Dr.Chi

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List

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Abstract

In the Traditional Chinese Medicine, doctors diagnose patients by reading pulses from their wrists, so as to give out proper receipts of herbs curing patients across generations. In our capstone project, a mobile app with sensor gadget has been developed to detect, gather, convert and process pulse signals, and offer users valuable health suggestions. To get accurate pulse signals from wrists, several sensor prototypes have been developed and prototyped. The best-performing sensor, a piezoelectric sensor, is chosen and implemented in detail. Pulse data was processed to extract a stable pulse signal, in aspects of: amplitude of peak signal, and signal time period. From this information the app makes 'diagnoses' about the stress level and health condition of different organs of users. Finally, our mobile app delivers feedback to users, guiding them to healthier lives. The price of the Dr. Chi hardware, and mobile app is projected to be 30 dollars, and so promises to be orders of magnitudes more affordable than existing products for convenient health diagnoses.

Introduction

According to Traditional Chinese Medicine Methods, herbalist doctors use their fingers to feel the arterial pulse from patients' wrist. Doctors use this to diagnose patients and provide health suggestions, in a process called pulse examination. By reading pulses, herbalist doctors can gather information about blood and assess pulse quality, which indicate the condition of several internal organs. In ancient China, patients went to herbalist doctors because the pulse examination works as an efficient method of diagnosing patients and helping people live healthier lives.

Nowadays, people are always busy with heavy work load, On the other hand, they are more aware of the importance of keeping healthy. This is the reason why we chose to develop our product- Dr.Chi, a mobile app. With Dr. Chi, people can read their pulses and get suggestions, fostering overall health change. In our project, we focus on measuring users' stress levels, which helps people to adjust their daily habits to balance their stress level so as to stay healthy.

Specifically, a prototype of our piezoelectric sensor is built-on the SDT1-028K platform and a mobile app is developed for signal processing and pulse examination, which offers users a convenient way to get advice for their health condition.

Chapter 1, Literature Review, introduces pulse reading in Traditional Chinese Medicine, which are the foundation of our mobile app. In addition, we have conducted a detailed survey about competing products in the market, which helps us target a specific market niche.

Chapter 2 describes our design approach. In order to build sensor hardware for sensing the pulse signal data, different types of pulse sensors and circuits were explored, prototyped and characterized. To get pulse data in PC, we use Python to collect real-time data from an Arduino microprocessor, and used Matlab to process data into usable stress level information. To communicate with the iPhone, we use Hijack as a connection device, which is based on TinyOS and nesC programming.

Chapter 3 analyzes hardware design and software performance results. It turns out that the optical sensor is not suitable because there is few related tissue on wrists. Therefore the piezoelectric sensor is chosen, and a prototype is made.

Chapter 1: Literature Review

1.1 Pulse Reading in Traditional Chinese Medicine Theory

According to the Traditional Chinese Medicine, there are three finger positions on human's wrist as figure 1: Distal (Cun), Middle (Guan), and Proximal (Chi), related to different internal organs.

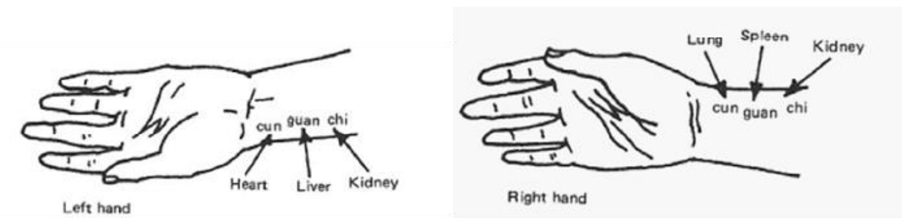


Figure1. Three position on every write for pulse reading

Also, herbalist doctors need to measure pulses at three different pressures to gather enough information: Superficial depth (skin level, surface of artery), Middle depth (muscle level, blood flow through artery), and Deep depth (bone level, bottom of vessel). According to the data obtained, amplitudes of peak and through, pulse frequencies and rhythms indicate patients' physiological and pathological states.

