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Modeling and Analysis of Meridian Systems Using Petri Nets

JinGong PAN and MengChu ZHOU

Abstract **The Meridian system conceived by the ancient Chinese has been described and referenced for more than a thousand years. The meridian meaning paths are the main trunks that run longitudinal and interiorly-exteriorly within the body. The Meridian system consists of about 400 acupuncture points and 20 meridians connecting most of the points. It deals with the routing and distribution of energy to achieve physiological functions. It integrates meridian, tissues and organs into an organic whole. This paper models and analyzes the meridian system using Petri nets (PN). To the authors' knowledge, this is the first work that adopts the PN methods to define and model the Meridian system. Finally, we analyze a real case on the treatment of influenza.**

Keyword: Bio-signal network, Petri nets, meridian system, system modeling, tennis elbow

1. INTRODUCTION

1.1 Meridian system-a bio-signal network of life

What is the Meridian system? What is qi? Why does the insertion of a needle trigger a whole set of biochemical reactions in the human body?

It is common knowledge that the human body contains a nervous system. The human body has this capacity in the autonomic nervous system as a signal carrier, via both the sympathetic and parasympathetic branches. The system influences secretion, smooth muscle response, blood vessel response, electrocardiogram, heart rate variability, etc. It functions also as a signal conductor in a detection mode of operation.

According to ancient Chinese medicine, there is also a Meridian system. It is more fundamental than the nervous and blood circulatory systems [4]. The elements of the Meridian system are thought of as the acupuncture points of the body. As there are hundreds of such points, they would provide an array or network system with the capacity to generate, store and transfer the information signal.

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J. G. Pan and M. C. Zhou are with the Department of Electronics and Computer Engineering, New Jersey Institute of Technology, University Heights, Newark, NJ 07102, USA. M. C. Zhou is also with Laboratory of Complex Systems and Intelligence Science, Institute of Automation, CAS, Beijing 100080, PRC. (e-mail: jp27@njit.edu and zhou@njit.edu).

An acupuncture point is like a frequency generator, TV station. Meridian acts like a cable in a cable television system. Different frequencies in the transmission line give different programs in the receiving television set, as different frequencies in Meridians have different effect on the related organs or physical system. But the meridian system is different from a nervous system. For example, if people nail their finger by accident, their nervous system carries a signal from their finger to their brain. They feel pain but do not feel anything traveling along their arm. In other words people do not feel electrical signals that move through the nervous system.

However, it is a quite common reaction of patients to feel sensation traveling along Meridians when a needle is inserted into an acupuncture point, and the sensation does not propagate randomly in any direction. It propagates only along the meridian in which the acupuncture points are located. Hence this propagation of sensation is unlikely to be electrical signals moving via the nervous system. It seems that meridian system has some mechanical frequency property.

Meridians are seen as an underlying system, governing all the other systems of the body, including the immune, reproductive system, nervous, gastrointestinal, and urinary systems. The Meridian system and acupuncture points are supported and verified through at least two thousand years and by millions of patients in clinical practice. But meridians are not taught in orthodox medical texts. Perhaps the main reason is that in anatomy we find nerves and blood vessels, but we do not find any sign of a meridian.

What is qi? Qi plays an important role in oriental medicine, but so far it lacks a modern scientific explanation. We conjecture that qi would be composed of frequencies, oscillations of matters in the meridians. Hence qi could carry some energy and certain types of information.

1.2. Petri nets

Petri nets (PNs) was conceived in 1962 by C. A. Petri. PNs are a graph theoretic and a visually graphical tool. They were originally developed to model asynchronous, concurrent processes in communication and computer systems and are now used to model various types of discrete event systems [12]. By introducing time delays associated with transitions and places in Petri net models, they can capture the system's temporal behavior. Petri nets can be used as visual-communication aids similar to flow

charts. As a mathematical tool, it is possible to set up mathematical models governing the behavior of the modeled system and derive system performance indices.

The work intends to construct ordinary Petri net models for the Meridian system. They are used to analyze such system properties as deadlock, boundedness, reversibility and conflict-freeness. The rest of the paper is organized as follow. Section 2 describes the meridian system. Section 3 discusses the modeling of the meridian system with Petri nets. The basic definitions of Petri nets are summarized. Finally conclusions are drawn and future research direction discussed.

2. DESCRIPTION OF MERIDIAN SYSTEMS

2.1 Twenty meridians

The Meridian system consists of two parts: twelve principal meridians, and eight extra meridians [11]. The twelve principal meridians are classified into: the three meridians of the hand, the three meridians of the foot, three yin meridians of the hand and three yin meridians of the foot. Why are they called "twelve principal meridians"? It is because these meridians are the chief pathways of qi and blood. “Qi” means vital energy supporting life in traditional Chinese medicine theory. The twelve principal meridians start and terminate at given parts, run along regular routes and meet in a specified sequence. They are associated with the *zang-fu* organs that are refer to heart, liver, lung, and kidney.

