Proceedings of the International MultiConference of Engineers and Computer Scientists 2015 Vol I,
IMECS 2015, March 18 - 20, 2015, Hong Kong

Research in Virtual Cotton Spinning Process based on CAPN

Wang Jun[1, 2, a], Feng Guanghui[2, b] Yu Weidong[1, 3, c]

***Abstract*--After the analysis of the features and the complexity of the cotton spinning process, a flow characterization model of cotton processing was proposed on the basis of CAPN. The efficiency and flexibility of this model was proved by the complexity calculation and computer simulation. Simultaneously the complexity of the system was effectively reduced by this model. Furthermore, the feedback control on processing system could be complied by this adaptive system.**

***Keyword*-- Complex Adaptive Petri Net, Complexity, Virtual cotton spinning**

Cotton spinning is a spinning technological process of making cotton fiber into cotton yarn. This technological process is also applicable in the textile and cotton type chemical fiber yarn, long fiber yarn and the other fiber cotton blended. Cotton fabric occupied a leading position in the textile industry because of its good wearability, low price, and relatively simple spinning process. According to the requirements of the product quality, cotton spinning system can be divided into general (coarse) comb, combed system and waste spinning system [1].

I. CHARACTERISTICS AND COMPLEXITY OF COTTON SPINNING PROCESS

A. *Characteristics of Cotton Spinning Process*

In the field of textile production, the fabrication of textiles is very complexity due to the flexible fiber as processing objects. There are more than 400 processing parameters only from mixed cotton to spooling in the spinning process. The changes of so many process parameters could be possibly influence on the quality index of product. The selected parameters for modeling method from fiber to yarn are also more than a dozen [2]. Cotton spinning production line, which is locally continuously integral discrete event and typical driving system, has the following characteristics:

a. The Diversity of Varieties and Specifications

In order to meet the requirement of the market demand, cotton spinning factory fabricated many varieties production. According to specification, there are thick yarn, special yarn, fine yarn and special fine yarn. According to processing method, there are carded yarn, combed yarn, single yarn and thread. According to usage, there are warp, weft knitting, yarn, special yarn etc. The requirements of quality are different for different varieties.

b. Continuous Multi- process, Multi- machine

There are 7-8 process from cotton or fiber raw materials into the workshop to processing into yarn or cloth. Furthermore, each process was linked with multiple device interaction, and formed a stage of continuous production line.

c. Flexibility of the Production Process

To meet the various market demand for products, the production line can adapt different technological process according to different products, so on basis of the device configuration it requires the production technology of cotton spinning production line of high flexibility.

d. The Complexity of the Production Process

Cotton spinning system consists of several elements, the interaction between them could result in the character of the whole system [3]. Because of the un-equivalent between the behavior characteristics of the system and the linear sum of characteristic for each element, it cannot be linear analysis with the number of equations or statistical traditional regression.

B. *The Complexity of Characterization for Textile Process*

The complexity of textile process characterization is mainly reflected as follows:

a. The modeling of the system is affected by many factors, including a variety of data types, such as environmental data, state data, production data, quality control data and so on. Each type of data and respective classification, the complex interactive relationship between data, all of these caused high dimension and the complex solving process.

b. Production process is complex and uncertain [4].The flexible materials as textile processing object, each of them is great uncertainty in quality, which could directly affect the production of results. At the same time, as the textile process for the collaboration of multiple devices, complex factors of interaction equipment also enhances the complexity of the system.

II. COMPLEX ADAPTIVE PETRI NET

The complexity of manufacturing systems may lead to quite complex of Petri net [5]. The above multi state interleaving is easy to produce space state explosion. Combined the characteristics of complex adaptive system and the problem encountered during characterization of present production process and in the limitations of Petri net [6], complex adaptive Petri net (CAPN) theory was proposed in this article. In one hand, this theory could make the complex adaptive process in flexible production process characterized by modeling systematic. In the other hand, it could not only solve the difficult characterization of complex adaptive during the process of modeling, but also solve the resource waste condition caused by applying the other type Petri net [7].

