# Students as Co-Researchers (ScR)

# APPLICATION FORM – 2020

## Proposal Details

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| Title of Proposal: | An End-to-end Machine Learning Based Platform to Monitor Atrial Fibrillation Patients using a Non-invasive Wearable PPG Sensor |  |

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| **Project Track** |
| Summer track (July 01 – August 31)  Senior project track (July 01 – December 31) |
| **Select the project domains to which you are applying:**  Basic/Applied Research Project  Policy Papers, Industry Analysis and Case Studies  Pedagogical Research Project  **If you selected Pedagogical Research Project, further select the streams to which you are applying:**  **** Pedagogical Interactions  Developing and implementing innovations at the course level |
| **Description of the Project** |
| 1. **Project Overview**   Due to the advancements in technology in recent years, particularly in fields such as microelectronics, engineers have been able to construct embedded systems that are powerful enough to process and store large amounts of data, while also being portable. This combined with the development of data science and machine learning techniques over the past few years, allows us to extract relevant information from the data collected which can be used to predict future cases based in the data collected. This project will involve the use of these innovations to identify arrhythmia, which is defined as irregular human heart behavior, and a common form of atrial fibrillation. Atrial fibrillation has numerous causes including, stress, hypertension and coronary heart disease and if not addressed can lead to a heart attack. However, its symptoms, such as chest pain heart palpitations and fatigue are either ignored or do not occur. With death resulting from heart failure on the rise in Pakistan, largely due to the delayed detection and diagnosis of patients with heart disease, the project we propose aims to create an end-to-end product that allows us to not only detect irregularities in the human heartbeat, using machine learning techniques but also monitor this behavior over a long time. We aim to gather information from non-invasive sensors like photoplethysmogram (PPG), a cheap and accurate substitute to the conventional electrocardiogram (ECG). The data gathered will first be processed to eliminate noise generated from movement, analyzed to detect any irregularities present in the PPG waveform and then predict the possibility of whether the patient is exhibiting symptoms of potential heart failure. We also plan to create a system which uploads the data collected from the patients to a cloud managed by the hospital and automatically informs the hospital when such symptoms appear. At the same time, the developed platform alerts the patient to get himself thoroughly checked and medically investigated for a potential heart disease. |
| 1. **Introduction**   Cardiovascular diseases (CVDs) are disorders of the blood vessels and the heart which include but are not limited to; coronary heart disease (CHD), hypertension, angina, myocardial infarction, rheumatic heart disease and cardiac arrhythmias such as atrial fibrillation (AF) etc., resulting from sedentary behavior, poor dietary choices, smoking and pollution, brewing against a background of genetic susceptibility. According to the World Health Organization (WHO), CVDs are the primary cause of death world-wide among non-communicable diseases, and reasonable predictions state that the situation will become worse. In Pakistan, according to WHO statistics, more than one third (34%) of all deaths are caused by CVDs, making it the leading non-communicable disease in the country [1]-[7]. In this scenario, a growing demand of medical assistance implies a large number of population require assistance in hospitals where multi-lead Holter monitoring devices for Electrocardiogram (ECG) signal recording and imaging modalities remain the most prevalent clinical standards of care for cardiac health assessment and monitoring; however, they are susceptible to poor patient compliance due in part to their bulky form factor, wired connections to leads, high cost and availability issues in the hospitals. Another main reason that attribute to the large number of deaths is the fact that majority of the patients either ignore or experience little to no symptoms, resulting in a diagnosis only after a heart attack is experienced. Fortunately, recent technological developments and digitalization have allowed for real time monitoring of heart patients [8]-[12]. By having patients wear a wrist worn device which contains photoplethysmogram (PPG) sensors, data from the PPG signals can be collected and analyzed using machine learning algorithms. Through this analysis, abnormal heart rhythms (atrial fibrillation) can be detected. Previously, the Emaptica E4 smart physiological band, which contains a PPG sensor along with several other sensors, such as a temperature and heat sensor, however, this device is extremely expensive and therefore unfeasible for mass production and usage in a practical environment. Hence, in the proposed project, our aim is to create our own novel wrist device along with robust machine learning techniques which can obtain at least the same level of accuracy as those obtainable through a commercial and clinical grade device such as E4 smart band. Moreover, the project also aims to develop machine learning algorithms to distinguish between changes in the heart rhythm of patients due to physical movement and atrial fibrillation, which currently is the main limitation in state-of-the-art. Lastly, the project aims to develop a warning/monitoring system that not only monitors the heart rhythm of the patient for abnormalities, but also, sends wirelessly the processed information to the cloud network of the hospital along with relevant patient details so that in the event an abnormality occurs, doctors are immediately informed and timely treatment can be provided. In the case an anomaly was detected, a warning message will be generated for the patient and his/her immediate family as well.  