

Time Petri net-based modelling of complex adaptive agent system

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Abstract. In order to depict internal mechanism of complex adaptive agent system and improve capabilities of computer-assisted modelling, a new modelling approach is presented by the combination of Time Petri Net (TPN) and multi-agent technology. In the methods, agent is viewed as basic modelling element and Petri net is used to describe the static rules of agent. Because of the TPN model combining the advantages of time Petri net and multi-agent technology, the state space explosion of complex adaptive agent system is prevented. As an example, the crane scheduling system is defined as complex adaptive agent system. The results that proposed system can complete scheduling task of the steel-making continuous casting and provide guidance for optimizing production systems and exploring operation mechanism.

1. Introduction

Manufacturing industry refers to the manufacturing resources (such as materials, energy, equipment, tools, funds, technology, information and human resources), which are converted into industrial and consumer goods that can be used and utilized by people according to the market requirements. Today, the manufacturing industry has many new characteristics, such as variety, small batch, big change in order, strong randomness in variety, short contract period and so on. In order to meet the variety requirement of the product in category and specification, the process of manufacturing enterprises tend to be networked and complicated, so the manufacturing system of modern enterprise is regarded as complex adaptive agent system.

Complex adaptive system (CAS) [1, 2] consists of diverse components (called agent) that are interdependent, act as a unified whole, and have the ability to learn from experience and to adapt to change in the environment. Examples of CAS are the global economy, stock markets, emerging cities, online social networks, and the internet. There are many research methods for complex adaptive systems, modeling and simulation are the main methods for the study of complex adaptive systems. Petri net [3] is powerful tool for describing information systems that are characterized of concurrent, synchronous and asynchronous activities, so it is used to model for the complex adaptive systems. Because of strong dependence and complex structure of model of Petri nets, these can easily lead to model space state explosion. Mendes J M [4] describes a solution for the control of service-oriented devices based on modular and special adapted High-Level Petri Net (HLPN) process description of intra- and inter-control activities, the HLPN is adapted to as sociable model applicable to describe control processes and sufficient elastic for different control strategies. Object-oriented paradigm provides excellent concepts to model real-world problems, object-oriented concepts allow us to build software systems easily, intuitively and naturally. In Colored Petri Net (CPN), objects and object attributes can be modeled with data structures, and the hierarchical structure of CPN is useful in



representing class inheritance and to describe dynamics of objects. Motameni H [5] presents a technique to transform an Object Oriented Design (OOD) into hierarchical (CPN) model with Object Oriented Petri Nets Model (OOPNM) approach. A new graphical framework, Abridged Petri Net (APN) is introduced by Volovoi V [6] for bottom-up modeling of complex stochastic systems. APN is similar to Stochastic Petri Net (SPN) in as much as they both rely on component-based representation of system state space, in contrast to Markov chains that explicitly model the states of an entire system. The specification and distributed control of discrete event robotic manufacturing systems using Petri net are considered, and a methodology of decomposition and coordination is presented for hierarchical and distributed control [7]. Vahidipour S M [8] resolve the conflicts among the transitions by building the model called learning automata-based adaptive PN (APN-LA), in which transitions are portioned into several sets of conflicting transitions and each set of conflicting transitions is equipped with a learning automaton which is responsible for controlling the conflicts among transitions in the corresponding transition set.

In this paper, complex adaptive system is defined as complex multi-agent system, which called complex adaptive agent system and the analysis and description of agent behavior is realized by using formal methods of extended Petri net. By combination time Petri net with multi-agent technology, we can effectively solve the description for static structure and dynamic behavior of complex adaptive system, and avoid the problem of system space explosion in dynamic Petri net model.

This paper proceeds as follows. Section 2 defines the time Petri nets and complex multi-agent system by exploring the characteristic of complex adaptive system; section 3 establishes the complex adaptive system model based on the time Petri net; section 4 makes a simulation experiment and analyze the result. Based on it, this part draws a conclusion.

2. Definition of Complex Adaptive Agent Systems and Time Petri Nets

Definition 1 Petri Net [1] is 5-tuple, $PN = (P, T, F, W, M_0)$ where:

$P = \{p_1, p_2, \dots, p_m\}$ is a finite set of places,

$T = \{t_1, t_2, \dots, t_n\}$ is a finite set of transitions,

$F \subseteq (P \times T) \cup (T \times P)$ is a set of arcs,

$W : F \rightarrow \{1, 2, 3, \dots\}$ is a weight function,

$M_0 : P \rightarrow \{0, 1, 2, 3, \dots\}$ is the initial marking,

$P \cap T = \emptyset$ and $P \cup T \neq \emptyset$.

