right)\right) = C\left(p\right)MS \right]$$

Definition 3 (Substitution Transition) (Jensen, 2008): Creating large, intricate nets can be a cumbersome task. But similar to modular programming, the construction of CP-nets can be broken into smaller pieces by utilizing the facilities within CPN Tools for creating substitution transitions. Conceptually, nets with substitution transitions are nets with multiple layers of details – you can have a somewhat simplified net that gives a broad overview of the system you are modeling, and by substituting transitions of this top-level net with more detailed pages, you can bring more and more details into the model.

Definition 4 (P-invariant and T-invariant) (Wu et al., 2006, Jensen, 1998): Given a Petri net: $N = \left(P, T; F\right)$, $\left|P\right| = m$, $\left|T\right| = n$, A is the incidence of this net. Any nonnegative integer solution Y of the equation $AY = 0$ is a P-invariant, where Y is a column vector. Any nonnegative integer solution X of the equation $A^T X = 0$ is a T-invariant, where X is a column vector.

P-invariant and T-invariant could analyze the properties of Petri net such as liveness and boundedness and as on.

4. MODELING USING CPN

Modeling the whole business system of an agricultural enterprise is complex. This section contains an example that models a production management system, one part of agricultural enterprises business management, in order to discuss how to model using colored Petri net. The key method to model this system is as follows.

At first, it is possible to give a whole system design but not to consider the details of the links of the system. Then build a top model based on CPN according to its hierarchical property. Finally model the details of those links respectively. If so the number of Places and Transitions of the model will decrease sharply and the model graph will be more concise.

Generally production management has two models (Wang et al., 2006). The first one is push model, for example MRP, which makes the input and output plan of every part according to the requirement of main production plain and issues production or order instructions according to this plan. Every work center builds its parts relying on the plan and sends its parts finished to its following work center. The second one is pull model, for instance JIT (Wang et al., 2006), which begins from the orders on behalf of customer needs and works out the main production plan and the assembly plan according to demands of the market. Every work center requests the former center and issues work instructions in accordance with the need for parts at the time. The former center works according to these instructions completely. This anti-process sequence pulls step by step the former work centers even supply factories or collaborative factories. This paper will model this "pull" production management system.

The basic assumptions for modeling are as follows

(1) There are two kinds of materials in the warehouse. Raw materials are for processing and the other material for packaging.
(2) Product warehouse has one produce.
(3) Semi-finished warehouse has one produce.
(4) Time for procurement, stock and delivery is so much less that they can be ignored.
(5) All orders can be available.
(6) The material loss and waste rate is equal to zero.

The top model of a production management system is shown below.

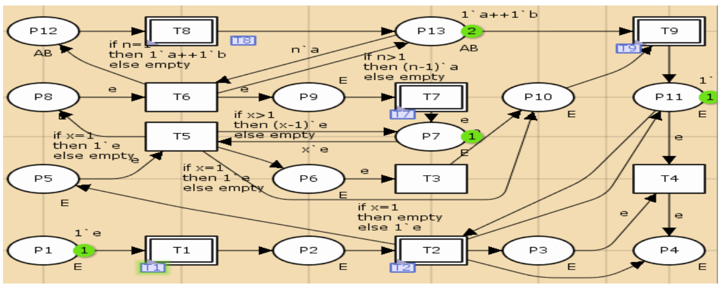

Fig.1. Production management system model

Table 1. and Table 2. show the Places and the transitions of the model respectively.

Table 1. Places of the model

Places	Definitions	Places	Definitions
P1	User order	P2	Invoice
P3	Waiting invoice	P4	Satisfied order
P5	Package list	P6	Waiting package list 1
P7	Warehouse for semi-finished products	P8	Product order
P9	Supply order	P10	Waiting package list 2
P11	Warehouse for products	P12	Purchasing order
P13	Warehouse for materials		

Table 2. Transitions of the model

Transitions	Definitions	Transitions	Definitions
T1	Transmit user order	T2	Process use order
T3	Transmit package list	T4	Stock out
T5	Process package list	T6	Process purchasing order
T7	manufacturing	T8	Purchasing management
T9	Package management		

Where: T1, T2, T7, T8 and T9 respectively are a Substitution Transition, and are on behave of their corresponding sub page.

5. MODEL SIMULATION AND ANALYSIS

Analysis and simulation are the main two ways to evaluate a model. Analysis is to analyze the properties of the model. Generally the properties discussed have boundedness, reversibility, and liveness, etc. these can be analyzed by P-invariant and T-invariant.