There are also eight extra meridians:

Du (督脉 or governing vessel),
Ren (任脉 or conception vessel),
Chong (冲脉),
Dai (带脉）,
Yinqiao (阴跷脉),
Yangqiao (阳跷脉),
Yinwei (阴维脉) and
Yangwei (阳维脉).

The eight extra meridians interlace in the twelve principal meridians, helping reinforce the communication between them and the twelve principal meridians. The eight extra meridians are not directly related to any of the internal organs.

Meridians usually start from the limbs, run deeper into the body and emerge from the body at the back of the neck. Again, these meridians have counterparts in both the left and right sides of the body. They are divided into yang and yin divergent meridians. What is Yang and Yin? The yang means that divergent meridians traveling along the outside of limbs and, after traveling through the body, rejoin the principal meridians. The yin means divergent meridians .traveling along the inside of limbs. However, after traveling through the body, they join the yang principal meridians with which they are externally and internally related

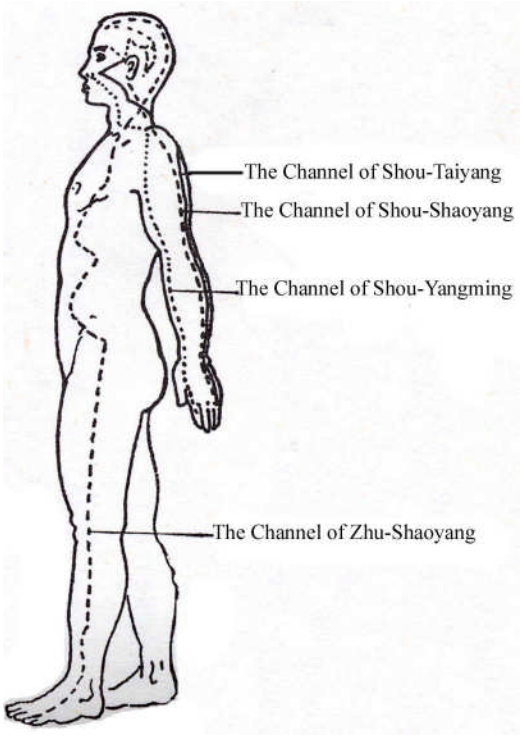

Fig. 1. Demonstration of yang meridian of human body [14]

The channels and collaterals are two comprehensive terms of the meridian system in traditional Chinese medicine. Collaterals, meaning networks, thinner and smaller than channels, are the branches that run crisscross over the body [11]. The twelve principal meridians are regular channels. These regular channels and eight extra channels and those subordinate to the twelve regular channels. are the major trunks of the system of the channels and collaterals. Their nomenclature is based on the organs and the areas they pass through. The twelve regular channels linking each other by their branches and the collaterals result in the formation of six pertaining and link relations.

2.2 Four Hundred Acupuncture Points

World Health Organization finalized the Standard Acupuncture Nomenclature in 1990. The meridian system consists of about 400 acupuncture points [8]. These four hundred acupuncture points along with 20 meridians consist of a rich array or bio-network inside human body. It is well known that an electrical resistance of about 50,000 ohms exists between any two acupuncture point, while over the same length of normal skin, the equivalent resistance is a factor of ~20 times higher. Most of this resistance is in the outer surface layer of the skin. This resistivity changes

strongly with the hypnagogic state, increasing by a factor of 2-3 during sleep [4], and in the case of emotional excitation , the points are observed to increase in area to the ~5mm^2 range. It is very interesting that only slight histological difference appears to exist between an acupuncture point and surrounding skin even through the local resistance is reduced by a factor of 10. As Helms pointed out [2] acupuncture points were situated in surface depressions located along the cleavage planes between two or more muscles. They are not good conductor. Placing small electrodes of different materials on two acupuncture points, a voltage difference is developed between the points of magnitude increasing as the electron work function difference increases. For a nickel/silver electrode pair, the potential difference is ~50 millivolts while the current developed is ~1 to 10 macroamperes. This current shrinks to almost zero between two skin points that are not acupuncture points. Using a ganged-electrode technique, Becker [5] provides conductance maps around several acupuncture points and have observed small electrical potential variations along the meridian channels. This observation provides us with evidences that electrodes in acupuncture point can generate information signals. The acupuncture needles in acupuncture points can also generate signals.

Meridians have low impedance. On normal skin, the impedance is lower at acupuncture points than neighboring points. Normal skin may have an impedance of 600 KΩ, and at an acupuncture point may never exceed 100 KΩ. It was found repeatedly in China, Japan, Korea, and Germany. These low impedance points mostly lie along the meridian system or within 5mm from the meridians.