1.2 Overview of Some Existing Products in Market

Industry leaders, such as GE health[9], provide professional pulse reading devices like the one shown in figure 2. However, they are expensive, costing several hundred dollars. Also, they are large and heavy, limiting their mobility.

Figure 2 Professional device from GE

Figure 3. Two existing mobile app for pulse reading

There also exist several mobile apps[10] for getting pulse signals and providing health condition signals and feedback. They are free for basic functions and charge for more complicated applications.

However, there are common disadvantages for these mobile apps. They use an internal camera as a sensor to get pulse data. This approach is convenient but cannot provide precise pulse data, or even the correct pulse rate. Camera-based sensing reports different pulse rate results every time, even for the same person. Without consistency, it is clear that these mobile apps are 'just for fun.'

Moreover, they cannot provide pulse figure including detailed pulse signal information. Some mobile apps claim to plot pulse signal, but we find that those pulse signal figures are just repeated pulse-like plots to make the mobile interface friendlier and more vivid. Generally, existing mobile apps sense only a blurry pulse frequency/ rate.

What’s more, existing mobile apps just provide pulse rate and there is limited analysis based on captured pulse signals. Based on traditional Chinese medicine theory, we can analyze different organs’ health conditions from a series of detailed pulse signals, and offer feedback and health suggestions for users. This approach offers our application unique advantages in the current market.

Chapter 2: Approach

2.1 Sensor Choices and Circuit Design

In order to analyze pulses according to Traditional Chinese Medicine Theory, we first need to acquire accurate high SNR pulse signals. After surveying different types of sensors, we concluded that optical sensors and piezoelectric sensors were the most promising choices. However, we did not know if they could actually deliver accurate pulse signals from wrists, so we developed prototypes first.

2.1.1 Piezoelectric Sensor

The principle of how a piezoelectric sensor works is that the voltage V at the output terminal is proportional to the applied force, pressure, or strain at the input. The output signal is then related to this mechanical force as if it had passed through the following equivalent circuit. The schematic symbol and equivalent electronic model of a piezoelectric sensor is modeled as following. [3]

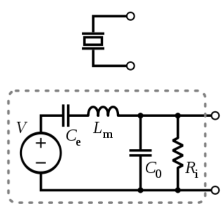


Figure 4 Electronic model of piezoelectric sensor

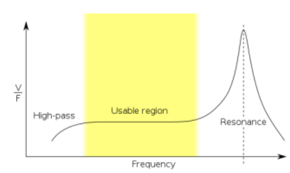


Figure 5 Frequency response of a piezoelectric sensor

The goal for this circuit design is to get accurate pulse signals with less and smaller electronic circuit components. Typically, for a given sensor, the flat region of the frequency response plot is selected as the sensor's operation region, between the high-pass cutoff and the resonant peak. Therefore, circuit design should enable the piezoelectric sensor to operate in this usable region and amplify the pulse signal.

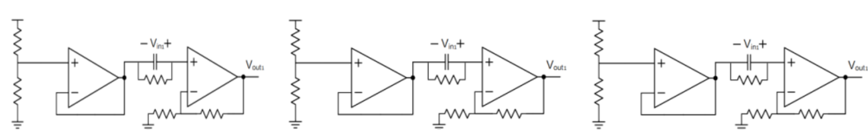


Figure 6 circuit schematic for piezoelectric sensor signal

Different circuit designs have been tried and we figured out that the Instrument amplifier has the better performance. Figure 6 is a circuit schematic of the amplifier topologies being used in the circuit. First, two resistances connected in series with a buffer provide the operating voltage point for the following circuit. A resistance with large values (we use 10M Ohm), is connected in parallel to acquire the output of the sensor.

