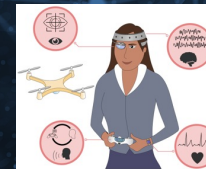# Cognitive Autonomy for Human CPS: From Novices to Experts
NSF CPS Frontier

Meeko Oishi, Sriram Sankaranarayanan, Ufuk Topcu, Inseok Hwang, Neera Jain, Tahira Reid Smith, Brandon Pitts, Tryphenia Peele-Eady, Lizandra Godwin
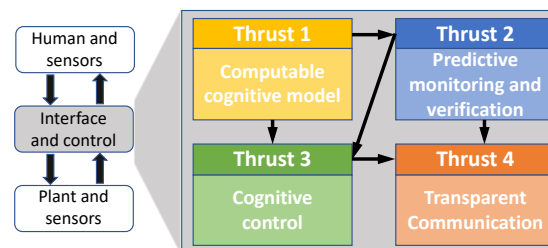
Analysis, design, and control to make autonomous cyber-physical systems highly responsive to human cognitive state.

Cognitive Autonomy

1. Is robust to uncertainty in the environment and in the human's actions
2. Assures desired human-CPS properties
3. Prevents loss of attention and over-reliance
4. Responds to the physical, computation, and human cognitive state
5. Provides guidance / takes control as needed, and communicates appropriately with the human
6. Anticipates and prevents willful misuse

Key innovations and new contributions

- Adaptation of human models and policies
- Generative AI for formative feedback on psychomotor learning tasks
- Limits of cooperation in linear quadratic games
- Cognitively aware function allocation
- Multi-step intent inference and planning

Zero-shot, real-time planning without prior training for multi-step intent

Human and sensors → Interface and control → Plant and sensors

| Thrust 1 Computable cognitive model | Thrust 2 Predictive monitoring and verification |
| Thrust 3 Cognitive control | Thrust 4 Transparent Communication |

Human cognitive state dynamics are required for effective analysis and control of human CPS.

Psychophysiological sensing for customized, intelligent tutoring

Learning Stage 1 · Learning Stage 2 · Learning Stage 3 · Learning Stage 4

Rule-based kernel embeddings for learning stage classification

Responsiveness to driving style preferences
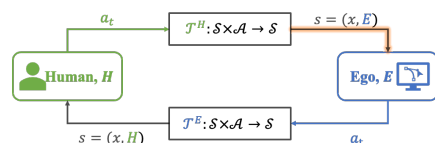
Impact on CPS Research

- Computationally tractable, data-driven models, for individual human state, actions, and priorities
- Offline verification + online predictive monitoring
- Control of physical *and* cognitive system state
- Model-based, multi-modal, transparent communication
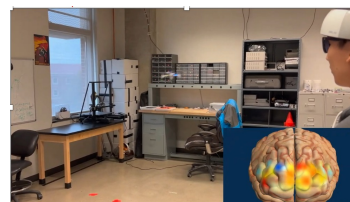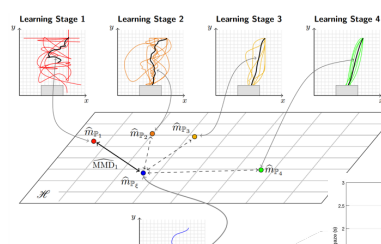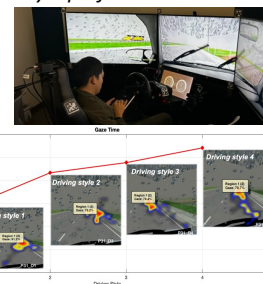
Broader impacts

- Prevention of "misuse, disuse, and abuse" of automation
- Human-centric algorithms and tools at the intersection of controls and learning
- Methods to accommodate human heterogeneity and variability

Summer Intensive Research Internship (SIRI)

- Undergraduate research program
- Targets students in New Mexico to work with Purdue faculty
- Characterization of environments for student success and belonging

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