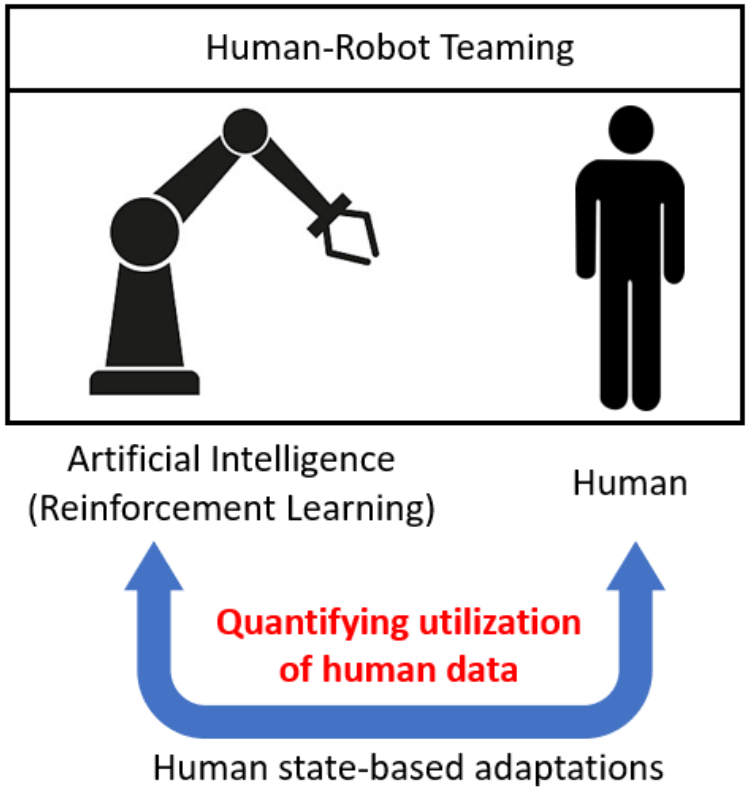
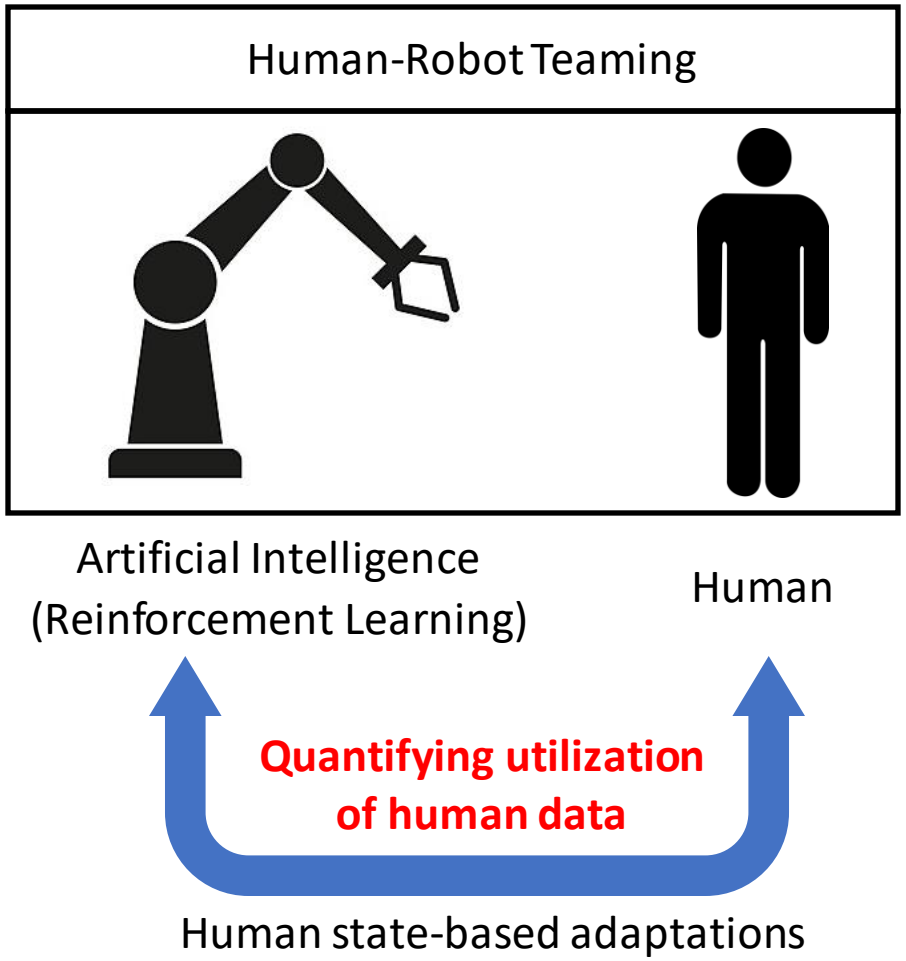
Measuring State Utilization During Decision Making in Human-Robot Teams