We use a non-inverse amplifier, which has higher impedance, to absorb less current from the sensor. We selected the TLC277CP instrument amplifier because it has higher slew rate and higher gain as well as the capability of keeping the SNR remains high.

There is an integrated piezoelectric sensor[2] available in the market as well. Based on traditional Chinese medicine theory, as mentioned earlier, we need to get pulse data from three positions on the wrist. This integrated piezoelectric sensor is too big for our capstone project. And also it is too expensive, $59 for one, $177 for three. Since our aim is to develop a marketable product, this cost is too expensive and so we make our own pulse sensor prototype.

Figure 7 integrated piezoelectric sensor

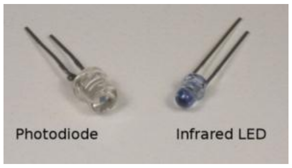


Figure 8 two important components for optical sensor

2.1.2 Optical Sensor

The principle of optical sensor is that certain amount of light energy from infrared will be absorbed by blood cells and the remaining amount of light will be bounced back and received by the photodiode. Based on the amount of light bounced back, we can calculate the flow of blood, which is directly related to heart beat.

Joel Murphy and Yury Giyman have developed open source optical pulse sensors [1]. They claim that this sensor can get heart rate easily and it can be used to develop related application.

Figure 9. Open source optical sensor sold

by Joel Murphy and Yury Giyman

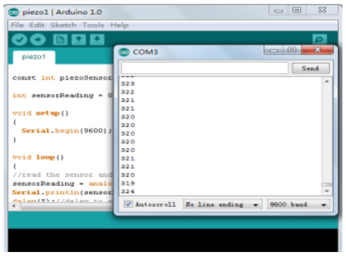


Figure 10 Arduino develop environment and serial monitor

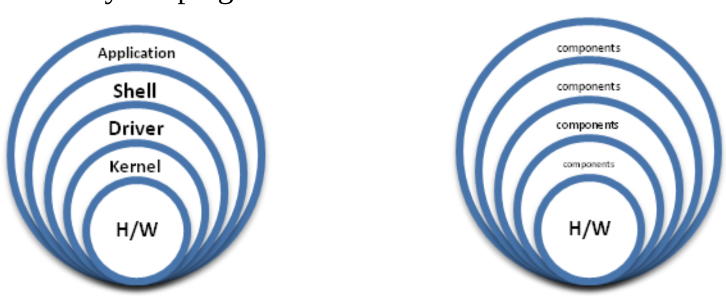
2.2 Real-time Data Plot on Computer

We use Arduino as an analog-digital converter (ADC) and-send the data to computer through serial port. Then we use Python with PySerial to collect real-time data from Arduino over a USB port. In order to plot 2D figure in python, we use the matplotlib library. We embed Matplotlib in wxWidgets and use timers to plot the real-time data from Arduino.

Once we get the data in the digital form, we process the pulse data in Matlab and give out the stress level report for the users. Gayl Hubatch, an Austin-based acupuncturist, is an expert in pulse reading, who contributed many different kinds of knowledge in stress level, becoming the main algorithm being used in our signal processing.

2.3 Sending Data to iPhone with Hijack

We use Hijack [7] to transmit sensor signals though iPhone's Audio Interface. We can develop applications on Hijack basef on TinyOS and nesC programming. "TinyOS is an event based operating environment designed for use with embedded networked sensors."[8] For traditional OS, the basis units are events of objects. For tinyOS, the basis unit is "component", which is connected by "wiring". Our development environment is eclipse with tiny OS plug-in.



