UNM SCHOOL of ENGINEERING

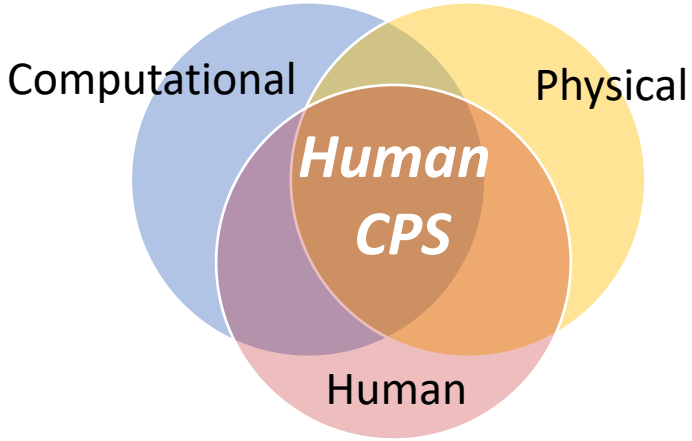
CPS Frontiers Panel
2022 CPS PI Meeting
Tuesday, November 8, 2022

Meeko Oishi
Professor, Electrical and Computer Engineering
University of New Mexico
oishi@unm.edu

Cognitive Autonomy for Human CPS

State of the art

- Users are responsible for becoming skilled through specialized training
- System behavior does not adapt to human cognitive workload, attention, trust, or priorities

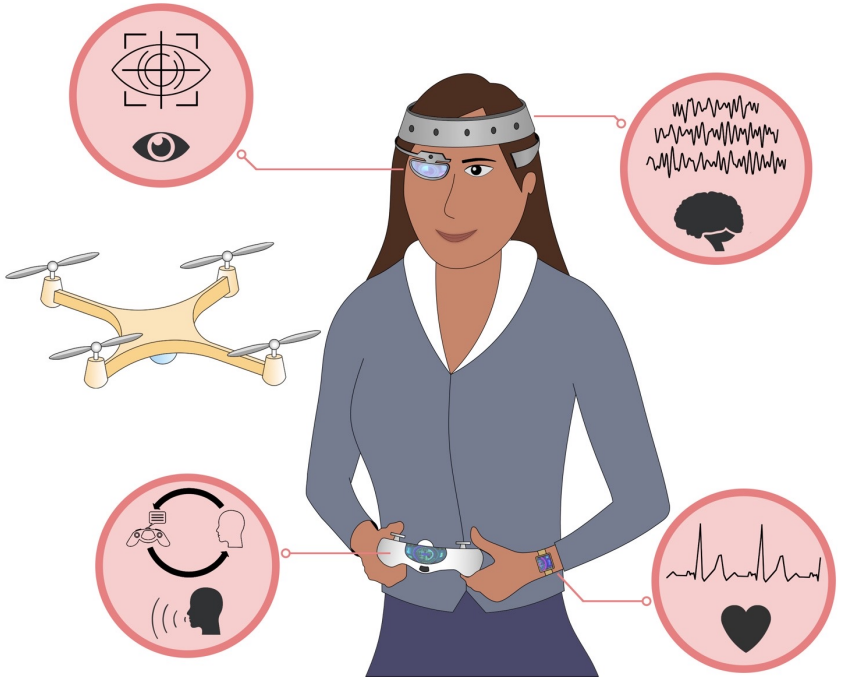


How can we design human CPS to be highly responsive to the human, yet amenable to formal guarantees?

Vision

Develop scientific and engineering principles so that cognitive autonomous systems can:

- Estimate workload, skill level, trust in real time
- Learn individual priorities and preferences
- Infer potential blind spots
- Anticipate and prevent “bad” behaviors
- Provide reasoned guidance post-hoc, and multi-modal communication in run-time
- Enable safe, effective, and reliable performance for *any* human skill level



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

Cognitive Autonomy for Human CPS

- *Control theory*
- *Autonomous systems*
- *Human factors*
- *Human-centered design*