A. *The definition of CAPN*

Definition 1: CAPN H={P，T，F，A，C，R，D，ω，M_0}

1 Textile college, Donghua University, Shanghai 201620, P. R. China,
2 Zhengzhou University of Industrial Technology, Henan 450000, P. R. China,
3 Key Laboratory of Textile Science & Technology, Ministry of Education, Donghua University, Shanghai 201620, P.R. China
E-mail: [a] cnwjun@gmail.com, [b]156556096@qq.com, [c]wdyu@dhu.edu.cn

(1) P：P is nonempty finite set of place, P={p_1，p_2，…，p_i，…，p_m}；

(2) T：T is nonempty finite set of transition, T={t_1，t_2，…，t_i，…，t_n}；

(3) F： F is directed arc set, F= P×T∪T×P, P and T also meet the condition of P∩T=Ø and P∪T≠Ø；

(4) A：A is attribute set, A={A_1，A_2，…，A_m，…，A_n}，A∉Ø；

(5) C：C is control function set, C∉Ø；

(6) R：R is feedback function set, R∉Ø；

(7) ω： ω is adjust function set, ω∉Ø；

(8) D：D is mapping of C∪R→A；

(9) M0：M0 is the initial state；

Definition 2: In the library of P, there are two types of place with input P (Pi) and output P (Po). The Petri net with strong connection could be obtained, if a transition, of T was joined between Pi and Po.

Definition 3: In the change of T, there are two categories of transition, with information processing transition, T (Tp) and information transition, T (Ti).

According to the need and different of information processing, processing transition, can be divided into adaptive production and processing transition, (Tp), production forecast change (Tf) and production feedback transition, (Tt).

Definition 4: In directed arc set, there must be one or more directed arc of P × T. This directed arc T located the relative front position of the network. The change P located the relative end position of the network.

Definition 5: In label set, there must be two types of label with real label "●" and virtual label "◎". Virtual label only existed in initial state, which used to activate the changes and transmit the information of virtual label to complex adaptive module, in order to make the change implement with reason and target.

B. Basic Unit of CAPN

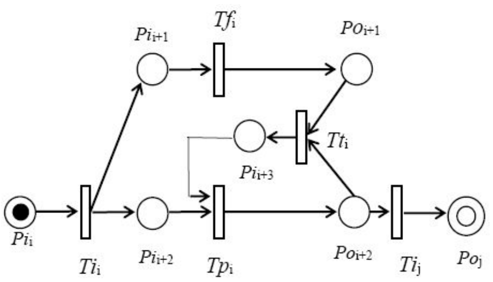

Fig. 1. Basic unit of CAPN

Figure 1 is a basic unit of CAPN. This basic unit is the smallest size of intelligent model to realize control, feedback, self-adaption during the flexible processing cycle. From Pii to Pii+3 are belong to place and attribute. Poi+1 acts as quality output for intelligent predict. Poi+2 acts as output for production process. Tii acts as transition for delivery. Tpi acts as transition for adaptive manufacture. Tfi acts as transition for intelligent predict. Tti acts as transition for feedback control. Tij acts as transition for virtual distribution. Poj is virtual label output to meet the quality standard. In this paper, Pi is the identification of input place, Po is the identification of output place; Ti、Tp、Tf、Tt are different identification of transition, i is the sequence identification of CAPN Uint (i=1,2,3,...,n).

C. Complexity Model of CAPN

The complexity for CAPN characterization reflects the complexity of the type, quantity and their about relationship for composed agents in system. In addition, the external environment is also as a quite key to influence the complexity of the system. The complexity of system in CAPN model is divided to three parts, including agent complexity C_a, relationship complexity C_r and environment complexity C_e, which expressed as C={C_a, C_r, C_e}. From the state of the system, it is divided into static complexity and dynamic complexity. The static complexity in this article could be regarded as a special case of dynamic complexity with the complexity of external influence as 0.

According to the different distribution for complex of systemic composition, the complexity of above three aspects was given different weights. If α, β and γ acted as influence coefficient for Ca, Cr and Ce respectively, the formula of C=αCa+βCr+γCe is right with α+ β + γ = 1.

In the model of CAPN, the number of nodes can intuitively reflect the number of agents. The definition of system can also reflect the types of agents during the application. The connection among the systemic agents is the directed arc. The number of arc can suggest the complexity between the internal relationships in system. Some of the systemic token change occurred at the initial state, the others came from the output. The token from output can reflect the influence condition to system by external environment. It also can judge the complexity influenced by external environment from the types of token. In generally, the more numbers and types of system agents, the value of Ca is larger in the certainty of other factors. In the same reason, the more numbers of directed arc, the value of Cr is larger, the more types of token, the value of Ce is larger.

Then:

$$Ca = f(|P|+|T|+|F|), Cr = f(|F|), Ce = f(A).$$

If the formula of are right.

$$Ca = 1 - \sqrt{\frac{1}{|F|*(|P|+|T|)}}, Cr = \frac{Max\ (|{\cdot}X|+|X{\cdot}|)}{Max\ (|{\cdot}X|+|X{\cdot}|)+Min\ (|{\cdot}X|+|X{\cdot}|)},$$

$$Ce = \frac{Max\ (K)}{\sum_{i=1}^{|P|} Ki}$$

In this formula, ${\cdot}X$ and $X{\cdot}$ are the in and out arc set of X node.