Definition 2 Time Petri Net is $TPN = (PN, T_i)$ where:

PN is a Petri Net,

T_i is a mapping called static time interval. $\forall t \in T, T_i(t) = [left(t), right(t)]$, where $left(t)$ is the static earliest firing time and $right(t)$ is the static latest firing time.

Definition 3 Complex adaptive agent system is 3-tuple $CAAS = (A, Ma, R)$ where:

$A = \{a_i, i = 1, 2, 3, \dots, n\}$ is the set of agent in complex multi-agent system,

Ma is the management agent of complex multi-agent system,

$R = \{r_{ij}, i, j = 1, 2, 3, \dots, m; i \neq j\}$ is the relationship set of agent in complex multi-agent system.

Definition 4 Management agent is a 4-tuple $Ma = (Link_P, Me, K, D)$ where:

$Link_P$ is a intelligent linker among agents,

Me is the message channel of agents,

K is the knowledge base,

D is the decision-making body.

Definition 5 TPN-based agent is 2-tuple $OTPNa_i = (TPNa_i, Me_I)$ where:

$TPNa_i$ is the time petri net of agent a_i ,

Me_I is the set of message interface of agents, including input message and output message.

3. TPN-based modelling of Complex Adaptive Agent System

According to the characteristics of the complex adaptive system, the complex adaptive system can be designed as multi-agent system, which consisted of task agents, management agent, interface agents and message agents. When tasks arrive at the system, management agent is responsible for tasks decomposition based on system environment and local knowledge, and complete assignment by means of bidding. After task agent gets the tasks, it establishes the solution plan according to the task target, and defines the information query process, in the end completes the execution of the task and returns the results.

3.1. TPNs model of task agent

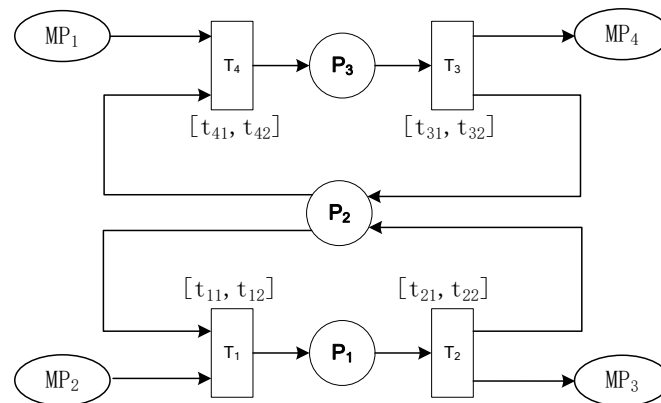


Figure 1. TPNs sketch of task agent

Table 1. Place and transition of task agent

Place	Message Place	Transition
P ₁ : work piece processing state	MP ₁ : maintenance start information	T ₁ : workpiece starting
P ₂ : device idle state	MP ₂ : request device start	T ₂ : workpiece ending
P ₃ : device maintenance state	MP ₃ : process end information	T ₃ : device maintenance starting
	MP ₄ : maintenance end information	T ₄ : device maintenance ending

3.2. TPNs model of interface agent

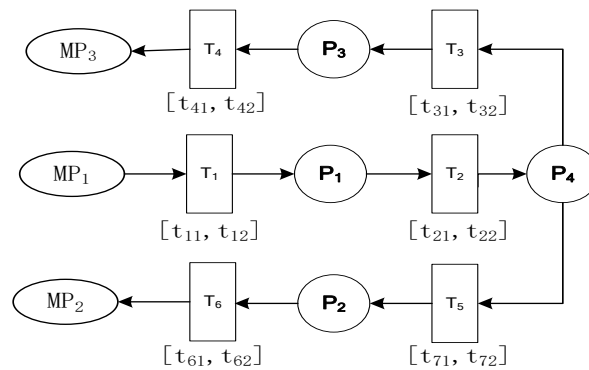


Figure 2. TPNs sketch of interface agent

Table 2. Place and transition of interface agent

Place	Message place	Transition
P ₁ : data receiving state	MP ₁ : receive data information	T ₁ : receive data starting
P ₂ : data storage state	MP ₂ : send data storage information	T ₂ : receive data ending
P ₃ : data format state	MP ₃ : send data format information	T ₃ : data format starting
P ₄ : data buffer state		T ₄ : data format ending
		T ₅ : data storage starting
		T ₆ : data storage ending

