WAVEFORM ANALYSIS OF PULSE WAVE DETECTED IN THE FINGERTIP WITH PPG

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ABSTRACT
Photoplethysmography is one of the biomedical Instruments and when combined with pulse wave analysis it becomes information rich. Photoplethysmography is a non-invasive techniques that measures relative blood volume changes in the blood vessels close to the skin. This instrument was specially designed for the analysis healthy, diabetes an arthritis person. Many problems were created while designing PPG instrument such as light source, skin thickness of fingertip, signal amplification, storing of signals, heart rate and respiratory rate. We present the results of analysis of photoplethysmography (PPG) signal for healthy and patient with cardiovascular disorder (diabetes and arthritis). PPG signal of 21 subjects were recorded from the fingertip. The analysis indicates the content of PPG signal is different for healthy and cardiovascular patients. We also investigated heart rate and respiratory rate using PPG signal. In the present method of PPG analysis, the aim of this study to analyze the waveform in relation with diabetes, arthritis and healthy persons. The peripheral pulse has a steep rise and notch on falling slope in the subjects and a more gradual rise and fall and very small dicrotic notch were observed. The analysis with falling slope indicates the type of diseases.

KEYWORDS: *Pulse Wave, Photoplethysmograph, Diabetes, Arthritis.*

I. INTRODUCTION

Human skin plays an important role in various physiological processes including thermoregulation, neural reception, and mechanical and biochemical protection. The heart-generated blood-pressure waves propagate along the skin arteries, locally increasing and decreasing the tissue blood volume with the periodicity of heartbeats. The dynamic blood volume changes basically depend on the features of the heart function, size and elasticity of the blood vessels, and specific neural processes. Therefore direct monitoring of skin blood pulsations may provide useful diagnostic information, especially if realized non-invasively. Optical technologies are well suited for non invasive monitoring of skin blood pulsation. Radiation of the red to near infrared spectral region penetrates several millimeter under the skin surface. Skin blood pumping and transport dynamics can be monitored at different body location (e.g. fingertip, earlobe, and forehead) with relatively simple and convenient PPG contact probes. Simultaneous data flow from several body locations the multi channel PPG technique increases the reliability of clinical measurements also allowing us to study heart beat pulse wave propagation in real time and to evaluate the vascular blood flow resistance an important physiological parameter for vascular diagnostics. In general each recorded PPG pulse contains useful information can be obtained by analysis of the PPG signal sequence recorded [1]. Plethysmograph is a combination of the Greek word. Plethysmos meaning is increase and Graph is the words for write [2]. It is an instrument used mainly to determine and register the variation in blood volume or blood flow in the body. We used photo electric type plethysmograph. Hence is known as Photoplethysmograph [3]. Pulse wave analysis helps to study diabetes & arthritis & it is unique for each individual so it would also give unique identification as biometric identification [4]. Pulse wave analysis also helps to study large artery damage& an abnormality in the cardiovascular disease which is one of the common causes of high mortality rate.PPG analysis emphasizes the importance of early evaluation of the diseases [5]. Several studied conducted by various groups of population showed that in PPG, the

reflectance of light from in vivo tissue is described as a function of light for the wavelength in the range from 420 to 940 nm [6]. The electrical signal from PPG is related to blood volume changes in tissue. This signal provides a means of determining the diseases related to cardiac cycle & changes in arthritis & diabetes. The suggested PPG method is reliable, simple, low cost & noninvasive which could become an effective new screening tool for the early detection of diabetes neuropathic foot [7].

II. LITERATURE SURVEY

2.1. Methods of Photoplethysmograph (PPG)

2.1.1. Reflected Photoplethysmograph

Reflection PPG method uses the back scattered Optical signals for analysis of skin blood volume pulsation [8].

2.1.2 Transmitted PPG

In the transmission method, an optical signal change according to its absorption at the pulsation as oxygenated allows red wavelength more and deoxygenated blood allows infrared wavelength. It employs the principle that oxygenated blood is bright red. Whereas reduced or deoxygenated blood is dark red so combination of red and near infrared LED's and photo sensors can be used to monitor the colour of blood [8].