If the formula of

$$\alpha = \frac{Ca}{Ca+Cr+Ce}, \beta = \frac{Cr}{Ca+Cr+Ce}, \gamma = \frac{Ce}{Ca+Cr+Ce}$$

are right.

Then the complexity of system can be expressed by：

$$C = (\frac{Ca}{Ca+Cr+Ce})\ (1-\sqrt{\frac{1}{|F|*(|P|+|T|)}}) + (\frac{Cr}{Ca+Cr+Ce})\frac{Max\ (|{\cdot}X|+|X{\cdot}|)}{Max\ (|{\cdot}X|+|X{\cdot}|)+Min\ (|{\cdot}X|+|X{\cdot}|)} + (\frac{Ce}{Ca+Cr+Ce})\frac{Max\ (K)}{\sum_{i=1}^{|P|} Ki}$$

Based on the above formula, the complexity base of basic model of Petri can be calculated as follow: Ca=0.55, Cr=0.5 and C=0.526. In the basic unit of CAPN static case, the complexity can be calculated used by the above formula as follow: Ca=0.916, Cr=0.75 and C=0.84. From the basic implementation of CAPN, this model can attain the complex adaptive systems modeling through the minimal complexity (basic PN complexity).

ISBN: 978-988-19253-2-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

D. Cotton Spinning Process Based On CAPN

At present, the characterization of cotton spinning process is mainly in the production process of simple transforming process with the hybrid Petri nets. It only describes the scheduling problem among the links. However, the solving to scheduling problem still depends on mathematical optimization method. The model of hybrid Petri nets has no substantial effect on solving the scheduling problem, just act as a simple visualization of cotton process. During the cotton processing in industrial production, the products of yarn have big differences on quality index because of difficult control in the process of fiber and tampon etc. Although the production line has set production technology, the quality of yarn is not consistent with the most requirements of the production process, and the production experiences cannot be timely adjusted towards the ideal index of the yarn production, all of which could result the waste of production resources.

Cotton spinning production line is typically driving system with locally continuous and overall discrete, and with character of variety in specifications, diversity, continuous multi process, multi machine, production process flexibility and complexity of the production process. Since the characteristics above not only meet the characteristics of flexible manufacturing system, but also act as the typical behavior of complex system, so this production line is a typical complex flexible manufacturing system. The method of modeling can be combined with the complex adaptive system and FMS. Therefore, in order to make the cotton production more intelligent, a complex adaptive Petri net is proposed to solve this problem in this paper.

III. CHARACTERIZATION AND ANALYSIS OF SINGLE / DUAL COTTON PROCESS BASED ON CAPN

A key issue for the use of complex adaptive Petri net modeling process is on what standard conditions are based to adaptively adjust. To overcome this key issue, the adaptive criteria require to be shown in the model. So the thought of modeling is continuous cross comparison of two output results between the actual production process and the ideal one, and realize the adaptive adjustment according to the adaptive adjustment scheme chosen by the result of comparison.

A. Characterization and Analysis of Single Cotton Process

First use a process modeling, such as cotton mixing process, solid part of the model in Figure 2 place and transition meaning in Table 1.

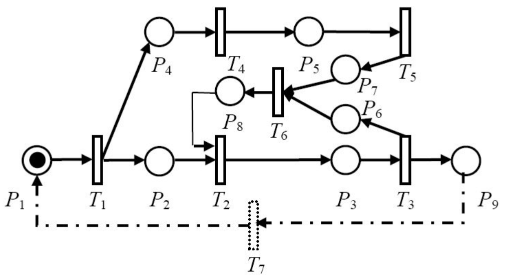

Fig. 2. The CAPN model of blending process

Table I
THE MEANING OF PLACE AND TRANSITION IN THE BLENDING MODEL

Place	Meaning	Place &Transition	Meaning
P_1	The data of cotton	P_9	Output of blending process
P_2	Input of blending process	T_1	Information transfer
P_3	Output of blending process	T_2	The adaptive process
P_4	Input of the prediction	T_3	Information transfer
P_5	Output of the prediction	T_4	Production forecast model
P_6	Input of the production feedback	T_5	Information transfer
P_7	Input of the production feedback	T_6	Feedback control model
P_8	Output of adaptive feedback	T_7	Information transfer

