Smart Ambulatory Blood Pressure Monitor: A Novel Approach

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Abstract: **Cardiovascular diseases (CVD) are a major cause of death globally and there are a lot of expense concerns associated. Heart failure (HF) is the CVD with the most incidences and is characterized by the heart not pumping enough blood to the body. The importance of non-invasive and continuous solutions for personal health systems is in ascension, and this project deals with blood volume and blood pressure.**

Blood pressure is one of the most important fundamental signs of human cardiovascular health. Accurate measurement of blood pressure is essential in diagnosis and treatment of hypertension and ascertaining blood pressure related risk. Although the auscultatory method using the mercury sphygmomanometer is still considered as the most accurate non-invasive blood pressure measurement method, it is complicated and only suitable for clinical assessment. Currently, automatic self-monitoring blood pressure measurement devices are very popular in the market and widely used at home. Most of those devices are developed on the oscillometric method, as it requires less professional training and is less susceptible to external noise. However most of these devices work well on young healthy persons.

Keywords: **Cardiovascular diseases; photoplethysmograph (PPG).**

INTRODUCTION

Wearable biosensors have the potential to become the attraction in healthcare technology by offering their capabilities for low-cost, weightless, small size, non-invasive and long term biosignal monitoring .Photoplethysmography (PPG) biosensors is one of the main sensors with many applications in monitoring, diagnosis and assessment. The signal quality is specifically critical for wearable PPG-based systems [1]. Photoplethysmography (PPG) biosensors is one of the main sensors with many applications in monitoring, diagnosis and assessment. The signal quality is specifically critical for wearable PPG-based systems [2]. PPG is a signal obtained by an optical sensor consisting of an emitting LED and a receiving photodiode. Briefly, a light is emitted towards blood vessels and the optical density received by photodiode reflects change of blood flow.

The sensor illuminates the figure, with light, and the photo-detector measures the slight variations in light intensity associated with volumetric change in blood in the tissue. It converts the light into a corresponding voltage signal.

Every time Doctors are not considering digital BP machine as a standard machine they always refer sphygmomanometer. Our contribution in this paper is first, we have getting results for PPG signal and related survey analyzed the problems using PPG Sensor. Second, we have solved the problems of biosensors like Infrared PPG Sensor, and discuss the solution.

SCOPE AND RELATED SURVEYS

High blood pressure (hypertension) is a leading chronic condition and has become the main risk factor for many high-risk diseases, such as heart attacks. However, the platform for chronic disease measurement and management is still lacking. To achieve the early diagnosis of hypertension, one BP monitoring system has been designed [3]. BP fluctuates continuously over time, either spontaneously or in response to a variety of external stimulations. The occurrence of these continuous and often marked BP variations is not only of pathophysiologic interest, but it may also have a clinical relevance. A Digital BP Meter concept which uses an integrated pressure sensor, analog signal-conditioning circuitry, microcontroller hardware/software and a liquid crystal display. The sensing system reads the cuff pressure (CP) and extracts the pulses for analysis and determination of systolic and diastolic pressure [4].

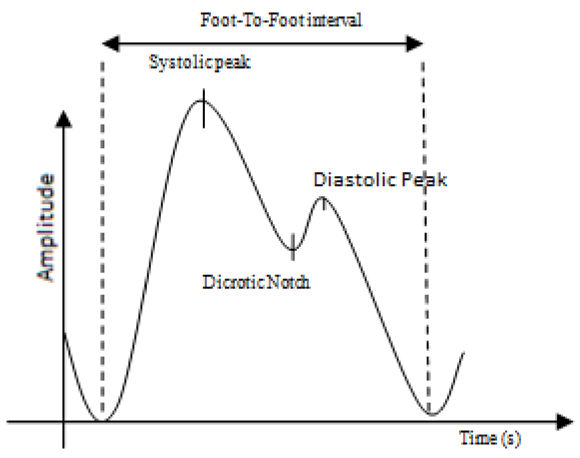

Figure 1: AC component of a typical PPG signal

The DC component of the PPG waveform corresponds to the detected transmitted or reflected optical signal from the tissue, and depends on the structure of the tissue and the average blood volume of both arterial and venous blood. Note that the DC component changes slowly with respiration. The AC component shows changes in the blood volume that occurs between the systolic and diastolic phases of the cardiac cycle; the fundamental frequency of the AC component depends on the heart rate and is superimposed onto the DC component Figure 2[5].

