Application of Pneumatic Muscle Actuator to Pulse Diagnosis System of Chinese Therapy

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In this paper, a rotational pneumatic muscle actuator (PMA) is applied to build a brand new pulse diagnosis system for the traditional Chinese therapy (TCT). In traditional Chinese therapy, a doctor uses his/ her fingers to press the patient's artery on the radial bone in order to feel the pulse signal of the patient. Based on empirical judgment, the doctor can realize and point out what kind of physical condition the patient is suffering from. However, this kind of pulse-sensing diagnosis technique relies mainly on the subjective feeling from the doctor's fingers. Therefore, it is possible that different doctor might have a different viewpoint for the same pulse signal. In this study, a well-accepted hypothesis of Organ-Resonance will be introduced to build the complete pulse diagnosis system for TCT. The rotational PMA proposed in this paper serves to imitate the finger motion of a TCT doctor. In addition, the spectrum theory and Fast Fourier Transform (FFT) are also employed to compute and acquire the biological message hidden behind the detected time-domain pulse signal. Finally, experimental results prove the validity of the presented automatic pulse diagnosis system for TCT.

Keywords: Pneumatics, Pneumatic Muscle Actuator, Chinese Therapy, Pulse Diagnosis, Fast Fourier Transform
Target audience: Pneumatic Industry, Welfare Industry, System Integration

1 Introduction

The pneumatic muscle actuator (PMA) is a soft, deformable fluid actuator able to contract and to exert a tension force when supplied with a given air pressure. One advantage of the PMA is its ability to simulate the real human muscle behaviours and motions. Therefore, it has been widely discussed and researched during the past several years [2-8]. On the other hand, due to its soft surface, the PMA can work with human, contact the human body and handle fragile objects. Consequently, such an actuator already finds many applications in the field of medical engineering, medical welfare system and so on. In this paper, an automatic pulse diagnosis system for traditional Chinese therapy (TCT) is designed and implemented. The main idea of this design is depicted in Fig. 1. More details will be described as follows. In the TCT, a doctor uses his/ her fingers to press the patient's artery on the radial bone in order to feel the pulse signal of the patient as shown in Fig 1 (b). Based on empirical judgment, the doctor can realize and point out what kind of physical condition the patient is suffering from. Though this kind of pulse-sensing diagnosis technique is quite popular because it is non-invasive, such a diagnosis, however, relies mainly on the subjective feeling from the doctor's fingers. Therefore, it is possible that different doctor might have a different viewpoint for the same pulse signal. It is also worth mentioning that such a questionable situation has been lasting for hundreds of years. Nowadays, scientists are still trying to establish an objective and quantitative standard for those TCT doctors. In this study, a well-accepted hypothesis of Organ-Resonance /1/ will be introduced to build the complete pulse diagnosis system for TCT. In addition to this hypothesis, the proposed rotational PMA shown in Fig 1 (a) also plays an important role in designing the automatic pulse diagnosis system. It serves to imitate the finger motion of a TCT doctor as shown in Fig 1 (c). The spectrum theory and Fast Fourier Transform (FFT) are also used to compute and acquire the biological message hidden behind the detected time-domain pulse signal. In the following, the introduction of PMA will firstly be outlined.