As it is shown in Figure 2 correlation matrix C of adaptive Petri net of the cotton blending process in the following formula for solving complex (1, 0, 0, 0, 0, 0, 0, 0, 0) T+CU= (0, 0, 0, 0, 0, 0, 0, 0, 1) T get the solution, U= (1, 1, 1, 1, 1, 1), i.e. by =T1 T2 T3 T4 T5 Qi sequence T6, the flow from the initial marking to the termination of identification, i.e. the model is live; formula solution of CY 0, Y exists only zero solution, the model is not bounded, unreliable. Through the improvement of the model, the improved model in Figure is achieved with the dotted line in Figure 2, the same method can be used to verify the improved model is reliable. The improved model is logical in actual production. Cotton production line can produce many products. Once the production reaches the requirements, by terminating the identification feedback to the initial marking, it needs to replace another process, another production.

$$C=\begin{pmatrix} -1 & 0 & 0 & 0 & 0 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & -1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{pmatrix}$$

$$C\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \end{pmatrix} \le 0 \Rightarrow \begin{cases} -y_1 \le 0 \\ y_1 - y_2 \le 0 \\ y_1 - y_3 \le 0 \\ y_2 - y_4 \le 0 \\ y_3 - y_5 \le 0 \\ y_4 - y_6 \le 0 \\ y_5 - y_6 \le 0 \\ -y_2 - y_6 \le 0 \\ y_3 \le 0 \end{cases}$$

B. Characterization and Analysis of Single and Double Cotton Process

From the performance analysis of mixed cotton complex adaptive Petri net, we get the improved model; whether cotton production systems in other processes can connect the model with series in a number of steps, there still needs to be explored. We took the mixing cotton and cotton opening and cleaning processes of two modeling, on the basis of blending cotton model, which are connected in series to get complex adaptive Petri net mixed cotton and cotton opening and cleaning process, as shown in figure 3.

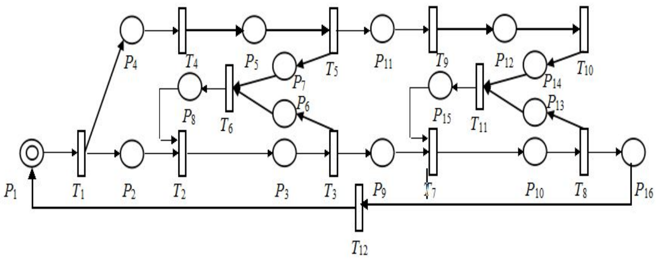

Fig. 3. Blending opening&cleaning model

C. Mixing and Static Complexity Analysis of Cotton Opening and Cleaning Process:

Here are comparisons before and after double process in the use of the CAPN modeling complexity: complexity of the system before using CAPN modeling are: Ca=0.97, Cr=0.6, C=0.83; the relative complexity of the basic model of Petri are: Ca=0.42, Cr=0.1, C=0.3; CAPN says after the use of modeling the complexity of Ca=0.83, Cr=0.5, C=0.71, relative the basic model of Petri complexity is: Ca=0.28, Cr=0, C=0.18, the complexity of the system of absolute ratio are decreased by 14%, 17%, 14%. The complexity of the overall relative ratio decreased by 40%, which fully reflects the reduced optimization modeling, CAPN model strongly shows complexity of modeling based on ability (complexity of the basic Petri model: Ca=0.55, the complexity of the relationship: Cr=0.5, the complexity of the system: C=0.53) .

IV. CHARACTERIZATION AND ANALYSIS OF SINGLE COTTON PROCESS BASED ON CAPN

According to the performance of blended cotton CAPN analysis steps we analyzed mixed cotton and cotton opening and cleaning of CAPN model, we can get the model is reliable. So through the process of the series will be CAPN OF cotton production system process model based on all processes form as shown in Figure 4, the results of the performance analysis will also be model is reliable.

In cotton production, the main difference between carding system and combing system is whether there is the combing process. In the production process, the number of drawing is not all the same, so we need, according to the production process, to decide whether to choose the number of road combed and selection of drawing, then we have the combing process selection graph (Figure5) and drawing process selection diagram (Figure6).

To obtain the complete process model based on the CAPN cotton serial production system, through the computer simulation, it shows that the complete model by reasoning is reliable, and can be stably simulated by computer operation for a long-term.