Traditional OS

TinyOS

Figure 11 Traditional OS and TinyOS

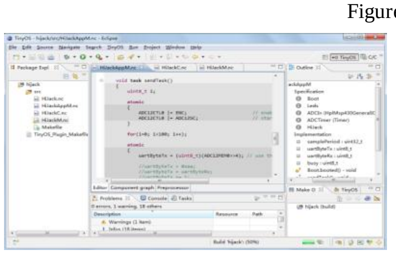


Figure 12 TinyOS Develop Environment

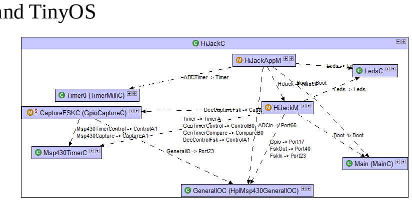


Figure 13 Hijack Component Graph

Figure 13 the component graph for Hijack. Finally, we can makefile and download in Cygwin.

Chapter 3 Finding and Results

3.1 sensor choice

It turns out that membrane piezoelectric sensor works better than optical sensor, therefore we selected the SDT1-028K membrane piezoelectric for this project.

3.1.1 Performance of Optical Sensor

Figure 14 the output of optical sensor

Our optical sensor could not provide enough signal detail for analysis with traditional Chinese medicine theory. We found that the output of this sensor is like a sea wave, and only the heart rate can be acquired from it. Further information such as pulse shapes cannot be obtained. Moreover, optical sensor can only sense pulse signal from fingertip or earlobe, but not from the wrist, because there is little tissue on the wrist for optical sensors to reflect pulse data. Based on traditional Chinese medicine theory, herbalist doctors need to put their fingers on patients' wrists and feel the pulse. Therefore, the optical sensor is not the right choice for our capstone project.

3.1.2 Performance of piezoelectric sensor

There are lots of piezoelectric sensors on market. We choose a membrane piezoelectric sensor because it will be comfortable for people to put on while measuring pulses. We have tested several piezoelectric sensors and found that the SDT1-028K membrane piezoelectric sensor works the best. Figure 15 are the output of SDT1-028K sensor.

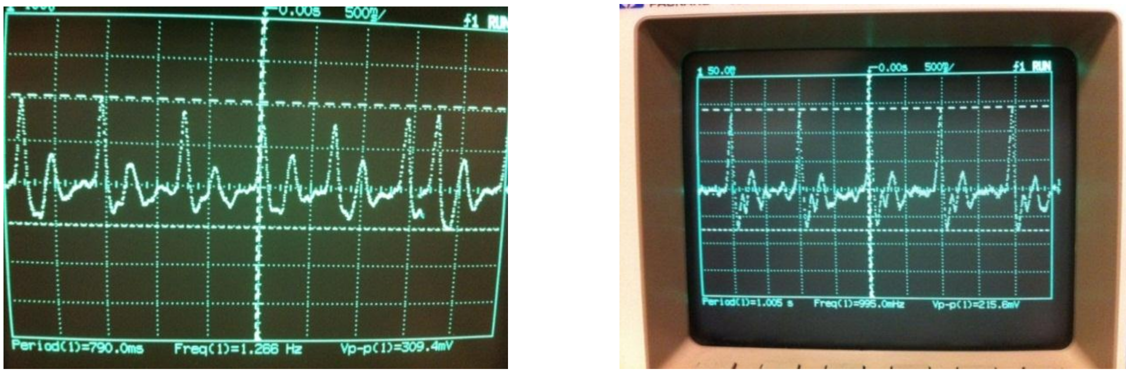


Figure 15 output of piezoelectric sensor

3.2 Plot of Pulse Data and Signal Processing

We also meet with expert Gayl Hubatch. Gayl used our sensor many times and we concluded that our sensors are are accurate enough to acquire pulse signals for simple analysis. These pulse signals can indicate the stress of different organs in the user, which promises to make an appealing product.