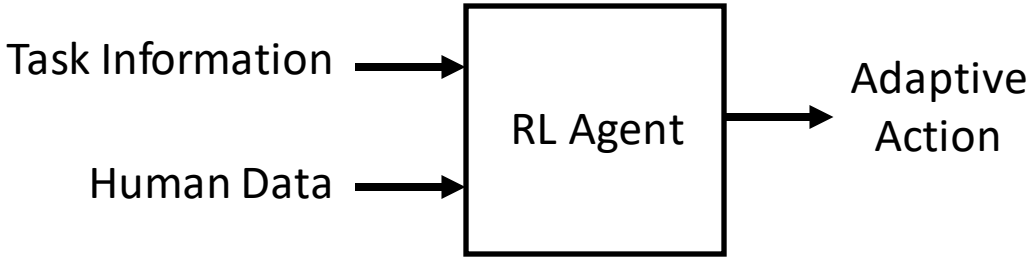
Saurav Singh
Rochester Institute of Technology
Rochester, New York, USA
ss3337@rit.edu

Jamison Heard
Rochester Institute of Technology
Rochester, New York, USA
jrheee@rit.edu

Motivation



- Human's complex behaviors significantly influence human-robot team performance.
- Requires robot adaptions based on external states and internal states.
- Uncertainties in how robots utilize human data in decision-making.

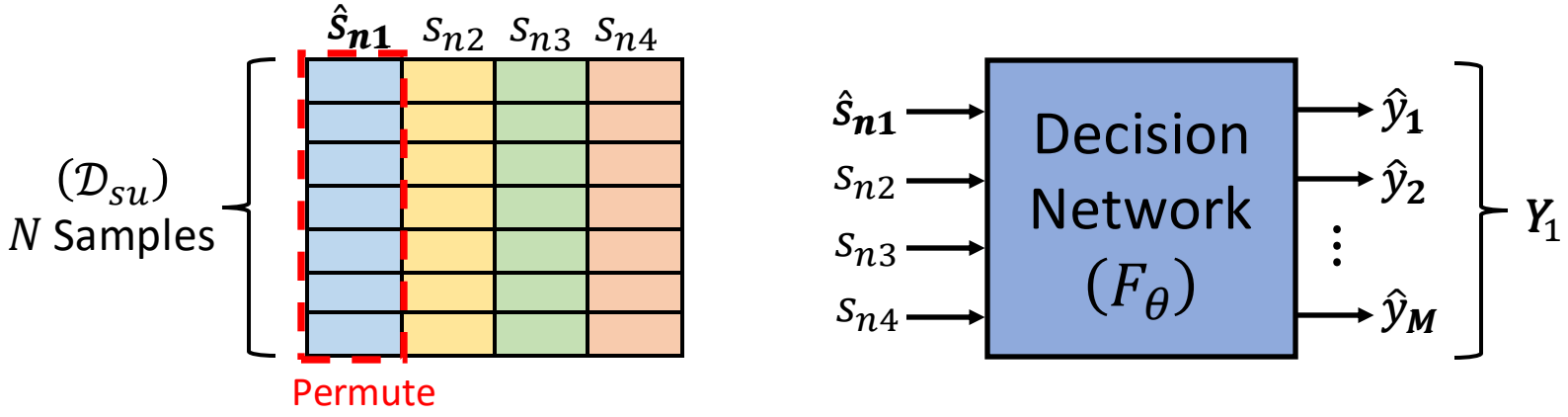


State Utilization (SU) metric for reinforcement learning that quantifies the utilization of state features and human data modalities by the robot.

