Preface

Photoplethysmography (PPG) is a simple and inexpensive optical technique that can be used to detect blood volume changes in the microvascular bed of tissues. With the advancement in optical technology, noninvasive assessment of cardiovascular functions by the peripheral arterial pulse has gained substantial research and clinical interest and PPG is one such technique which has gained popularity during recent decades.

Photoplethymographic signal characteristics have been studied to identify vascular diseases. There has been a resurgence of interest in the technique in recent years, driven by the demand for low cost, simple and portable technology for the primary care and community based clinical settings and the wide availability of low cost and small semiconductor components, and the advancement of computer-based pulse wave analysis techniques. The PPG technology has been used in a wide range of commercially available medical devices for measuring oxygen saturation, blood pressure and cardiac output, assessing autonomic function and also detecting peripheral vascular diseases. PPG being a noninvasive technique has its own attraction when compared to other expensive invasive methodologies used for cardiovascular diagnostics.

The basic PPG waveform comprises of a pulsatile (‘AC’) physiological waveform attributed to cardiac synchronous changes in the blood volume with each heart beat, and is superimposed on a slowly varying (‘DC’) baseline with various lower frequency components attributed to respiration, sympathetic nervous system...
activity and thermoregulation. With suitable signal processing techniques the AC and DC components of the PPG signal can be extracted and used for further pulse wave analysis. In the studies reported here the signals were acquired using an indigenously developed hardware setup.

The thesis presented in seven chapters deals with the work involved in the design, development of a sensor probe head and some selected studies on the PPG signals using definite protocols for noninvasive diagnostics.

**Chapter 1** gives an insight into the principle of Photoplethysmography and the different modalities used in this technique. The interaction of light with tissue, early and recent history of PPG, instrumentation, measurement protocol and pulse wave analysis are also discussed. The last part of the chapter focuses on the applications of PPG in clinical physiological measurements, including clinical physiological monitoring, vascular assessment and autonomic function.

**Chapter 2** elaborates on the design, development and characterization of a high sensitivity, low power, low cost sensor for detecting the blood volume pulse using transmission mode PPG from the finger tip for short term monitoring. The mechanical design aspects of the sensor head and material selection for the same are also discussed. A typical application of this sensor head in implementing a heart rate meter using a microcontroller is also explained. A comparison of the performance of the developed sensor with a commercial equipment is
also included. The denoising of the recorded PPG signals using wavelet transform is briefly outlined towards the end of the chapter.

Chapter 3 deals with age related studies using the PPG signal and its second derivative (SDPPG). Age-related changes in the PPG pulse shape characteristics can yield valuable diagnostic information about the cardiovascular system. This chapter is devoted to the noninvasive studies of the systolic and diastolic characteristics of the resting peripheral volume pulse using a normalized mean pulse as a function of age. The second derivative of the PPG signal has also been used to derive a parameter related to the distensibility of large arteries.

Chapter 4 is based on the investigations carried out on the PPG signals after local mild cold exposure. The cold exposure test is often used to assess vasoconstrictive responses because it simulates the vasoconstrictive conditions commonly encountered in the clinical setting. Cold exposure is likely to introduce vasoconstriction and increased peripheral resistance as a result of which the PPG waveform will change owing to the alteration in vascular wall properties and pulse wave reflection. This chapter gives an insight into a few new parameters that could be derived from the finger PPG signal during the cold exposure test. The morphological features used in this study allow the detection of changes in the pulse characteristics by monitoring how the shape of individual cardiac pulses change with time. The parameters studied include the normalized pulse width, skin vasomotor reflex, half width amplitude, area index, and the latency between the systolic and the diastolic peaks.
Chapter 5 describes the variations observed in the Photoplethysmographic waveform due to positional changes of the lower limbs during the recording of the PPG signals. Certain parameters have been derived from spontaneously breathing subjects using Passive leg raising (PLR) which is a reversible maneuver that can mimic rapid fluid loading (FL). Photoplethysmographic assessment of the haemodynamic variations using the pulsatile tissue blood volume due to the position of the lower limb height seems to follow the theory of basic blood flow dynamics.

Chapter 6 deals with the studies carried out on the characteristics of PPG signals of non-diabetics and diabetics affected by retinopathy. A measure of the right – left correlation coefficient for the diabetics based on the PPG amplitude was determined and it has been found that this parameter is low compared to that of normal subjects and also less dependent on age. Statistical signal processing approach was also used to confirm this result. The second derivative of the photoplethysmogram (SDPPG) has been used to derive a parameter that is closely related to the distensibility of large arteries. From the studies conducted, we have found that this parameter is lower for age matched diabetic subjects when compared with normals.

Summary and conclusions of the work carried out are given in chapter 7.
List of Publications - International journal


International conference:

1. **Jayasree V.K**, Sandhya T V, Shaija P J, Radhakrishnan P
   “Photoplethysmographic assessment of Skin Vasomotor Reflex using the blood volume pulse measured at the finger tip”

2. Sandhya T V, **Jayasree V.K**, Shaija P J, Radhakrishnan P
   “Studies on the effects of air pollutants on the peripheral blood volume pulse using an optical plethysmograph”


4. **V.K.Jayasree**, M.G.Mini, V.P.N Nampoori , P.Radhakrishnan,
   “Wavelet based denoising of Photoplethysmographic signals”

5. **V.K. Jayasree**, V.G. Sreeja, M.Kailasnath, P. Radhakrishnan,
   “Fiber optic evanescent wave carbohydrate sensor”
   , *Proceedings of the Eigth International conference on*


**National conference/seminar/symposium:**

1. **Jayasree V.K**, Sandhya T V, Shaija P J, Radhakrishnan P
   “Assessment of skin microcirculation using Photoplethysmographic signal measured at the finger tip employing cold exposure test”, *All India Seminar on emerging trends in information and communication technology*, August 29 to 30, 2008.

2. Sandhya T V, **Jayasree V K**, Shaija P J, Radhakrishnan P,
   “Statistical signal processing approach to assess bilateral symmetry of blood volume pulse recorded at the finger tip using an optoelectronic configuration”, *All India Seminar on emerging

