

A Petri Net Model of Internal Organs and Meridian System Based on Five-Elements Theory of Traditional Chinese Medicine

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Abstract

In traditional Chinese medicine, internal organs imply five viscera and six bowels. Five viscera mean liver, heart, spleen, lung and kidney, and six bowels mean gallbladder, small intestine, stomach, large intestine, urinary bladder and triple energizer. Also, meridian system represents the passage of metabolites in the human body. In this paper, we deal with construction of Petri net model of internal organs based on five-elements theory of traditional Chinese medicine. At first, we introduce relations of mutual generation and mutual restriction between five viscera, and make a Petri net model for five viscera based on a known control model. Then we analyze the relation between five viscera and six bowels to make a model of internal organs. Finally, we propose a Petri net model of internal organs and meridians.

Keywords: traditional Chinese medicine, five-elements theory, five viscera and six bowels, Petri net, modeling

1 Introduction

Traditional Chinese medicine or oriental medicine has been widely applied in treating disease since ancient times. This is because its less secondary effect as well as its possible curing for ahead sick and incurable disease. Especially acupuncture and moxibustion therapy have spread rapidly since the time when acupuncture and moxibustion therapy were admitted by WHO in 1989 and 361 acupuncture points were standardized by WHO in 2006. However mechanism of meridians are still not elucidated scientifically and much of the research and treatment have been made empirically and clinically. Therefore establishment of acupuncture and moxibustion treatment unified by new knowledge is required ^[1]. Till now, many studies have been done to clarify the mechanism of the human body and meridians.

In traditional Chinese medicine, internal organs include five viscera and six bowels. Five viscera mean liver, heart, spleen, lung and kidney, and six bowels mean gallbladder, small intestine, stomach, large intestine, urinary bladder and triple energizer. Five viscera and six bowels implies the systematic functions of human body rather than internal organs of human anatomy.

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They are closely related each other and have the correspondence relationship between liver and gallbladder, heart and small intestine, spleen and stomach, lung and large intestine, kidney and urinary bladder, respectively. Once one becomes sick, the other has high possibility of abnormalities. Such relationship is expressed in five-elements theory ^[2].

Five-elements theory is a basic theory of traditional Chinese medicine and recently five viscera have been studied through modeling and quantitatively analyzing ^[3]. Fusing five-elements theory and fuzzy system theory, Sun et al. have proposed a fuzzy model (called Sun model hereafter) of five viscera by focusing on the physiological equilibrium states of liver, heart, spleen, lung and kidney ^[4]. Based on the evolution law of five viscera, Guo et al. have proposed a quantitative measurement model in order to realize five-elements theory ^[5]. However, these models have a common problem that they are difficult to be used to simulate behaviour of five viscera as well as six bowels. On the other hand, Petri net is a modeling and analyzing tool of systems and can represent and analyze static structure and dynamic behaviour of a system ^[6]. There have been many success stories about modeling biological systems and elucidating the mechanisms by Petri nets. We aim to elucidate the mechanism of five viscera and six bowels by using Petri nets.

In this paper, we propose a method of modeling five viscera by using Petri nets. Section 2 introduces five-elements theory and gives definitions of Petri nets. Section 3 shows the modeling method and Section 4 gives simulation results by using the proposed model.

2 Five-Elements Theory and Petri Nets

2.1 Five-elements theory

According to ancient Chinese five-elements theory, the five elements, wood (木), fire (火), earth (土), metal (金) and water (水) are indispensable to the daily life of mankind. And in five-elements theory of traditional Chinese medicine, five viscera, liver (肝), heart (心), spleen (脾), lung (肺) and kidney (腎), are mapped to the five elements respectively. Liver flow Qi (氣) through over the body free of all care, as a tree getting longer; Heart warm the body as fire; Spleen produce nutrients, as soil that produce all things; Lung take down Qi and Bodily Fluid (津液), as astringent action of the metal; Kidney pool Mind (精) and adjust the moisture of the body, as water that flows to the low place from on high.

In five-elements theory, there are generation and restriction relationships between five viscera. Generation is that of mother-to-child relationship to grow birth to the other party and is circulating in the order of wood → fire → earth → metal → water ^[2]. Restriction is to suppress the other party in the order of wood → earth → water → fire → metal ^[2]. In traditional Chinese medicine, health is maintained if generation and restriction relationships are balanced, and hence cause of the disease and methods of treatment can be investigated from the interrelationship of five viscera. Fig.1 shows the generation and restriction relationships.

