Ankle Brachial Index (ABI) Based Leg Attack Diagnosis using LabVIEW

M. Abraham Lincoln, P. Balaji, A. Chithra, A. Mohamed luqman, M. Kalaivani and C.L. Annapoorani

***Abstract*---** *Leg Attack is a Peripheral Vascular Disease (PVD), which results from the restricted blood flow, such as that caused by an arterial blockage in a lower limb. This work describes a new approach in diagnosing the leg attack and other diseases non-invasively through ABI (Ankle Brachial Index). This novel cuff-less Blood Pressure (BP) estimation method is based on the Pulse Transit Time (PTT) technique. And this PTT is determined by calculating the time interval between the R-peak of ECG and peak of PPG using LabVIEW. Following this, BP is obtained from PTT using a conversion factor. The ratio of systolic pressure recorded at the ankle to the systolic pressure recorded at the brachial artery gives the ankle brachial index. Simultaneously BP is measured using a digital Blood Pressure monitor in order to correlate with the calculated blood pressure and the results are tabulated. When the ABI value goes below the normal range, there is an increased risk of Leg Attack and other peripheral disease. Hence the assessment and severity of leg attack disease is prognosed by this work.*

***Keywords*---** *Cuff Less, Pulse Transit Time, Electro Cardio Gram, Photo Plethysmo Gram, Ankle Brachial Pressure Index, LabVIEW*

I. INTRODUCTION

A. Peripheral Vascular Disease

PERIPHERAL vascular disease (PVD) refers to any disease or disorder of the circulatory system outside of the brain and heart. Although the term peripheral vascular disease can include any disorder that affects any of the blood vessels, it is often used as a synonym for peripheral artery disease (PAD). PVD or PAD, commonly referred to as peripheral artery occlusive disease (PAOD) is caused by arteriosclerosis, or hardening of the arteries. It is the condition of the blood vessels that leads to narrowing and hardening of the arteries that supply legs and feet.

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Peripheral artery disease is a common disorder that usually affects men over age 50. People are at higher risk if they have a history of:

- Abnormal cholesterol
- Diabetes
- Heart disease (coronary artery disease)
- High blood pressure (hypertension)
- Kidney disease involving hemodialysis
- Smoking
- Stroke (cerebrovascular disease).

B. Symptoms of PAD

PAD can build up over a lifetime, and the symptoms may not become obvious until later in life. For many people, the outward symptoms will not appear until the artery has narrowed by 60 percent or more.

Symptoms of advanced PAD may include:

- A burning or aching pain in the feet and toes while resting, especially at night while lying flat.
- Cool skin in the feet.
- Redness or other color changes of the skin.
- Increased occurrence of infection.
- Toe and foot sores that do not heal.

II. NEED FOR A NEW DESIGN

As wearable cuff less blood pressure devices becoming popular nowadays for the following reasons [2]. No specialists or nurses are required for measuring BP which has been the case for ordinary blood pressure meter with a cuff. And therefore the patient can do the following procedures of their own whenever needed.

In case of full body injury or burns where traditional blood pressure meter with the cuff cannot suit. A cuff less blood pressure meter is less irritative and helpful in measuring BP in unconscious condition [3]. It is portable with a laptop assist supporting Labview. This software is available free of cost.

III. METHODOLOGY

Design OF PPG Amplifier Circuit & Acquiring PPG and ECG Signals from the Subject

A. Photoplethysmography (PPG)

PPG is an optical measurement technique that can be used to detect blood volume changes in the micro vascular bed of tissue. The basic form of PPG technology requires only a few opto-electronic components: a light source to illuminate the

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tissue (e.g. skin), and a photo detector to measure the small variations in light intensity associated with changes in perfusion in the catchment volume. PPG is most often employed non-invasively and operates at a red or a near infrared wavelength. The most recognized waveform feature is the peripheral pulse, and it is synchronized to each heartbeat [6].

There are two main PPG operational configurations:

- Transmission
- Reflection

In Transmission ('transillumination') mode operation, the tissue sample (e.g. fingertip) is placed between the source and detector, and in reflection ('adjacent') mode operation, the LED and detector are placed side-by-side. Clearly, transmission mode PPG imposes more restriction than the reflection mode PPG on the body locations available for study. The PPG probe should be held securely in place to minimize probe-tissue movement artifact. There are other sources of artifact that need to be considered in the measurement technology. For example, artifact can arise from ambient light interference but can be reduced by suitable probe attachment to the skin (e.g. using a dark Velcro wrap-around cuff).

PPG amplifier circuit which acts as an inverting amplifier with gain 14. The point A represents a voltage divider connected to V_{cc} at one end and a resistor and a LDR at the other end.

