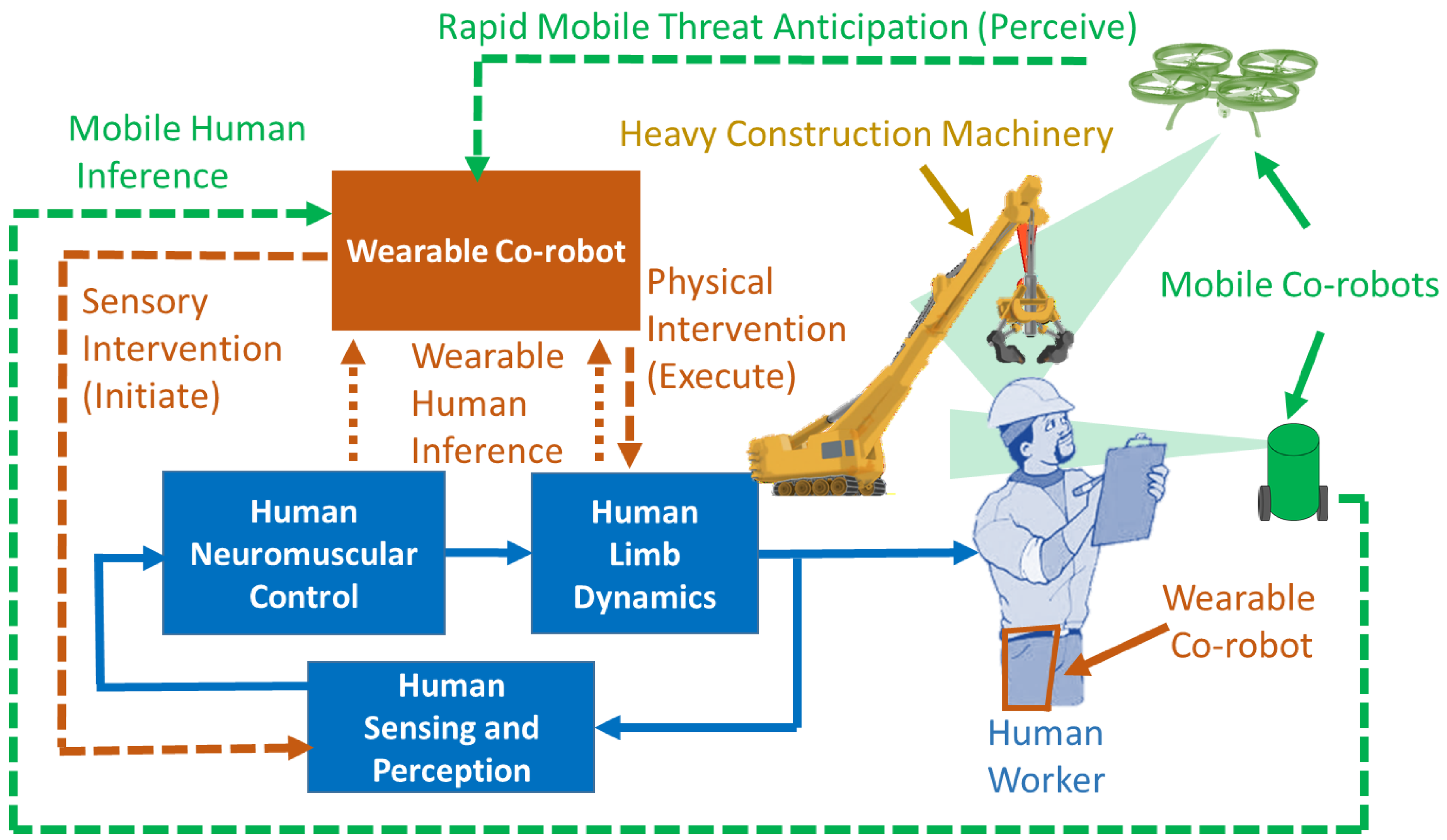
Rapid Operator Awareness via Mobile Robotics (ROAMR), *Customizable Human Safety using Mobile and Wearable Co-Robots* (NRI 1830498)

