Abstract

Photoplethysmograph Signal Modeling towards Preventive Cardiology

Clinical assessment of human cardiovascular system is significant in view of emerging coronary artery disease (CAD) epidemic in developing countries. Identification and usage of suitable non-invasive methods for mass screening is a prudent and cost-effective step towards preventive cardiac health care. Photoplethysmography (PPG) is an easily deployable noninvasive technique which is investigated in this thesis for possible use in cardiac health care.

The overall aim has been to explore an elegant model for approximating a measured PPG signal using well defined Rayleigh functions and to examine the validity of the model in identification of arterial degeneration for preventive cardiovascular health care applications.

A new mathematical model, named 'Two-Pulse Synthesis (TPS)' model, has been presented for satisfactory approximation of a pulsatile PPG signal, obtained from measurement. An experimental setup used for measurement of PPG signal and the data collection methodology have also been described in the thesis.

PPG signals have been collected from about 300 volunteers, aged between 20 and 90 years, over a period of three years and the signals have been categorized as per their disease conditions. The major diseases that have been considered for a series of studies include hypertension, diabetes, diabetes induced hypertension and coronary artery diseases. The results obtained following conventional approach of time-domain differentiation of PPG signals have been analyzed in detail for all the disease conditions and compared with those of a normal population. Next, the newly proposed TPS model has been applied on all measured PPG signals to bring out a different set of results. In-depth analysis of TPS model derived parameters and their comparison with conventional parameters have been presented through tables, graphs and other suitable diagrams (such as Bland-Altman plot, box diagram).

The new set of parameters, obtained using the TPS model usually resulted in more clinical insight into the extent and nature of arterial degeneration due to the type and

duration of the diseases. Principal component analysis of the model based parameters has been included to successfully delineate a diseased arterial condition from a healthy one. Such degree of separation has not been possible with conventional measurement methods. Barring some stray cases, successful identification of risk level due to arterial degeneration has been possible for more than 60% instances on an average.

A systematic scheme for usage of photoplethysmography in cardiovascular health monitoring for rural population has been suggested based on encouraging results of a longitudinal study involving about 40 subjects over a period of two and a half years.

Some of the contributions reported in the thesis are:

a) A novel mathematical model, called Two Pulse Synthesis model, proposed for clinical analysis of photoplethysmograph signal.
b) Two new clinically important parameters, viz. Differential Pulse Spread and Spread-Delay ratio, related to arterial health, have been introduced.
c) The proposed TPS model has been applied on a variety of PPG signals to successfully differentiate between a normal and a diseased condition
d) A procedure for longitudinal study of cardiovascular health, as a part of preventive cardiac health monitoring, has been suggested for rural population.

Keywords: - Arterial Stiffness, Atherosclerosis, Coronary Artery Disease, Diabetes, Differential Pulse Spread, Foot-to-Foot Delay, Hypertension, Photoplethysmograph, Pulse Wave Velocity, Spread Delay Ratio, Two Pulse Synthesis model