

A Petri Net Model of Internal Organs and Pericardium Meridian Based on the Acupuncture Efficacy

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Abstract: This paper aims at constructing a Petri net model of internal organs with triple energizer and pericardium meridian, and its simulation model based on Traditional Chinese Medicine (TCM). Till now, we have proposed a model of the internal organs without triple energizer. In this paper, we add triple energizer to propose a new model of the internal organs as well as its combined model with pericardium meridian according to the acupuncture efficacy. Then, we develop a related simulation model in order to automatically simulate the behaviour of the internal organs. Finally, we show simulation results by stimulating acupuncture points of the meridian.

Keywords—Traditional Chinese Medicine, Modeling, Petri Net, Five Viscera and Six Bowels, Pericardium Meridian

1. Introduction

Traditional Chinese Medicine (TCM for short) or oriental medicine has been widely applied in treating disease in China as well as in various Asian countries since ancient times. Especially acupuncture and moxibustion therapy that stimulate acupuncture points in meridian system to treat disease have spread rapidly since the times when acupuncture and moxibustion therapy were admitted by WHO in 1989 and 361 acupuncture points were standardized by WHO in 2006. However mechanism of meridian system is still not scientifically elucidated and many of related researches and treatments have been made empirically and clinically. Therefore it is required to develop new knowledge to elucidate acupuncture and moxibustion treatment [1].

In traditional Chinese medicine, internal organs include five viscera (五臟) and six bowels (六腑). Five viscera mean liver (肝), heart (心), spleen (脾), lung (肺) and kidney (腎), and six bowels mean gallbladder (胆), small intestine (小腸), stomach (胃), large intestine (大腸), urinary bladder (膀胱) and triple energizer (三焦). Five viscera and six bowels 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 [2]. Human body is also thought of a complex and interconnected system, and consists of meridian system. The elements of meridians are acupuncture points. Stimulating acupuncture points on the body, various diseases can be treated and prevented [2].

Recently, five viscera of traditional Chinese medicine have been studied through modeling and quantitatively analyzing [3], [4], [5]. Nevertheless these models have a common problem that they are difficult to be used in simulating the behaviour of five viscera as well as six bowels. Modeling and simulation of meridian system using Petri net [6] have also

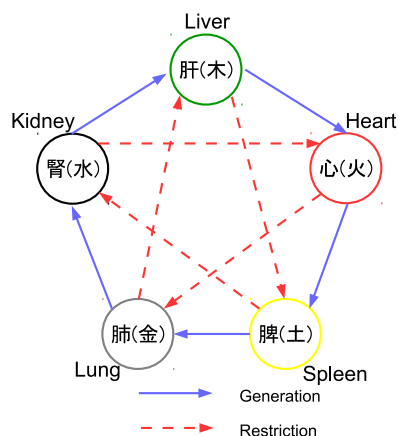


Figure 1. Generation and restriction relationships

been done [7], [8]. However, these studies deals with meridian system only, without taking into account of the internal organs, five viscera and six bowels.

We aim to develop a Petri net model for both internal organs and meridian system, and have proposed a model of internal organs including both five viscera and six bowels (except triple energizer) based on five-elements theory [9] in order to finally elucidate the mechanism of meridian system as well as the internal organs. In this paper, we add triple energizer to the previous model to propose a new model of the internal organs as well as its combined model with pericardium meridian according to the acupuncture efficacy.

2. Five-Elements Theory and Petri Net Model

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 there are generation and restriction relationships between five elements. Generation is circulating in the order of wood → fire → earth → metal → water [2] and restriction is to suppress the other party in the order of wood → earth → water → fire → metal [2]. In five-elements theory of TCM, five viscera, liver (肝), heart (心), spleen (脾), lung (肺) and kidney (腎), are mapped to the five elements respectively [2]. Fig.1 shows the generation and restriction relationships.

2.2 A control model of five viscera

Sun et al have proposed a fuzzy model (called Sun's model hereafter) for five viscera based on five-elements theory [4] and in Sun's model, physiological equilibrium states are quantitatively defined in domain $(-1, 1)$ individually for each

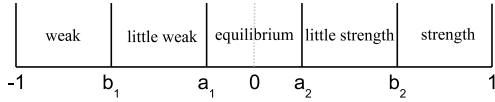


Figure 2. Five viscera's state.