It is even more interesting to study the effect of electrical signals transmitted through the needle in acupuncture points. If one uses ac voltage of a few volts on the needles, prominent effects come from signals in frequencies from 1 Hz to 100 Hz. Currently acupuncturists seldom use frequencies that are much higher than 100 Hz. A normal human impulse might use a higher frequency, with the idea that the higher frequency the better, as in the case of transmission of radio signals where one goes from KHz in the long wave band to mega Hz in the short wave band. In the transmission of TV signals, the frequency goes even higher. However, for acupuncture to have an effect, one stays in the low frequencies [4].

One can also measure the electrical resistance between symmetrical points on the left and right sides of the body. These points are in the same meridian channel. The resistance is different between the forward direction (R), which is from head to feet, and that in the reverse direction (R') which is from feet to head. When a person is healthy with respect to the organs associated with that meridian, these two resistances are the same (R=R'). However, if pathology is developing in one or more of these particular organs, R is different from R' , $\Delta R=R-R' \neq 0$. As the degree of pathological advancement increases, $|\Delta R|$ increases. This difference has been called the semiconductor effect [10]. It is the electrical correlation of the well-known heat response time difference between acupuncture points when pathology is present [6].

It has also been noticed that, when a serious imbalance exists in the meridian circuitry, and as an acupuncture needle is placed in the appropriate point, a suction-like force holds the needle in place so that, if one tries to withdraw it, the skin pulls up around the needle and it is not easily withdrawn. However after the needle has remained in place for the proper length of time so as to bring about a temporary balance to the circuit, the needle may be withdrawn with no effort and skin does not pull up around the needle. This sanction force that is probably due to an osmotic pressure difference, ΔP between the points seems to be proportional to ΔR. For the pathological condition, an electrostatic potential difference, $\Delta \emptyset$, is also noticed among the points [4]. Because the connective tissues are thermoelectric [14], the application of heat leads to electric current flow and associated electrical potential changes.

Oriental medicine is a systems science in that it looks at the relationships among the different parts of the body. The body is evaluated as being in harmony or not. Meridians are the fundamental system of the body, governing the whole. The channels and collaterals of meridians connects the entirety of the body, so that a needle insert at one acupuncture point can affect an area distant from the needle.

So far we may have a brief idea of the meridian system. Actually, there are collaterals that are smaller and subsidiary to the main meridian system. There are capillaries that are even smaller than collaterals. This is similar to the blood circulatory system, which has main arteries, ordinary blood vessels, and capillaries. This network of meridian systems covers the whole body, and is able to transmit signals from any acupuncture point to internal organs or tissues that resonate with such signals.

2.3 Resonant frequency array of imprinted cluster water

Since the most of the body is made up of water, so the meridian could be composed of water and other matter. But this water in meridians may have different electrical properties that are different from ordinary water. Such water has been found, and it contains stable water clusters. These stable water clusters are clusters of water molecules that are polarized.

As proposed in our previous paper [7], the meridian system may consist of protein and cluster water. If we can find some evidence that cluster water can store information, we may say the meridian system can store information as well.

As reported in [7], we found that templated clustered water had different NMR(Nuclear Magnetic Resonance) spectrum, laser Raman spectra solubility, surface tension and crystal imaging. However, there is no evidence to identify the distinct frequency in water directly.

In our study we use Quantum FAFA equipment that is based on Dr. Nelson's invention [16] . The equipment was first used in 1985 as the Electro-Physio-Feedback-Xrroid (EPFX) System. In 1989, it received FDA permission (510K clearance) to be distributed as a biofeedback device. The quantum coherency effect is achieved by matching the virtual photon and voltametric signature pattern of a reactive substance in the tested target and then watching the voltametric resistance changes that occur in the tested target in response to the item. If there is a coherency, a reactive positive or negative pattern can be induced. According to Dr. Nelson this equipment can rapidly test thousands of items in a short period of time using electrophysiological means.

At first we try to compare the difference between distilled water (DW) and clustered water (CW). As shown in Fig. 2, it is clear that the resonant frequency valley of CW is significantly different from DW's, especially in the range between 3500Hz and 3628 Hz.

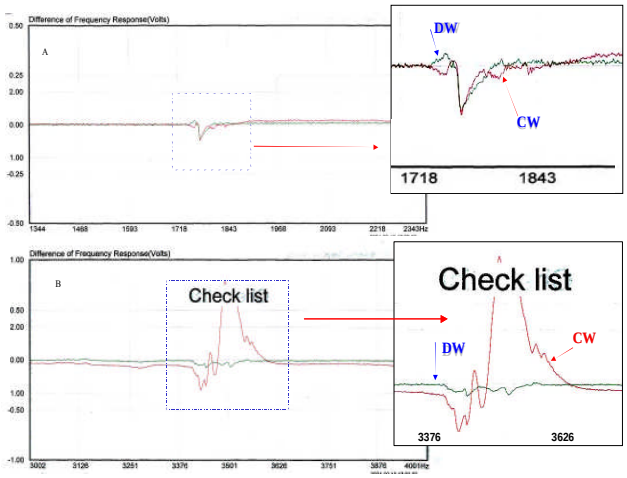

Fig. 2. The resonant frequency valley of CW and DW.

