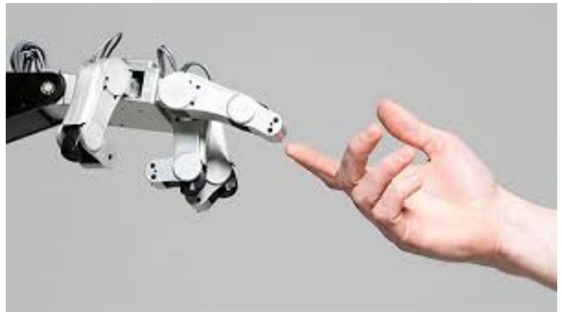
Designing Robots for Humans

Holly Yanco

Distinguished University Professor
Professor, Computer Science
Director, New England Robotics Validation and Experimentation (NERVE) Center

University of Massachusetts Lowell

Human-Robot Interaction…

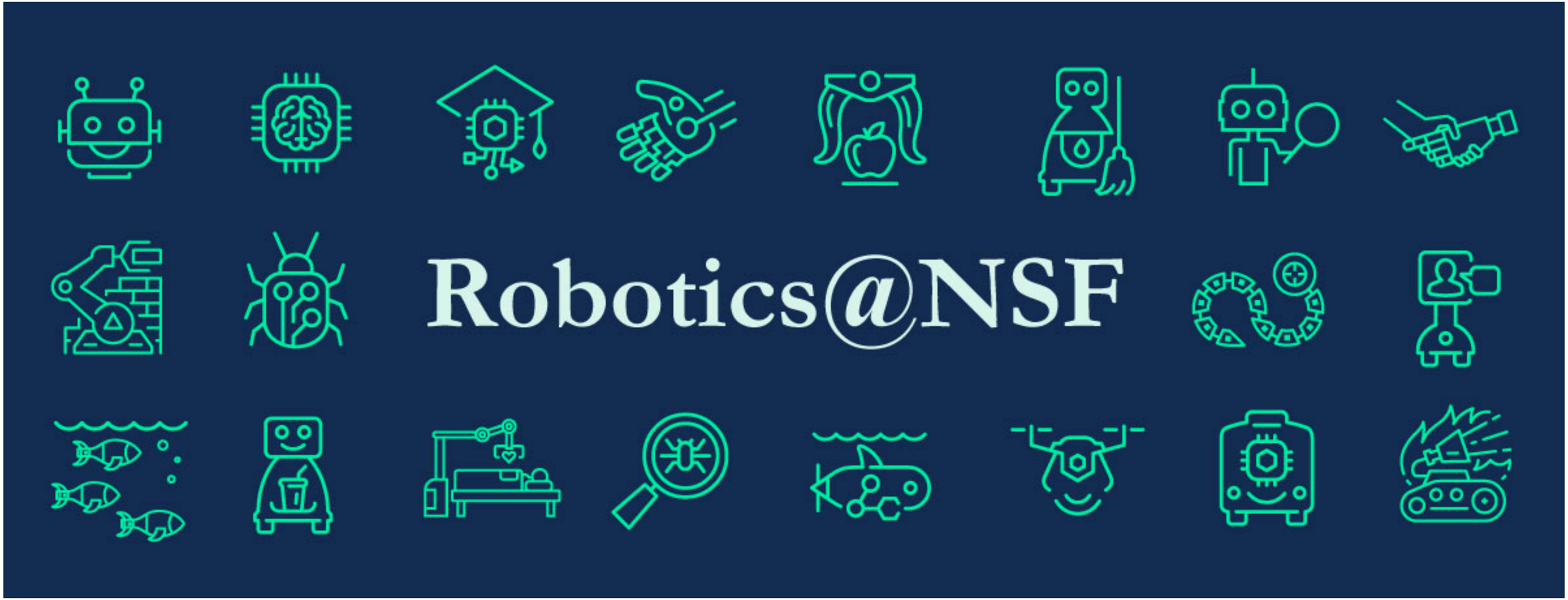






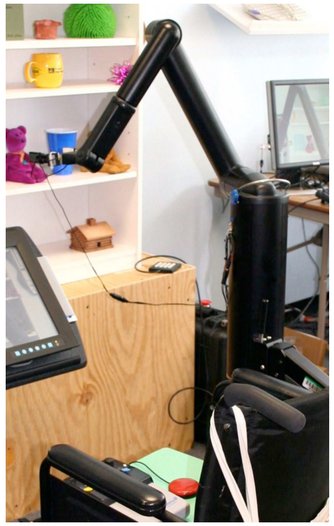



…According to Google Images



https://www.nsf.gov/eng/robotics.jsp

