Phase I Project Summary

Firm: Intelligent Automation, Inc.
Contract Number: NNX10CB27C
Project Title: Cognitive Modeling for Closed-Loop Task Mitigation

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)

Human operators play an important role in aviation and other safety critical missions. In existing aviation systems, the functional state of the operator is usually not monitored and remediation is not implemented. In practice, two types of hazardous states of awareness are more likely to lead to human errors: a stress state due to high workload for a prolonged period of time or a complacent/bored state in extremely low workload situations. It has been found that proper assessment of the cognitive workload offers potential to improve mission effectiveness and aviation safety.

Although a wide range of research has been performed to examine operator functional states during high workload condition, the disengaged state developed in low workload conditions has not received an equal attention. Disengagement is usually accompanied by poor situational awareness, leading to severe consequences in the multi-tasking aviation domain. This is especially true in commercial flights, which have long periods of low workload as the pilot cruises enroute toward the destination with the aircraft on autopilot. When unexpected events occur, the disengagement in the tasks being performed could lead to operational errors. As such, the monitoring of the pilot's state is critical for aviation safety.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

Objectives: The main objective is to develop and implement a closed-loop Adaptive Task Management System (ATMS) for both over-load and under-load conditions based on the Operator Functional State (OFS) assessment in real-time.

Work Plan
Task 1: Refine Phase II requirements
Task 2: Enhance individualized OFS assessment model
Task 3: Perform OFS reference analysis
Task 4: Design/perform experiments for OFS assessment
Task 5: Analyze EEG/Non-EEG sensing modalities for OFS assessment
Task 6: Develop the software and perform software testing
Task 7: Performance evaluation using benchmark datasets
Task 8: Integrate the cognitive model with CATS
Task 9: Develop Relationships with Industrial Partners to Commercialize the Technology

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)

We developed a system for Operator Functional State (OFS) monitoring (engagement, more specifically), considering individual variations in an aviation environment. The key contributions we made include a systematic ground truth finding procedure and individualized Enhanced Committee Machine (ECM)-based engagement assessment model. The derived engagement ground truth is continuous in time compared to a very sparse estimation of engagement based on an expert review or subjective evaluations. It can capture the variations of engagement during a mission to better guide the training process of the engagement assessment model. On the other hand, the individualized engagement assessment model framework is based on ECM and we investigated two different model individualization approaches: similarity-based and dynamic ensemble selection-based. In addition, we developed a Wavelet Neural Network (WNN)-based novel Electroencephalogram (EEG) artifact removal method.

To evaluate the developed approaches, we have collected data from a high fidelity Boeing 737 simulator involving 20 pilots. Experimental results show highly accurate engagement/disengagement detection. For example, when evaluated with four subjects' data, the 5-fold cross validation performance can range from 97.2% to 99.8%. And the performance of the dynamic ensemble selection-based model individualization approach is comparable to that achieved from an individual model.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)

The adaptive task management system provides sensitive and robust monitoring of human operator functional status in-situ and allows human and automated agents to adapt appropriately in NASA's aviation safety mission and in manned space flight and exploration missions.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)

The closed-loop task adaptive management system can also be applied to other operational environments such as military and civilian aviation, military UAV mission controllers, general transportation operators (particularly long haul trucking),and other supervisory control environments.

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