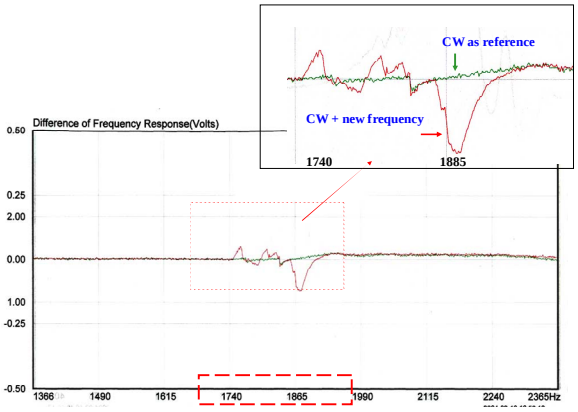

Fig. 3. The resonant frequency valley of new imprinting CW compared with non-imprinted CW.

In order to prove whether the cluster water is able to store frequency information, we divide CW into two parts. One part cluster water was imprinted with an additional low resonant frequency signal, and another part not, but used as reference water. Then we utilize Quantum FAFA analysis equipment to analyze both parts. The results show that several new resonant frequency peaks (1740-1885 HZ) are detected in the new imprinted cluster water sample compared with non-imprinted cluster water as shown in Fig. 3.

The differences are compared between distilled water (DW) and cluster water (CW). It is clear that the resonate frequency valley of CW is significantly different from DW's especially in the range between the 3500HZ and 3628HZ. In order to prove whether the CW is able to store frequency information, we divided CW into two parts. One part of cluster water is imprinted with an additional low resonate frequency signal, and another part not, but used as reference. Then we utilize Quantum FAFA analysis equipment to analyze both solutions. The results show that several new resonate frequency peaks (1740-1885 HZ) are detected in new imprinted cluster water sample compared with non-imprinted clustered water.

According to the preliminary experiment, CW seems able to store and transfer certain frequency information. Since the meridian system consists of protein and cluster water, we can conjecture that it is a water-wire based network system.

2.4 Qi and Meridian system

The word *qi* means vitality, energy, and life force, The Chinese and many oriental people believe that the primary function of qi is a spontaneous balancing and enhancing of the natural healing resources in the human system. Over thousands of years, millions of people have benefited from these practices believing that improving the function of qi maintains good health and heals disease.

Qi is the electromagnetic (EM) standing wave riding on the meridian systems, with acupuncture points as its nodes. The standing wave within each segment of the channel separated by acupuncture points is in natural oscillation thus the segment may be analyzed as a $\lambda/4$ open circuit that behaves like a series RLC resonator. The mechanism of bu (gaining qi) and xie (distributing qi) are charging or discharging the capacitor to bring the capacitor (or inductive) behavior of the segment back to that of the resonant state. Kirlian photograph may serve as a visual observation of the EM waves on channels [4].

In the paradigm of mechanistic Western science, the practice of Qigong triggers a wide array of physiological mechanisms that have profound healing benefits. It increases the delivery of oxygen to the tissues. It helps the elimination of waste and improves the transportation of immune cells through the lymph system. It shifts the chemistry of the brain and nervous system.

We have proposed in our previous paper [7], the meridian system is a good carrier storing and transferring low resonant frequency signals. The function of the meridian system is to maintain the free channels so that the frequency signals, qi and blood can travel all over the body freely. In general the acupuncture treatment is by needling certain acupuncture points in the meridian system to activate certain frequency generator. The generated frequency is passed to the blocked channels, restores or overwrites the distorted frequency signal, and regulates the functions of the target organs. In clinical practice, selecting acupuncture points along the route of channels is important. In addition, we find that traditional Chinese medicine doctors prefer to select acupuncture points distant from affected channel**.** **T**his is because longer distance between an acupuncture point and the disorder area can reduce the effect of distorted frequency to that acupuncture point**.**

In order to model this meridian system, let us take a close look at the meridian system. As shown in Fig. 4, the acupuncture points of the meridian system can be classified into two categories

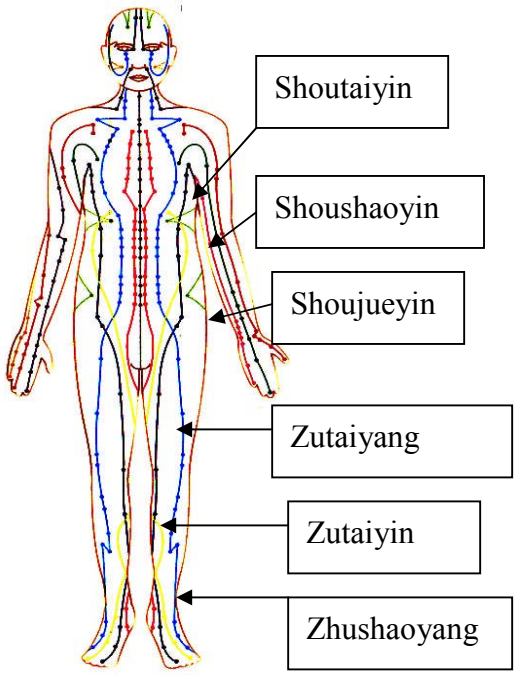

Fig 4. The demonstration of human meridian system.

