Dynamic Cognitive Workload Allocation Method for Human-Robot Interaction

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Abstract

A method to dynamically allocate and measure visual perceptual and cognitive workload in the area of Human Robot Interaction to help understand the state of people with the help of a workload allocation algorithm, an affective prediction algorithm and a user study is being researched. A user study involving two participants to perform a task at a given time was conducted and data from biosensors and behavioral sensors were collected and analyzed. Husformer, which is an end-to-end multi-modal framework that uses cross-modal transformers to help recognize human state was used to help with this process. An algorithm was developed to evaluate performance metrics for workload allocation. Hence, based on each participant's cognitive load, the workload allocation algorithm allocates the task at hand as calculated to the participants dynamically. This study was an extension of a previous phase of a user study that was used to test and find correlations between cognitive workload allocation of an individual participant as the number of camera views in a GUI increased or the velocity of objects moving on the screen increased. We validated the effectiveness and productivity of the proposed affective workload allocation through the user experiment.

Research Team

Introduction: Workload Allocation

- **Cognitive (Visual Perceptual) Workload**
  - Utilized when performing tasks that require viewing multiple things at the same time, like in Figure 1.
  - No psychological tool exists for taking real environment into account for stimuli, and we are developing and validating a novel tool

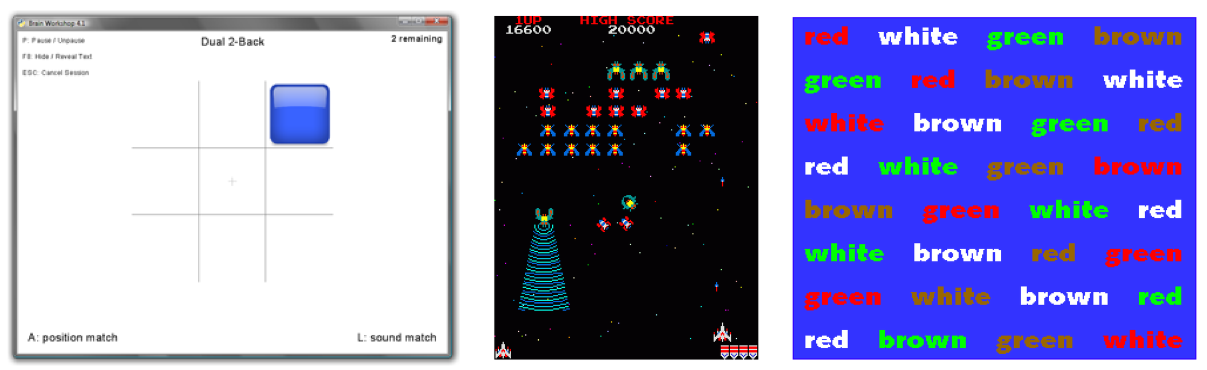

Fig 1. *Examples of psychological test for cognitive loads: dual n-back, Galaga, and Stroop tests*

- **Dynamic Workload Allocation**
  - Using multi-modal transformer, Husformer [2], along with workload measured and dynamically allocated to measure and improve performance, training users in visual perceptual load
  - Primary Factors in assessment: speed of moving objects, number of views, user's reporting of load (ISA, NASA-TLX)

Overall Concept

- **User Studies for Validation**
  - Participants asked to click on a screen when there are abnormal characters, robots controlled by teleoperated Multi-Robot System (Fig 5).
  - Load allocation between participants based on performance (success rate, score, sensor readings)

