# Students as Co-Researchers (ScR)

# FINAL REPORT FORM – 2020

## Project 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

SRP Call: ScR-200

SRP Grant ID: ScR200-2020-EED

Date: 13th January 2021

Faculty Mentor: Dr. Muhammad Tahir

Department: Electrical Engineering

School: School of Science and Engineering (SSE)

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| **TEAM LEAD SHOULD PROVIDE THE FOLLOWING DETAILS** |
| 1. **Achievements of the Stated Objectives:**   The achievement of the research so far is summarized below:   * Our first approach was to better understand the nature of PPG and what information is available to us in a raw PPG signal obtained from a wrist worn device. For this initial comparison, we opted towards a high-end device (Empatica E4) operating at 64 Hz which had a pre-implemented algorithm to remove redundant noise and low-end devices (MAXREFDES103# and MAX86140EVSYS#) which gave us the raw PPG signal with no pre-processing. The MAX86140EVSYS# (purchased through the ScR Grant) is an evaluation kit containing the MAX86140 and MAX86141 Sensor. The MAX86140 has a single photodiode channel whereas the MAX86141 has a double photodiode channel. Like the MAXREFDES103#, it gives us the flexibility of optimizing its parameters such as sampling rate, sensitivity, and LED output. MAX86140EVSYS# was perfect for us as it allowed us to create a prototype using the evaluation kit using the MAX86140/ MAX86141 sensor to measure the Raw PPG signal obtained via placement on the wrist using a health band.     Figure Empatica E4    Figure MAXREFDES103#  The figure below shows the evaluation kit of MAX86140EVSYS#:    Figure : MAX86140 and MAX86141   * Initial comparison between the data signal obtained was completed with the appropriate configuration of sampling rate along with its sampling average, and which LED output to opt for. We opted for the green LED as it is most strongly absorbed in the blood and least prone to motion artifacts with a sampling rate of 512 Hz with a sampling average of 8 to give us the average sampling rate of 64 Hz like Empatica E4. As we experimented, we observed that the raw PPG signal obtained through the low-end devices was subject to baseline variation (perfusion waveform) which was subject to various factors such as breathing rate, movement, stress, activity etc. Separating this waveform would mean we could analyze it further for the extraction of such vital parameters.     Figure shows the raw PPG signal obtained via MAXREFDES103.   * Perfusion waveform was separated from the PPG waveform using an approximating and filtering technique.     Figure Approximating the perfusion waveform (Red) from the Raw PPG signal (Blue)   * The PPG waveform obtained after filtering was inverted as shown below.     Figure raw PPG signal along with its frequency spectrum of a healthy individual    Figure Inverted PPG waveform and perfusion waveform obtained from the raw PPG signal in Figure 6.   * The perfusion waveform obtained was then processed to estimate the breath-rate using a band stop filter applied to the perfusion waveform at a frequency of 0.3 Hz. Peaks were found as shown in figure 8 and the average of the distance between the peaks was computed to find our breath rate in minute using the following formula:   We intend to extend the estimation and justification of these vital parameters as we progress our research in SPROJ-II.    Figure shows the respiratory signal obtained by apply bandpass filter to the perfusion waveform at the frequency of 0.3 Hz   * A correlation between the accelerometer data of the PPG waveform obtained (from both high-end and low-end) device was observed in the frequency spectrum where the frequency of motion induced by the accelerometer was introduced in the PPG waveform as well. It was then filtered out to eliminate these frequencies of motion. Hence, leading to the removal of motion artifacts to some extent and improvement in signal to noise ratio.     Figure shows the PPG signal along with its 3 axis accelerometer data for a healthy individual.    Figure shows the same PPG signal filtered to remove the frequency of motion using a band stop filter. Improvement in signal quality can be observed.  We intend to further explore this domain in our SPROJ-II as we work more on the elimination of these motion artifacts affecting the PPG signal. |
| 1. **What is the final output of the project?**   **Prototype**  **Is the final output different from expected output (stated in your proposal)? If yes, please explain.**  No but the work is still under progress as part of our SPROJ. The Covid-19 situation in Pakistan and closure of university affected the progress of our project immensely due to limited to the lab resources to the group members. Our main objective was to create a prototype that could monitor the health of the user using the PPG sensor. To understand how the cost could be cut down, we used the low-end devices to implement data processing algorithms for the cleansing and pre-processing of the raw PPG signal such that the processed waveform is comparable to the one provided by a costlier high-end device. Similarly, to monitor the health parameters, once the work on the pre-processing was completed, we started working on the estimation of the vital health parameters such as breath rate. More work on this domain will be done in our SPROJ-II to understand how if a monitoring system is implemented in real time, can use the raw PPG signal obtained towards the estimation and diagnosis of health condition of the user with the help of the cleansed and more robust PPG waveform obtained from motion artifacts removal techniques. |
| 1. **Any Potential Research Paper to be Published?**   **Yes**  No |
| 1. **Any Potential Patents?**     Yes  **No**  If yes, details: |
| **THE NEXT SECTION IS TO BE COMPLETED BY FACULTY MENTOR** |
| 1. **Have the research objectives met?**   **Yes**  No   1. **Are you satisfied with the performance of the student(s)?**   **Yes**  No   1. **Did you observe contribution by all the team members?**   **Yes**  No |
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| **Is the final report submitted within stipulated deadline?**  Yes  No  **Confidential comments:** |