Category 1. 12 regular channels, that are the major trunks of the system.

- Shoutaiyin (手太阴)
- Shouyangming (手阳明)
- Zuyangming (足阳明)
- Zutaiyin (足太阴)
- Shoushaoyin (手少阴)
- Shoutaiyang (手太阳)
- Zushaoyin (足少阴)
- Zutaiyang (足太阳)
- Shoujueyin (手蕨阴)
- Shoushaoyang (手少阳)
- Zushaoyang (足少阳)
- Zujueyin (足蕨阴)

Note that the original Chinese names in Chinese are given in parentheses.

Each of these meridians is like a macro network. It has its own route and different number of acupuncture points.

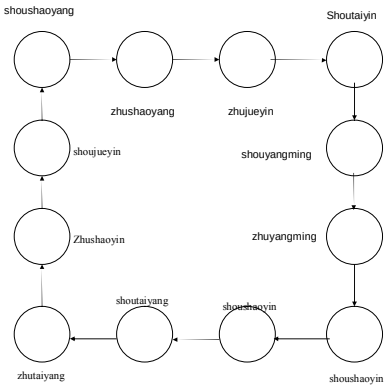

Fig. 5. Basic model of 12 meridians.

But based on each meridian's starting point, termination points, connecting point with other meridians, we can lay out a basic network model as shown in Fig 5. Each node represents a macro network.

Category 2. 8 extra meridians.

- Dumai (督脉)
- Renmai (任脉)
- Chongmai (冲脉)
- Daimai (带脉)
- Yinqiaomai (阴跷脉)
- Yangqiaomai (阳跷脉)
- Yinweimai (阴维脉)
- Yangweimai (阳维脉)

Their courses are unique. The function of these meridians is to help reinforce the communication between them and the twelve principal meridians, strengthening the association between the twelve regular channels. The Dumai and Renmai are most important two among extra 8 meridians. Renmai travels at the front side body, and Dumai travels along the back side of human body.

Among all 400 acupuncture points, they are divided into three degrees of priority:

1. Acupoints of the 14 meridians. Also known as the regular points, they are along the twelve meridians, Dumai and Renmai. As the major part of acupuncture points, they are all have their unique names, locations and pertaining channels.
2. Extraordinary points, that are points with regular names and regular locations. But they are not along the 14 meridians. These points are

especially effective in the treatment of certain diseases.

3. Ashi points. They are also known as tender spots. These points have no specific names and definite locations. These point and other sensitive points, are used for needling.

3 MODELING MERIDIAN SYSTEM WITH PETRI NETS

3.1 Definition of Petri nets

A Petri net can be defined as a particular directed graph populated by four types of objects. These objects are places, tokens, transitions, and directed arcs connecting places to transitions and transitions to places [15].

A marked Petri net Z=(P, T, I, O, m) is a five-tuple where

(1) $P= \{ p_1, p_2,\ldots p_n\}$, $n>0$
(2) $T= \{t_1, t_2,\ldots t_s\}$ $s>0$, with $P \cup T \neq \emptyset$ and $P \cap T=\emptyset$
(3) $I: P\times T\rightarrow\{0, 1\}$
(4) $O: P\times T\rightarrow\{0, 1\}$
(5) $m: P\rightarrow\{0, 1, 2, 3,\ldots\}$

In this definition p_i is called a place, and t_i is called transition. I is input function defining the set of directed arcs from P to T. O is an output function defining the set of directed arcs from T to P. m is an n-dimensional marking whose i-th component represents the number of tokens in the i-th place p_i. m(p) denote the number of tokens in place p.

Pictorially places are represented by circles and transitions by horizontal bars. If I(p, t)=1, a direct arc links from place p to transition t. and If O(p, t)=1, a direct arc links from t to p. A marking assigns to each place a nonnegative integer k. We say that p is marked with k tokens. We place k black dots (tokens) in place p or use a numeral k in a place to represent k tokens.

The behavior of a system can be described in terms of system states and their changes. In order to simulate the dynamic behavior of a system, a state or marking in a PN changes according to the following execution rule:

(1) A transition t is enabled
if and only if $m(p)\geq I(p, t)$, $p \in P$.