In addition, five viscera and six bowels have relations that interact with each other. That is, liver and gallbladder, heart and small intestine, spleen and stomach, lung and large intestine, and kidney and urinary bladder interact with each other, respectively. Triple energizer consists of upper energizer, middle energizer and lower energizer, which are the paths for Qi and Bodily Fluid to pass. Since triple energizer does not corresponds to any one of five viscera, we are not to detail with it in this paper.

2.2 Petri Nets and Colored Petri Nets

A Petri net is one of several mathematical modeling languages for the description of concurrent systems^{[6] [7]}. A Petri net is a weighted directed bipartite graph and consists of two types of nodes, transitions (i.e. events that may occur, signified by bars) and places (i.e. conditions, signified by circles). Places may contain a number of marks called tokens. Any token distribution over the places will represent a configuration of the net called a marking. The directed arcs with weights describe which places are pre- and/or postconditions for which transitions (signified by arrows). A Petri net is expressed by a 5-tuple $PN=(P, T, A, W, M_0)$. Here, $P=\{p_1, p_2, \dots, p_{|P|}\}$ is a set of places, $T=\{t_1, t_2, \dots, t_{|T|}\}$ is a set of transitions, $A \subseteq (P \times T) \cup (T \times P)$ is a set of arcs, W is weight function $A \mapsto \{1, 2, \dots\}$ and M_0 is initial marking $P \mapsto \{0, 1, 2, \dots\}$.

Colored Petri nets (CPN) is extended from Petri nets by adding colors to tokens and is a discrete-event modeling language combining the capabilities of Petri nets with the capabilities

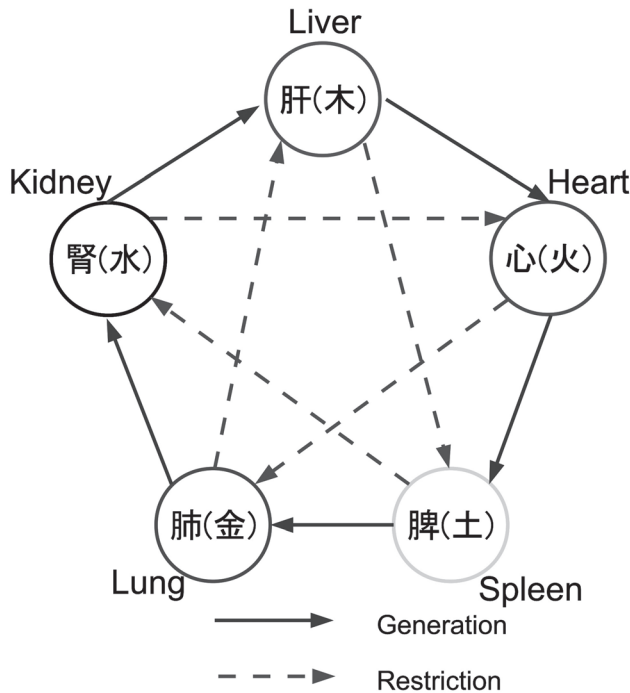


Figure 1: The interrelationship of five viscera.

of a high-level programming language. It allows tokens to have a data value attached to them. This attached data value is called token color. A Petri net is a tuple $CPN = (P, T, A, \Sigma, C, N, E, G, I)$ [8], where, P, T and A are the same as Petri net, Σ is a set of color sets and contains all possible colors, operations and functions. C is a color function and maps places into colors. N is a node function and maps A into $(P \times T) \cup (T \times P)$. E is an arc expression function and maps each arc into the expression. G is a guard function and maps each transition into guard expression. I is an initialization function and maps each place into an initialization expression.

3 A Petri Net Model of Five Viscera

3.1 A Control Model of Five Viscera

In Sun model [4], physiological equilibrium states are quantitatively defined in domain $(-1, 1)$ respectively for liver, heart, spleen, lung and kidney, and a fuzzy model had been proposed based on five-elements theory. The domain is divided into $(-1, b_1)$, $[b_1, a_1)$, $[a_1, a_2]$, $(a_2, b_2]$, $(b_2, 1)$ as shown in Fig.2, which respectively five states, weak, little weak, equilibrium, little strength, strength. These five states respectively represent dysfunction and no power of generation $((-1, b_1))$, delicate health and weak power of generation $([b_1, a_1))$, health and stable state $([a_1, a_2])$, Excess and disease state with power of restriction $((a_2, b_2])$, and severe state of excess $(b_2, 1)$.

Among five viscera, there are generation and restriction relationships. In the case of heart, it is generated by liver but restricted by kidney, which is shown in Fig.3. Meanwhile, liver may loss its energy itself. Therefore, the state of liver at time t , $f(t)$, is expressed by the following equation [4]:

$$f(t) = a_s \cdot f_s(t-1) - b_k \cdot f_k(t-1) + c \cdot f(t-1) \quad (1)$$

where, t is the time, a_s, b_k, c are non-negative parameters, $a_s \cdot f_s(t-1)$ represents generation affection (f_s is the state of kidney) and $b_k \cdot f_k(t-1)$ represents restriction affection (f_k is the state of lung).

