Healthcare often remains reactive rather than preventive, with critical conditions discovered too late. My research harnesses **cyber-physical systems (CPS)** to create **real-time health monitoring solutions**. By merging **IoT technology**, **mobile platforms**, and **data-driven algorithms**, I seek to transform healthcare from a reactive model to one centered on proactive, personalized intervention.

Research & Technical Contributions: My work focuses on the design and implementation of **embedded platforms** for monitoring physiological signals (e.g., ECG and respiration) in real time. By integrating advanced sensing hardware, robust machine learning algorithms, and **low-latency edge processing**, I have achieved **over 96.5% accuracy** in detecting cardiac and respiratory anomalies [1,2]. In addition, generating high-fidelity data for **underrepresented arrhythmias** improves detection sensitivity by **more than 7%** for critical events. Key elements of my research include:

On-Device Processing & Hardware-Software Integration: Developed the **CardioHelp mobile app**, which connects via Bluetooth to ultra-low-power custom boards that stream physiological signals for real-time processing. The mobile app runs **resource-optimized algorithms** (e.g., CNNs, LSTMs, Hybrid models) to enable continuous monitoring without relying on offline computation or cloud services.

Advanced Sensing Hardware: Fabricated **inkjet-printed (IJP)** flexible electrodes that ensure reusability, prolonged daily use, and comfort while enhancing data quality and user compliance [3]. Additionally, to enable effective power solutions, I designed inkjet-printed flexible **supercapacitors** for energy storage in wearable devices. The measured capacitance of a single Metal-Insulator-Metal (MIM) capacitor exceeded 1 nF.

Seamless Mobile Integration: Our mobile application delivers instantaneous feedback on heart rate, respiration rate, and potential abnormalities, ensuring quick alerts and timely interventions for users and healthcare providers [4,5].

Adaptive Learning & Edge Optimization: Applied adaptive learning to adjust models based on user data and used pruning and quantization techniques to optimize ML/DL models.

Short-Term Agenda: I plan to develop **unified multi-modal** models that incorporate ECG, respiratory, EEG, and PPG signals, providing a holistic view of health [6]. By reducing false positives in real-world conditions, I aim to ensure that personalized health insights remain both reliable and rapidly actionable.

Long-Term Vision: Over the next decade, I will develop AI-driven platforms that integrate wearable devices, mobile applications, and secure cloud services. I will extend these technologies to **bio-inspired microrobotics** for autonomous medical interventions and **AI-powered sensor networks** for environmental monitoring. Additionally, I plan to develop edge-intelligent systems for smart city infrastructure. To ensure data security and privacy, I will collaborate on **privacy-preserving AI** models and **encrypted communication** protocols to protect sensitive health information in interconnected systems. [7].

Conclusion: My research integrates **on-device machine learning, edge computing, and user-centric design** to enhance efficiency, accuracy, and scalability in real-time health monitoring. By continuously improving these methods and exploring interdisciplinary applications, I aim to advance **personalized and preventive healthcare** while ensuring data security and adaptability across various domains.

References:

1. Utsha UT, Morshed BI. CardioHelp: A smartphone application for beat-by-beat ECG signal analysis for real-time cardiac disease detection using edge-computing AI classifiers. Smart Health. 2024 Mar 1;31:100446.

2. Utsha UT, Morshed BI. Edge-Computing Enabled Real-Time Respiratory Monitoring and Breathing Pattern Detection. In2024 IEEE 20th International Conference on Body Sensor Networks (BSN) 2024 Oct 15 (pp. 1-4). IEEE.

3. Mitra N, Utsha UT, Morshed BI. Inkjet-printed Dry Flexible Electromyography Electrode Array for Classifying Finger Movements with AI Algorithms. In2024 IEEE 15th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON) 2024 Oct 17 (pp. 85-89). IEEE.

4. Utsha UT, Hua Tsai I, Morshed BI. A smart health application for real-time cardiac disease detection and diagnosis using machine learning on ecg data. InIFIP International Internet of Things Conference 2023 Oct 26 (pp. 135-150). Cham: Springer Nature Switzerland.

5. Utsha UT, Morshed BI. A smartphone app for real-time heart rate computation from streaming ECG/EKG data. In2023 IEEE International Conference on Electro Information Technology (eIT) 2023 May 18 (pp. 1-6). IEEE.

6. Parreira JD, Chalumuri YR, Mousavi AS, Modak M, Zhou Y, Sanchez-Perez JA, Gazi AH, Harrison AB, Inan OT, Hahn JO. A proof-of-concept investigation of multi-modal physiological signal responses to acute mental stress. Biomedical Signal Processing and Control. 2023 Aug 1;85:105001.

7. Raheja N, Manocha AK. IoT based ECG monitoring system with encryption and authentication in secure data transmission for clinical health care approach. Biomedical Signal Processing and Control. 2022 Apr 1;74:103481.