THE UNIVERSITY OF NEW MEXICO

PURDUE UNIVERSITY

University of Colorado Boulder

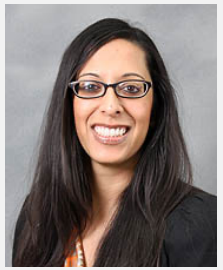
TEXAS The University of Texas at Austin

Meeko Oishi

Sriram Sankaranarayanan

Ufuk Topcu

Inseok Hwang

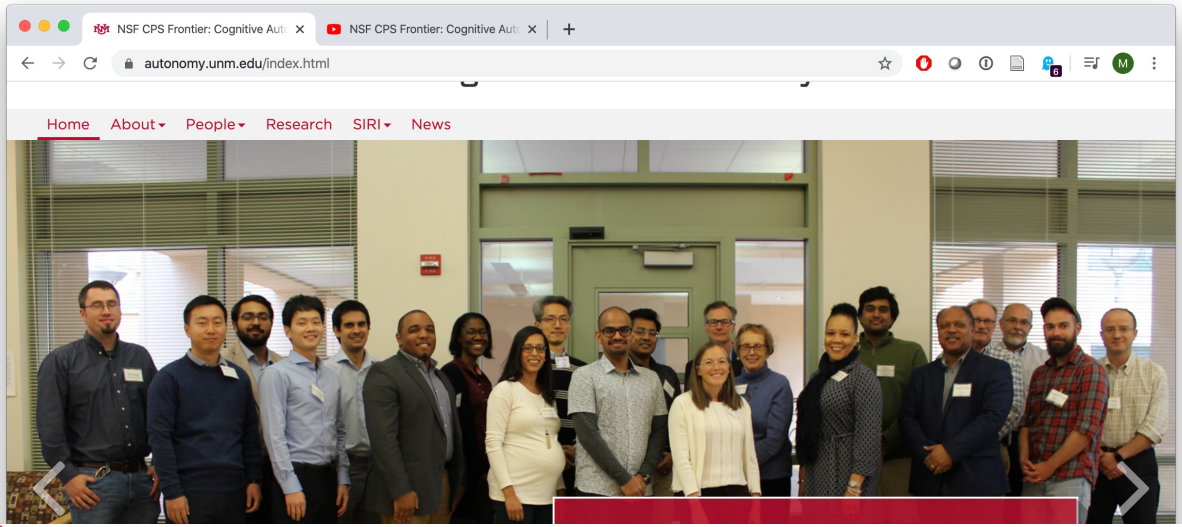

Neera Jain

Tahira Reid Smith

Brandon Pitts

Tryphenia Peele-Eady

http://autonomy.unm.edu



Raytheon Technologies

Air Force Research Laboratory

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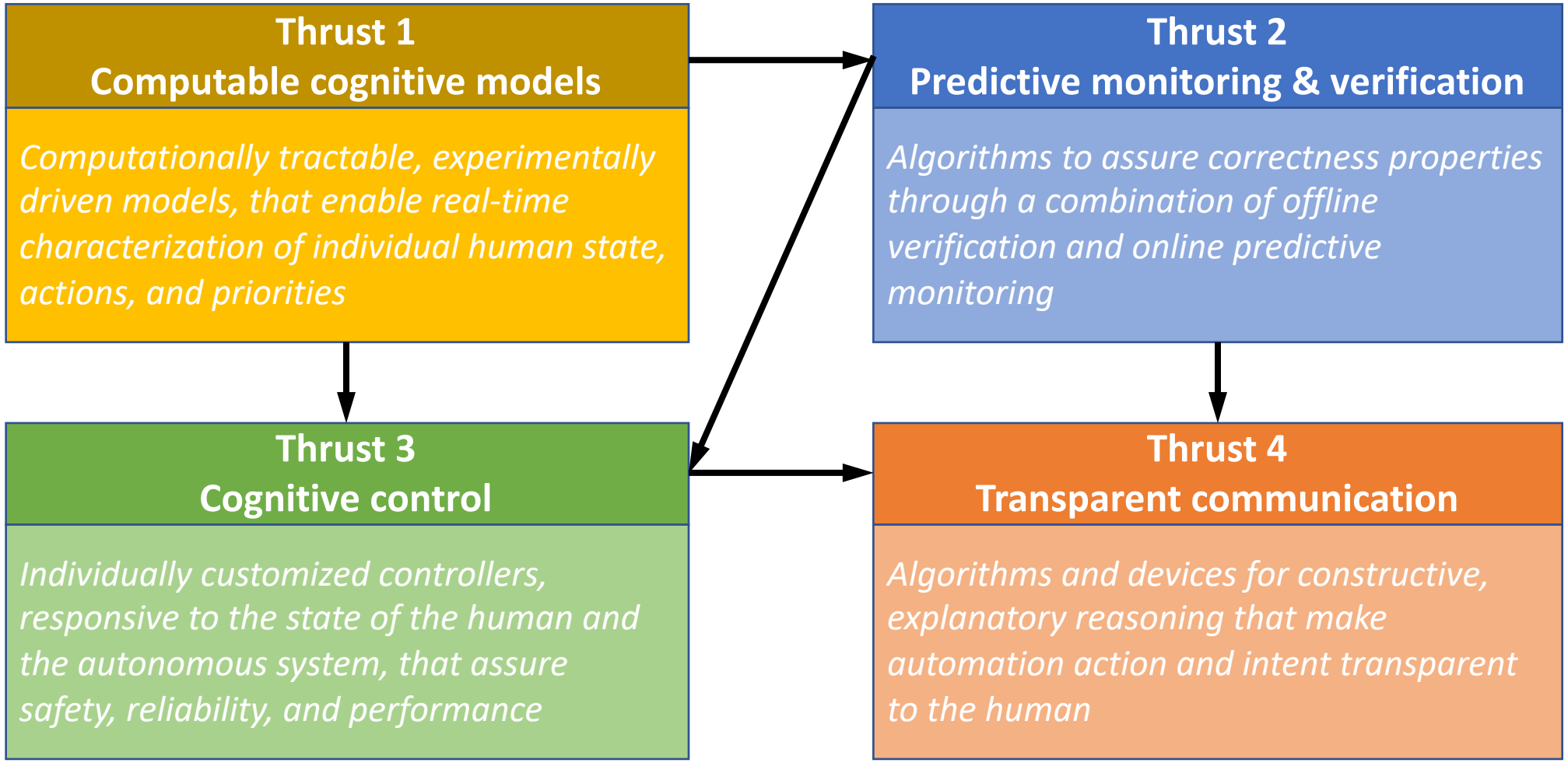
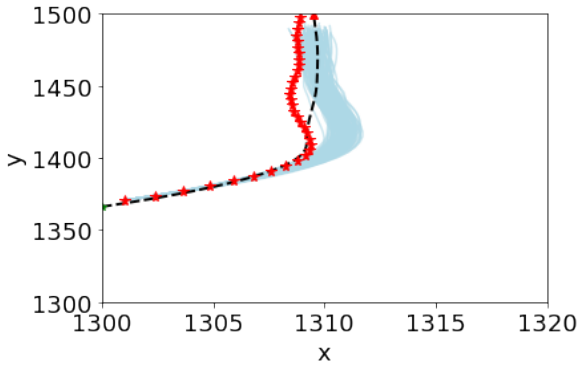