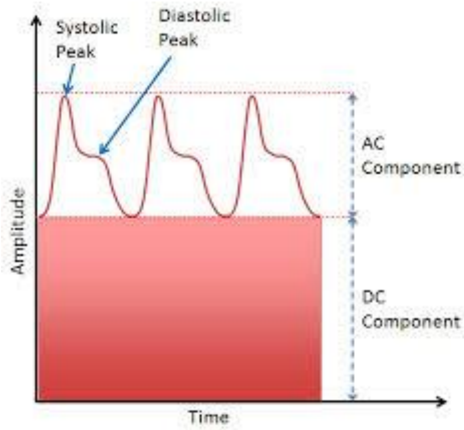

Figure 2: Variation in light attenuation by tissue.

For measure the blood pressure considers the AC as well as DC components which are most important so small variation will affect the results of Plethysmograph.

SYSTEM DESCRIPTION

Based on user requirements, as summarized in Table I, we proposed the Smart Ambulatory Blood pressure Monitor: A Novel Approach which includes the following three main domains.

TABLE I

PROBLEMS, DESIGN OBJECTIVES, AND PROPOSED SOLUTIONS FOR THE NEW SYSTEM

Problems	Design Objectives	Proposed Solutions
Existing commercial electronic BP machine too expensive and there is lack of communication between patients and Doctors	Low cost , reliable ,convenient and sustainable portable	Measurement Device GSM card for SMS platform

Existing commercial electronic BP machine too complex	User Friendly self operation terminals automatic detection	Automatic control and measurement device, for automatic detection PPG sensor is used.
A continuous awareness required self Monitoring.	Patients involvement into the monitoring process	SMS Platform

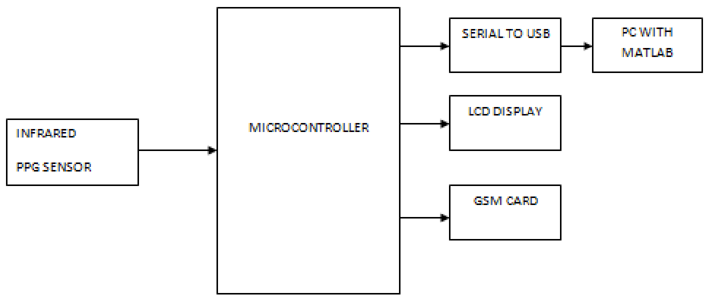

Figure 3: Block Diagram Of Smart Ambulatory BP Monitoring System

Figure3 shows Smart Ambulatory BP Measurement System with the first stage is a Infrared PPG sensor. The sensor illuminates the figure, with light, and the photo-detector measures the slight variations in light intensity associated with volumetric change in blood in the tissue. It converts the light into a corresponding voltage signal. The second stage Microcontroller. The sensor input is supplied with incoming PPG signals which include the DC components (average light intensity) and the AC components (a small varying signal caused by changing BP). Being connected to the ADC, which is inbuilt in microcontroller, a microcontroller eliminates noisy components and then transmits the PPG signals to an oscilloscope or LCD or PC for the displaying systolic, diastolic blood pressure. MATLAB with single PPG signal as input and its peaks detected .The original acquired PPG signal, peak detection, threshold peak signals and final peaks. To take number of samples to calculate systolic diastolic blood pressure of healthy person. For provision of patient extra care one GSM card will be connected to the BP machine. If in case any uneasiness with patient he/she press the button on the GSM board then message goes to their family Doctor and relative.

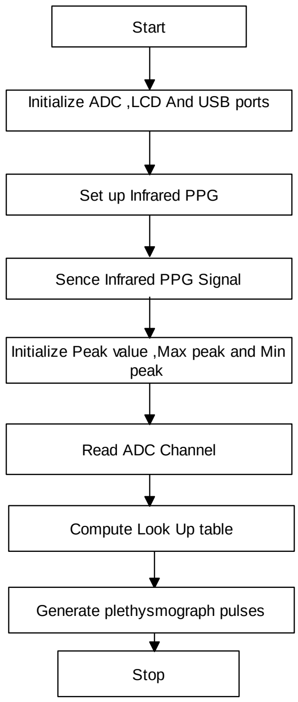

Fig. 4: Flow Chart For main Program

SYSTEM MATERIALIZATION AND TEST

This session will introduce the validation of the recent concept Smart Ambulatory Blood Pressure Monitor systems and evaluation results of technical and user tests. These results will be used for system development.

System Materialization

Since "Smart ABPM" is specially designed and developed for

the local background and a main design criterion is low cost, the major innovation of the system is the simplified wearable device with affordable but reliable components and user-friendly interfaces for patients ,their relatives and community doctors.

Device Test

To test the feasibility of development toward reliability and Stability of our system, we set up experiments. Most of them focused on the wearable BP measurement device. First, we developed an experiment system and chose six groups, the standardized BP values 120 mmHg/80 mmHg (SP/DP).