2.2. Issues Regarding PPG

2.2.1. First Issues Regarding PPG

The first issue concerns the contact and noncontact PPG, in which both are has nearly same potential only difference in the amplitude of the received signal and clarity. In the noncontact PPG signals are not so cleared as compared to contact type PPG [2].

2.2.2 Second Issues Regarding PPG

The second issue concerns the dynamic range of the detected signal. The detected pulsatile (AC) signal is very small compared to the non-pulsatile (DC) signal as shown in figure1 [2].

2.2.3 Third Issues Regarding PPG

The third issue is ambient light artifact. The detector will receive increased ambient light due to the probe separation from the tissue bed. Introducing close packaging of finger bed with detector could reduce this effect [2].

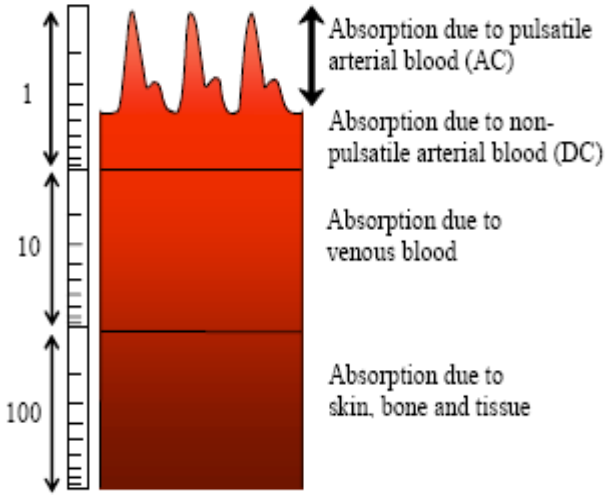

Figure 1. Breakdown of the component of the detected PPG signal

III. MEASUREMENT SYSTEM

3.1. Block Diagram

We used red light source as sensor, i.e. LED. LED gives brighter light at low power as compare to other. Also by using LED, the problem of localized heating can be avoided [9]. The PPG device incorporates a light source and detector, which are placed against the surface of skin [10]. Incident light passes through the tissue and blood and diffuses in the tissue bed. Variation in the intensity of light arises from changes in the blood fractional volume of arteries and tissues, which alter light absorption. This variation occurs with arterial pulsation. The absorption coefficient of tissue bed at various wavelengths for pulsation blood it has maximum output at wavelength 420 to 900 nm[6].For detectors we used LDR whose dark resistance is 10 KΩ when the cell is not illuminated (i.e. dark resistance). The spectral response of LDR is good for visible region and we used red colored source. In our project we used LDR as detector which gives output change in resistance and this change in resistance is directly proportional to light incident on its surface. Coupling capacitor used which blocks the dc component present in our signal. As in previous work we showed that the detected signal consist ac and dc components.PPG signal = DC blood and tissues + AC blood modulates. Thus dc components can be filtered out [2]. The wave form different specimens (i.e. different male/females) depend on the skin thickness to overcome these problem we used variable gain (pot) to set the gain as per requirement. Lastly we used comparator to compare to shift the waveform as per subject requirement, thus added comparator due to which the dc level can be shifted, because of skin thickness and different artifacts i.e. movements etc. the wave form may be shifted. Thus we get final output which is PPG signal. Once we get PPG wave forms then our main aim is to show the effect of diabetic or arthritis on the waveforms. This depends upon the dicrotic notch.