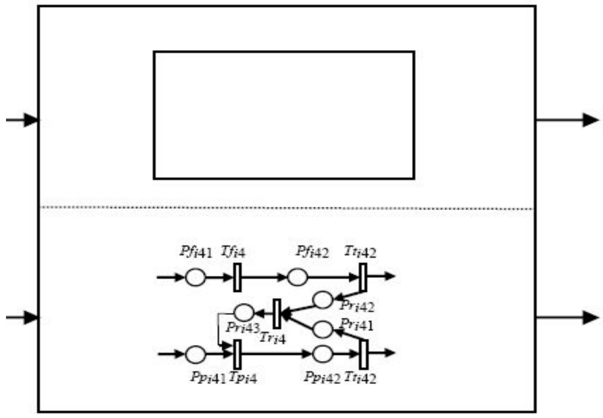

Fig. 5. The choice of combing process

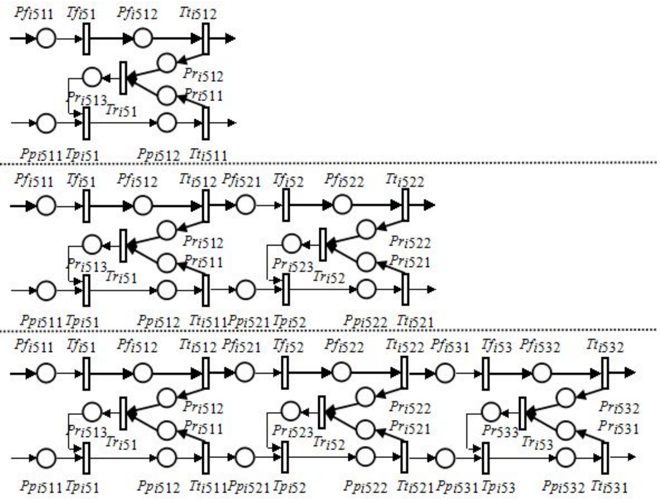

Fig. 6. The choice of drawing process

V. CONCLUSION

Characterization of Cotton Single / dual process based on CAPN effectively proves that in reducing complexity of the CAPN model system, improving flexibility the modeling it is superior to the traditional Petri net modeling. To increase the availability of the model through the improvement of the CAPN of the basic unit, the model improves the performance of adaptive feedback through the definition of different changes. The next step is mainly on study of the model characterization of multi process interaction.

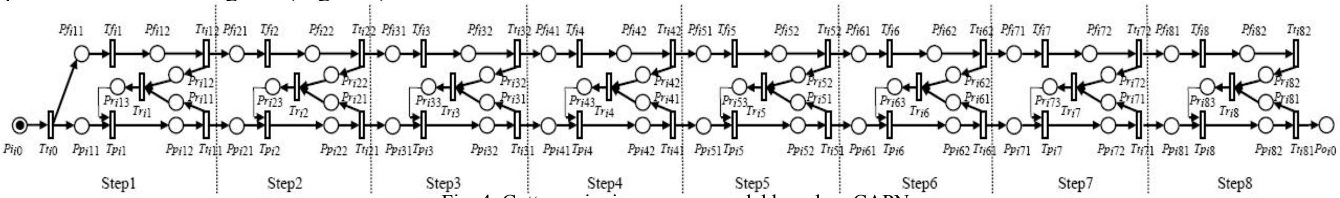

Fig. 4. Cotton spinning process model based on CAPN
Step1:blending;Step2:opening&cleaning;Step3:carding;Step4:combing;Step5: drawing; Step6:roving;Step7:spinning;Step8:winding

ISBN: 978-988-19253-2-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

REFERENCE

[1] G. Liu, W. D. Yu, “Modeling on the worsted fore-spinning working procedure,” In: Edited by State Key Laboratory for Modification of Chemical Fibers and Polymer Materials, Donghua University, *the international conference on advanced fibers and polymer materials* (ICAFPM). Shanghai,2007,Oct 15-17:Vol1,59-62

[2] P. Massimo, S. Quirico, “Understanding ART-based neural algorithms as statistical tools for Manufacturing process quality control,”,*Engineering application of artificial intelligence*, 2005, Vol 18 (3) , p645-662

[3] W. S. Tommy, J.Y. Li, “Higher-order Petri net models based on artificial neural networks,” *Artificial Intelligence* 92 (1997) 289-300

[4] P. Matej, K. Matej, P. Janez, M. Gasper, V. Goran, K. Stanislav, “Analysis of multi-agent activity using petri nets,” *Pattern Recognition* 43 (2010)p1491-1501

[5] G. Looney, “Fuzzy Petri net for rule-based decision making,” *IEEE Trans. Syst. Man Cyber*., vol. 14, 1988. p178-183

[6] W. M. Zuberek, “Timed Petri Nets Definitions Properties and Applicationgs,” *Microelectron. Reliab.* 1991,Vol31, No4,p 627-644

[7] T. Murata "Petri nets: Properties, analysis and applications", *Proc. IEEE*, vol77, no. 4, 1989 .p541 -580

ISBN: 978-988-19253-2-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)