1. During Exercise

Table 2: Results of people During Exercise

Time	SBP(mmHg)	DBP(mmHg)	PPG(mmHg)
9.15am	115	79	50
9.30am	119	81	65
9.45am	129	75	65
10.00am	145	102	60
10.15am	153	96	55

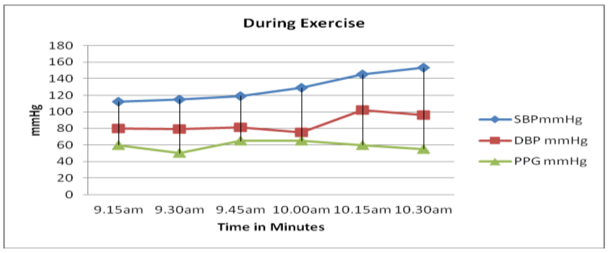

Figure 5: Results of people During Exercise

Physical exercise induces several changes in the cardiovascular system. With it, the working muscles and tissues need an increased level of oxygen and nutrients and the body adapts the cardio respiratory system to correspond to this need. Breathing rate increases to increase oxygen intake and the heart will contract faster and stronger to increase blood flow to the tissues. There are also significant changes in small blood vessels, for different regions of the body, consequently shifting blood flow to the active muscles. Another way to approach physical exercise changes and regulation is stating that the body accepts a higher value of BP.

2. During Sleeping

Table 3: Results of people During Sleeping

SBP(mmHg)	DBP(mmHg)	PPG(mmHg)
120	81	37
134	82	39
134	82	38
130	72	30
132	78	54

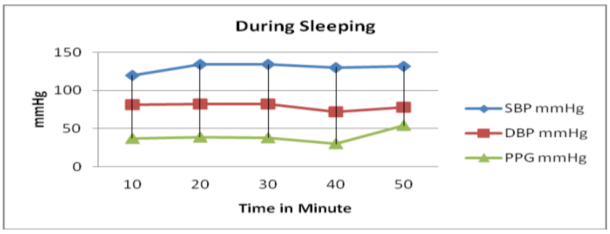

Figure 6: Results of people During Sleeping

Plethysmograph runs in stable form there is no major change .Because at that time blood volume will not much be changes blood flows through arteries smoothly. A grade in SP, DP and PPG estimation. 75% of the results had difference less than a ±3mmHg approximately.

3. Diabetic Patients

Table 4: Results of Diabetic Patients

Gender	SBP(mmHg)	DBP(mmHg)	PPG(mmHg)
Male	128	91	58
Male	125	90	62
Male	130	92	65
Female	130	94	59
Female	125	92	58
Female	147	63	57

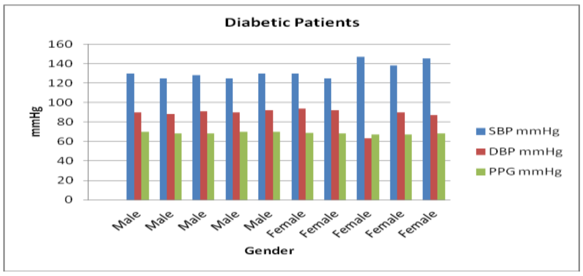

Figure 7: Results of Diabetic Patient

It is necessary to take gender wise survey because after some age their some changes in male and female. At that time different disease will be detected. The cardio disease is considered as a problem of male after 30+ age and women in post menopause i.e. after 35 years. In above figure 5.3 we take BP of male and female diabetic patient those are suffering from medium diabetic i.e. those blood sugar level is not change drastically their Plethysmograph runs in stable form there is no major change. For diabetic patients blood volume will be low that's why we getting PPG is comparatively low as compare to healthy person. Because of artery stiffness.

4. Hypertensive Patients

Table 5: Results of Hypertensive Patients

Gender	SBP(mmHg)	DBP(mmHg)	PPG(mmHg)
Male	142	96	68
Male	138	87	67
Male	138	83	64
Female	135	90	59
Female	139	92	60
Female	140	94	63

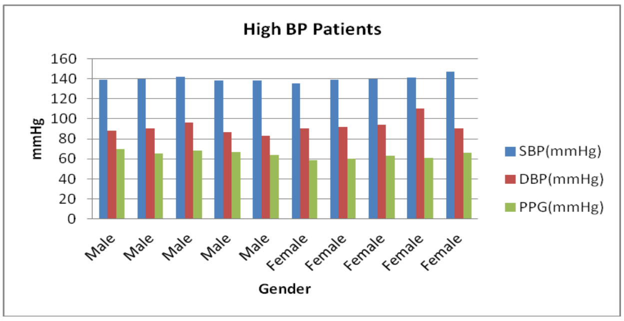

Figure 8: Results of Hypertensive Patients

The patients that form the sample group whose age in between 39 to 45 years; will be monitored at the Hospital of Dixit Heart Care center. With the cooperation of Dr. Rohit Dixit and medical staff, whenever an event of interest in blood pressure variability occurs in one or several patients, their vital signs will be recorded and saved for our analysis. For hypertensive patients blood volume will be low that's why pressure will be high in that type of patients we getting PPG readings are comparatively high with healthy person. And also their SBP and DBP is high as normal BP 120/80 mmHg.