2022 National Robotics Initiative Foundational Research in Robotics Principal Investigators' Meeting

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

Overall Project Vision

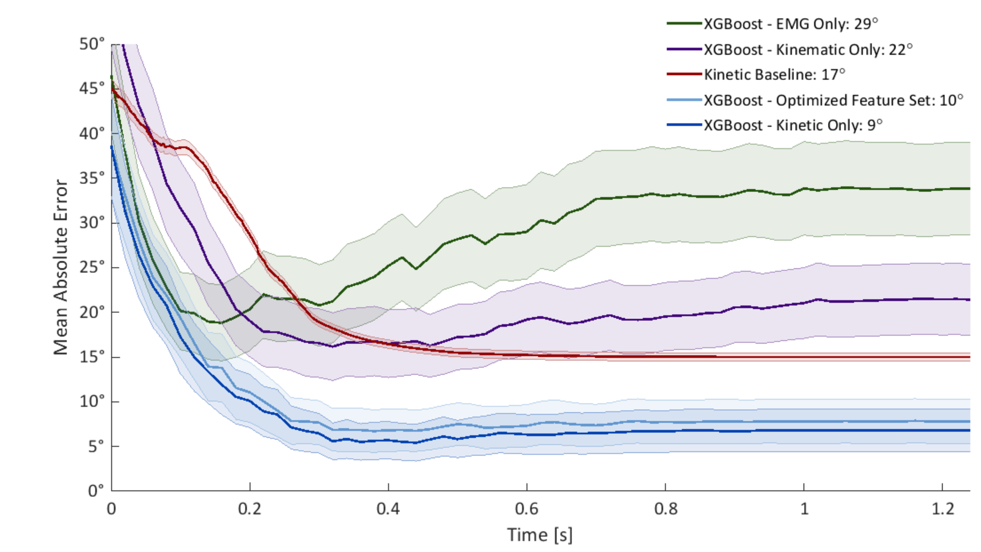


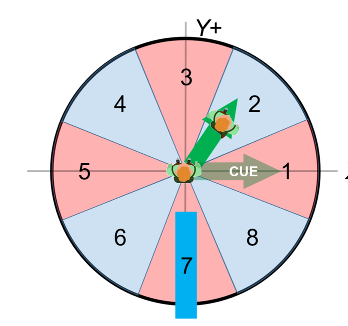
- Unstructured environments such as construction sites, disaster areas, and conflict zones rely on human intuition, dexterity, and versatility.
- These environments require teams of humans and machines to work together safely but lack the controlled safety of manufacturing plants or other indoor settings.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

Predict Human Avoidance Response (Infer)

