A Microprocessor-Based Wrist Pulse Simulator for Pulse Diagnosis in Traditional Chinese Medicine

Steven McLellan[1], Christina Liese[1], Melissa Andrews[1], Mona Boudreaux[2], G.F. Boudreaux-Bartels[1], Eugene Chabot[1], & Ying Sun[1]
[1]Department of Electrical, Computer, and Biomedical Engineering,
University of Rhode Island, Kingston, RI 02881-0805 USA
[2]A Time to Heal, Wonder Lake, IL 60097 USA

Abstract— **Pulse diagnosis has been an important practice in traditional Chinese medicine for diagnosing various diseases. It is based on the patterns of blood pressure pulses at the wrist felt with three fingers. The device developed in this study mimics the outward forces generated by blood flow patterns through the radial artery. The embedded system platform allows for the implementation of various pulse patterns in response to the depression pressure of the fingers. The resulting pulse simulator is useful for demonstrating and teaching the art of pulse diagnosis.**

Keywords— ***pulse diagnosis; simulator; pulse patterns; blood pressure; traditional Chinese medicine***

I. Introduction

The ability to diagnose a disease based on the arterial pulse patterns that can be felt in the wrist is a method often referred to as pulse diagnostics originating from the traditional Chinese medicine. In the area of pulse diagnostics, as many as 29 patterns have been identified and related to diagnosis of a wide range of diseases and conditions [1],[2]. These range from detecting liver and gall bladder diseases to detecting pregnancy [3]. In order to distinguish between these patterns, six characteristic qualities of the wrist pulse patterns have been defined including pulse width, depth, strength, rate, length, and rhythm [4]. The detection of these pulse patterns requires the use of three fingers (index, middle, and ring fingers) placed over the radial artery at the wrist of the subject. Three different pressures (light, medium, and high) are applied to the artery to reveal different responses [5].

Despite the relatively large number of pulse patterns, frequently encountered patterns are fewer than 10. Thus, some of the rarely encountered pulse patterns are difficult to demonstrate. The purpose of the presented work is to create a device that simulates the pulse patterns for the purposes of demonstrating and teaching the art of pulse diagnosis.

II. Methods

A. Device Design

As shown by the block diagram in Fig. 1, the mechanical part of the system consists of three solenoids presenting the pulse waveforms to the three fingers that feel the pulses. The electronic part of the system consists of a microprocessor that

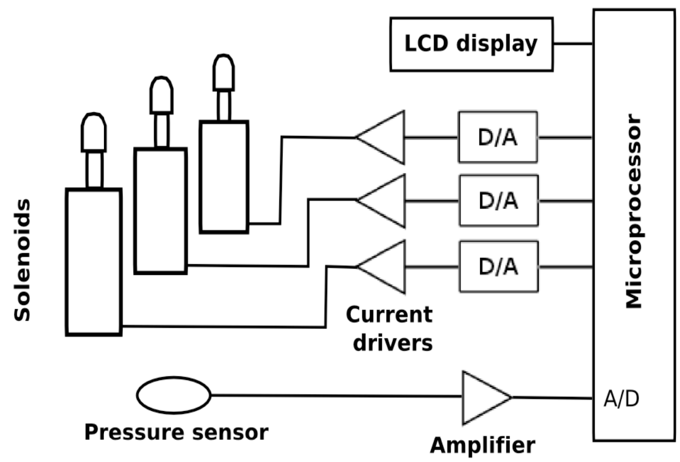

Fig. 1. Block diagram of the pulse simulator.

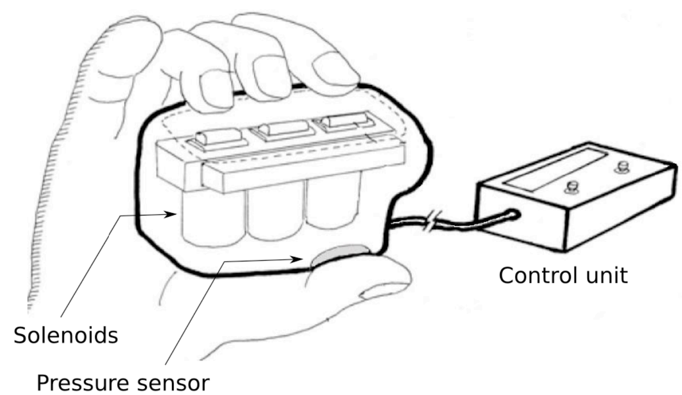

Fig. 2. Schematic diagram of the pulse simulator.

outputs the stored digital pulse waveforms to the solenoids via three digital-to-analog (D/A) converters. A pressure sensor detects the gripping forces applied to the simulator. The pressure is sensed by the microprocessor and evokes different responding pulse waveforms. As shown by the schematic diagram in Fig. 2, the overall device is composed of two subunits connected via a cable. One enclosure contains the solenoids in a stable position creating an artificial wrist model made of silicon. The wrist model has a pressure sensor at the base for the user to apply pressure with their thumb while measuring the wrist pulse. When more pressure is applied with the thumb, the pulse either increases or decreases in strength which varies with the selected mode. The user places three fingers, as is the standard practice for pulse diagnostics, to measure the pulse characteristics. The pistons of the solenoids generate forces corresponding to the pulse waveforms through a thin layer of the encasing silicone rubber. A second component is the control unit that provides user interventions through a LCD display and push buttons. The control unit also contains the microprocessor, the electronics, and a battery power source.