3.3. TPNs model of management agent

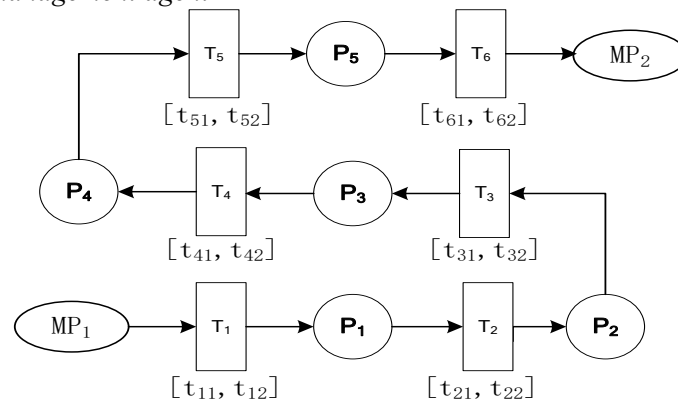


Figure 3. TPNs sketch of management agent

Table 3. Place and transition of management agent

Place	Message place	Transition
P ₁ : task receiving state	MP ₁ : receive task information	T ₁ : receive task starting
P ₂ : task buffer state	MP ₂ : send task assignment information	T ₂ : receive task ending
P ₃ : task decomposition state		T ₃ : task decomposition starting
P ₄ : task buffer state		T ₄ : task decomposition ending
P ₅ : task serialization state		T ₅ : form task sequence starting
		T ₆ : form task sequence ending

4. Simulation and Results

In order to verify the validity and reliability of the model, the crane scheduling systems serve as an example of how each component can be used. To generate the category of the class, we use the

agent UML modelling tool in the Java language of the role class to achieve the bottom support to this system. Multi-threading mechanism is used to implement concurrent execution of multiple workstations in different processes of the system. Through the interaction mechanism, the user can set up the cranes and the station number in the process of the upstream and downstream, and increase the flexibility and flexibility of the system. The operation rule library and update rule base of the station and process are realized by the database technology to increase the security and convenience of the system. We assume that there are three cranes in charge of materials handling in main span of the continuous casting workshop for steel plant. The cranes receive the ladles from the three Basic Oxygen Furnace (BOF), and transport them to the corresponding Continuous Casting Machine (CCM), and put an empty ladle on a trolley, then the trolley transport ladle to a repair shops. Based on the previous analysis and combined with actual production data, the thirty ladles arriving at the continuous casting workshop is simulated in the crane scheduling system according to time-series, the tracks of crane are shown for figure 4. The horizontal axis in figure 4 is the simulation time and the vertical axis in figure 4 is the position of BOF and CCM (position 5 is BOF1, position 10 is BOF2, position 15 is BOF3, position 45 is CCM1, position 75 is CCM2, position 80 is CCM3).

