Reimagining Human-Machine Interactions Through Trust-Based Feedback

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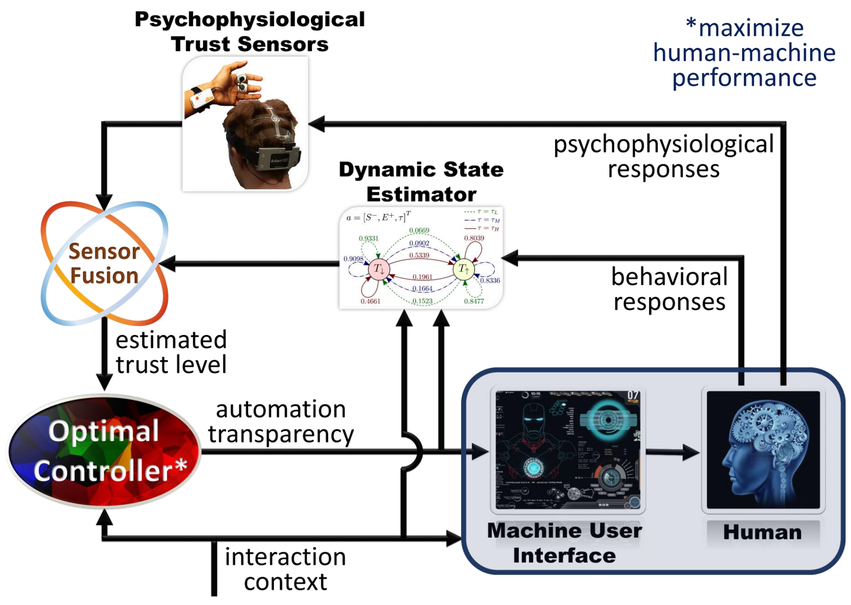
Problem Statement

- Automation loses its utility if humans override such systems due to a fundamental lack of trust [1]
- Accidents may occur due to mistrust [2]
- Trust should be appropriately calibrated to avoid disuse or misuse of automation [3]

We aim to design intelligent machines that can respond to changes in human trust in real-time.



Feedback approach to dynamically vary machine user interface based on human trust

[1] B. M. Muir, "Trust between humans and machines, and the design of decision aids," International Journal of Man-Machine Studies, vol. 27, no. 5-6, pp. 527 – 539, 1987.
[2] M. Richtel and C. Dougherty, "Googles driverless cars run into problem: Cars with drivers," New York Times, vol. 1, 2015.
[3] J. Lee and K. A. See, "Trust in Automation: Designing for Appropriate Reliance," Human Factors, vol. 46, no. 1, pp. 50–80, 2004.

Methodology

Human Subject Studies
Collection of time-domain data of human **psychophysiological & behavioral responses**

System Identification and Machine Learning

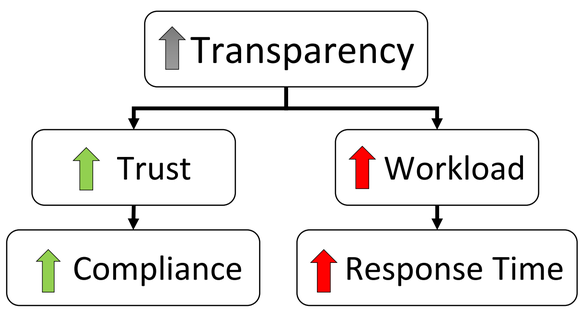
Plant Model
Variations in machine UI to human behavioral responses

Sensor Model
Psychophysiological responses to trust level

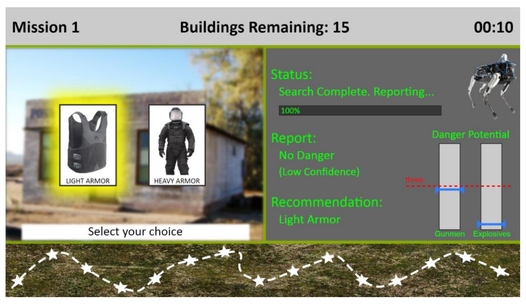
Control Algorithm Design
Optimal controller to maximize Human-Machine Interaction performance

Background

- Automation transparency: **amount and utility of information** to assist operator's comprehension about an automation's intent and reasoning
- Automation transparency affects human trust and workload



Human Subject Study



- Reconnaissance mission with a **robotic assistant** (transparency varied)
- Search 15 buildings quickly
- Participants decide to send light-armored or heavy-armored squad to search building based on the robot's recommendation

Data Collection

- 203 participants' behavioral data used for model estimation
- 48 in-lab participants recruited for psychophysiological data collection
- 80 participants' behavioral data used to validate the control algorithm