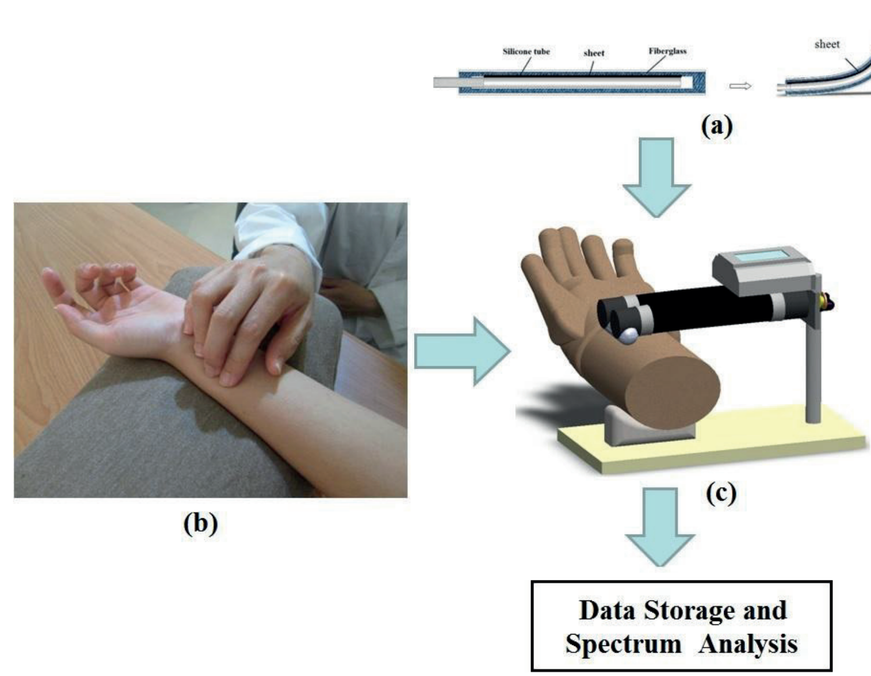


Figure 1: Main idea of this study - Scheme of the pulse diagnosis system of traditional Chinese therapy.

2 Translational and Rotational PMA

Figure 2 shows the basic translational type of PMA. It consists of silicon rubber tube covered with a thin fiber-glass layer. When the compressed air is supplied to the PMA, it contracts in the axial direction as shown in Fig. 2. The contraction length reaches 10 mm corresponding to maximal inlet pressure of 6 bar. Another commonly used PMA is the rotational type as shown in Fig. 3. Compared to scheme shown in Fig. 2, an extra thin metal sheet is inserted between the silicon rubber tube and fiber-glass surface. Since the metal sheet is not deformable, the PMA rotates when the compressed air is supplied as shown in Fig. 3. The rotational angle reaches 30° when the inlet pressure is the maximal 6 bar as shown in Fig. 4.

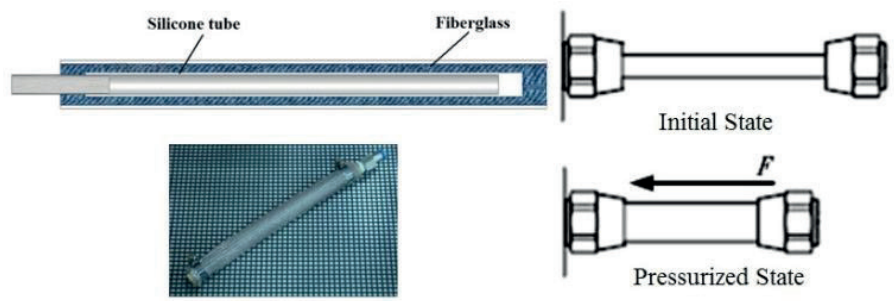


Figure 2: Translational PMA.

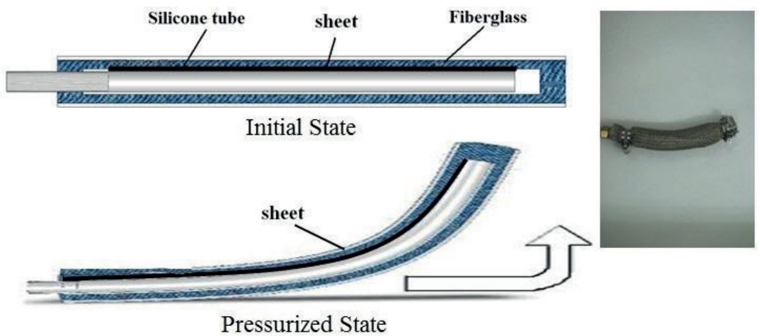


Figure 3: Rotational PMA.

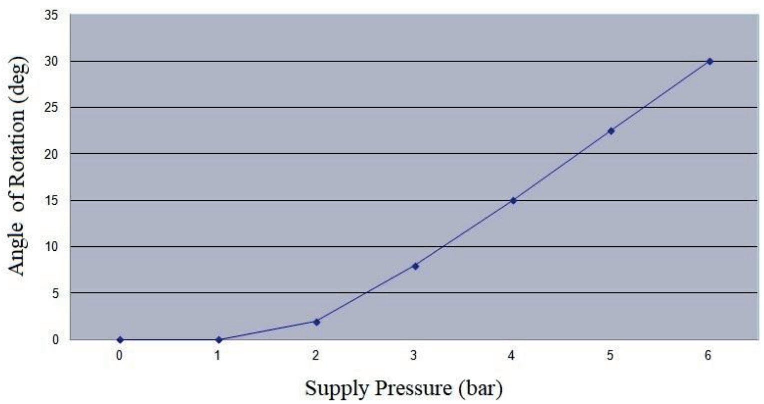


Figure 4: Rotational angle as a function of supply pressure.