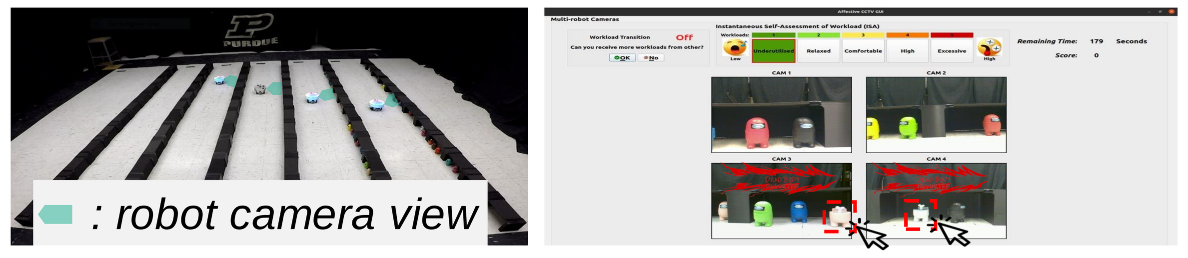

Fig 2. Robot camera views and CCTV Monitoring GUI

- **Dynamic Workload Allocation Algorithm**
  - A Greedy algorithm, modeled by Fig. 4, used to allocate workload between participants, including equations 1, 2 and 3
  - Robot speeds are in the range [40%, 80%] of maximum speed and the number of cameras are in the range [1, 5]

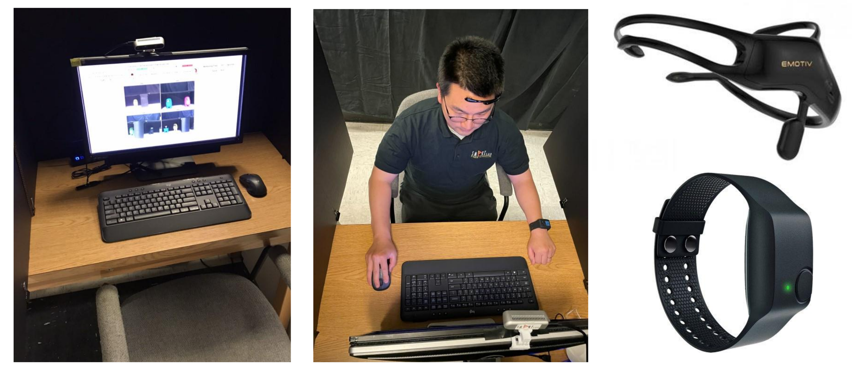

Fig 3. Participant Setup for User Study (left, middle), biosensors used (right: EEG – top, EMG – bottom)

(1) $\Delta c = \alpha_{cam}\Delta N_{cam} + \beta_{speed}\Delta Nspeed_d$

(2) $c_{t+1}^{isa} = c_t^{isa} + \Delta c$

(3) $c_{t+1}^{pred} = c_t^{pred} + \Delta c$

Eqn. 1, 2, 3. Workload Allocation Algorithm eqns.

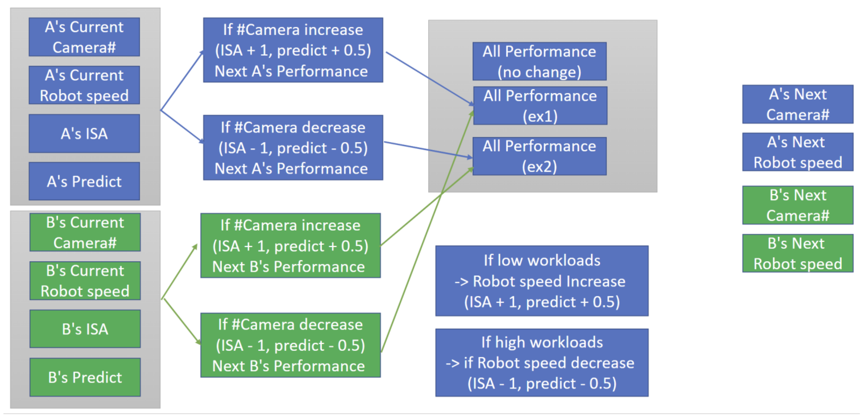

Fig 4. Greedy Algorithm for Workload Allocation

- **Performance Metrics Algorithm**
  - Calculating the performance using varying weights on the predicted and ISA equations, as seen in Fig. 6 (bottom)