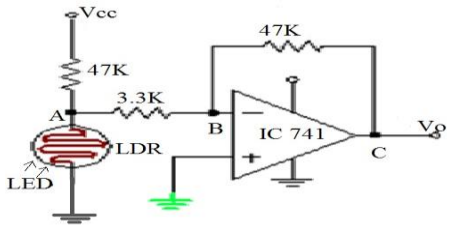

Figure 1 : PPG Amplifier Circuit

The changes in blood flow corresponds to change in resistance in the LDR due to the trans-illumination which is converted into voltage since V=IR. And this voltage is amplified by the op-amp and it is shown in the output voltage Vo

The gain of an inverting amplifier is given by the equation 1,

$$A = -Rf / R1 \quad (1)$$

where Rf is 47KΩ and R1 is 3.3KΩ

B. *Acquiring PPG Signals*

In the PPG amplifier circuit, the sensor is represented by a Velcro part that is fixed with light emitting diode (LED) and detector sensor (LDR). The Velcro is tied in the manner, such that LED and LDR are placed in the two side of the finger. This method of PPG waveform acquisition follows the principle of transmission. During this procedure the finger should be kept firmly without any artifacts. The similar procedure of placement is followed for the lower limb extremities.

C. *Acquiring ECG Signals*

ECG sensor is used with three disposable surface electrodes. Lead I representation where one lead (green) is placed at the right arm and another lead (red) at the left arm and the other lead (black) at the right leg for grounding.

D. *Data Acquisition*

The data acquisition device is interfaced between the amplifier circuit and the PC.

It acts as an input and /or output device .The NI USB-6008 DAQ devices deliver multifunction capabilities with 8 channels of 12 or 14-bit analog input, two analog outputs, 12 digital I/O lines and one counter. Both devices draw power from the USB bus, so they do not require an external power supply to operate.

IV. LABVIEW PROCESSING OF ECG AND PPG SIGNALS

A. *LabVIEW*

LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) is a platform and development environment for a visual programming language from National Instruments. The purpose of such programming is automating the usage of processing and measuring equipment in any laboratory setup. LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms.

LabVIEW programs/subroutines are called virtual instruments (VIs). Each VI has three components: a block diagram, a front panel and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VIs. Controls and indicators on the front panel allow an operator to input data into or extract data from a running virtual instrument.

B. *Pulse Transit Time and BP Conversion*

PTT is defined as the time interval between the R wave peak of ECG and the peak of PPG in the same cardiac cycle [1].

With sampling rate known, using the difference in index values of the peak onset of the two signals, we are able to calculate the Pulse transit time. BP increases with decrease in PTT [4] and vice versa.

Low PTT ⟹ High BP

High PTT ⟹ Low BP

Blood pressure is the force of blood pushing against the wall of the arteries. Each time our heart beats it pumps out blood to the arteries. Systolic pressure which is the highest blood pressure occurs when our heart is pumping. Diastolic pressure is lowest blood pressure when our heart is resting.

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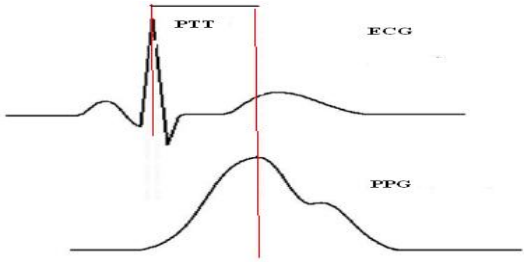

Figure 2 : Pulse Transit Time

Since blood pressure is an indirect measurement of heart beats, the blood pressure will changes according to time and emotion. For instance, blood pressure will rise when we are awaken and excited. The unit for blood pressure is in mmHg and the notation will be systolic followed by diastolic pressure. Normal blood pressure is less than 120/80mmHg.

Blood pressure is calculated by using the following formula given in the equation 2[7]:

$$BP = \frac{1}{\alpha}\left[\ln\left(\frac{L^2 dP}{E_0 h}\right) - 2\ln(PTT)\right] \quad \textbf{(2)}$$

Where,

- E0 is Young's Modulus of arterial wall at zero pressure,
- α is a constant that depends on the vessel,
- h is the brachial artery wall thickness,
- d is inner radius of brachial artery,
- ρ is the blood density,
- L is distance of heart from fingertip,
- PTT is the pulse transit time.