3 The Automatic Pulse Diagnosis System

Figure 5 shows the schematic hardware of the developed automatic pulse diagnosis system for TCT, in which a proportional pressure control valve together with a LabVIEW software control program are utilized. Through the precise control of the proportional pressure control valve, the rotational PMA is able to simulate three operations in TCT, including the Light Touching (155 mmHg), Moderate Feeling (165 mmHg) and Heavy Pressing (175 mmHg) as shown in Fig. 6. Finally, the Fast Fourier Transform (FFT) package provided by LabVIEW toolbox is used to compute and acquire the biological message hidden behind the detected time-domain pulse signal.

In this study, a well-accepted hypothesis of Organ-Resonance is introduced to build the complete pulse diagnosis system for TCT. In addition to this hypothesis, as mentioned previously, the proposed rotational PMA also plays an important role in designing the automatic pulse diagnosis system as shown in Fig. 5. It serves to imitate the finger motion of a TCT doctor. Figure 7 depicts the details of the hypothesis of organ resonance. It is proposed that every organ in human body has a corresponding resonance peak in the spectrum diagram derived from the time-domain pulse signal. For example, the first resonance peak represents the heart and the second resonance peak represents the liver, and so on. Thus, it is basically possible to diagnose the health condition of a human by evaluating the change of peak value of these resonant waves.

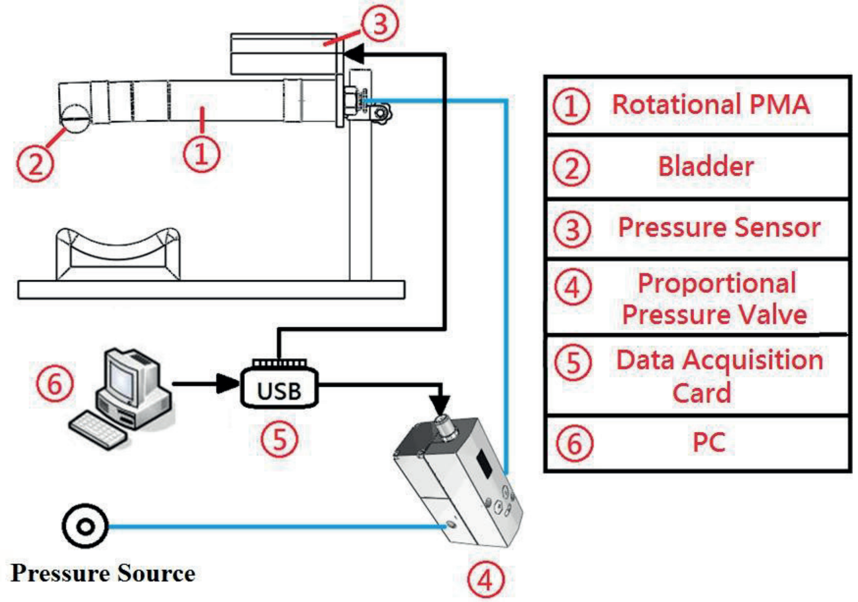


Figure 5: Hardware of the developed automatic pulse diagnosis system.