(2) An enabled transition t fires at marking m' yielding a new marking
$m(p)=m'(p)+O(p, t)-I(p, t)$ $p \in P$

The marking m is said to be reachable from m'. Given Z and its initial marking m_0, the reach-ability set is the set of all marking reachable from m_0 through various sequences of transition firing denoted by $R(Z,m_0)$, Reach-ability is a fundamental basis for studying the dynamic properties of any modeled system.

A Petri net (Z,m_0) is said to be live if, no matter what marking has been reached from m_0, it is possible to ultimately fire any transition of the net by progressing through some further firing sequences. The liveliness implied that a system is free from deadlock.

A Petri net is said to be B-bounded or simply bounded if the number of tokens in each place does not exceed a finite number B for any marking reachable from m0. A Petri net is said to be safe if it is 1-bounded [15].

3.2 Petri Net Model

We first construct Petri Net models in order to analyze system behavior. A certain order of activities needs to be followed by each acupuncture points of the meridian system. For example the activity sequences of channels should be followed by acupuncture points needled.

Therefore, the first important issue is the modeling of sequential activities. A sequence {insertion, manipulating angle and depth of insertion, retaining and withdrawing} should be followed at each acupuncture point. The Petri net modeling of such sequences given in Fig. 6(a).

The second modeling issue is synchronization. The acupuncture points are on the different meridians. The tokens from different meridians, reach transition ti, and they work together to fire transition t. After firing it, the tokens are sent to the next place. Next channel is then ready and available.

The third one is concurrence. By concurrence we mean that there are parallel relationships among the concerned factors. For example, several needles can be used in different channels simultaneously. They can represent concurrent activities.

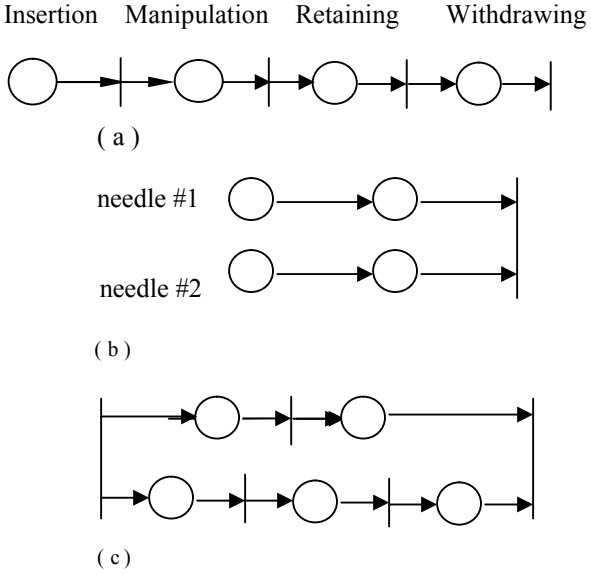

Fig 6. Example of Petri net model: (a) sequence, (b) synchronization, and (c) concurrence.

Given the specification of the meridian system in Section 2, we construct a Petri net based on the following general methodology,

- Identify the acupuncture points.
- Ordering these acupuncture points according to the channel.
- For each acupuncture point or activity in order, create and label a place to represent its status. Add a transition (start activity) with an output arc(s) to the places. Add a transition (stop activity) with an input arc from the place.
- Specify the initial marking.

According to such procedure we design a Petri net model as shown in Fig. 7 and Table 1, on the assumption that all acupunctures points are in the same priority class.

Table 1. Meanings of places and transitions in Fig. 7.

Places	Interpretation
p_1	Macro place of Zujueyin, representing a sequence of acupuncture points on Zujueyin channel
p_2	Macro place of Zushaoyang, representing a sequence of acupuncture points on Zushaoyang channel
p_3	Macro place of Shoushaoyang, representing a sequence of acupuncture points on Shoushaoyang channel
p_4	Macro place of Zushaoyin, representing a sequence of acupuncture points on Zushaoyin channel
p_5	Macro place of Zutaiyang, representing a sequence of acupuncture points on Zuyaiyang channel
p_6	Macro place of Shoushaoyin representing a sequence of acupuncture points on Shoushaoyin channel
p_7	Macro place of Shoutaiyang, representing a sequence of acupuncture points on Shoutaiyang channel
p_8	Macro place of Zutaiyin, representing a sequence of acupuncture points on Zutaiyin channel
p_9	Macro place of Zuyangming, representing a sequence of acupuncture points on Zuyangming channel
$_{10}$	Macro place of Shouyangming, representing a sequence of acupuncture points on Shouyangming channel
Transitions	Interpretation
t_1- t_{10}	Links between each pair of channel
t_{du}	Links between Dumai and meridian channel
t_{ren}	Links between Renmai and Meridian channel