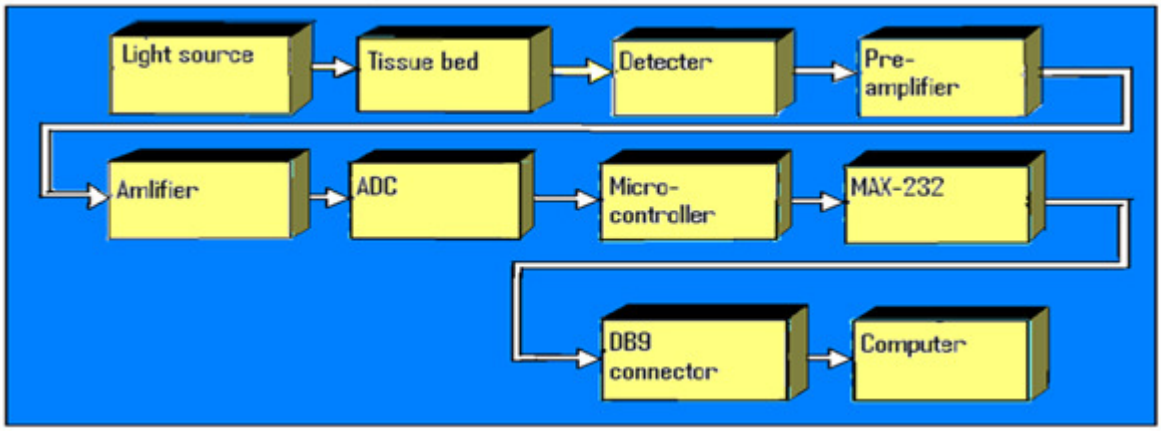

Figure 2. Block Diagram

3.2. Physiological Measurement

Photoplethysmographic signal measurements were obtained from 21 subjects (13 male, 8 female). Subjects were in the age of 22-70. Measurements were performed in a laboratory. Each subject was asked to relax and sit on the chair and rest the forearm on the lab table to help the entire hand keep steady. An operator then attached the finger sensor to the forth fingertip of the left hand. It is important to have a comfortable arm position in order to keep the finger relatively motionless for a stable and repeatable recording. The length of the recorded signal was 10 seconds.

3.3. Analysis

The analysis of the healthy, diabetes, arthritis person is as shown in figure 3, 5, 7. From figure 3, we observed number of peaks; from this peak we calculated heart rate and respiration rate.
Heart rate = No. of peaks × 12
Heart rate = 6 × 12=72
Respiratory rate=Heart rate÷2
Respiratory rate=72÷2=36

3.3.1. Analysis of Healthy Person

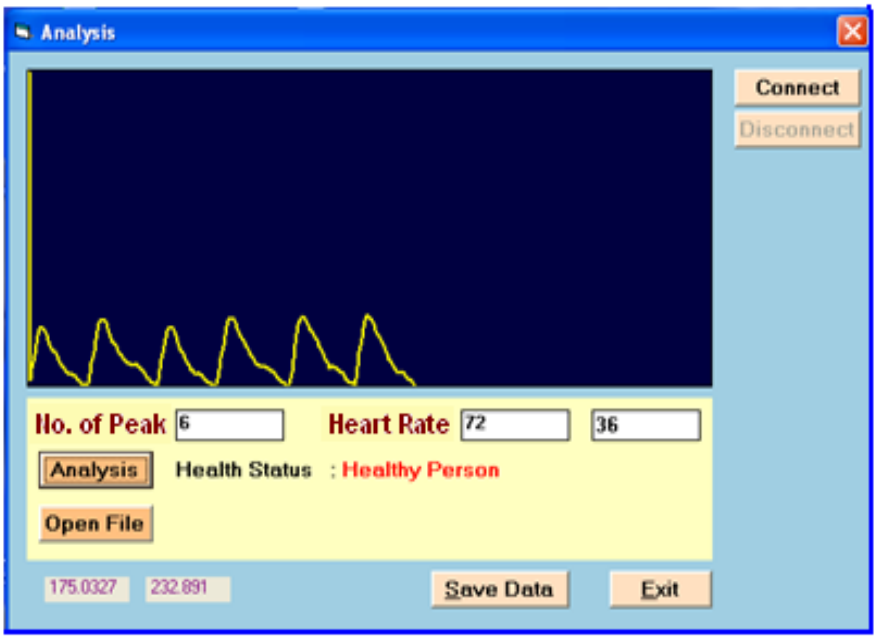

Figure 3. Healthy subject status

Analysis of healthy person is as shown in figure 3. Figure 4 shows the SPPPG (single period photoplethysmograph) and animated signal of healthy person.