System Architecture Diagram

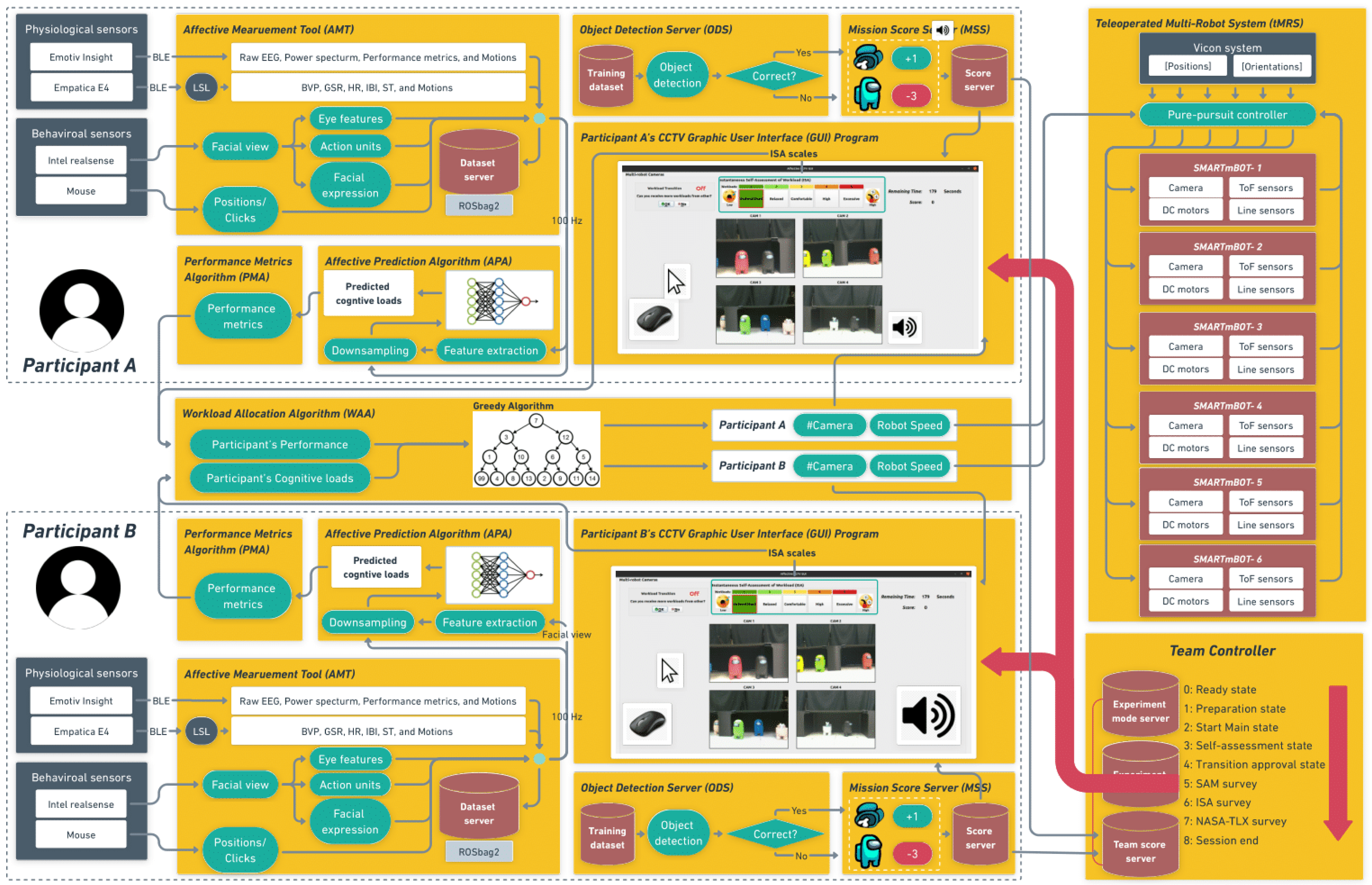

Fig 5. System Architecture diagram

Results and Visualizations

- **ISA Reporting vs Model Prediction (Phase 1 study)**

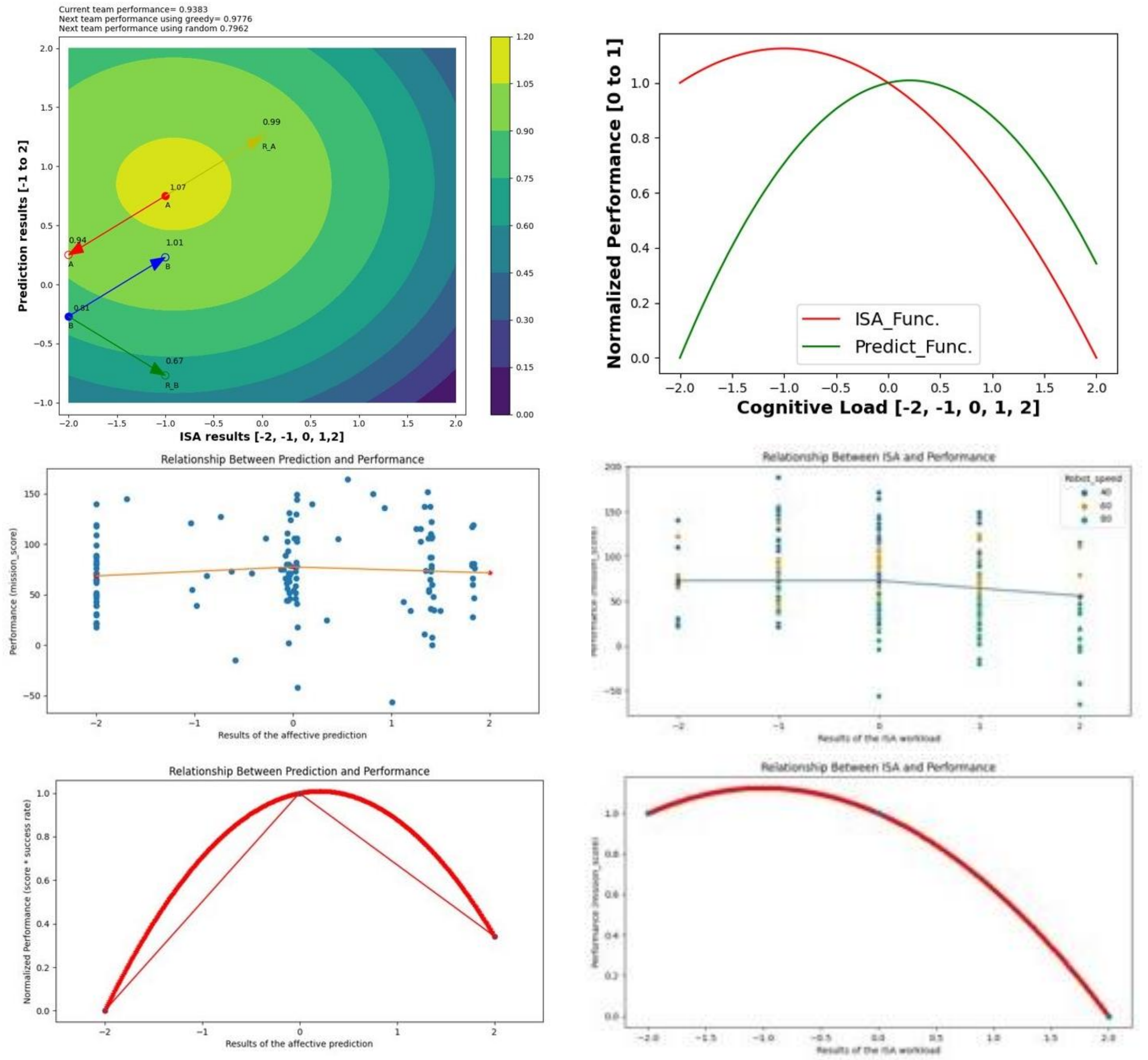

Fig 6. Performance metrics results (top), Prediction and ISA (middle) and Normalized Prediction and Normalized ISA both against performance

The user studies and corresponding results are in accordance with approval from Purdue University IRB (#IRB-2021-1813).

Future Works

- Making the GUI more generically usable for training users for visual perceptual load
- Performing Phase 2 user study successfully to validate results for dynamic workload allocation
- Improving dynamic workload allocation algorithm using deep

References (APA)

[1] Jo, W., Kim, J., Wang, R., Pan, J., Senthilkumaran, R. K., & Min, B.-C. (2022, March 16). *SMARTmBOT: A ROS2-based low-cost and open-source Mobile Robot Platform.* arXiv.org. Retrieved November 11, 2022, from https://arxiv.org/abs/2203.08903

[2] Wang, R., Jo, W., Zhao, D., Wang, W., Yang, B., Chen, G., & Min, B.-C. (2022, September 30). Husformer: A multi-modal transformer for multi-modal human state recognition. arXiv.org. Retrieved November 13, 2022, from https://arxiv.org/abs/2209.15182?context=cs.RO

Acknowledgements

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