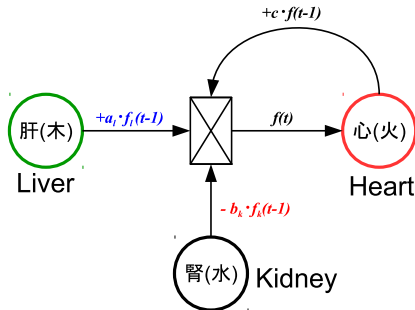


Figure 3. Expression of generation and restriction

viscus. The domain is further 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.

In the case of heart, it is generated by liver but restricted by kidney and meanwhile heart may lose its energy itself. Therefore, the state of heart at time t , $f(t)$, is expressed by the following equation as also shown in Fig.3, which is modified from Sun's model:

$$f(t) = a_l \cdot f_l(t-1) - b_k \cdot f_k(t-1) + c \cdot f(t-1) \quad (1)$$

where, a_l, b_k, c are non-negative parameters, $a_l \cdot f_l(t-1)$ and $b_k \cdot f_k(t-1)$ respectively represent generation affection of liver and restriction affection of kidney.

2.3 Previously proposed Petri net model

Based on Sun's model, we have proposed a Petri net model of internal organs and pericardium meridian. Pericardium meridian is an important meridian and begins near the heart, goes down each arm to the palms and then goes to the tip of the middle finger. It contains 9 acupuncture points, Tianchi (天池), Tianquan (天泉), Quze (曲泽), Ximen (郄门), Jianshi (间使), Neiguan (内关), Daling (大陵), Laogong (劳宫) and Zhongchong (中冲) as shown in Fig.4.

We investigated the relationships between the acupuncture points and internal organs through "syndrome" (証) that is a measure to evaluate the state and physical condition of human body [2], [10], [11]. Based on the relationships, we have designed a Petri net model of internal organs without triple energizer and pericardium meridian as shown in Fig.5.

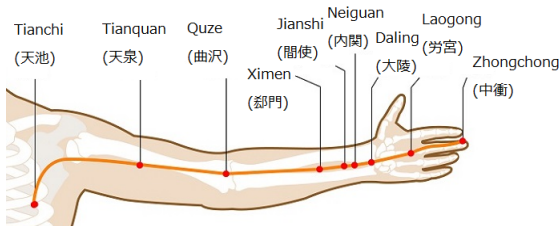


Figure 4. Pericardium meridian with 9 acupuncture points

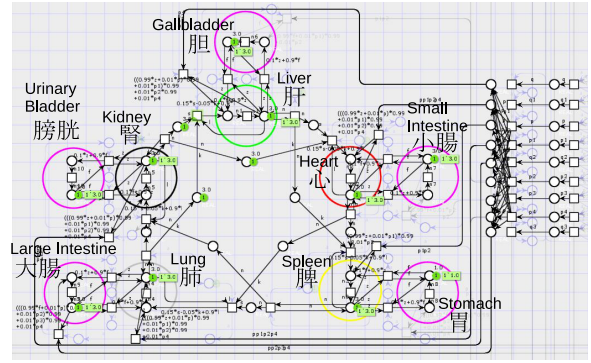


Figure 5. A previously proposed model

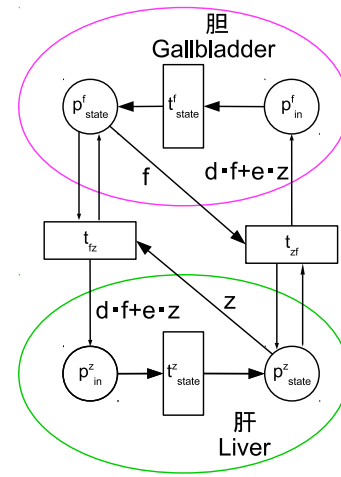


Figure 6. A Petri net mode of liver and gallbladder

3. A Petri Net Model with Triple Energizer

3.1 A model of internal organs and triple energizer

Triple energizer is considered as one of six bowels in TCM. Different from other bowels, it has no shape but works as the lymphatic vessels through whole human body [12]. Triple energizer consists of upper energizer, middle energizer and lower energizer, which are respectively related to lung and heart, spleen and stomach, and kidney. Five viscera and five bowels (except triple energizer) have the relationship of front and back. 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 [9]. In the case of triple energizer, upper and middle energizers individually have two viscera as their opposite. For these two energizers, we need only to connect each energizer to its related two viscera in the same way as shown in Fig.6. Thus, we construct an internal model including triple energizer as shown in Fig.7.