5. Hypotensive Patients

Table 9: Results of Hypotensive Patients

Gender	SBP(mmHg)	DBP(mmHg)	PPG(mmHg)
Male	89	58	45
Male	87	60	48
Male	88	57	46
Female	90	60	38
Female	90	55	39
Female	86	60	38

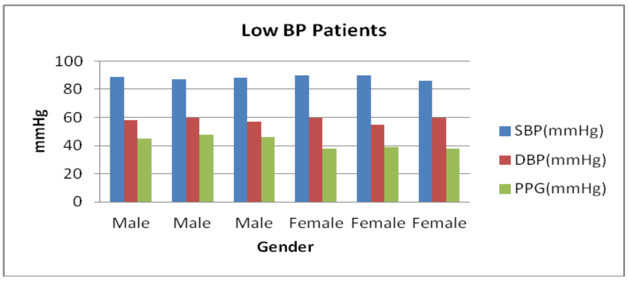

Figure 9: Results of Hypotensive Patients

The hypotnsive patients BP analysis. When patients BP is below 90/60mmHg then it becomes a Hypotensive .Most of the weakest i.e. under weight persons are suffering from hypotension specially females are suffering from hypotension. Above table 6.5 shows the male and female reading those are suffering from low BP comparatively their Plethysmograph also low. As we compared with Sphygmomanometer it gives accuracy with infrared PPG sensor.

6. Cardiac Patient

Table 6: Results of Cardiac Patient

SBP(mmHg)	DBP(mmHg)	PPG(mmHg)
121	89	65
124	88	63
121	82	68
130	90	65
124	83	69
130	90	68

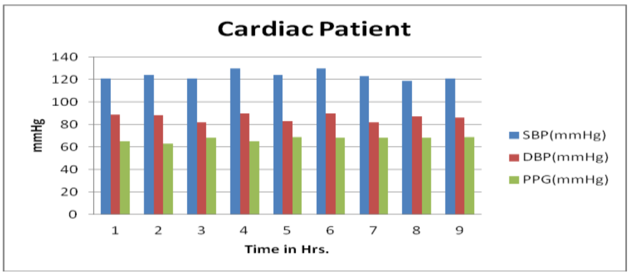

Figure 10: Results of Cardiac Patients

The readings are same as normal patents there is no major change in SBP ,DBP and PPG readings. As per medical expert says there is no major change is shown in cardiac patient. After surgery there heart will be work as normal person so there is no change in BP readings.

Discussion

The obtained results suggest that PPG are good measures to monitor physical exercise induced BP changes in a young, healthy population. The limited measurement accuracies of the used setups may be one of the reasons why. Specifically, the measurement accuracy to extract PPG based too large if one had theoretical expected 8-16ms PPG changes for a 10mmHg BP change. Plotting PPG variation against SBP variation together with theoretical values. Therefore, this points to the fact that if there are any small PPG variations due to exercise, the used setup may not have the necessary sensitivity for correctly detecting them.

During sleeping condition there is less variations in PPG graph. The measurement accuracy is too good, the theoretical expected 6-10ms PTT that much of less variation in sleeping condition.

For diabetic patients male and female its systolic level goes high also PPG level goes high, the theoretical expected 10-12ms PPG that much of maximum variation in diabetic patient. The mean systolic BP was significantly higher in diabetic patient.

Mostly the males are High BP Patient and females are hypotnsive. From above table 5.4 we conclude maximum increasing pulse Plethysmograph shows for hypertension.

CONCLUSION

To help in addressing the Blood pressure problem, a monitoring platform of BP by using finger Plethysmography and SMS has been designed. The investigations are meant to help to bridge the gaps in hypertension control, such as lack of continuous monitoring of patient and lack of hypertension records management, diabetic patient regular record etc. Recently, this concept has been prototyped and revaluated like ambulatory. The conclusion is that can be developed toward sufficient reliability and affordability. Furthermore, the test result about finger tip BP measurement device shows that the current device is feasible in order to transfer the prototype into a product after advanced optimization and less time required for measuring BP results checked by Clinical expert. Also, we propose to develop the design further and carry out implementation. For this, a number of stakeholders are necessary. The design will function effectively when a complete design and development phase is executed, including attention to user testing and their needs, technological optimization.

Acknowledgments

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