B. *Pulsatile Waveform Generation*

The microprocessor based system manipulates a series of solenoids creating the pulses of these waveforms. Of the six pulse characteristic quantities, the pulse width is related to the width of the artery, which is not represented in the current system. The strength is represented by the stroke distance of the solenoid's piston. The pulse depth is represented by varying the waveforms in response to the applied pressure measured with the pressure sensor. The rate is controlled by the microprocessor, which sets the playback sampling frequency of the stored digital waveforms. The length represents the duration of one pulsation, which is controlled by the duty cycle of the stored waveforms and the playback frequency. The rhythm is represented by the irregularity of repeating the playback waveform. A condition of irregular rate (arrhythmia) can be introduced by randomizing the playback frequency each time the waveform corresponding to a cardiac cycle is repeated.

C. *Hardware and Software*

The pulse simulator system was developed by use of a PIC microprocessor (PIC18H4525, Microchip, Chandler, AZ). The software was coded in the C language using the MPLab development tool (Microchip, Chandler, AZ). The software algorithms include the retrieval of pulse waveforms from lookup tables, a real-time playback engine driven by timer interrupts, the applied pressure measurement via the on-chip analog-to-digital converter, and schemes for varying the pulse magnitudes and playback rates.

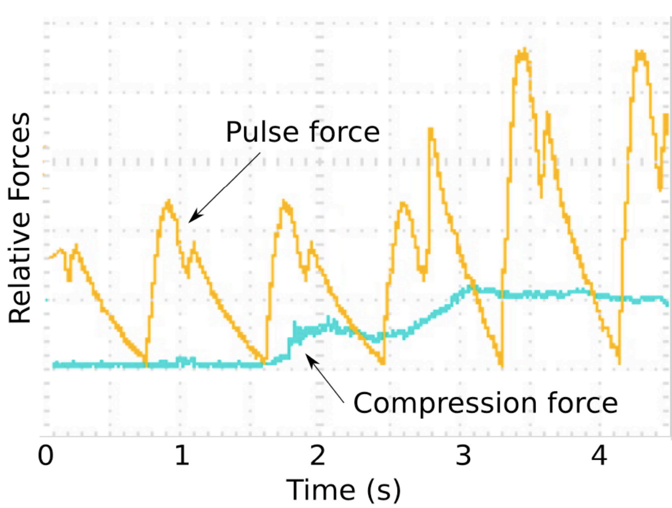

Fig. 3. Playback pulse waveform (orange) was altered by the compression force (blue) detected by the pressure sensor.

III. Results

The hardware and software of the pulse simulator system have been successfully implemented. The force waveforms generated by the solenoids resemble the actual pulses felt at the wrist. As shown in Fig. 3, the pulse waveforms can be programmed to respond to the applied pressure in a dynamic way. For this example, the magnitude of the pulse waveform increases in response to an increase in the gripping pressure. This represents a typical pulse pattern of a healthy subject that shows an increase in strength when the fingers are pressed down harder on the radial artery.

For the current implementation, a total of three different force waveforms are implemented, which include a normal depth pulse, a deep pulse, and a floating pulse. The same waveform is applied to all three solenoids but with a delay of 1 ms between adjacent solenoids. For rate variations a total of four rhythms are implemented, which include normal heart rate, bradycardia, tachycardia, and arrhythmia. Thus, the current system can switch among 12 different pulse patterns (3 waveforms x 4 rhythms). For the normal depth pulse, there is a maximum amplitude at mid-range pressure. The superficial or floating pulse has a maximum amplitude at low pressure and the deep pulse has a maximum amplitude at higher pressure. The user interface allows for the selection of the playback pattern, which is shown on the LCD display.

IV. Discussion

In this study an instrument has been developed to simulate the wrist pulse patterns used in the pulse diagnosis of the traditional Chinese medicine. The project has resulted in an embedded system that produces three force waveforms via three solenoids in response to the applied gripping pressure. The playback rate of the waveforms can also be programmed to reflect either normal or abnormal heart rhythms. To our knowledge, this is an innovative device that provides a unique opportunity for training practicians of pulse diagnostics.

Future work is planned to implement additional pulse diagnostic characteristics including frail, wiry, rolling, and choppy pulses through software modifications. In order to address the pulse width characteristic, further hardware design changes are necessary as the current design utilizes fixed-size pistons. Improvements on the user interface are also considered to show the pulse waveforms on a graphic LCD display and to provide more descriptive information about the pulse patterns.

References

[1] S. Walsh, E. King. Pulse Diagnosis: A Clinical Guide. 1st edition. Publisher: Churchill Livingstone. December 2007.

[2] B. Flaws. The Secret of Chinese Pulse Diagnosis. 2nd edition. Boulder, CO: Blue Poppy Press. March 1997. Wiley.

[3] A. Stone. Pulse diagnosis made ridiculously simple. Retrieved from TCM TV. http://HealthStream.tv, February 23, 2010.

[4] G. Maciocia, S.X. Ming. Pulse Diagnosis in The Foundations of Chinese Medicine, China, Elsevier, 2005.

[5] Diagnostics of Traditional Chinese Medicine. Xue Yuan Academy Press, 2002.