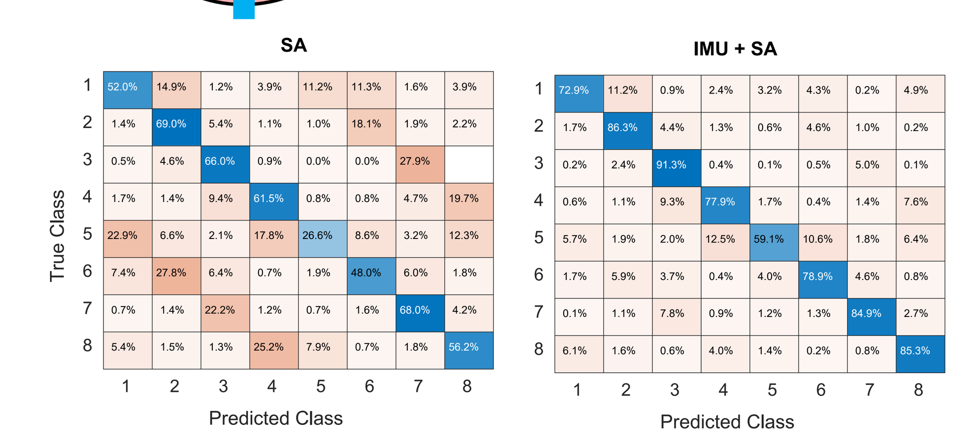
G2

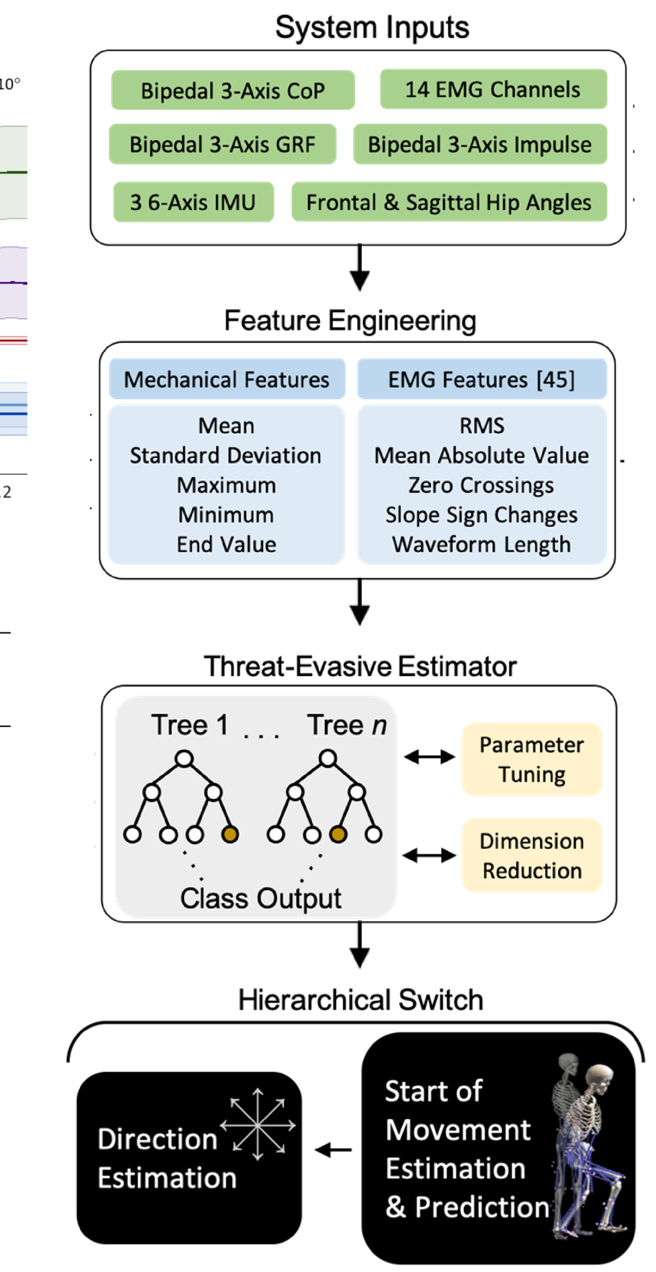
- A human-centric approach relies on assisting human motions.
- Our team has already demonstrated how machine learning can be used to infer desired human speed.
- We seek to infer transient avoidance behaviors in order to provide suitable physical assistance.
- Primary desired output: direction of motion.
- 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.
- Intention recognition algorithms will be implemented on wearable sensors for human-centric performance outside of controlled settings.
- We can also feed in planner information that is dispatched to the operator.





	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.

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

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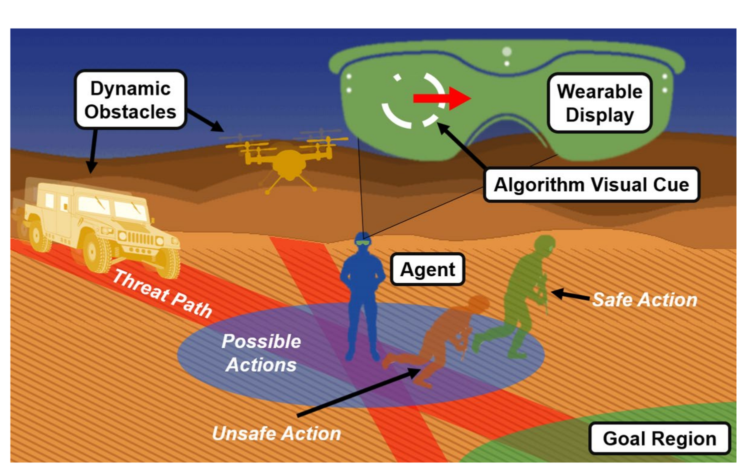