3.2.1 Basis Pulse Signal Plot

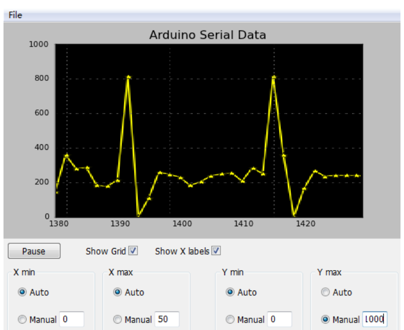


Figure 16 real-time data plot from Arduino in Python

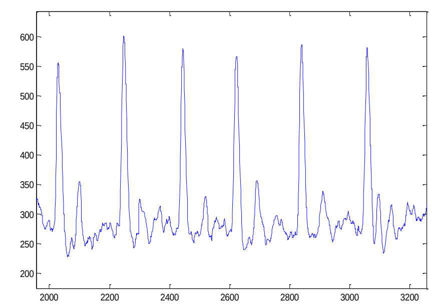
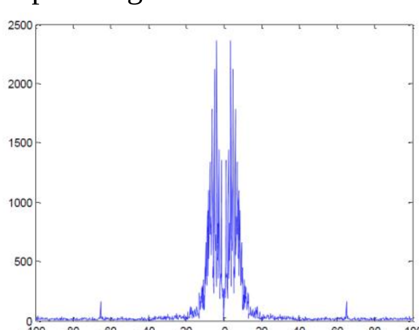


Figure 17 Pulse Signal in Time Domain

We can plot pulse signal in time domain and frequency domain in Matlab.



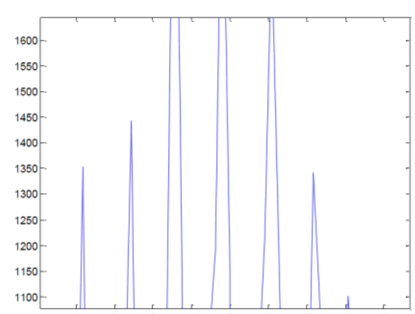


Figure 17 Pulse Signal in Frequency Domain

Harmonics of pulse signal, the right figure in figure 17, can be analyzed by zoom in the FFT plots, the left figure in figure 17. The first harmonic should be ~ 1 HZ, reasonable compared to our heart rate.

3.2.2 Signal Processing

After successfully sensing the heart pulse data, it is necessary to interpret the data in a medical sense. Here are three ways to exert three pressures: light pressure, medium pressure, and heavy pressure. It is easy to separate them during signal processing because when changing the pressure form one type to another, a sudden jump/noise was produced in the graph, requiring several seconds for the pulse to stabilize. We should analyze the stable data of three pressures. We gradually developed an AI system/library, type by type, to accommodate many different types of medical diagnosis.

According to our expert, Gayl Hubatch's, knowledge, pulse amplitude variance reflects people's stress level. Also, if time period between two pulses is shorter, it means the user is under stress in the short term. If time period between two pulses is longer, it means the user is under stress in the long term. To analyze people's stress according to Chinese Medicine theory, we need to process the pulse signal to get its peak, trough and period, while avoid the interference from noise. Here is the way to do it:

1. In the Frequency domain, filter all the frequency above the normal range of human heart pulses. (This filters Impulse shaped noises)
2. Since the normal human heart rate ranges from 40 beats/min ~ 120 beats/min, it would be reasonable to sweep a window of 0.75 second, and take the local maximum as the peak for this period. Then trough can be found following the peak.
3. Find the average interval between peak and trough, then the period can be deduced.
4. The standard deviation of the amplitude, using normal distribution, is related to users' stress level
5. A learning AI algorithm stores the average of all valid history data from the user. If the incoming data deviates a small amount, we absorb it using a Markov chain method. If the new data is off significantly, then the person is under stress. If the new data is off very significantly, then the data should be rejected since it likely represents noise.

