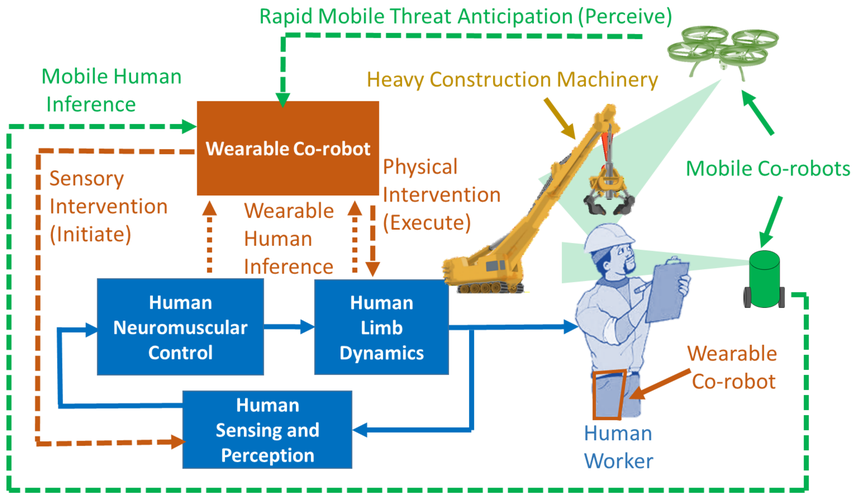
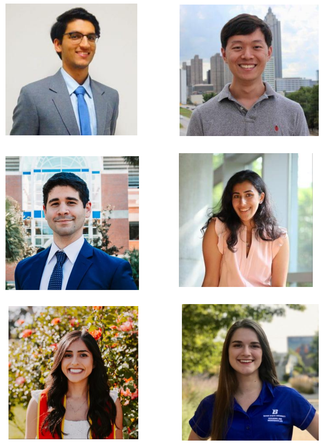
# Rapid Operator Awareness via Mobile Robotics (ROAMR),
## *Customizable Human Safety using Mobile and Wearable Co-Robots*
## (NRI 1830498)

Anirban Mazumdar (PI), Aaron Young (Co-PI), Aakash Bajpai, Carlos, Carrasquillo, Divya Iyengar, Pooja Moolchandani, Kevin Choi, Jessica Carlson, Alexander Lu, Rajan Tayal
George W. Woodruff School of Mechanical Engineering

2023 Foundational Research in Robotics
National Robotics Initiative
Principal Investigators' Meeting

## Overall Project Vision

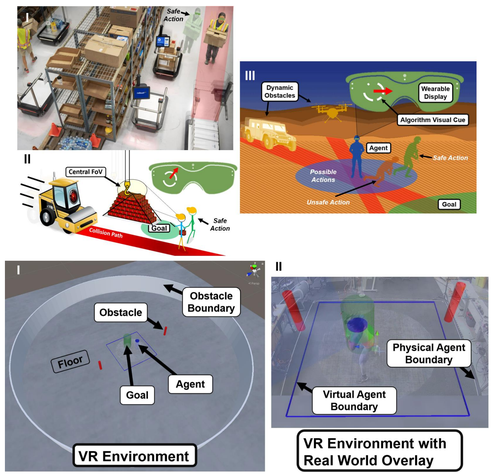


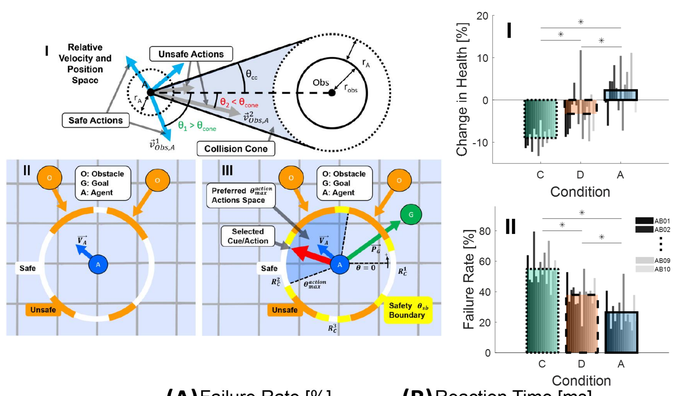



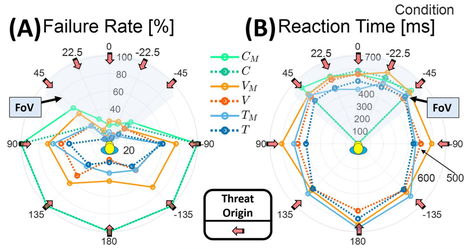
- Unstructured environments such as construction sites, disaster areas, and conflict zones rely on human intuition, dexterity, and versatility.
- These environments require teams of humans and machines to work together safely but lack the controlled safety of manufacturing plants or other indoor settings.
- Mobile and wearable co-robots can provide ***customizable*** human-centric safety by enhancing the situational awareness and physical response of the human operator.
- Project has supported 5 graduate students, an REU student, and multiple undergraduate students.

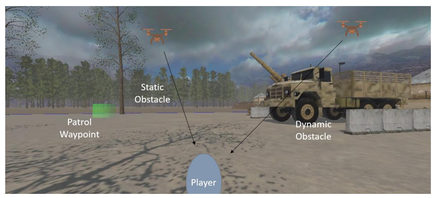
## Communicate Threats and Safe Paths to the Human Operator (Initiate)

### G1



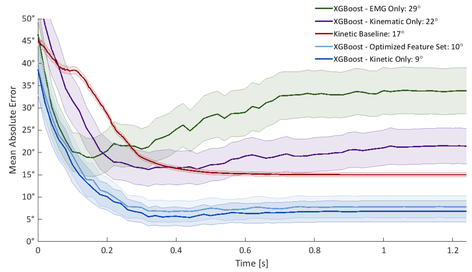

- Have examined a range of perceptual cues for dynamic threat avoidance.
- Tactile cues have shown particular promise in the presence of visual distraction.
- Currently combining perceptual cues with motion planning algorithms for AI-enabled human performance.