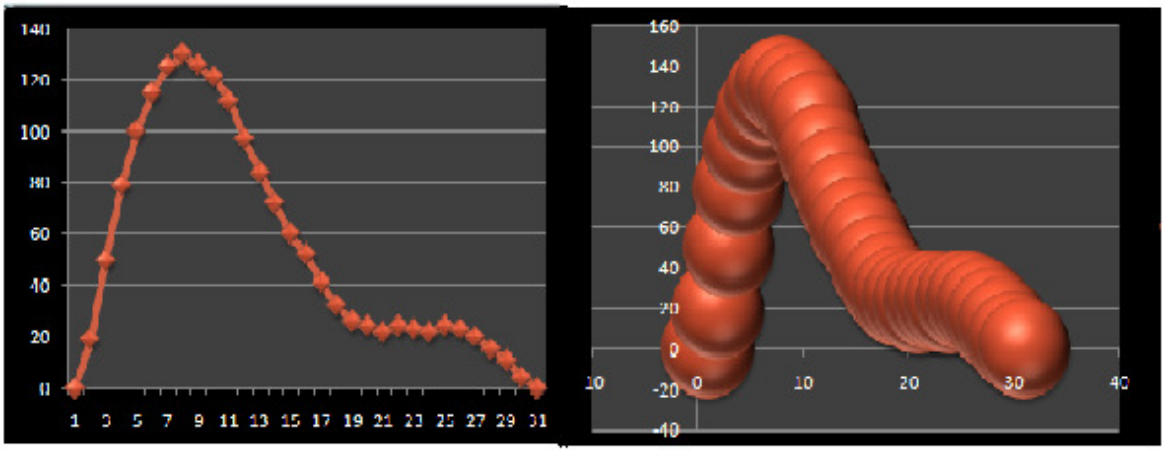

Figure 4. SPPPG and animated signal of healthy person

3.3.2. Analysis of Diabetes Person

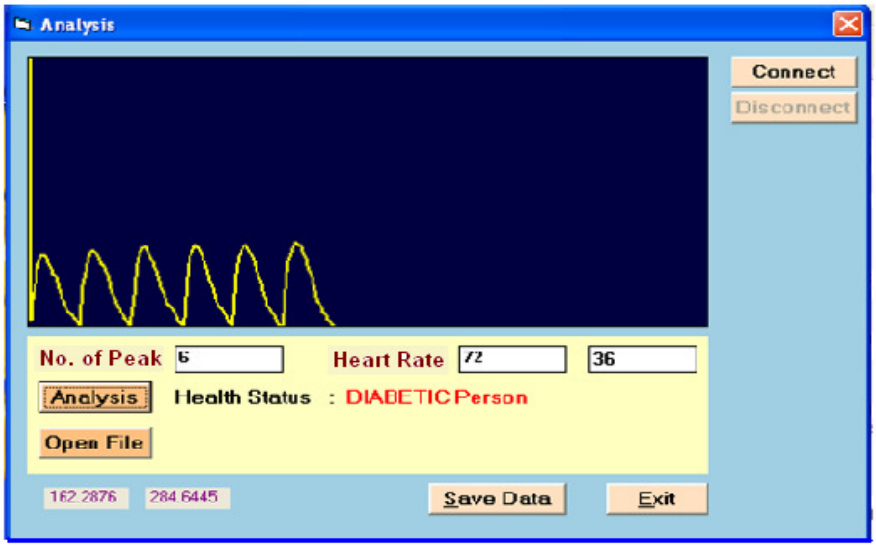

Figure 5. Diabetes subject status

Analysis of diabetes person is as shown in figure 5. Figure 6 shows the SPPPG and animated signal of diabetes person.

