Topic 1: Real-Time Edge-AI & Computer Vision for Clinical Safety Monitoring

- **Domain: Advanced Machine Learning, Computer Vision, Spatial Analytics**
- **The Challenge:** This project focuses on designing an embedded, real-time safety monitoring system for operating rooms with mobile imaging devices such as C-arms, which generate radiation during operation. The system will use a microcontroller-based tracking architecture to monitor the motion state of the C-arm (e.g., rotation angle and arm position) using embedded or external sensing modules. Based on this live spatial input, the system continuously updates a virtual safety boundary model and visualizes a dynamically shifting safe zone within the operating room environment. The goal is to evaluate how real-time physical state tracking can be used to compute adaptive safety boundaries and trigger proactive alerts or guidance for clinical staff to remain within safe exposure regions. This creates a low-latency, hardware-driven safety layer that complements existing imaging systems.
- **Core Technologies:** Microcontrollers (e.g., STM32 / Arduino / ESP32), IMU sensors or external tracking modules, real-time data acquisition, wireless communication (e.g., BLE), optional edge processing unit (Raspberry Pi or similar)

Topic 2: Virtual Reality Safety Briefing Application for External OR Visitors

- **Domain:** Virtual Reality, 3D Environment Design, Interactive Onboarding Tech
- **The Challenge:** Before engineers, research partners, or technical corporate vendors can enter a real operating room to collaborate on projects, they must undergo a safety briefing so they do not accidentally compromise patient safety or sterile zones. This project focuses on building a functional VR briefing environment that walks these non-clinical visitors through an interactive tour of an operating room. The student will be responsible for creating the 3D OR environment and designing a guided, step-by-step walkthrough system. As the visitor moves through the virtual space, the app will visually guide them on how to behave, where they are allowed to stand, how to avoid sterile fields, and how to stay clear of medical equipment.
- **Core Technologies:** Unity or Unreal Engine, Meta Quest Ecosystem, C# or C++

Topic 3: Surgical Phase Estimation via Real-Time Tool Tracking and Motion Analytics

- **Domain:** Computer Vision, Surgical Workflow Analysis, Machine Learning, Motion Tracking
- **The Challenge:** Understanding the progression of a surgery in real time is a fundamental step towards the future of autonomous, smart operating rooms. This project focuses on developing an AI-driven system capable of predicting the current phase of a surgical procedure by analyzing the movement and flow of surgical tools. The core research task is to track instruments within video streams and analyze their

trajectories, usage frequency, and motion patterns. By modeling these behavioral data streams, the system will learn to estimate which phase the surgery is in and predict upcoming transitions, providing a critical framework for assisting systems like automated clinical documentation.

- **Core Technologies:** Python, Machine learning, Object Detection & Tracking, Temporal Modeling