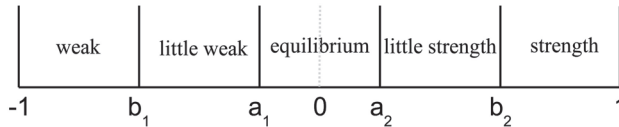


Figure 2: Five viscera's state.

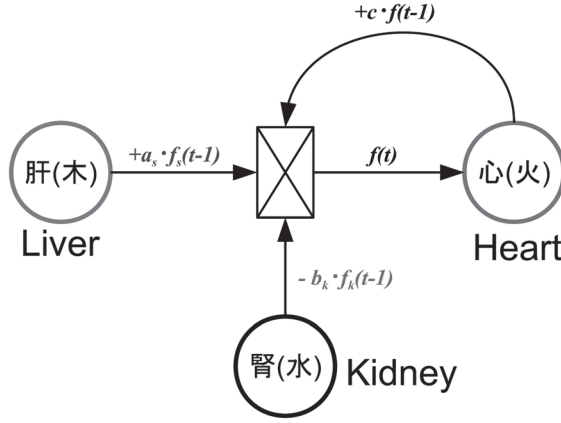


Figure 3: Generation and restriction relationships.

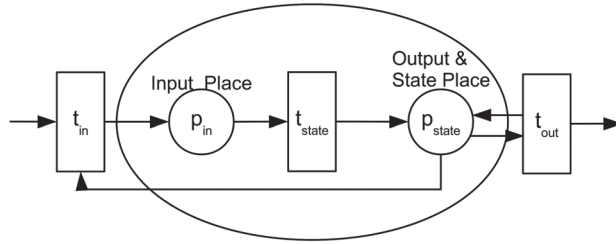


Figure 4: A Petri net model for a single viscus.

3.2 A Petri Net Model of Five Viscera

Here, we propose a Petri net model of five viscera based on Sun model. Firstly, we give a model for a single viscus as shown in Fig.4. Places, p_{in} and p_{state} , are called input place and state place, and the token in state place is called state token whose value expresses the state of the viscus. t_{in} is called input transition that works to calculate the state value of Eq. (1). The token with calculated state value passes through p_{in} and t_{state} and then arrive at p_{state} . t_{out} is called output transition and works to generate and restrict other viscera.

Fig.5 shows a Petri net model including relationship of generation and restriction between viscera. This model is comprised of three single viscus models, the models of liver, heart and spleen, which are connected by places p_s^1 , p_k^1 and p_s^2 . Places p_s^1 and p_k^1 express liver's generation and restriction affection to heart and spleen, respectively, and these two places are respectively called generation-output place and restriction-output place of liver. Tokens in generation-output and restriction-output places are respectively called generation token and restriction token. Similarly, p_s^2 is generation-output place of heart.

Since liver generates heart and restricts spleen, state token of liver flows through output transition t_{out}^1 to generation-output place p_s^1 (that is also an input place of heart model) and to

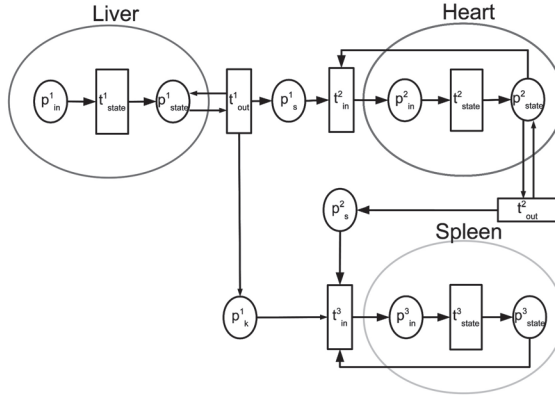


Figure 5: A model including generation and restriction.

restriction-output place p_s^1 (that is also an input place of spleen model). In the same way, state token of heart flows to generation-output place p_s^2 that is an input place of spleen model.

4 A Petri Net Model of Internal Organs

The Petri net shown in Fig.6 can be treated as a mode of any one of six bowels. Hence to make a full model that includes both five viscera and six bowels, we need only to consider how to connect these models of six bowels and five viscera.