Method

- Inspired by permutation feature importance [1] and modality utilization [2], extended to reinforcement learning.
- Compute the output Y of the decision network (e.g., Q-network in DDQN).
- Randomly permute the samples of state feature s_{ni} while keeping the state features $s_{nj}, j \neq i$ unchanged.
- Compute the new output Y_i of the decision network and observe the discrepancies in the output.

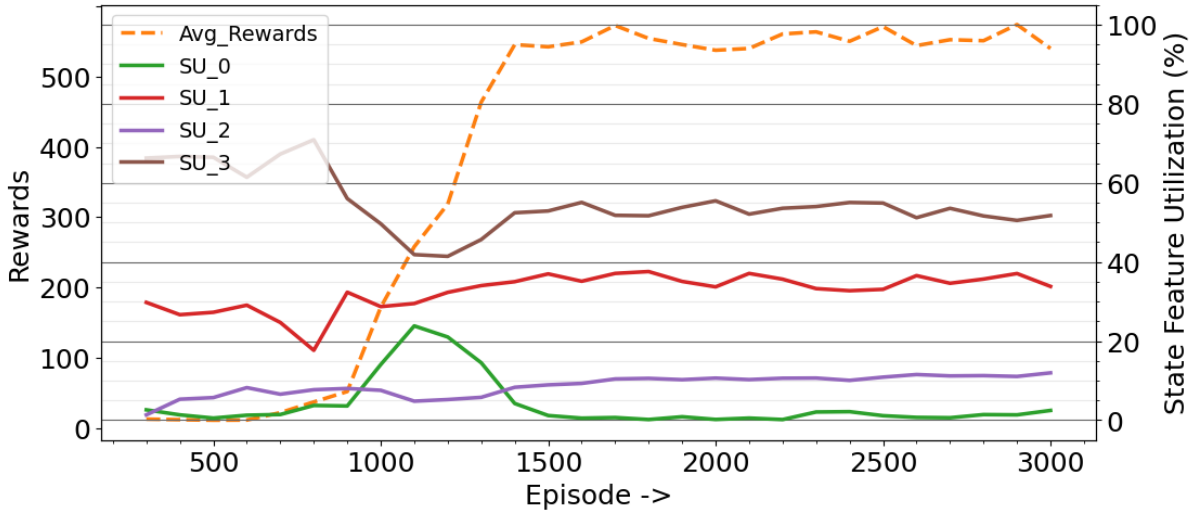
$$SU_i = \frac{\|Y_i - Y\|}{\sum_{j=1}^{S} \|Y_j - Y\|}$$



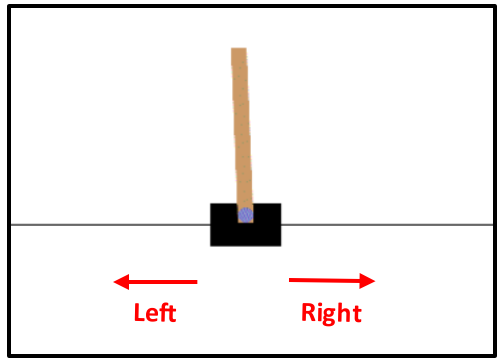
[1] Leo Breiman. 2001. Random forests. Machine Learn. 45 (2001), 5–32.
[2] Saurav Singh, Panos P Markopoulos, Eli Saber, Jesse D Lew, and Jamison Heard. 2023. Measuring Modality Utilization in Multi-Modal Neural Networks. In 2023 IEEE Conf. on Artificial Intelligence (CAI). IEEE, 11–14.