Potential Impacts and Key Outcomes

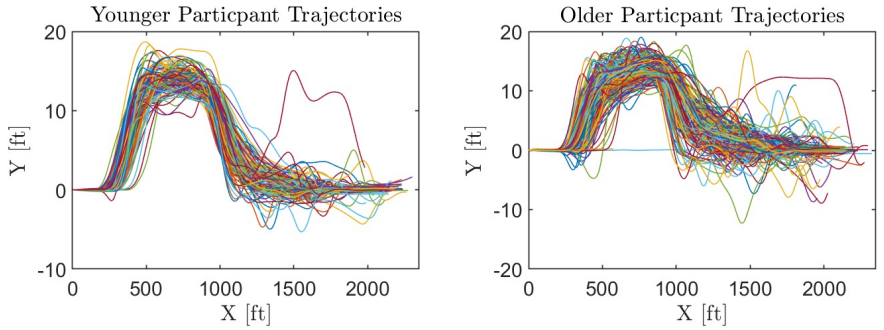


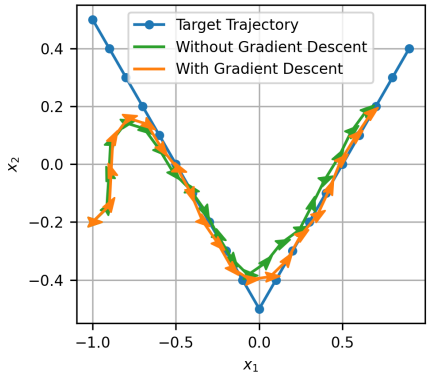
Potential Impacts and Key Outcomes

- Integration of data-driven and model-based methods is important for capturing the breadth and complexity of naturalistic human action
  - Risk fields for predictive models of probabilistic human action in an advanced driving simulator
  - Conditional distribution embeddings characterize relative impact of tactile alerts in a collision avoidance maneuver.



