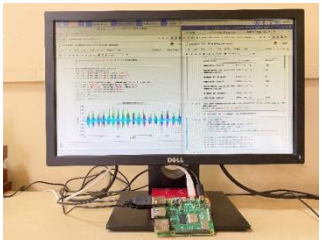
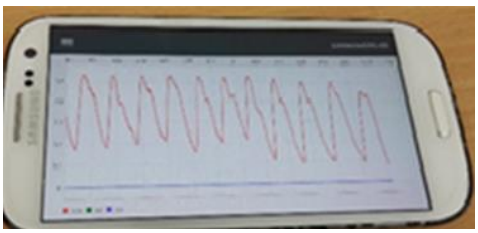
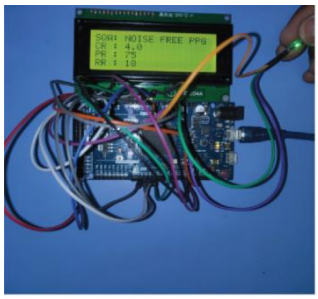
As per the World Health Organization report, cardiovascular diseases (CVDs) are the major cause of death worldwide and also leading to increase the prevalence of chronic disability in both developed and developing countries. Among noncommunicable diseases, CVD increases noncommunicable morbidity and mortality rates in low- and middle-income countries due to the lack of healthcare services, including the non-availability of medical devices, diagnostic systems, and trained nurses or medical experts, the unaffordable for the medical treatment and hospitalization, and the limited cardiac health centres equipped with specialized cardiac signal and imaging systems, and CVD diagnostic software tools. In addition to these inadequacy and high demands which can be systemically addressed to provide better quality of cardiac care with reduced overall costs by exploring recent advancements in the fields of biosensors, micro and nanoelectronic, high speed processor, wireless and internet of things, artificial intelligence, the people's socioeconomic status (economic stress, psychological distress, low job satisfaction, threat of unemployment, discrimination, work-life conflict, and lack of control over life) and lifestyle behaviours (unhealthy diet and obesity, smoking, excess alcohol consumption, poor self-rated health, and low physical activity) highly impact health and wellness of an individual and also increases prevalence of cardiovascular risk factors. Further, long-term exposure to the environmental pollutants and climate change can significantly contribute to a person's risk of developing heart diseases including the heart attacks, irregular heart rhythm, ischemic heart disease, arrhythmias, and lead to a variety of negative effects on cardiac health.

For timely identifying different kinds of CVDs, providing accurate treatment with reduced cost, predicting life threatening cardiac arrhythmias and also reducing CVD risk factors, there is high demand for wearable and portable cardiac health monitoring devices. These medical devices can enable continuous long-term health cardiac monitoring and also remote health monitoring which can play a vital role in improving quality of care and reducing economic burden of an individual and nation. Although there are portable and wearable medical devices in markets, it is not clear whether cardiac signals sensed by using these devices can be used for clinical applications without knowing recording conditions (resting, ambulatory, and exercise) , emotional/stress states, physical activity and other environmental factors which also influences the function of cardiovascular system. Many studies have demonstrated physiological parameters can be influenced under different recording conditions for healthily person that measurement can lead to wrong diagnosis and treatment. Furthermore, under ambulatory and exercise recording conditions, cardiac signals can be distorted because the wearable and portable devices are more susceptible to the movements of the body. The noisy cardiac signals lead to inaccurate and unreliable measurement vital signs and cardiac indexes and can result to frequent false alarms which will be more annoying for the caregivers and physicians/doctors. Since most affordable wearable and portable medical devices have limited resource constraints including limited battery power due to the tiny size of battery, there is a demand for increasing the longevity of battery life or maximising battery life so that the modern devices can be effectively utilized for continuous long-term cardiac health monitoring applications.

For addressing the major design, development and deployment issues by considering the improvement of diagnostic accuracy and reliability, false alarm reduction, affordability, and battery lifetime, researchers from IIT Indore and IIT Palakkad submitted the proposal entitled " Development of an affordable wearable IoT-GPS enabled intelligent vital signs monitor for smart health monitoring services" to the Indian Council of Medical Research (ICMR), Government of India by Dr. Ram Bilas Pachori, Professor, Department of Electrical Engineering from IIT Indore and Dr. M. Sabarimalai Manikandan, Associate Professor, Department of Electrical Engineering, IIT Palakkad as Principal Investigators. Research team received the grants for the design and development of affordable smart vital sign monitoring devices with non-invasive sensors with plug-sense, and intelligent cardiac health monitoring software that can be used for measuring pulse rate or heart rate, respiration rate, blood oxygen saturation (SpO2), blood pressure and body temperature. The proposed smart devices can have great potentials in non-invasive measurement of vital signs from noise-free cardiac signals, recognizing different kinds of cardiac arrhythmias and also enable predicting of life threatening cardiac diseases. In addition to this, the proposed medical devices can have the flexibility in sensing the physical activity information, emotional state information, environment factors and other inputs of lifestyle factors. These devices will be integrated with IoT platform and GPS sensor for transferring the sensed and processed data to the edge and cloud computing platforms for further analysis and diagnosis by the experts. Our research team members have developed intelligent energy-efficient cardiac signal processing

system with major innovative technological solutions, including the sensor disconnection alert, automatic signal quality assessment before further processing, quality-aware parameter extraction, event-triggered wireless communication protocol, data cryptocompression and deep learning based CVD recognition and prediction for achieving the major requirements such diagnostic accuracy and reliability, false alarm reduction, energy efficiency (maximizing battery life) and contextual information aware diagnostic process. Most of our innovative signal processing deep learning methodologies were implemented on resource constrained computing platforms including the Arduino and Raspberry Pi which are interfaced with biosignal acquisition system and wireless modules to demonstrate the percentage of the energy saving by using our quality-aware vital signs and cardiac signal analysis systems. Based on new research findings and innovative solutions, research team is in the process of developing prototypes of medical devices and filing patents.

Research team includes the Nabasmita Phukan (Senior Research Fellow) and Achinta Mondal (Junior Research Fellow) from IIT Indore and Fawaz Abdul Razak (Senior Research Fellow) and Jomole Varghese (Junior Research Fellow) from IIT Palakkad.

Snapshots of the ongoing research activities in the development of medical devices.

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