Ablation Studies

$S = \{x, \dot{x}, \theta, \dot{\theta}\}$



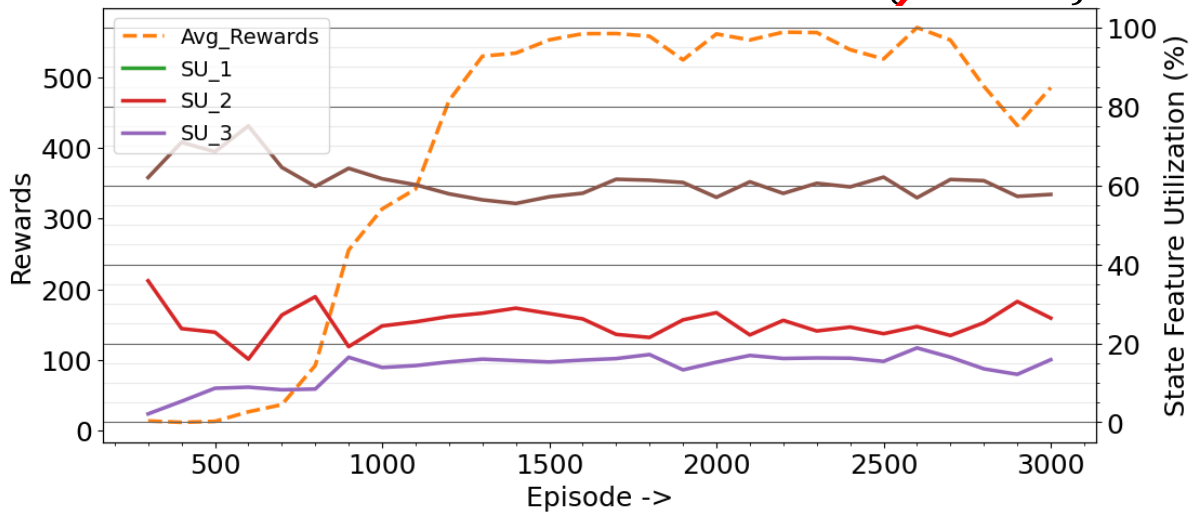
Cartpole by OpenAI Gym



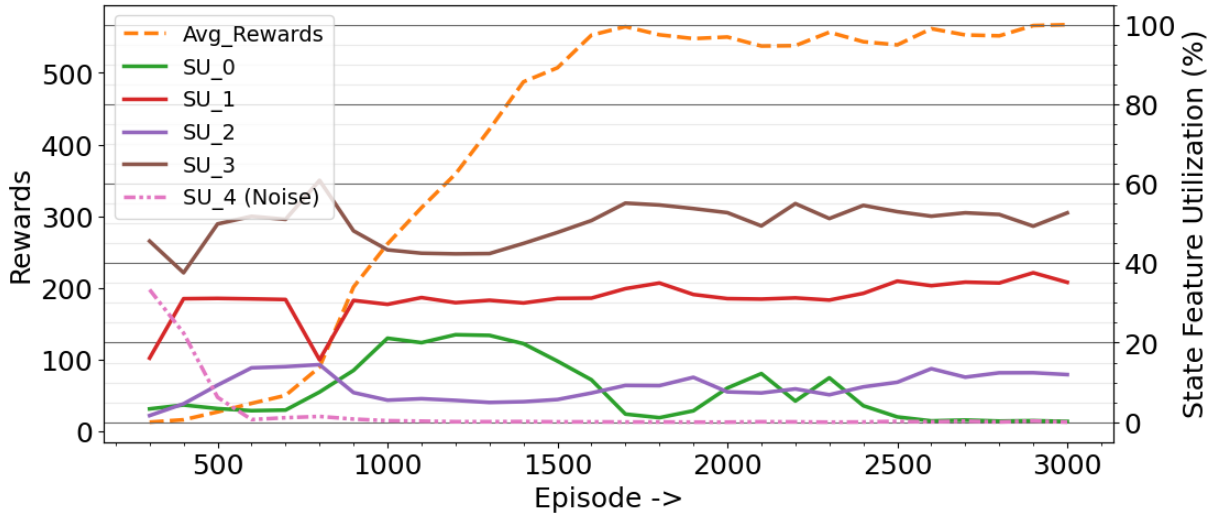
$S = \{\cancel{x}, \dot{x}, \theta, \dot{\theta}\} \boldsymbol{Noise}\}$