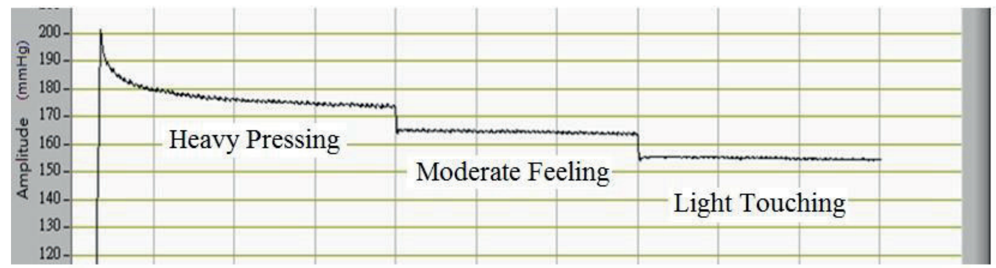
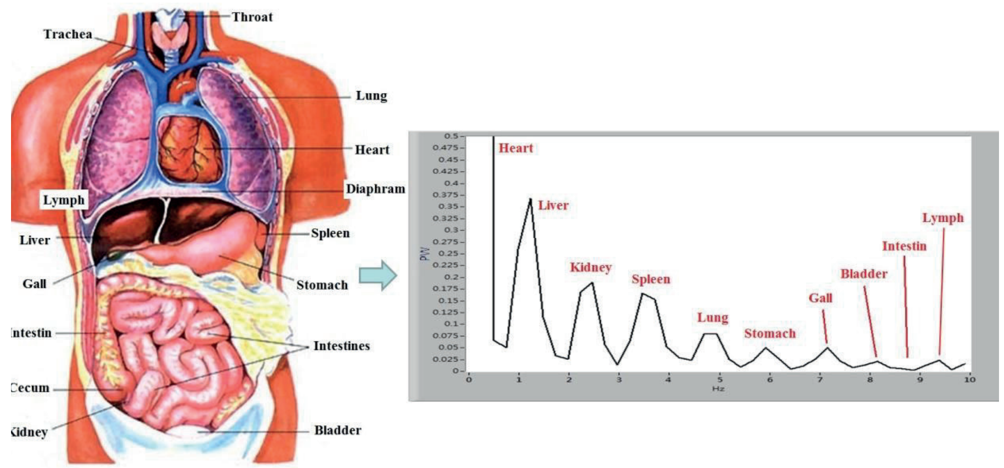


Figure 6: Three operations in traditional Chinese therapy.



4 Experimental Test Results

Due to the medical law that prohibits any medical experiment on a sick person without prior permission, an alternative simple test program for a healthy person is utilized to examine the validity of the proposed automatic pulse diagnosis system for TCT. The detailed test program is described as follows. At the beginning, a first measurement of the time-domain pulse signal for a healthy person is executed. Then the tested healthy person runs continuously for 30 minutes. After the running, the tested healthy person takes a rest for 10 minutes. Finally, the second time-domain pulse signal is measured. Through the FFT analysis, the spectrum diagrams of the first and second measurements can be derived. The basic idea of these tests is trying to diagnose the health/organ condition of the tested healthy person by evaluating the changes of peak value of the resonant waves between the first and second spectrums. Figure 8 shows the measured first and second time-domain pulse signals. Clearly, it is quite difficult to tell the differences between these two time-domain pulse signals. However, through the spectrum analysis and FFT technique, the differences of the resonant peak values are quite obvious as shown in Table 1. It is worth mentioning that the peak value of the first resonance (representing the heart) is normalized to be unity, and the other peak values are relative and dimensionless.

After careful examination of the experimental results shown in Table 1, it is observed that the peak value of the second resonance (representing the liver) increases significantly after the test program. In the meantime, all other peak values change slightly only. From the viewpoint of TCT, the change of one resonant peak value indicates that the condition of its corresponding organ changes as well. As a matter of fact, the reason why a TCT doctor uses his/ her fingers to press the patient's artery on the radial bone is exactly the effort to acquire these resonant peak values. Consequently, the doctor can precisely point out what kind of physical condition the patient is suffering from.

On the other hand, it has to be explained why only the peak value of the second resonance changes significantly. It is well-known that, during any body exercise like the running, the liver glycogen has to be consumed and converted to energy for supporting the body exercise and to maintain the blood-sugar balance. Thus, it is reasonable to believe that the liver is a very busy organ to do such energy or calorie transformation. Therefore, among all resonant peak values, the second one representing the liver changes significantly.

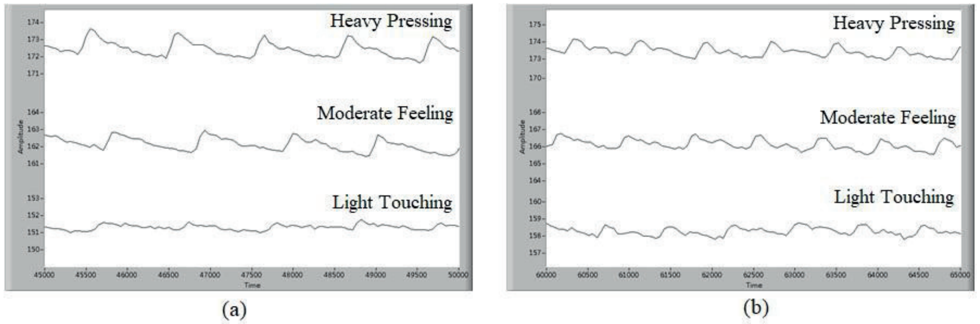


Figure 8: (a) The first time-domain pulse signals (before running), (b) the second time-domain pulse signals (after running).