3.2 A combined model with pericardium meridian

Meridians connect skin and inner organs of body. Stimulating an acupuncture point, the signal is transmitted to the meridian and then circulation of energy and flood is improved, which makes internal organs active [2]. In the case of stimulating Quze, heart, lung and stomach are activated. We have investi-

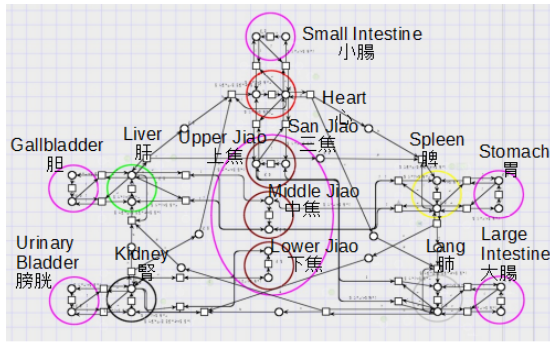


Figure 7. A model of internal organs and triple energizer

Table 1. The relationship of organs and pericardium meridian

Five Viscera	liver	heart	spleen	lung	kidney	
Tianchi (天池)		*				
Tianquan (天泉)		*		*		
Quze (曲泽)		*		*		
Ximen (郄门)		*		*		
Jianshi (间使)		*				
Neiguan (内关)		*				
Daling (大陵)		*				
Laogong (劳宫)		*				
Zhongchong (中衝)		*				
Six Bowels	gallbladder	small intestine	stomach	large intestine	urinary bladder	triple energizer
Tianchi (天池)						
Tianquan (天泉)						
Quze (曲泽)			*			
Ximen (郄门)						
Jianshi (间使)		*	*	*		
Neiguan (内关)	*	*	*	*		
Daling (大陵)			*			
Laogong (劳宫)		*	*	*		
Zhongchong (中衝)						

gated such acupuncture efficacy for pericardium meridian and summarized them in a table as shown in Table 1.

We model the influence of a single acupuncture on a single organ as shown in Fig.8. Acupuncture point is represented by a transition, stimulation of the acupuncture point is represented by firing the transition. Fitting together with state token of the single organ, the token generated by the firing goes through transition t_p to the input place of the organ, and it further moves to the state place (Output&State Place). Thus activation of the organ is represented. Applying the same way as Fig.8 for all the organs according to Table 1, we finally get a complete model of internal organs and pericardium meridian as shown in Fig.9. Note that plural tokens generated by plural acupuncture points are accumulated at one place.

4. Simulation model and simulation results

4.1 Construction of simulation model

In a Petri net, a marking is changed to another by firing a transition. In simulation of a Petri net model by using CPN Tools [13], there may exist plural firable transitions and the

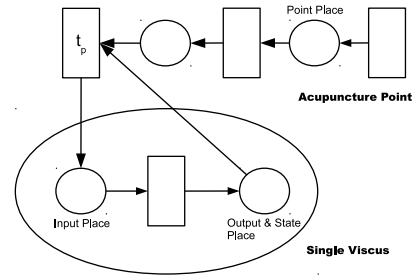


Figure 8. Modeling an acupuncture point and an organ.

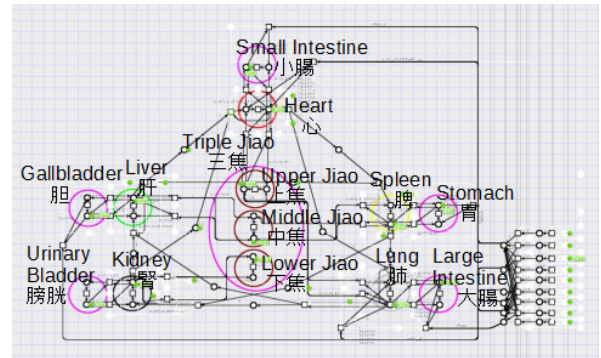


Figure 9. A model with pericardium meridian

firings are nondeterministic. However in traditional Chinese medicine, human life activities, the activities of each organ and physiological activities are all working based on certain rhythm; and it is fundamental that work of all the internal organs should be balanced. Therefore, it is necessary to construct such a simulation Petri net model that the activities of internal organs and meridian are simulated in a good balance.