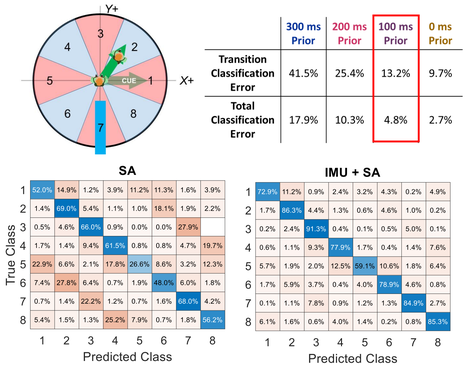
A. Bajpai, J. Powell, A. J. Young, A. Mazumdar, "Enhancing Physical Human Evasion of Moving Threats Using Tactile Cues," IEEE Transactions in Haptics, Dec. 2019. [doi: 10.1109/TOH.2019.2962664]
A. Bajpai, K. Feigh, A. Mazumdar, A. Young, "Influencing Human Escape Maneuvers with Perceptual Cues in the Presence of a Visual Task," IEEE Transactions on Human Factors, Aug. 2021. [doi: 10.1109/THMS.2021.3108962]
A. Bajpai, A. Lu, K. Choi, A. Young, A. Mazumdar, "Using Autonomous Motion Planning to Improve Human Safety in Dynamic Environments," (*In Prep*).

## Predict Human Avoidance Response (Infer)

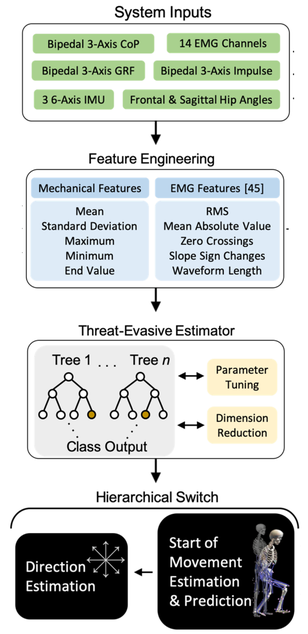
### G2

- A human-centric approach relies on assisting human motions.
- Our team has already demonstrated how machine learning can be used to infer desired human speed.
- We seek to infer transient avoidance behaviors in order to provide suitable physical assistance.
- Primary desired output: direction of motion.
- Secondary desired output: type of motion (jump, lunge, sidestep).
- Machine learning will be used to gauge human intention based on human kinematics, kinetics, muscle recruitment, and knowledge of the environment.
- Currently examining how to identify high-level human behaviors for tailored assistance.



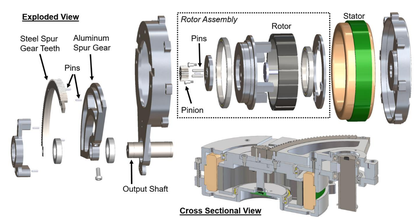

| | 300 ms Prior | 200 ms Prior | 100 ms Prior | 0 ms Prior |
|---|---|---|---|---|
| Transition Classification Error | 41.5% | 25.4% | 13.2% | 9.7% |
| Total Classification Error | 17.9% | 10.3% | 4.8% | 2.7% |

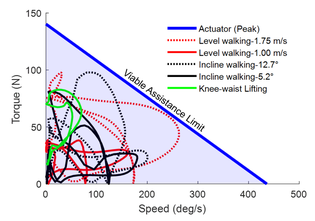


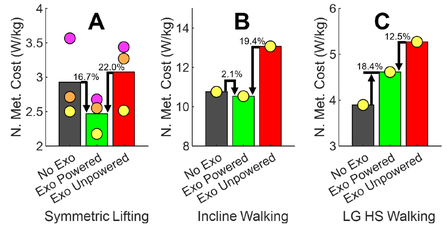

P. Moolchandani, A. Mazumdar, A. Young, "Design of an Intent Recognition System for Dynamic, Rapid Motions in Unstructured Environments," ASME Letters in Dynamic Systems and Control, April 2021.

## Physically Assist Human Response (Execute)

### G3

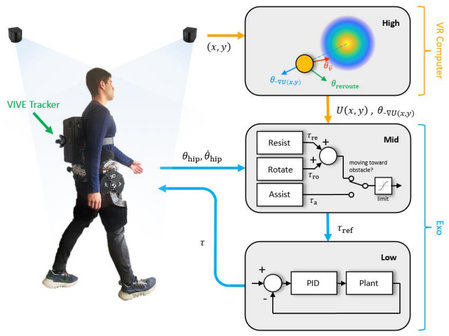




- We seek to physically enhance the human response using a human-worn co-robot.
- Physically assisting rapid human behaviors remains relatively unexplored.
- Current devices do not seem to enhance human agility, but can enhance human metabolic performance.
- A range of physically assistive impedance controllers have shown versatile benefit on a novel hip exoskeleton device.
- We use artificial potential fields to navigate humans around virtual hazardous obstacles.
- Exoskeleton assistance has the potential to improve safety in the presence of visually obstructed conditions.




A. Bajpai, C. Carrasquillo, J. Carlson, J. Park, D. Iyengar, K. Herrin, A. J. Young, A. Mazumdar, "Design and Validation of a Versatile High Torque Quasi-Direct Drive Hip Exoskeleton," IEEE Transactions on Mechatronics, (In Review)