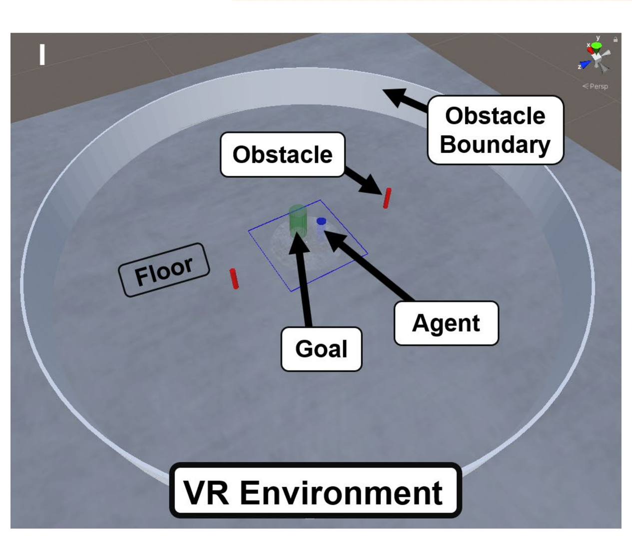

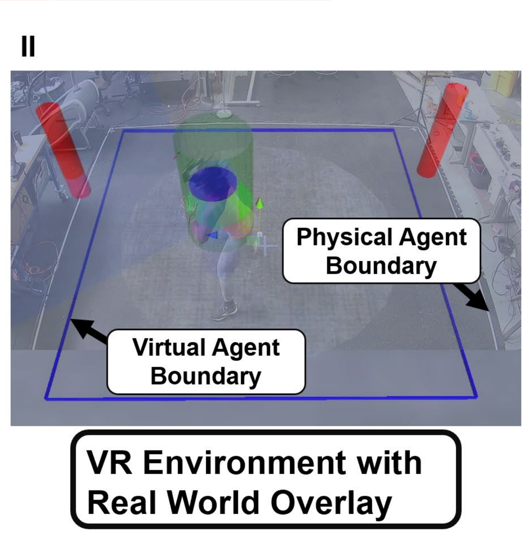

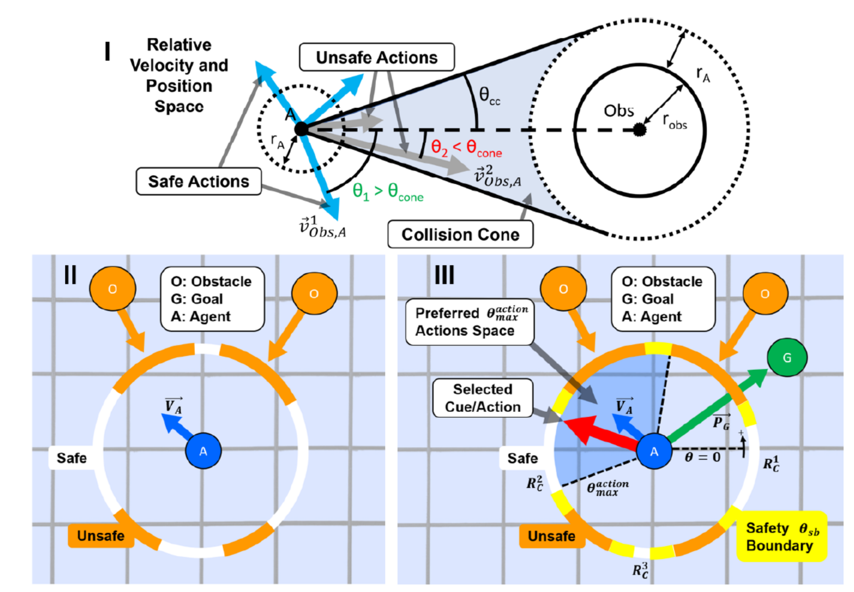

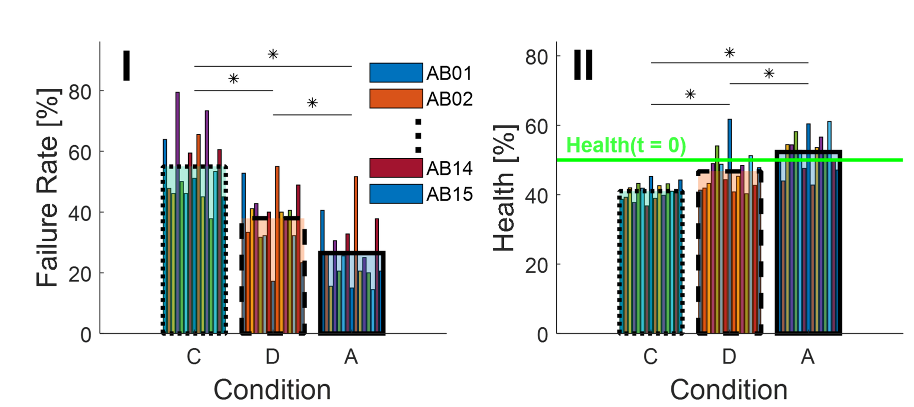

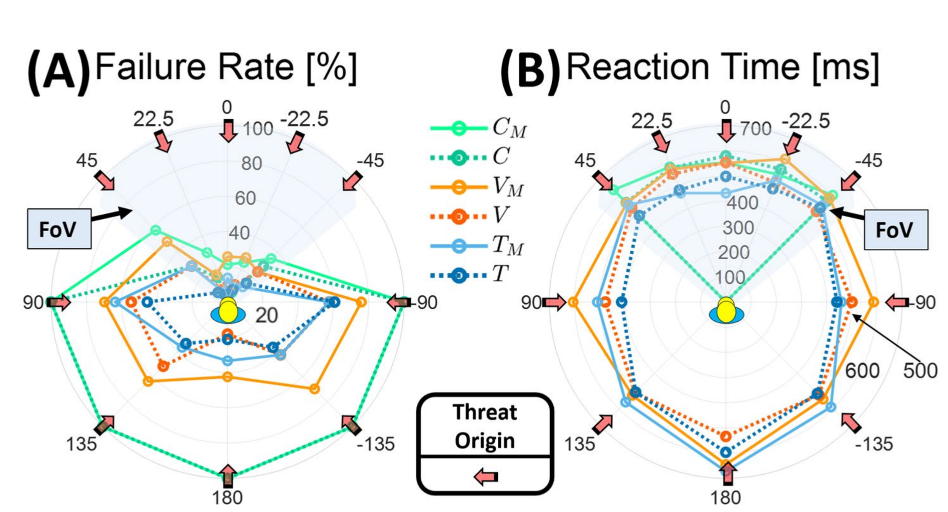

- Have examined a range of perceptual cues for dynamic threat avoidance.
- Tactile cues have shown particular promise in the presence of visual distraction.
- Currently combining vibrotactile cues with motion planning algorithms for AI-enabled human performance.

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.Mazumdar, A. Young, "Using Autonomous Motion Planning to Improve Human Safety in Dynamic Environments," IEEE Robotics and Automation Letters (*In Review*), Feb. 2022.

Physically Assist Human Response (Execute)