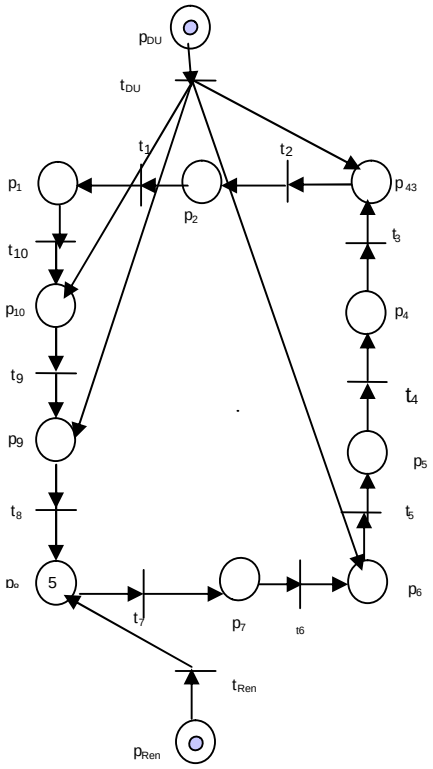

Fig.7. Petri net model of a meridian system.

4. CASE STUDY

4.1 Influenza

Influenza is an acute infectious disease of the respiratory tract due to influenzal virus characterized clinically by sudden onset, high fever, headache, myalgia, acratia, anorexia. It may be accompanied with nasal obstruction, rhinorrhea, cough, and sore throat. Influenza occurs more often in autumn and winter.

Based on the traditional Chinese medicine, there are three major types of influenza.

- Wind-cold type: mild fever, headache without sweating, nasal obstruction, running nose, and soreness of limbs.
- Wind-heat type: High fever, slight aversion to cold, headache, cough, thirst, and sore throat.
- Gastrointestinal type: headache, fever, nausea, vomiting, abdominal pain, and distension.

These three types of influenza are all associated with three meridians. Since they lead to different symptoms, they may need extra token for each type.

Let us take the gastrointestinal type as an example. It is associated with three meridians, and an extra point that does not belong to any meridian. They are:

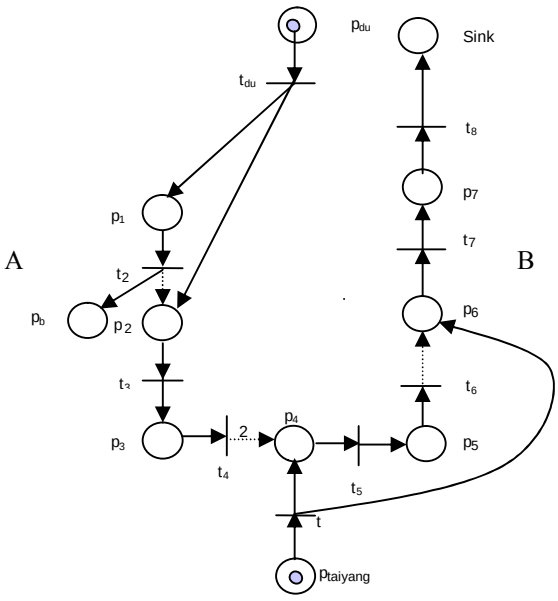

Fig. 8. Petri net model of Influenze.

- Shouyangmin meridian
- Zhuyangming meridian
- Du mai meridian
- Extra point: Taiyang

According to traditional Chinese medicine, this disease is caused by obstructing the flow of qi and blood in the shou channel, since the blockage is formed. Thus qi and blood cannot transfer from one place to another. Hence, if we can resolve the blockage, qi and blood can freely transfer from channel A to channel B. The disease is then cured.

This case involves two channels. In the right side of Petri net model as shown in Fig. 8 and Table 2 is shouyangming channel, a major channel in this case. In the left side is Zhuyangming channel, a secondary channel in this case. Places p_1 through p_7 are local acupuncture points of both channels. Places $p_{1\text{-}3}$ are acupuncture points along the secondary channel. This disease usually caused by transitions t_2, t_4 and t_5 that cannot fire, since all or part of them causes some deadlock in a related channels. This blockage or deadlock prevents qi and blood from freely traveling through the meridian system, specially traveling through ShouYangming channel. This blockage results in influenza. In order to recover from influenza, and remove these blockages, the simplest way is to give a token (needling the acupuncture point) to p_2, p_4, and $p_{taiyang}$. Hence, transitions t_{3}-$_5$ are enabled, and can fire. Then a token is given to $p_{taiyang}$, which enables t_7. Once p_7 receives a token, t_8 can fire and now Petri net becomes live again.

Table 2. Meanings of places and transitions in Fig. 8.

Places	Interpretation
P_1	Local acupuncture point of Zuyangming channel (Acupuncture pointZushanli)
P_2	Local acupuncture point of Zuyangming channel (Acupuncture point Tianshu)
P_3	Extra point not belong to any meridian (Acupuncture point Asi)
P_4	Local acupuncture point of Zuyangming channel (Acupuncture point Taiyang)
P_5	Local acupuncture point of Shouyangming channel (Acupuncture point Hegu)
P_6	Local acupuncture point of Zuyangming channel (Acupuncture point Shaoshang)
P_7	Local acupuncture point of Dumai channel (Acupuncture point Quchi)
P_{DU}	Next to local acupuncture point of Dumai channel.
P_b	Blocking point

A token inside places can be a token with parameters: such as depth, vibration, time, and direction respectively.