- Carefully designed human subject experiments are required for design and validation
  - Conditional distribution embeddings for dynamics-aware, stochastic optimal control





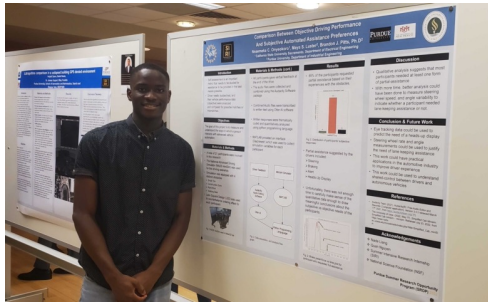
Potential Impacts and Key Outcomes

- Exploiting psychophysiological sensing for feedback can dramatically impact performance
  - Stochastic IRL for shared controller synthesis under human learning

- Cognitive state feedback (via trust and self-confidence) can accelerate human learning
  - Calibration of self-confidence enables pilot performance and accelerates improvements in task performance.

SIRI: Summer Intensive Research Institute

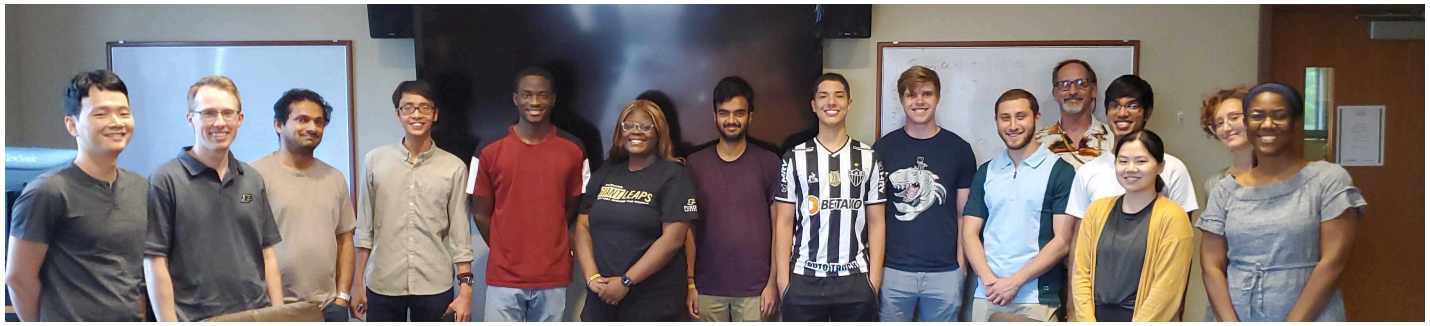
Culturally responsive undergraduate research program



- Collaboration between UNM and Purdue
- Goals
  - Encourage underrepresented students to pursue CPS
  - Develop professional competencies
  - Provide opportunities for students to connect their research experience with their cultural background
- Research to characterize transitions to belonging

Engineering Student Success

PURDUE UNIVERSITY **Summer Research Opportunities Program (SROP)**



Challenges and Strategies

- Disciplinary boundaries and conceptual differences
  - Presumed knowledge (jargon) and concepts
  - Cross-cutting sub-groups within the project
- Experiment design for prediction and control
  - Creating sufficiently rich environments
  - Generalizability of experiments

Opportunities and Rewards

- Time and space to work with depth on meaningful problems
- Establish new collaborations, cement existing ones
- Student opportunities
  - Student exchange
  - Internships
- Larger impact
- Broadening participation and creating pipelines

UNM SCHOOL of ENGINEERING

NSF

COGNITIVE AUTONOMY FOR HUMAN CPS: TURNING NOVICES INTO EXPERTS

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AIR FORCE RESEARCH LABORATORY