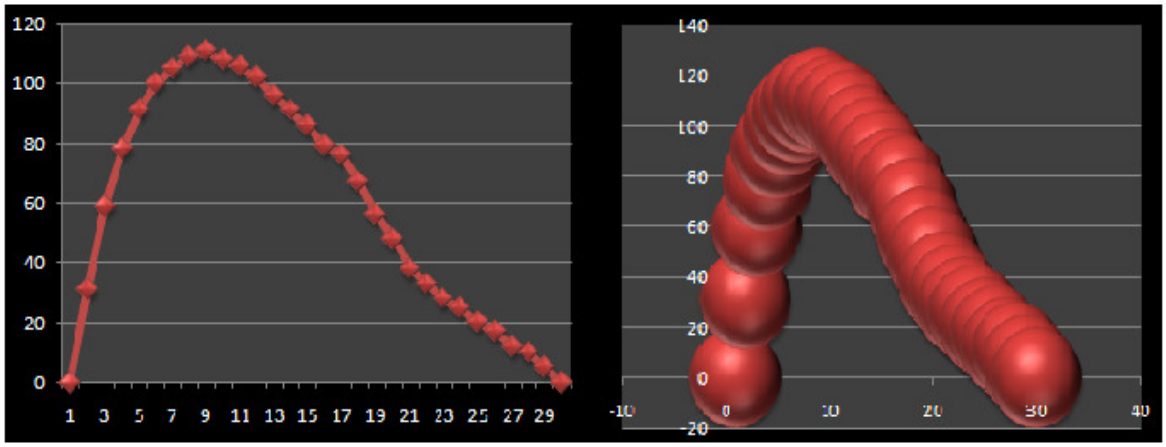

Figure 6. SPPPG and animated signal of diabetes person

3.3.3. Analysis of Arthritis Person

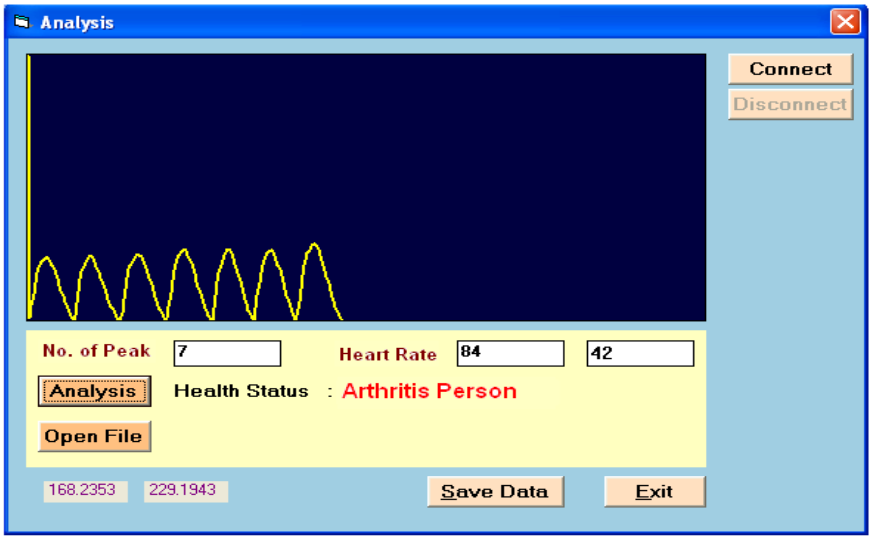

Figure 7. Arthritis subject status

Analysis of arthritis person is as shown in figure 7. Figure 8 shows the SPPPG and animated signal of arthritis person.