The value for substituting in the above given formula for converting blood pressure from PTT may vary for men and women and also in their upper and lower limbs. They are tabulated as follows:

Table 1: Normal Values to Calculate BP

PARAMETER	ARM	LEG
A	0.018	0.016
L(women)	0.85	1.25
L(men)	0.95	1.35
D	2.3	2.6
P	1060	1060
$\sum_0$	$3.15*10^3$	$3.15*10^3$
H	0.45	0.45

V. DETERMINATION OF ABI

ABI and its Range of Values

The ratio of Leg pressure Vs Arm pressure gives the ABI (Ankle Brachial Index). The ABI result is used to predict the severity of Peripheral Arterial Disease (PAD).

ABI or ABPI (Ankle Brachial Pressure Index), it is given by the following relation:

$$ABI = P_{leg} / P_{arm} \quad (3)$$

Where P_{Leg} is the Leg Pressure and P_{Arm} is the Arm Pressure.

The ABI result can help diagnose peripheral arterial disease (PAD). A lower ABI means you might have PAD. A slight drop in the ABI with exercise, even if you have a normal ABI at rest, means that you probably have PAD.

1. Normal ABI

A normal resting ankle-brachial index is 0.9 to 1.3. This means that your blood pressure at your ankle is the same or greater than the pressure at your arm, and suggests that you do not have significant narrowing or blockage of blood flow.

2. *Abnormal ABI*

A resting ankle-brachial index of less than 0.9 is abnormal. If the ABI is:

0.41 to 0.9, you likely have mild to moderate peripheral arterial disease.

0.4 Or below, you likely have severe peripheral arterial disease.

ABPI VALUES	INTERPRETATION
Above 1.2	Abnormal vessel hardening
1.0 to 1.2	Normal range
0.9 to 1.0	Acceptable
0.8 to 0.9	Some arterial disease
0.5 to 0.8	Moderate leg attack
Under 0.5	Severe leg disease

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VI. RESULTS AND DISCUSSION

Pulse transit time and BP calculated for more than twenty subjects with age less than 60 and values are tabulated for about ten subjects in Table 1.

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Table 1: PTT and BP Calculated for Subjects with Age <60

SUBJECT	PTT FOR ARM	BP ARM	BP MEASURED	PTT FOR LEG	BP LEG	BP MEASURED
Subject 1	0.4160	109	113	0.5287	150	155
Subject 2	0.4014	113	110	0.5164	152	150
Subject 3	0.4001	117	120	0.5077	154	158
Subject4	0.4419	103	108	0.5193	151	157
Subject 5	0.4313	105	110	0.5222	150	151
Subject 6	0.3997	116	120	0.4566	177	173
Subject 7	0.4142	110	112	0.5107	153	150
Subject 8	0.4139	110	114	0.5177	150	145
Subject 9	0.3853	120	121	0.5079	154	158
Subject 10	0.3816	123	120	0.4915	158	160

The second category of subjects with age more than 60 have variation in their in pulse transit time and thus have changes in their corresponding BP which is shown in the Table 2 given below. BP arm and leg are determined using PTT and values for BP measured are those obtained using a digital BP meter.

Table 2: PTT and BP Calculated for Subjects with Age>60

SUBJECT	PTT FOR ARM	BP ARM	BP MEASURED	PTT FOR LEG	BP LEG	BP MEASURED
Subject 1	0.3989	117	108	0.5001	137	140
Subject 2	0.3998	116	102	0.5405	130	135
Subject 3	0.4648	110	110	0.6237	115	120
Subject4	0.3980	118	115	0.4998	138	140
Subject 5	0.4247	113	110	0.5393	131	135

Ankle brachial index is given by the ratio of leg pressure to arm pressure. ABI for subjects with age < 60 is given in the table. ABI for subjects with age > 60 is given in the Table 4. From the tabulation, it has been clearly seen that blood pressure in the lower limb decreases steadily due to aging and the ABI values decreases due to thickening of the surrounding bones and blockage of leg arteries due to plaque (cholesterol) formation mainly due to less physical work. Their range of ABI usually revolves around less than 1.15. And this show firmly that there is an increasing risk of atherosclerosis and it might result in the leg attack at the later years of the life.

Table 3: ABI Values for Subjects with Age <60

SUBJECT	BP ARM	BP LEG	ABI
Subject 1	109	150	1.376
Subject 2	113	152	1.345
Subject 3	117	154	1.316
Subject4	103	151	1.466
Subject 5	105	150	1.434
Subject 6	116	177	1.525
Subject 7	110	153	1.43
Subject 8	110	150	1.37
Subject 9	120	154	1.25
Subject 10	123	158	1.46

Table 4: ABI Values for Subjects with Age >60

SUBJECT	BP ARM	BP LEG	ABI
Subject 1	117	137	1.15
Subject 2	116	130	1.12
Subject 3	110	115	0.9
Subject4	118	138	1.16
Subject 5	110	131	1.15

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