**[Title of your research project]**

The research question that this project seeks to address is: How can machine learning classify common weight training exercises in real-time through motion data collected on a strategically placed IMU while also being able to judge correct form and posture?

The research aims to be able to be able to create a system to classify weight training exercises in real-time and generate reliable motion data.

This research advances knowledge in machine learning and motion recognition using Inertial Measurement Units (IMUs) by investigating the role of contemporary machine learning algorithms to identify complex recurring patterns in real-time by relying on motion data collected on a microcontroller, IMU and some peripherals. The research goals strongly align to the Fulton Research Theme of Health as the work on this paper will directly affect the long-term muscle and bone health of athletes. Being able to recognize correct posture and movement during workouts is extremely important for proper muscle growth and to prevent chronic injuries. [Dr. Chao Wang’s Experience here and how it relates to this research]

At completion, the resulting system will be handheld and will be able to collect data for various exercises using an IMU, train on the data (on the handheld embedded device or an external machine) and perform real-time classification on an embedded device. If the research follows the timeline accurately, the handheld system with the embedded device and the IMU will also be configured to work with multiple such systems for more complex classifications involving multiple limbs.

**Abstract**

Machine learning has seen a great increase in popularity in the past few years due to its outstanding pattern recognition withing complex systems and even replicating those patterns for generation. It can imitate human pattern recognition. Personal trainers can instinctively recognize patterns in a bad form or a bad movement. Good personal trainers can help an individual prevent injury and help them achieve their goals in fitness. They help with a lot more stuff than form corrections like workout routines and diet. However, it is hard to find personal trainers either because there aren’t as many to train every individual, or their services are expensive. There is a need for a device that can help athletes train safely by monitoring their form and keeping them safe. The device cannot be heavy or big to influence the movement of the athlete or cause them any discomfort while also being sturdy and have a high computing power.

**Current literature and state of the art review**

1. Detection of Human Body Movement Patterns Using IMU and Barometer
2. Deep-Learning-Based Character Recognition from Handwriting Motion Data Captured Using IMU and Force Sensors
3. Improving gait classification in horses by using inertial measurement unit (IMU) generated data and machine learning
4. Golf Swing Segmentation from a Single IMU Using Machine Learning
5. OptiTrack

**Research Plan**

**Research Method:** We will start by creating a system/device to collect data and ask for athletes’ reviews on the size and comfort of the wearable and how they would like to get notified on their exercises’ form (haptics, sound etc.). We will use the device to collect data from many athletes performing the same exercise to get an unbiased dataset. Then train the model(s) to fit the data, validate using test data. Training will take place on-device or externally, TBD based on microcontroller’s performance analysis.

**Materials/Resources:**

1. Arduino Nicla Sense ME: A very capable and small package hosting a wide range of sensors with high reliability and a fast processor.
2. Arduino Nano 33 BLE Sense Rev 2: Another capable board with multiple onboard sensors and a fast AI enabled processor.
3. Raspberry Pi 5: Powerful Wi-Fi and BLE enabled single board computer to offload the training from the microcontrollers.
4. ESP32 and Adafruit 9-DOF Absolute Orientation IMU Fusion Breakout - BNO055: A Wi-Fi and BLE powerful microcontroller combined with an external IMU.
5. ASU Agave Cluster / Google Collab: GPU clusters / services used for training models.

**Procedure:**

1. Me and Professor Wang already have a STM32 based microcontroller with an IMU on it. Initial testing will be done on that board. I have already performed basic gesture recognition on that board using classical algorithms and will switch to Machine Learning.
2. We will start with a more in-depth analysis of the state of the art. We will track the microcontrollers, IMUs, ML algorithms, device placement, results and speed.
3. A comparison will be drawn from the analysis to determine which microcontrollers and IMUs we will use. Currently the identified metrics to decide a microcontroller are speed and size and for deciding the IMU are drift and sample rate.
4. Another comparison will then be drawn for the analysis to decide the Machine Learning algorithm we will use. Currently, the required metrics to decide a Machine Learning algorithm are size and speed.
5. After the Hardware and Software are finalized, we will begin collecting data from trained athletes for one exercise and classify it as positive(correct form) or negative(bad form).
6. We will then train the network on the data we collected and measure performance.
7. We will repeat the process for multiple exercises to collect data on multiple exercises.
8. Another model will be trained in order to classify the task the exercise the user is performing, and that data will be fed to the second model for classifying the form in real-time.
9. Another class will be added to the second model to detect fatigue, where the user was not able to complete the repetition.
10. We will then start experimenting with newer ML techniques for better models. This step is optional if we achieve good enough accuracy in our earlier steps.
11. If time permits:
    1. We will implement multiple such systems to detect and analyze complex exercises with multiple limb movements.
    2. Implement an interactable GUI or Button interface for athletes.
12. Summarize findings, results and methods into a research paper.

**Facilities:**

SCAI manufacturing lab 3D printers will be used for any 3D printing related tasks. BYENG 387 will be used for soldering related tasks and for signal analysis using oscilloscopes and signal analyzers.

**Expected Outcome:**

The built system should be able to classify different kinds of exercises based on body movement and classify those exercises to indicate good and bad form in real time.

In order to address the research question/hypothesis described above, the following research plan is proposed.

1. *Describe the design of your research plan - what general methods will you use and why? What are the specific tasks?*
2. *Materials - Description of materials (e.g., Software, hardware, equipment, chemicals, tests) used in your study*
3. *Participants (if applicable) - are any other people participating in your study, if so, explain how many and why.*
4. *Facilities (if applicable) - will you use any special facilities (e.g. Research Computing)*
5. *Procedures - Describe the steps of your proposed research from beginning to end. How are you implementing the design? How and in what order will you use the materials? This should include a high-level step-by-step process from when you start the research study.*
6. *Describe what the expected outcome or results from each task will be and how these will be analyzed.*

*Additional tips for writing a successful proposal*

1. *Use the full 2 pages for your research description without double line spacing.*
2. *A clear and relevant figure can be useful to help give the reviewer an idea of what your project will be about, but be careful not to waste space with an unnecessary figure.*
3. *Limit your content to things that are specifically asked for in the FURI application inss*
4. *Make it abundantly clear that you have addressed all rubric items; you can use bold face to draw attention to a key element, e.g.: “this research aligns with the****Fulton research theme****of …”*
5. *Conducting a literature review is not a good research task.  This is something you should do in preparing your proposal.*

***References (not included in two page limit)***

*All references cited in the proposal text should be listed here using a consistent format.  Google scholar is a good tool for preparing these.  List at least five resources you reviewed regarding your research area.*

***Timeline (not included in two page limit)***

*Create a reasonable and descriptive timeline that relates to the proposed research activities for the requested semester(s).*

***Personal statement***

*(1 page limit): write about the relationship between your personal goals and the proposed research activity.*