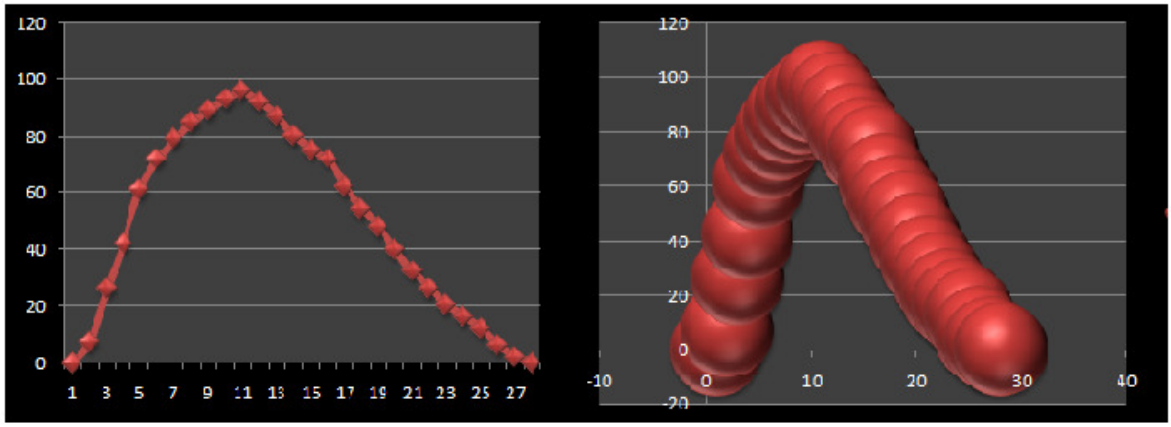

Figure 8. SPPPG and animated signal of arthritis person

IV. DISCUSSION AND CONCLUSIONS

The main differences in the PPG with healthy, diabetes and arthritis patients were observed with the presence or absence of dicrotic notch & trailing edge slope. As vessels get stiffer during aging process, the reflected wave returns faster and due to the summation of wave the resultant pulse wave changes [11]. After filling in the patient data AC-component of his/her PPG signal is detected and stored. The analysis of healthy, diabetes and arthritis person is illustrated at figure 3, 5 and 7, which shows that the health status, heart rate and respiratory rate. The SPPPG and animated signal is illustrated at figure 4, 6 and 8.The shape of the single PPG pulse detected at the periphery (e.g. fingertip) can differ significantly from that at the magistral arteries; it primarily depends on resistance of the vascular system. If the vessel resistance is abnormally high due to diabetes, arthritis or other vascular pathology that narrow the vessels, velocity of blood flow from big arteries to small capillaries decreases. In the summary comparisons of the PPG wave form shows that it can provide a simple non-invasive means of studying diabetic & arthritic patients [13].

V. RESULTS

The main objective of this work was to show the relation of trailing edge slope with diabetes and arthritis patient shows the change in slope than healthy subject i.e. the difference in the pulse shape changes as a function of disease which can be well observed visually. In the diabetic patients PPG waveform shows very small dichrotic notch & slope is less, where as arthritis patients PPG waveform shows very sharp slope and no dichrotic notch were observed. Single period PPG signal comprises a fast raising part or anacrota and subsequent falling part or catacrota. Anacrota reflects the stretching of the blood vessel walls under the increased blood pressure after each heartbeat and catacrota – relaxation processes of the blood vessel wall in-between each two heartbeat. The catacrota can be variously shaped depending on the vascular condition; it normally contains so called predicrotic dip, and secondary peak (notch) caused by elastic reflection in the arterial system. A typical healthy person's SPPPG signal shape is presented at figure 4.The propagating blood pressure pulse wave becomes broadened and delayed and may completely lose its secondary (dicrotic) peak, when the periphery is reached. SPPPG signals were bell-shaped without any secondary peak at the catacrota. A typical diabetes person's SPPPG signal shape is at figure 6.A typical SPPPG signal of arthritis person's is as shown in figure 8.This peak is a clear evidence of increased blood flow via the damaged vessels.

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APPENDIX

```
#include <REG51.H>

#define adc_port P1          //ADC Port
sbit rd = P3^7;              //Read signal P1.0
sbit wr = P3^6;              //Write signal P1.1
sbit cs = P3^4;              //Chip Select P1.2
sbit intr = P3^5;            //INTR signal P1.3

void conv();                 //Start of conversion function
void read();                 //Read ADC function
void delay(unsigned int);
unsigned char serial_read();
void serial_send(unsigned char);
void serial_init();
unsigned char adc_val;
```

```
void main()
{
      intr = 1;

      serial_init();
      while(1)
      {                          //Forever loop
            conv();              //Start conversion
            read();              //Read ADC
            serial_send(adc_val);
            delay(10);

      }
}

void conv()
{
      cs = 0;                 //Make CS low
      wr = 0;                 //Make WR low
      wr = 1;                 //Make WR high
      cs = 1;                 //Make CS high
      while(intr == 1);             //Wait for INTR to go low
}

void read()
{
      cs = 0;                 //Make CS low
      rd = 0;                 //Make RD low
     adc_val = adc_port;      //Read ADC port
      rd = 1;                 //Make RD high
      cs = 1;                 //Make CS high
}

void delay(unsigned int count)
{
   unsigned int i;
   while(count)
   {
      i = 115;
      while(i > 0)
      i--;
      count--;
   }
}

void serial_init()
{
      TMOD = 0x20;
      SCON = 0x50;
      TH1  = 0xFD;
      TL1  = 0xFD;
      TR1  = 1;
}
 void serial_send(unsigned char dat)
{
      SBUF = dat;
      while(TI == 0);
      TI = 0;
}
unsigned char serial_read()
```

```
{
      while(!RI);
      RI = 0;
      return SBUF;
}
```

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