Five viscera and six bowels are in the relationship of the front and back, such as liver and gallbladder, heart and small intestine, spleen and stomach, lung and large intestine, and kidney and urinary bladder. Each of these pairs interacts with each other to maintain life. Such a pair, for example liver and gallbladder, is modeled by Petri net as shown in Fig.6. This model is made by adding transitions t_{zf} and t_{fz} and connecting them to the single models of liver and gallbladder. t_{zf} and t_{fz} represent the affections from liver to gallbladder and from gallbladder to liver, respectively.

Synthesizing the models we have made till now, we can complete a model of internal organs. The process is summarized as follows: (1) Make a single model for each of five viscera as Fig.4; (2) Connect these single models according to generation and restriction relationship between five viscera as Fig.5; (3) Make models for each of six bowels (except triple energizer) and connect them to their related viscera individually as Fig.6. The complete model is shown in Fig.7.

To model the whole body, we need to further make Petri net models for meridians and combine them with the internal organs model. Here, we omit the detailed discussion but give an example, shown in Fig.8, to show an internal organs model with pericardium meridian that is one of most important meridians with the least acupuncture points.

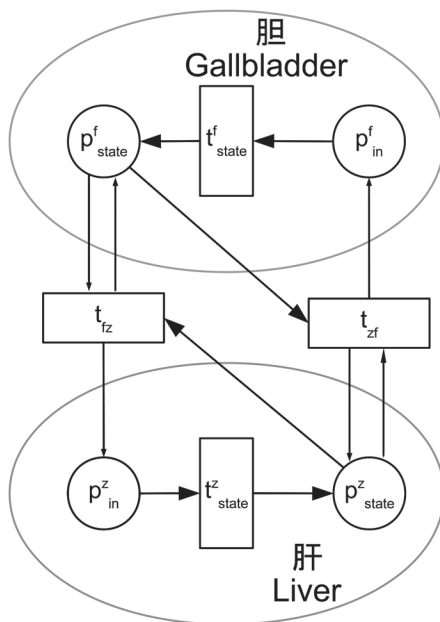


Figure 6: A Petri net mode of liver and gallbladder.

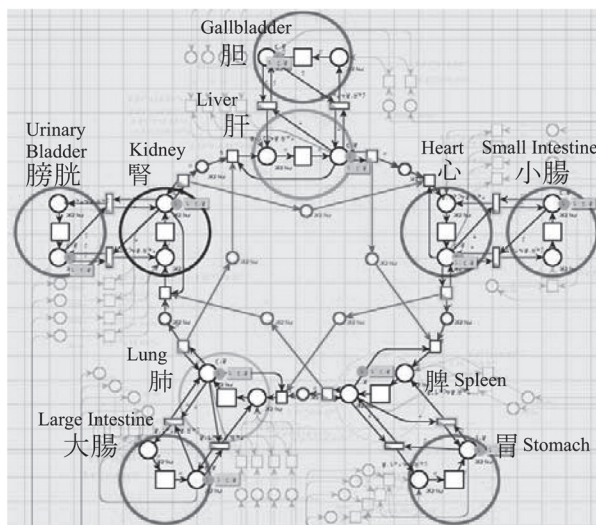


Figure 7: A complete Petri net model of internal organs.

5 Conclusions

We have proposed a method of constructing Petri net models for internal organs that mean five viscera and six bowels in traditional Chinese medicine.

Basing on five-elements theory and the control model proposed by Sun et al., we have proposed a Petri net model of five viscera by considering the generation and restriction

relationship between five viscera. Further taking into account of the relationship of front and back between five viscera and six bowels (except triple energizer), we have made a model of internal organs. Finally, we have given an example to show how to model the whole body by adding pericardium meridian to the proposed internal organ model.

As the future works, we are to (1) decide parameters for all the transitions and places, as well as for tokens and arcs; (2) do simulation to verify the validity of the proposed model and the parameters, in order to complete the model; (3) develop a method to construct a Petri net model for the whole human body.

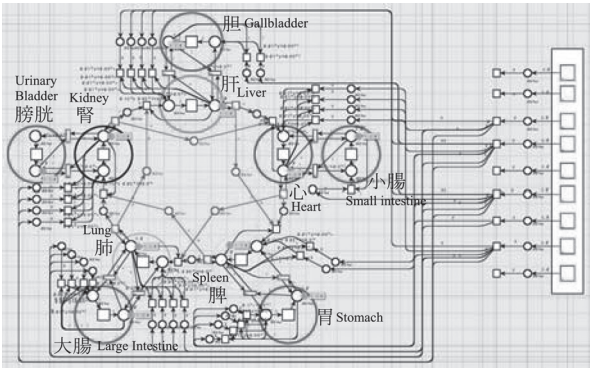


Figure 8: An internal organs model with pericardium meridian

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