The incident matrix of the net shown in Fig.1 can be drawn.

$$A=\begin{pmatrix} -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 \end{pmatrix} \quad (1)$$

According to the equation $AY = 0$, we can get P-invariants.

$$Y_1 = (2,\ 2,\ 1,\ 1,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0)^T \tag{2}$$

$$Y_2 = (1,\ 1,\ 0,\ 0,\ 1,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0)^T \tag{3}$$

Clearly the net of the model is correct. It is also clear that for every reachable marking μ we can have

$$\begin{aligned} &\mu(p1) + \mu(p2) + \mu(p5) \\ &= \mu_0(p1) + \mu_0(p2) + \mu_0(p5) = 1 \end{aligned} \tag{4}$$

where μ_0 is the initial marking. So there exists a P-invariant Y with $Y(p) > 0$, for each $p \in P$, the colored Petri net is bounded (Jensen, 2008, Zhang et al., 1998, Özgür ARMANERİ, 2006).

According to $A^T X = 0$ we can get a T-invariant.

$$X = (0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0,\ 0)^T \tag{5}$$

All elements of T-invariant are equal to zero. Then it is claimed that is impossible to come back to the initial marking after firing a sequence of transitions. From a manufacturing point of view, this means that it will be impossible to come back to the initial state if we perform the operation represented by the transitions. So this colored Petri net is not reversible.

Simulation means that the system model can be simulated to operate by using a program to get its function analysis and evaluation. After establishing the model, it can run correctly (shown in Fig.2 in the left) through the function of symbols checking and imitation of CPN Tools, so this model is right. And there does not exist any deadlock, so it is also live. The result of simulation (shown in Fig.2 in the right) also shows that we can get the correct result.

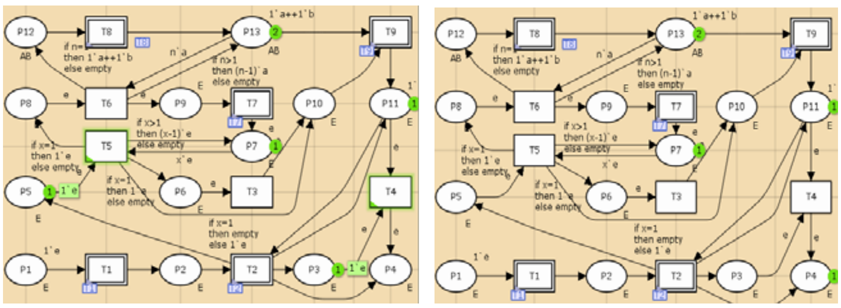

Fig.2. Simulation of a model of product management

6. CONCLUSION

Modeling an agricultural production management using colored Petri net and simulating the model using CPN Tools are presented in this paper. The paper also analyzed the properties of liveness, deadlock, boundedness, etc. of this model. The result of analysis and simulation shows that it is feasible and effective to model an agricultural enterprise business management using colored Petri net.

Using colored Petri net can make our research more overall and deeply, and our models more concise and clear. And it also has a very important application value to develop the system later. Because the concept of time does not be introduced into the system model, the evaluation of system performance could not get better. And this work will also be done in the next research. Of course we can also model other links of an agricultural enterprise business management, and this will build a good foundation for modularization and hierarchy for the structure of the management software.

REFERENCES

C. A. Petri. Introduction to General Net Theory. Proceedings of the Advanced Course on General Net Theory of Processes and Systems: Net Theory and Applications, Year of Publication, Vol.84, Pages: 1-19, 1979

Chen Xiang, Liu JunLi. Workflow Modeling based on colored Petri net, Computer Engineer. 2006, (4): 86-88 (in Chinese)

Kurt Jensen，Soren Christensen，Lars M．Kris tensen．CPN tools state space manual, http://wik.daim.au.dk/cpntool

Kurt Jensen. An introduction to the practical use of colored Petri nets, Lecture Notes in Computer Science Vol.1492, Pages: 237-292; 1998

Kurt Jensen. Colored Petri nets-basic concepts, analysis methods and practical use, New York Springer, Vol.1, 1997.

Liu JiYu. Modeling and Simulation tools applied in software engineer-CPN, China Science and Technology Information. 2006, (2): 28(in Chinese).

Özgür ARMANERİ.Modeling, analysis and simulation of simple one machine -two product system using Petri nets, Doğuş Üniversitesi Dergisi, 2006, 7 (1): 15-24

Wang Yachao, Ma Hanwu. Modeling and Simulation of Production Logistics System, Beijing. Science Press. 2006, (8) (in Chinese)

Wu Zhehui. Petri Net Induction.Beijing: China Machine Press, 2006 (in Chinese).

Yuan Chongyi. Petri net Principle. Beijing: Publishing House of Electronics Industry, 1998(in Chinese)

Zhang zongmao, Ye Feifan. A Comparative Study of MRP System and JIT System, Industrial Engineering and Management. 1998, (3):43-47 (in Chinese)