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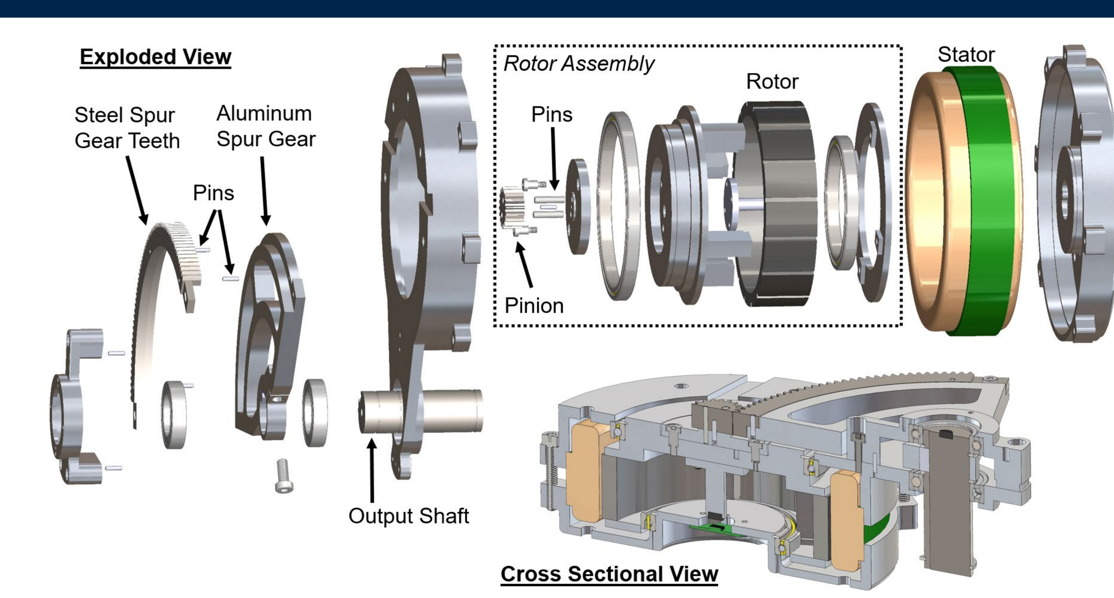
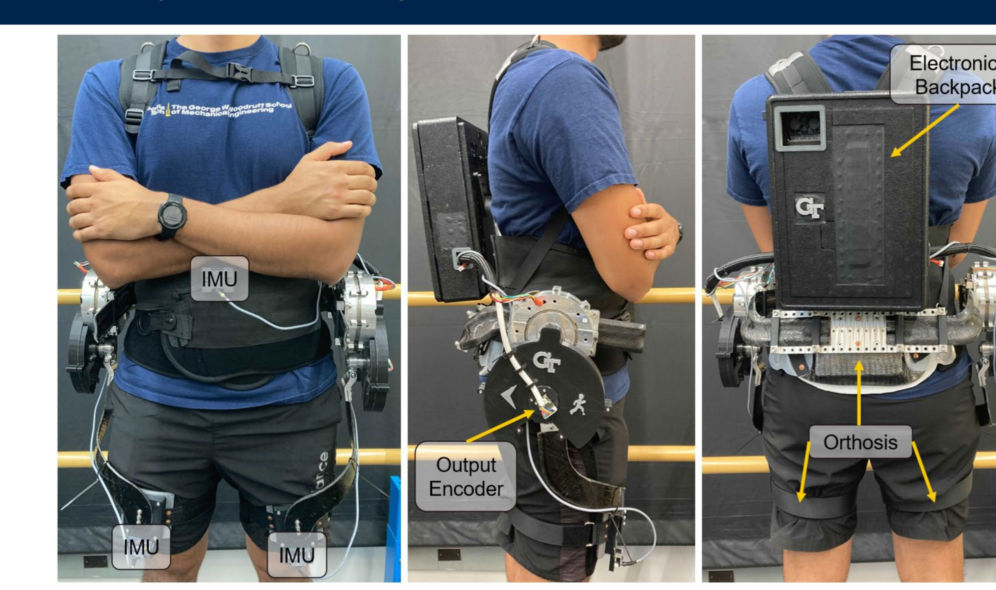
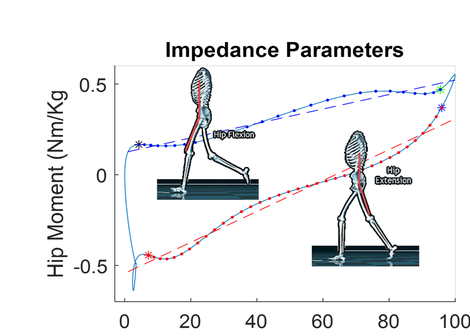
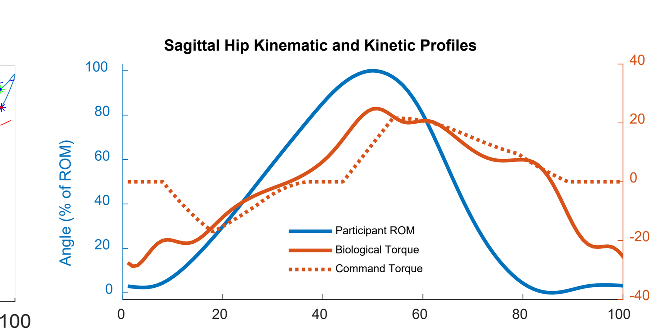
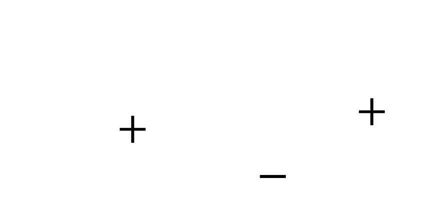




$$\tau(\theta,\dot{\theta}) = m[\alpha * k(\theta - \theta_0) + \gamma * \beta(\dot{\theta})]$$







- We seek to physically accelerate the human response using a human-worn co-robot.
- Physically assisting rapid human behaviors remains relatively unexplored.
- Obstacle avoidance experiments will be performed with flying objects and/or padded ground robots. Physical obstacles enable humans to utilize their range of senses and physical intuition.
- Metrics of performance include time to reach safe zone, ability to avoid moving obstacles.
- Results can help inform a different class of assistive robots intended for enhancing transient behaviors rather than steady-state ones.
- A range of physical assistance strategies will be explored using a novel hip exoskeleton device.
- EMG based control can enhance customizability.