PURDUE MECHANICAL ENGINEERING

Results

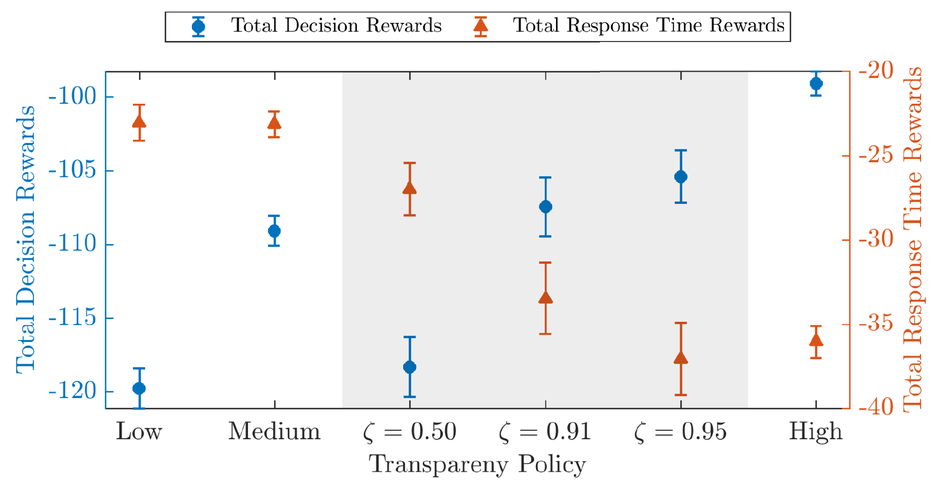
Plant Model [4]

- Trust and workload modeled as a Partially Observable Markov Decision Process (**POMDP**)
- Baum-Welch algorithm used to estimate models with collected data
  - **Independent** trust and workload models
  - **Coupled** trust-workload model

Control Algorithm [4]

Control objective is to balance the **trust-workload tradeoff** based on:

- decision rewards: to **safely** complete the task
- response time rewards: to achieve **time-efficiency**

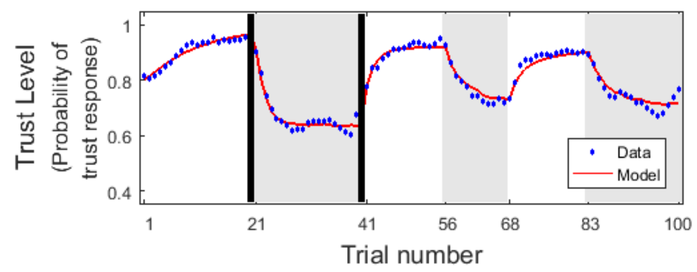


- Control policies can dynamically vary transparency to address the tradeoff (shown in gray region) whereas a fixed transparency (low, medium, or high) throughout the interaction cannot

Psychophysiological Sensor Model [5] [6]

Real-time sensing of trust using psychophysiological sensors needed to **augment trust estimate** when behavioral data is limited or unavailable

- Two-stage feature selection (ReliefF and SFFS) conducted from exhaustive set of time & frequency domain features of **EEG** & **GSR**
- A quadratic discriminant analysis classifier used for probabilistic classification of trust level
- An average accuracy of **78.55%** obtained for sensing categorical trust



Reliable trials (white)
100% accuracy

Faulty trials (gray)
50% accuracy

[4] K. Akash, G. McMahon, T. Reid, and N. Jain, Human Trust-based Feedback Control: Dynamically varying automation transparency to optimize human-machine interactions." IEEE Control Systems Magazine, July 2019. (Under Review)
[5] K. Akash, W.-L. Hu, N. Jain, and T. Reid, "A Classification Model for Sensing Human Trust in Machines Using EEG and GSR." ACM Transactions on Interactive Intelligent Systems. (Accepted)
[6] W. Hu, K. Akash, N. Jain, and T. Reid, "Real-Time Sensing of Trust in Human-Machine Interactions." 1st IFAC Conference on Cyber-Physical & Human-Systems, Florianopolis, Brazil, December 7-9, 2016.

Next Steps

Sensor Fusion Design

- Combining trust estimation from dynamic state estimator and psychophysiological response data to improve overall trust estimate

Generalization to other Contexts

- Extending the framework to other autonomous contexts such as **automated driving**, **industry automation, smart buildings**, etc.

Potential Impact of Research

- More **reliable** and **efficient** operation of safety-critical systems
- Extensions to other research domains interested in dynamic models of human trust (e.g. sociology, e-commerce)

Acknowledgements

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