5. DISCUSSION

This paper for the first time proposes to use Petri nets to model the Meridian system. The research is concerned with the mathematical analysis of a meridian system. It is a long-term project, which on the one side is practical, and on the other side involves deep and nontrivial mathematics. Our future research plan consists of continuation of the current project. Briefly, the ongoing work includes expanding the research to the whole meridian system. The future work intends to

a) Complete the Petri nets model for whole meridian system. This will be a complete model developed using Petri nets to describe the bio-signal information generation, storage, and transfer inside human body;
b) Extend the current research to a new generation model. The model will employ the color token concept and model various parameters into the token. We can then use such model to analyze the different parameters used in each process, and how they impact each other; and
c) Develop new multidisciplinary experiments for both applied mathematic analysis and bio-signal engineering devices.

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Jingong Pan received his B.S. degree in Computer Engineering and M.S. degree in System Engineering, respectively in 1982 and 1994 from Harbin Institute of Technology, China, M.S in computer Engineering in 2002 from New Jersey Institute of Technology, USA.

He is Ph.D candidate of Computer Engineering in New Jersey Institute of Technology. He is receipient of first place of Best Paper Award from 2003 and 2004 CIE Annual Conferences, He is a student member of IEEE.

MengChu Zhou received his B.S. degree from Nanjing University of Science and Technology, Nanjing, China in 1983, M.S. degree from Beijing Institute of Technology, Beijing, China in 1986, and Ph. D. degree in Computer and Systems Engineering from Rensselaer Polytechnic Institute, Troy, NY in 1990. He joined New Jersey Institute of Technology (NJIT), Newark, NJ in 1990, and is currently a Professor of Electrical and Computer Engineering and the Director of Discrete-Event Systems Laboratory.

His research interests are in computer-integrated systems, Petri nets, semiconductor manufacturing, multi-lifecycle engineering, and system security. He has over 200 publications including 5 books, over 70 journal papers, and 14 book-chapters. He co-authored with F. DiCesare Petri Net Synthesis for Discrete Event Control of Manufacturing Systems, Kluwer Academic, Boston, MA, 1993, edited Petri Nets in Flexible and Agile Automation, Kluwer Academic, 1995, co-authored with K. Venkatesh Modeling, Simulation, and Control of Flexible Manufacturing Systems: A Petri Net Approach, World Scientific, 1998, and co-edited with M. P. Fanti, Deadlock Resolution in Computer-Integrated Systems, Marcel Dekker, 2005.

He was invited to lecture in Australia, Canada, China, France, Germany, Hong Kong, Italy, Japan, Korea, Mexico, Taiwan, and US. He served as Associate Editor of IEEE Transactions on Robotics and Automation from 1997 to 2000 and currently Managing Editor of IEEE Transactions on Systems, Man and Cybernetics: Part C, Associate Editor of IEEE Transactions on Automation Science and Engineering, and Editor-in-Chief of International Journal of Intelligent Control and Systems. He was General Co-Chair of 2003 IEEE International Conference on System, Man and Cybernetics, Washington DC, October 5-8, 2003 and 2004 IEEE Int. Conf. on Networking, Sensors and Control, Taipei, March 21-23, 2004. He organized and chaired over 70 technical sessions and served on program committees for many conferences. He was Program Chair of 1998 and Co-Chair of 2001 IEEE International Conference on System, Man and Cybernetics (SMC) and 1997 IEEE International Conference on Emerging Technologies and Factory Automation, and Guest Editors for IEEE Transactions on Industrial Electronics, and IEEE Transactions on Semiconductor Manufacturing. He is General Chair of 2006 IEEE Int. Conf. on Networking, Sensors and Control, Miami, FL, April 2006.

Dr. Zhou has led or participated in twenty-six research and education projects with total budget over $10M, funded by National Science Foundation, Department of Defense, Engineering Foundation, New Jersey Science and Technology Commission, and industry. He was the recipient of NSF's Research Initiation Award, CIM University-LEAD Award by Society of Manufacturing Engineers, Perlis Research Award by NJIT, Humboldt Research Award for US Senior Scientists, Leadership Award and Academic Achievement Award by Chinese Association for Science and Technology-USA, Asian American Achievement Award by Asian American Heritage Council of New Jersey, and Outstanding Contribution Award from IEEE SMC Society. He is named Distinguished Lecturer of IEEE SMC Society for 2005-2006. He was the founding chair of Discrete Event Systems Technical Committee of IEEE SMC Society, and Co-Chair (founding) of Semiconductor Factory Automation Technical Committee of IEEE Robotics and Automation Society. He is Fellow of IEEE and a life member of Chinese Association for Science and Technology-USA.