$A = \{Left, Right\}$

$S = \{\cancel{x}, \dot{x}, \theta, \dot{\theta}\}$

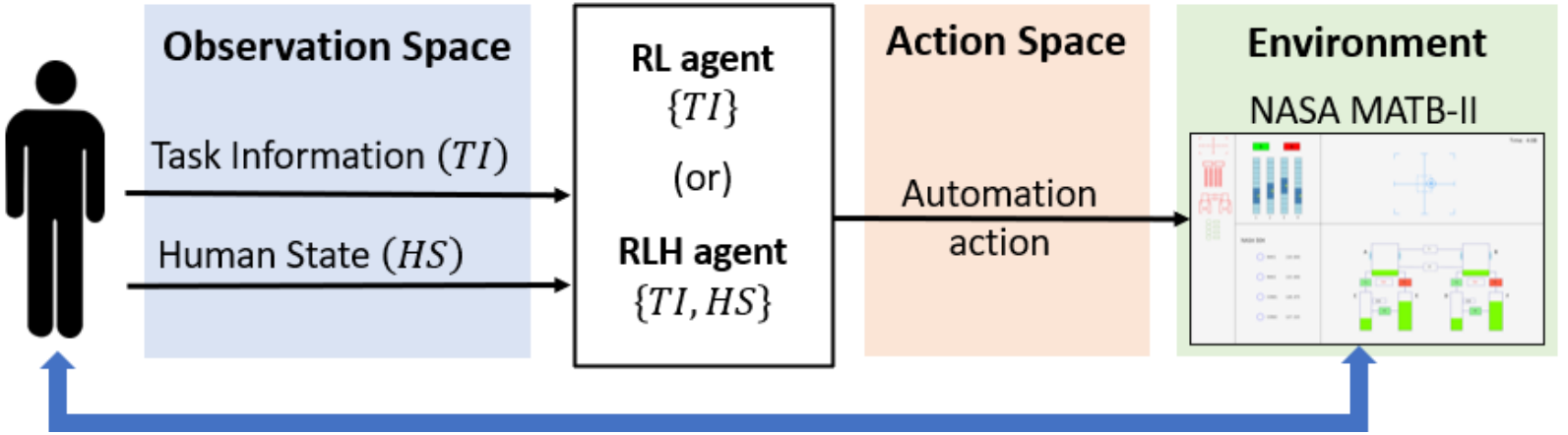


$S = \{x, \dot{x}, \theta, \dot{\theta}, \boldsymbol{Noise}\}$

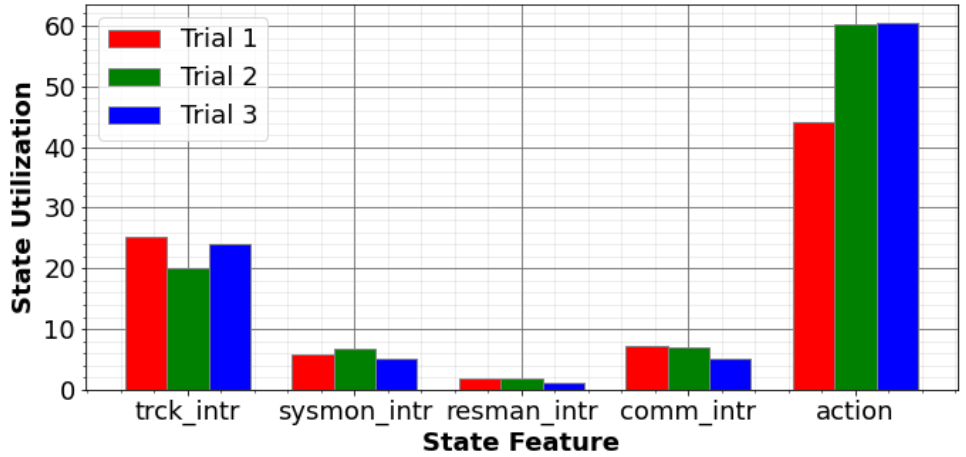


Human Subjects Study

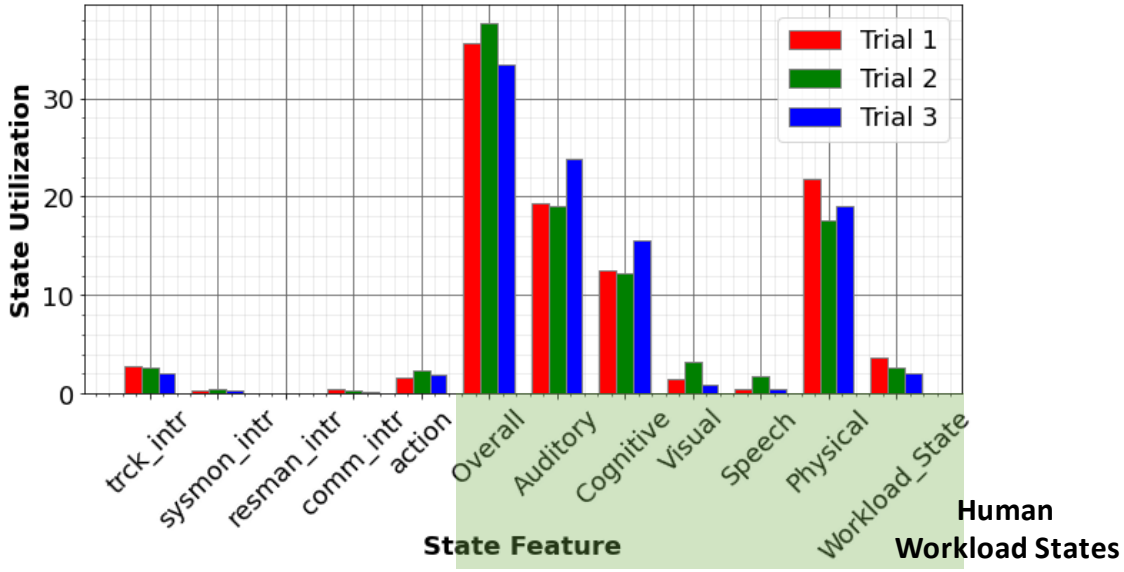
- State Utilization metric can give insight into the robot's reliance on human data.
- SU computed in prior human-robot studies [3][4] showed the RL agent's dependence on human input.



RL agent with Task Information



RLH agent with Task Information and Human States



[3] Saurav Singh and Jamison Heard. 2022. A Human-Aware Decision Making System for Human-Robot Teams. In 2022 17th Annual System of Systems Engineering Conference (SOSE). IEEE, 268–273.
[4] Saurav Singh and Jamison Heard. 2022. Human-aware reinforcement learning for adaptive human robot teaming. In 2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI). IEEE, 1049–1052.

Summary

- Developed State Utilization metrics for Reinforcement Learning to quantify the reliance of decision networks on specific modalities, including human data in human robot teaming scenarios.
- SU metric enhances RL agent's policy explainability.
- Future work focuses on AI's reliance on multiple modalities via SU-based training promises to revolutionize decision-making, elevating overall performance across diverse tasks.

Paper Title: *Measuring State Utilization During Decision Making in Human-Robot Teams*

Saurav Singh (ss3337@rit.edu)

Connect With Me LinkedIn

Jamison Heard (jrheee@rit.edu)

Connect With Me LinkedIn