	Heavy Pressing	Moderate Feeling	Light Touching
Heart	1.000	1.000	1.000
Liver	0.454	0.469	0.501
Kidney	0.377	0.341	0.401
Spleen	0.179	0.224	0.246
Lung	0.111	0.151	0.134
Stomach	0.128	0.121	0.212
Gall	0.073	0.085	0.143
Bladder	0.049	0.065	0.156
Intestin	0.052	0.049	0.168
Lymph	0.014	0.082	0.117

(a)

	Heavy Pressing	Moderate Feeling	Light Touching
Heart	1.000	1.000	1.000
Liver	0.628	0.609	0.896
Kidney	0.476	0.395	0.446
Spleen	0.170	0.186	0.193
Lung	0.051	0.108	0.190
Stomach	0.091	0.200	0.183
Gall	0.115	0.151	0.131
Bladder	0.065	0.070	0.200
Intestin	0.056	0.112	0.107
Lymph	0.053	0.082	0.052

(b)

Table 1: Resonant peak values after FFT, (a) before running and (b) after running.

5 Summary and Conclusion

In this paper, a brand new pulse diagnosis system for the traditional Chinese therapy using a soft rotational pneumatic muscle actuator is developed. After real tests, this system is proved to be successful and satisfactory. Besides, three conclusions may also be drawn from this research.

1. Using the spectrum theory and Fast Fourier Transform together with the hypothesis of Organ-Resonance, it is possible and successful to acquire the biological message hidden behind the measured time-domain pulse signal.
2. A feasible, objective and quantitative model for the traditional Chinese therapy is proposed and successfully implemented, which is expected to overcome the inherent disadvantages of traditional Chinese therapy, such as over-subjective dilemma and not precise diagnosis.

3. The soft pneumatic muscle actuator is again proved to be very suitable for the welfare and medical applications.

6 Acknowledgements

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References

/1/ Huang, J. M., Spectrum Diagnosis of Chinese Therapy, Chi-Yin Publishing Company, Taiwan (in Chinese), 2001.

/2/ Renn, J. C., Li, B. H., "A Robot Arm Based on Parallel Pneumatic Flexible Muscle Actuators," Proc. of the 2nd International Conference on Precision Machinery and Manufacturing Technology (ICPMMT), Paper No.: 29, Kenting, Taiwan, 2017.

/3/ Masaya, A., 2008, "Power Assist Wear for Upper Limb Driven by Sheet-Like Pneumatic Rubber Muscle," Proceedings of 7th JFPS International Symposium on Fluid Power, Vol. 1, pp. 787-792, Toyama, Japan.

/4/ Caldwell, D.G., Tsagarakis, N., Medrano-Cerda, G. A., Schofield, J., and Brown, S., 2001, "A pneumatic muscle actuator driven manipulator for nuclear waste retrieval, "Control Engineering Practice, Vol. 9, pp. 23-36.

/5/ Sasaki, D., Noritsugu, T. and Takaiwa, M., 2011, "Development of wearable master-slave training device for upper limb constructed with pneumatic artificial muscles," Proceedings of 8th JFPS International Symposium on Fluid Power, paper No.: 1A2-2, p. 18, Okinawa, Japan.

/6/ Tadano, K., Araya, H., Kawashima, K., Youn, C. and Kagawa, T., 2011, "Development of jump assist system using pneumatic artificial rubber muscle," Proceedings of 8th JFPS International Symposium on Fluid Power, paper No.: 2D3-3, p. 91, Okinawa, Japan.

/7/ Liu, H., Zhang, D., Zhao, Y. and Li, Z., 2014, "Design and control of an upper-limb power-assist exoskeleton driven by pneumatic muscles,' Proceedings of 9th JFPS International Symposium on Fluid Power, paper No.: 3C2-1, p. 125, Matsue, Japan.

/8/ Mori, K., Wakimoto, S., et al., 2014, "Development of thin McKibben artificial muscle and its application to biomimetic mechanism," Proceedings of 9th JFPS International Symposium on Fluid Power, paper No.: 1B2-3, p. 26, Matsue, Japan.