SKIH 2123 (MODELING & SIMULATION)
A232 – Group Project (20 %)

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"Do not be satisfied with stories, how things have gone with others. Unfold your own myth." [*Rumi*]

CASE STUDY: HUMAN FIGHTER PILOT PERFORMANCE

Imagine a fighter pilot strapped into a high-performance jet, soaring through the sky at breakneck speeds. Their success hinges on a delicate balance; a constant negotiation between their mental resources and the demands of the mission. The high pilot mental workload - and the subsequent decline in performance result from the imbalance between the mental resources available to perform the task and the number of resources needed to perform it. When the pilot's proficiency is evaluated, s/he should deliver an acceptable performance while being able to reserve enough mental capacity for unexpected, additional resource demands. The task demands and cognitive stressors of air combat have the potential to degrade pilot performance to an unacceptable level. Therefore, it is important to understand the amount of mental workload the pilots are experiencing and how much spare capacity they have available to cope with the possible additional resource demands through the concept of fighter pilot performance.

Human Fighter Pilot Performance refers to a pilot's ability to effectively fly and fight in a high-performance fighter jet. It's a complex mix of physical and mental skills that need to be at their peak during missions. Fighter pilots operate under extreme conditions and are required to maintain high cognitive and physical performance levels. Their performance can be influenced by several physical, psychological, and environmental variables. Understanding these variables can help in improving training programs, mission planning, and support systems to enhance overall performance and mission success.

There are five main input features related to human fighter pilot performance. First, the heart rate measures the pilot's physical stress level in beats per minute (bpm). High heart rates can indicate possible physical exertion that shows high stress has occurred. A pilot is experiencing a high heart rate due to intense pre-mission physical activity or anxiety. This high heart rate could impact their cognitive function and decision-making ability, as it may reduce the pilot's ability to react quickly. Another indicator called sleep quality (a measure of how well the pilot slept before the mission) relates to cognitive load and reaction time. Lack of sleep resulted in a pilot experiencing fatigue, and later reducing their ability to perform complex tasks effectively (due to a high cognitive load). Besides, higher heart rates and lower sleep quality increase physical fatigue. Another concept called mission complexity, like sleep quality, will increase cognitive load and stress. The cognitive load represents the mental effort required for the mission. It is common to know that cognitive load reduces a pilot's ability to perceive and understand a situation (or situational awareness). As a result, it is harder for the pilot to process information and make quick decisions.

However, most well-trained pilots have some fundamental ability to manage their situational awareness from their intensive training before the mission. Furthermore, in this case, the higher number of years the pilot has been flying (experience level) shows that more experienced pilots may handle stress better and perform more consistently by reducing their cognitive load. Additionally, if the mission takes place under poor weather conditions, such as heavy rain, strong winds, or low visibility (adverse environmental conditions), it can increase stress and require additional cognitive and physical effort to manage. Thus, pilots may struggle with navigation and maintaining control of the aircraft. From a psychological perspective, combined with a high heart rate and mission complexity, this environmental stressor increases experienced stress levels. These factors are not isolated; they interact and influence one another. Cognitive load, physical fatigue, and stress all work against performance, while good situational awareness and quick reaction times enhance it. Understanding this interplay is crucial for optimizing training programs, mission planning, and support systems. By mitigating these challenges, we can empower fighter pilots to walk the tightrope of performance with confidence and effectiveness.

QUESTIONS & INSTRUCTIONS

Assuming this model will receive and process a set of input/values from 0 to 1, form a group of 2-3 people (note: you can do this alone too). You are required to answer all questions and submit your solution based on:

1. Report that contains the answers
2. Codes
3. Prototype (Interface Design)

Part I: Model Development:

1. Identify and define the key input features influencing fighter pilot performance.
2. Explain how you mathematically represent all key input features in this model.
3. Explain the dynamics and interplay of all internal variables (instantaneous vs temporal interplays).
4. Develop mathematical specifications/equations for internal variables.
    a. Identify possible parameters
    b. Write all possible mathematical specifications to explain the overall interplay between key input features and internal variables

Part II: Simulation

1. Create **at least SIX (6)** simulation scenarios with varying levels of key input variables
    a. Describe those selected scenarios.
    b. Discuss how you would set up an experimental scenario for this model
    c. Convert your chosen scenarios into a set of input and parameters that has a range of 0 to
2. Implement this model in a programming language of your choice (e.g., MATLAB/Octave, Python, Java, C++) and simulate all scenarios.
3. Generate all graphs to show the simulation results for all input features and internal variables.

Part III: Evaluation

1. What techniques would you use to verify the correctness of the mathematical model and its implementation?
    a. Perform your chosen verification techniques to prove the correctness of your model.
    b. Explain possible verified cases and how they relate to real-world conditions
2. Explain the process of conducting a face validity check. Who would you involve, and what criteria would you use?
3. How can sensitivity analysis contribute to the model's validation process? Provide an example.
4. Perform a local sensitivity analysis and its relationship to the pilot fighter performance on:
    a. Sleep Quality
    b. Experience Level
    c. Mission Complexity
5. How would you approach validating the model using historical performance data from real fighter pilot missions?
6. Given a set of data (file name: SKIH213-GroupProject-ValidationDataset.xlsx) obtained from human experiments related to fighter pilot performance, validate the performance of this model.
    a. Build the appropriate hypotheses (H_0 and H_1)
    b. Explain your choice of test statistic
    c. Given your significance level, α=0.05, make a conclusion and decision about your model

Part IV: Application

1. Discuss how the model can be incorporated into training scenarios to better prepare pilots for high-stress situations. Explore adaptive training methods that use the model's predictions to tailor training to individual pilot needs.
2. Explore the feasibility of using wearable technology, sensors, and other devices to gather the necessary data without interfering with the pilot's performance. Discuss data transmission, storage, and processing requirements.
3. Design a user-friendly interface (preferably using Figma), one that presents data and insights in an accessible manner. Consider the needs of different users, such as pilots, trainers, and commanders, and how they will use the information provided by the model.

Policy:

All grading of deliverables will be based on standards indicated for each deliverable. Deliverables may not be turned in late, and no cheating! For this class, cheating will include plagiarism (using the writings of another without proper citation), copying of another (either current or past student's work), working with another on individually assigned work, or in any other way presenting as one's work that which is not entirely one's work. The occurrence of plagiarism will result in removal from the course with a failing grade.