More specifically, we aim:  • To design and create a device that can be attached to the wrist as a wearable device, and collect data.  • Develop machine learning techniques that will take into account and adjust for physical movement of the patient called motion artifacts.  • Create a warning/monitoring system that continuously monitors the patient, uploads the collected data onto a cloud network and alerts the hospital should irregularities in the heart be observed. |
| 1. **Clearly stated research question you are trying to answer through your project**   The precise nature of the proposed project is to deal with the problem of remote and ambulatory cardiac health monitoring and assessment using machine learning techniques by utilizing PPG signals as recorded by a wrist-worn wearable prototype device. More specifically, we will be focusing on atrial fibrillation (AF) which is the most dominating CVD in this study. The challenge in PPG based classification framework is that although the PPG based algorithms (for wearable devices) show a lot of potential, we need to consider the difficulties associated with the usage of such devices; first, PPG recordings from these devices can often be noisy due to the continuous movements of the users. Secondly, the occurrence of cardiac events can be rare and the noisy recordings can often mask such events. Thus, there is a need to develop signal processing and cleaning algorithms that account for the aforementioned factors for a robust detection and classification of any troubling cardiac event. |
| 1. **Background/Literature Review**   In order to diagnose any CVD, there are two standard approaches: medical imaging such as MRI, CT scan, OCT, IVUS etc., [13-16] and bio-signal analysis obtained from heart. While medical imaging remains the choice, which can only be executed in hospitals by expert professionals using costly and bulky medical equipment, anomaly detection in bio-signals obtained from the heart, has drawn significant attention among researchers and practitioners. Four different types of bio-signals can be captured and observed in order to infer about the health of human type:   1. **Acoustical:**   Produced due to beating heart, pressure change in vessels and blood flow speed. Common techniques for heart condition monitoring based on acoustical signal analysis are Doppler Effect Sonography, Cardiac Auscultation and Phonocardiogram.   1. **Mechanical:**   Produced due to beating heart and surface artery dilation. Common techniques for heart condition monitoring based on mechanical signal analysis are Ballistocardiogram and Manometry.   1. **Electrical:**   Produced by recording electrical activity of heart muscle as done by ECG, or due to change in impedance of tissue due to hemodynamic flow as done by Impedance Cardiography (ICG).   1. **Optical:**   Produced due to change in optical density due to vessel dilation. PPG is based on this principle.  These techniques based on heart signal analysis are non-invasive but they all have their own pros and cons. Such as cardiac auscultation, i.e., listening to the heartbeat with the aid of stethoscope, is used by physicians to diagnose CVDs [17]. The efficiency of cardiac auscultation is often hindered due to lack of ability to hear or interpret the heartbeats by a physician and is prone to human errors or inaccuracies [18]. ECG is a non-invasive and efficient technique that represents the electrical activity of heart and ECG signals are useful to analyze and diagnose CVDs [10-12], [19]. It is widely used to monitor patients’ cardiovascular activities. Any deviation from the usual heart rhythm (60–100 beats per minute) including disturbances in the heart rate, regularity or conduction of the cardiac electrical impulse appears in ECG signal which is useful in CVDs diagnosis [20]. In addition to CVDs, analysis of ECG signal also helps in deriving conclusions about the lifestyle of the patient. For instance, a high-frequency cardiac rhythm disturbance indicates that a person is suffering from sleep disorders [21] Capturing ECG signals for CVDs detection often demands special equipment and clinical setup along with expertise. At a large scale, this is not possible, especially in developing or under-developed countries, where the availability of medical experts, clinics, and medical devices is meager. Moreover, many people take standard ECG or medical image examination only when they have severe or obvious symptoms. Above factors might indicate that many patients with CVDs are not properly diagnosed. This fueled the need for automatic, low-cost, real-time, and efficient physiological monitoring that can be used in the home or under ambulatory settings alike. This gradually led to CVDs detection and health diagnosis by wearable devices and systems. PPG in this regard is a promising technology [22]. Developing a noninvasive ambulatory screening device for CVDs is one of the major purposes of this research study.  