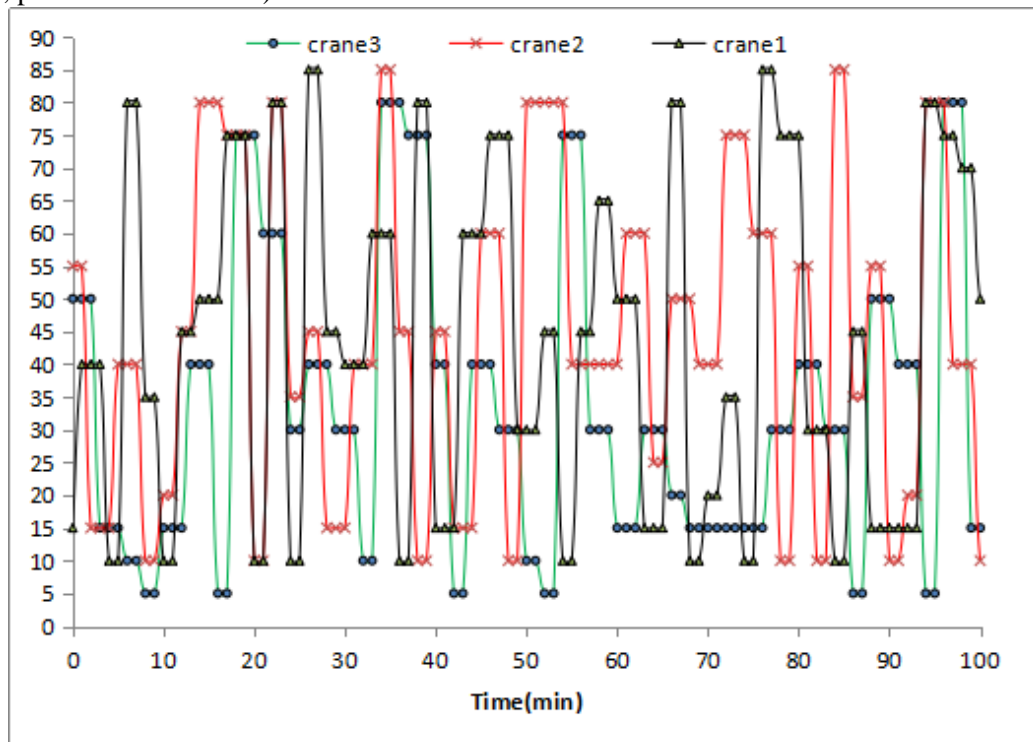


Figure 4. Crane operations across of span from BOF to CCM

The first crane (crane1) is mainly responsible for transporting the ladle from BOF1 to CCM1, and the second crane (crane2) is mainly responsible for transporting the ladle from BOF2 to CCM2, the same reason can be known the third crane (crane3) is mainly responsible for transporting the ladle from BOF3 to CCM3. The all cranes are responsible for transporting the empty ladle and exist in passive transportation. Through the simulation, the operating rates of three cranes are obtained as shown in figure 5 (S_data stands for simulation results, and A_data stands for the production results). As can be seen from figure 5, the simulation data is close to the actual data, and it is smaller than the actual data. This means that there is a space for further optimization in the cranes actual operation.

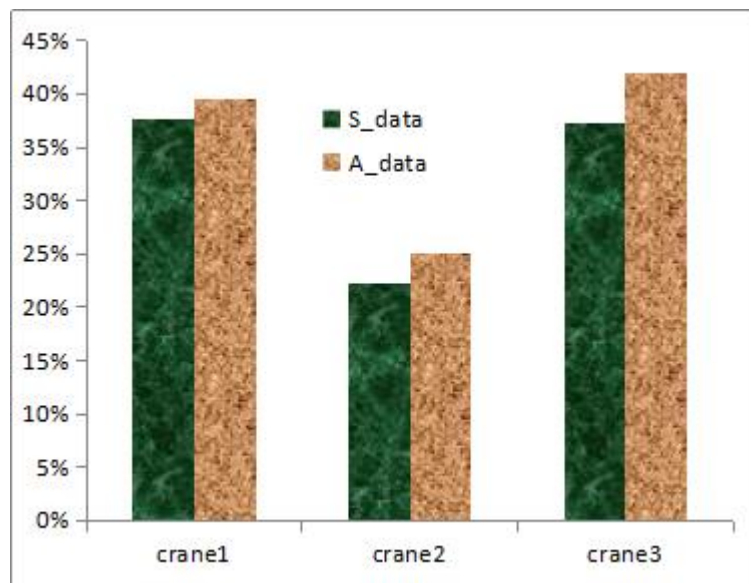


Figure 5. Comparison chart of operation efficiency of crane

5. Conclusions

In this paper, complex adaptive system is defined as complex multi-agent system, which realized by using formal methods of extended Petri net. By combining time Petri net with multi-agent technology, we solve the description for static structure and dynamic behaviour of complex adaptive agent system, and avoid the problem of system space explosion in dynamic Petri net model. The crane scheduling system serves as an example of complex adaptive agent system, which composed of task agents, management agents, interface agents and message agents. The results of the simulation and real examples demonstrate that proposed system can complete scheduling task of the steel-making continuous casting and provide guidance for optimizing production systems and exploring operation mechanism.

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References

- [1] Lansing J S 2003 complex adaptive systems *Annual Review of Anthropology*. **32** 183-204
- [2] Buckley W 2008 society as a complex adaptive system *Emergence Complexity & Organization*. **10** 86-112
- [3] Murata T 1977 petri nets: properties, analysis and applications *Proceedings of the IEEE*. **77** 541-580
- [4] Mendes J M, Restivo F, Leitão P, Colombo A W 2010 injecting service-orientation into multi-agent systems in industrial automation *Lecture Notes in Computer Science*. **6114** 313-320
- [5] Motameni H, Movaghar A, Shirazi B 2008 analysis software with an object-oriented petri net model *J. World Applied Sciences*. **4** 565-576
- [6] Volovoi V 2013 abridged petri nets *Computer Science*.
- [7] Yasuda G, Ge B 2017 petri net model based specification and distributed control of robotic manufacturing systems *The Japan Society of Mechanical Engineers*. **2017** 699-705
- [8] Vahidipour S M, Meybodi M R, Esnaashari M 2017 learning automata-based Adaptive petri net and its application to priority assignment in queuing systems with unknown parameters *IEEE Transactions on Systems Man & Cybernetics Systems*. **45** 1373-1384