### Team Name

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### Project Title

Knowledge-Informed Deep Learning for Robust Heart Rate Estimation Using PPG Signals

### Project Summary

This project aims to develop a deep learning model that accurately extracts heart rate (HR) from photoplethysmography (PPG) signals while mitigating motion artifacts (MA). Wearable devices like smartwatches commonly use PPG to monitor heart rate, but motion artifacts from user movements degrade signal quality and lead to unreliable HR estimations. The motivation for this project is the need for improved HR monitoring, particularly for people in motion or during physical activities, where current models struggle. We will build on existing approaches by integrating knowledge from the medical and signal processing domains into the deep learning framework to better isolate the heart-related signal from MAs. This project is particularly interesting as it aims to address a real-world challenge that affects the accuracy of health-monitoring devices.

### What You Will Do (Approach)

We will implement the KID-PPG (Knowledge-Informed Deep Learning for Heart Rate Estimation) framework described in the paper, which incorporates expert knowledge of PPG signal morphology, adaptive filtering, and probabilistic inference into the deep learning model. Our approach will begin by replicating the two-layer convolutional network used for motion artifact removal from accelerometer signals and PPG signal decomposition. The model will be trained using spatio-temporal convolutions to learn how motion from accelerometer signals contaminates the PPG readings. Additionally, we will extend the model by applying probabilistic HR estimation, which will predict HR as a distribution instead of a point estimate to account for uncertainty during motion artifacts. We plan to conduct experiments that test this model on different datasets and evaluate its performance against current state-of-the-art methods. Key metrics will include the mean absolute error (MAE) of HR estimation.

### Resources / Related Work & Papers

Several state-of-the-art methods address motion artifact removal and HR estimation. One traditional approach is to use signal processing techniques like filtering and spectral analysis, but these methods fail during complex or irregular motion. Recent methods using deep learning have shown promise in simultaneously filtering motion artifacts and estimating HR, such as the DeepPPG and NAS-PPG models, which use convolutional neural networks and attention mechanisms. The core innovation in this project will come from incorporating prior expert knowledge through adaptive filtering, guided probabilistic inference, and targeted data augmentation, as outlined in the paper "KID-PPG: Knowledge Informed Deep Learning for Extracting Heart Rate from a Smartwatch." Our work will extend these concepts and test their robustness against complex real-world motion artifacts in a kaggle competition.

### Datasets

We will use the publicly available \*\*PPGDalia dataset\*\* (https://archive.ics.uci.edu/ml/datasets/PPGDalia) for training and evaluating the model. This dataset contains synchronized PPG, accelerometer, and ECG signals from 15 subjects performing various daily activities, such as walking, running, and resting. Additionally, we plan to validate the model's generalizability using the \*\*WESAD dataset\*\* (https://ubicomp.eti.uni-siegen.de/home/datasets/icmi18), which also includes physiological recordings during different stress-inducing tasks. Both datasets provide the ground truth HR (via ECG), making them ideal for testing our model's accuracy.

<https://www.kaggle.com/c/24-exercise1>

### Group Members

- Member 1: Muhammad Daud Sheikh

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