PPG is an optical measurement technique that can be used to detect blood volume changes in the micro vascular bed of tissue [23]. It has widespread clinical application, with the technology utilized in commercially available medical devices, for example in pulse oximeters, vascular diagnostics and digital beat-to-beat blood pressure measurement systems. The basic form of PPG technology requires only a few opto-electronic components: a light source to illuminate the tissue (e.g. skin), and a photodetector 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. Despite its simplicity the origins of the different components of the PPG signal are still not fully understood. It is generally accepted, however, that they can provide valuable information about the cardiovascular system [24]. A lot of work has already been performed to measure heart rate and blood pressure using wearable devices relying on PPG signals [25-26]. However, the accuracy of PPG signals is low enough to give good and reliable estimates of other cardiac events related to different CVDs [27]. At this point, researchers are exploring the ways to use the power of modern machine learning techniques such as deep learning to be used on PPG signals in order to increase the accuracy of CVDs detection and screening [28-30]. Early attempts leveraged hand-crafted features about inter-beat intervals in PPGs while recent approaches trained deep neural networks on PPGs to detect different CVDs. However, PPGs used in these studies were collected in controlled environments often inside a hospital, or were only a few minutes long. As an example, for screening of AF, a few attempts were made to detect it from PPG in ambulatory free-living conditions for prolonged periods of time. These approaches either obtained moderate performance [31], or deleted a significant portion of PPG segments – e.g. at least 33% of PPGs in [32]. This is largely due to the presence of noise and motion artifacts which corrupt the PPG. As a result, previous attempts have not been able to accurately identify AF episodes in PPG collected in an ambulatory free-living setting for a prolonged period of time. This constitutes the main scientific challenge and research hypothesis for the proposed research work to develop a prototype wearable device for PPG signal acquisition, processing and robust classification for the considered CVDs (CHD and AF) using advanced deep learning techniques in order to obtain a promising accuracy in the presence of different artifacts in the PPG signals such as motion, noise, sensor artifacts for false alarm reduction.  **REFERENCES:**  [1] E. J. Benjamin et al., "Heart disease and stroke statistics 2017 update: A report from the American heart association", Circulation, vol. 135, no. 10, pp. e146-e603, 2017.  [2] E. Wilkins et al., European Cardiovascular Disease Statistics, Brussels, Belgium:European Heart Netw. AISBL, 2017.  [3] P. Bizopoulos and D. 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| 1. **Research Design**   The overall model of this system can be simplified using the following diagram:    For our project we intend to:   * Create a smart and relatively cheaper physiological band that continuously monitors the hearth rhythms of the patient with the help of PPG signals. * Ensure continuous transfer and storage of data both locally and on server using a Diagnosis App developed for smartphone which will have receive data from the device through a Bluetooth connection. * Real time Alert for the prescribed Doctors as well as Emergency Alert to the patient in case a warning symptom is detected. The alerts will enable both the medical staff as well as the patient to carry out preventive measures. * Collect more data from known patients for increased accuracy and reliability of our research. * For real time monitoring, work on motion artifacts and figure out a way to remove these artifacts in the processing stage of the signal.   Considering the complexities and the high work load involved in this project, it will be extended to our SProj 1 and 2. For the summers, due to unforeseen circumstances led by Covid 19, we will rely on already available data and work on to devise up with a computer design and simulation for our hardware i.e. Smart physiological band. For that to be successful, we will have to go through the previously completed progress of this project which includes understanding the system level design as well as the instruments and tools which includes software packages and their code for signal processing in python language as well as the working principle behind the Emaptica E4 smart band  . |
| 1. **Proposed project team:**   Project lead:  Mohammad Afaq – 21100214  Co-investigators:  Sheraz Hassan – 21100285  Salaar Ali Assad – 21100087 |
| 1. **Overall timeline of planned activities:**   Summer and Senior Year Project Track (August 2020 – Dec 2020):  The timeline may be subject to change as per the current working situation at the time. |
| 1. **Expected Outcome:**   Research Paper  Conference Paper  Book  Book Chapter  Report  Case  Documentary  Hardware  Software  Prototype  Design  Other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  (Details):  We are aiming to design and give a prototype as the end product. |