According to this consideration discussed above, we construct a simulation model to let all the transitions fire one by one. Fig.10 shows a simulation model of five viscera and six bowels, while Fig.11 shows a simulation model combined with internal organs and pericardium meridian.

4.2 Simulation by CPNTools

Simulation has been done by using CPN Tools [13] for the model of Fig.11. State value of each organ is defined in $(0.5, 5.5)$, which means that $(0.5, 1.5)$, $[1.5, 2.5)$, $[2.5, 3.5)$,

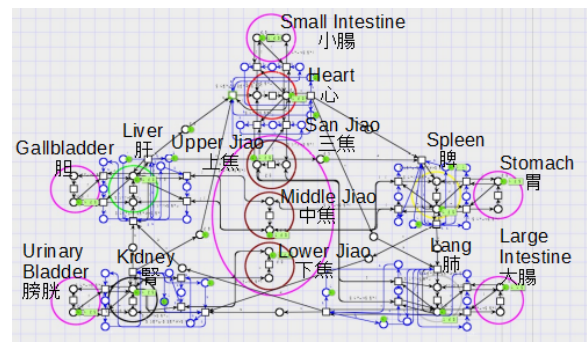


Figure 10. A simulation model of internal organs

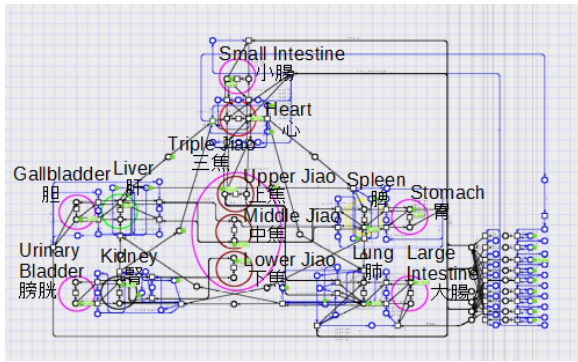


Figure 11. A simulation model combined with internal organs and pericardium meridian

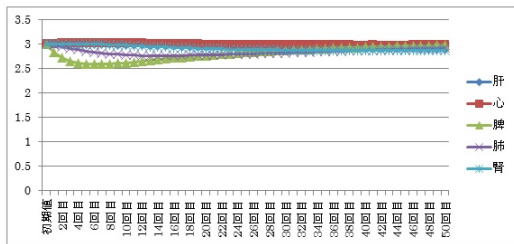


Figure 12. Changes of five viscera

(3.5, 4.5], (4.5, 5.5) respectively represent weak, little weak, equilibrium, little strength, strength. We suppose that initially stomach is in weak state with state token value “1” and all the other organs are in normal state with “3”. Among acupuncture points, Quze, Neiguan, Daling and Laogong have influence on stomach, and we choose Daling to do the stimulation for 50 times. The results are shown in Fig.12 and Fig.13.

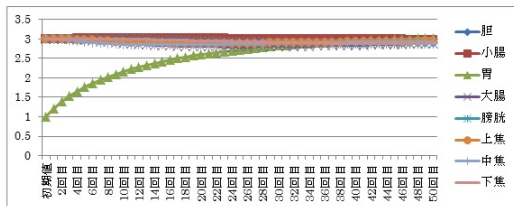


Figure 13. Changes of six bowels

From Fig.12 and Fig.13, at first weak stomach adversely affects spleen directly, and spleen weakens rapidly, lower than 2.5. Due to weakening of spleen and the relationship of generation and restriction between five viscera, all the viscera gradually weaken except heart. On the other hand, spleen directly strengthens stomach and Daling is stimulated continuously. These actions strengthen stomach rapidly and as the result stomach recovers its state value to 2.5 when Daling is stimulated 18 times. After that, all the organs recover gradually and finally get to health state with state values 2.9 when Daling is stimulated 50 times.

5. Conclusions

We have proposed a complete Petri net model for five viscera and six bowels with triple energizer, as well as its combined model with pericardium meridian through investigating the efficacy of acupuncture points of pericardium meridian. To automatically simulate stimulation of acupuncture points, we have also developed a simulation model and used it to do simulation in order to show how our model works by using CPN Tools. It should be pointed out that this work does not intend to be a scientific contribution to medical science in the sense as it is usually understood. As the future works, we are to develop a method to construct a Petri net model for the whole human body.

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