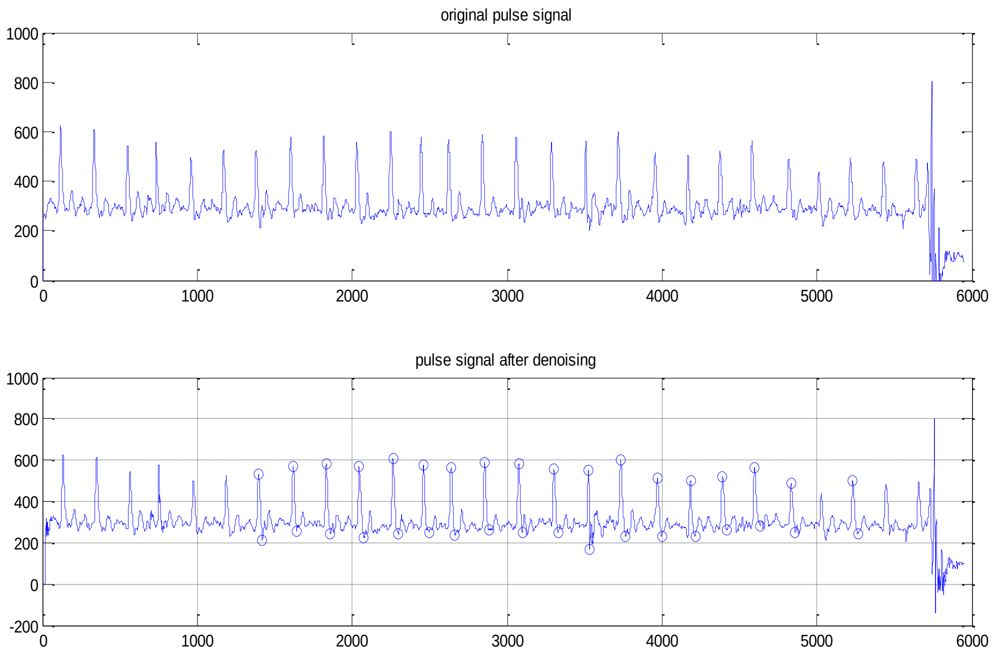


Figure 18 result of the signal processing

3.3 Final Dr.Chi Prototype

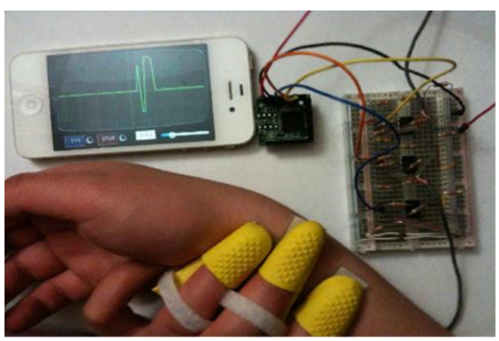


Figure 19 Dr.Chi prototype

Summary

Traditional Chinese Medicine has helped the Chinese lead healthy lives since ancient times. Our mobile app, Dr.Chi, introduces this approach to a broad audience, and people can balance their stress conveniently. However, there are still opportunities to improve the performance of our mobile app. It would be exciting to include the whole Traditional Chinese Medicine Theory into a single small mobile app. To get this performance, considerable amount of signal processing and machine learning are needed. Some institutes are researching this application, hopefully, making this true in the near future.

Reference:

[1] http://pulsesensor.com/

[2] http://www.seeedstudio.com/wiki/Piezoelectric_pulse_sensor

[3] http://en.wikipedia.org/wiki/Piezoelectric_sensor

[4]http://eli.thegreenplace.net/2008/08/01/matplotlib-with-wxpython-guis/

[5]http://matplotlib.sourceforge.net/

[6]Matplotlib for Python Developers, Sandro Tosi

[7]Hijacking Power and Bandwidth from the Mobile Phone's Audio Interface, Ye-Sheng Kuo, Thomas Schamid, Prabal Dutta. from University of Michigan

[8]http://www.tinyos.net/

[9]http://www.gehealthcare.com/euen/patient_monitoring/products/imm-monitoring/pulse-oximeters/trusat.html

[10] https://play.google.com/store/apps/details?id=si.modula.android.instantheartrate