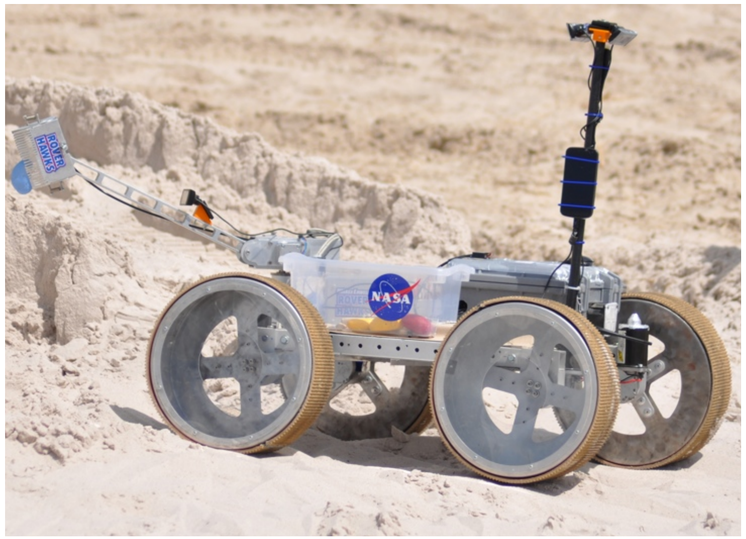

V&D

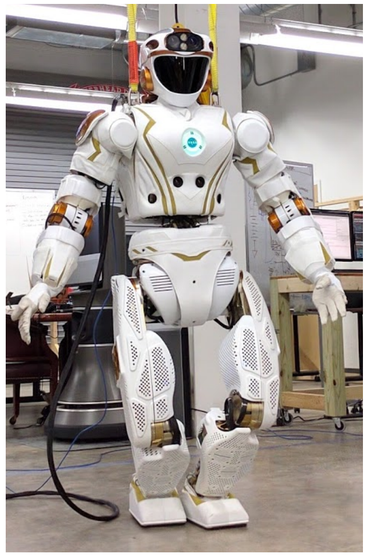


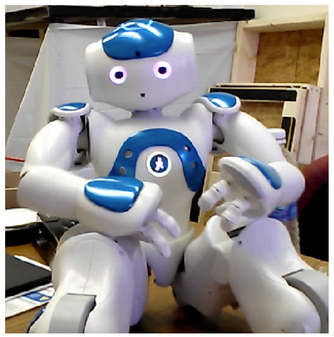

NERVE
CENTER
@ UMASS LOWELL
New England Robotics Validation
and Experimentation (NERVE) Center
DRC
Hubo
UMASS
University of
Massachusetts
Lowell

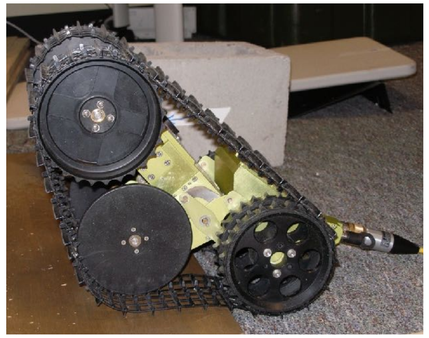

fetch
fetchrobotics


hello robot


NASA





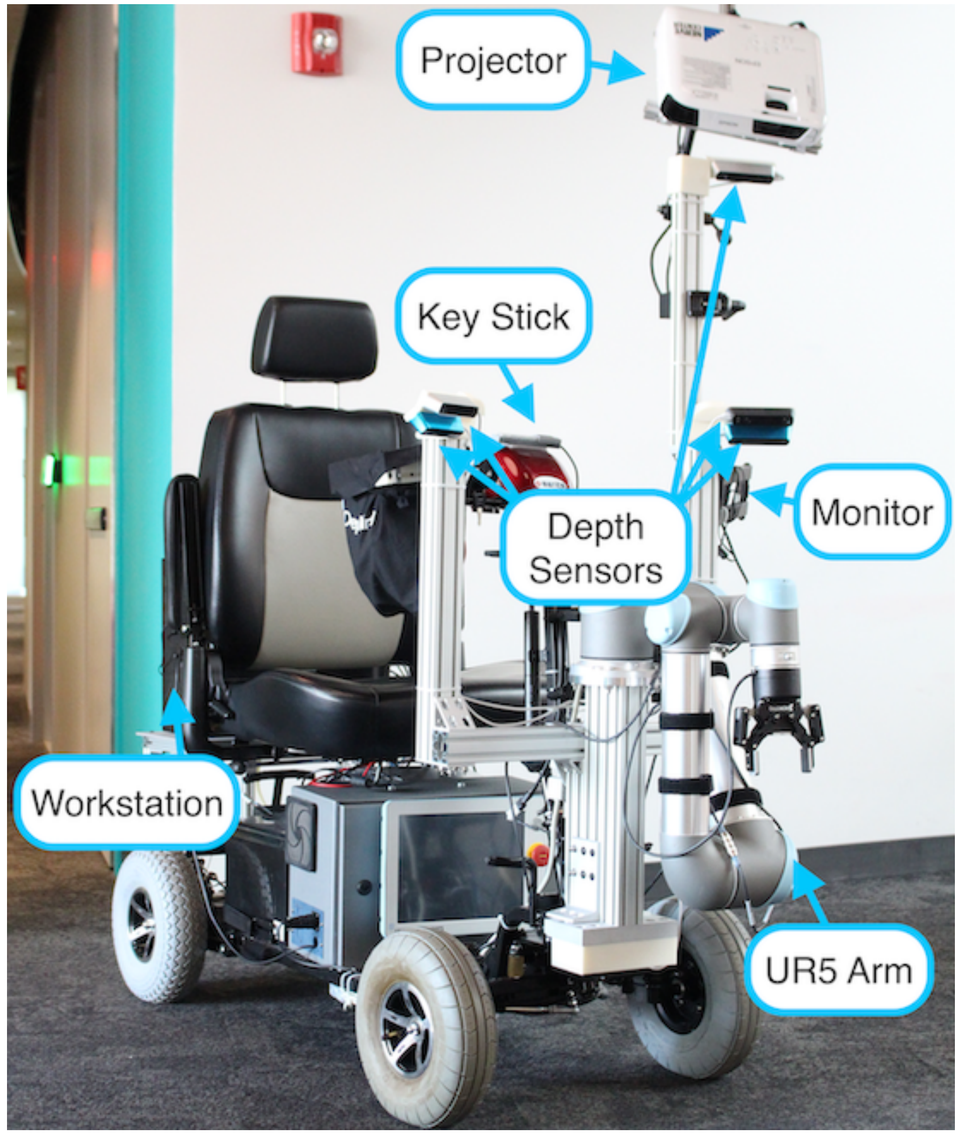


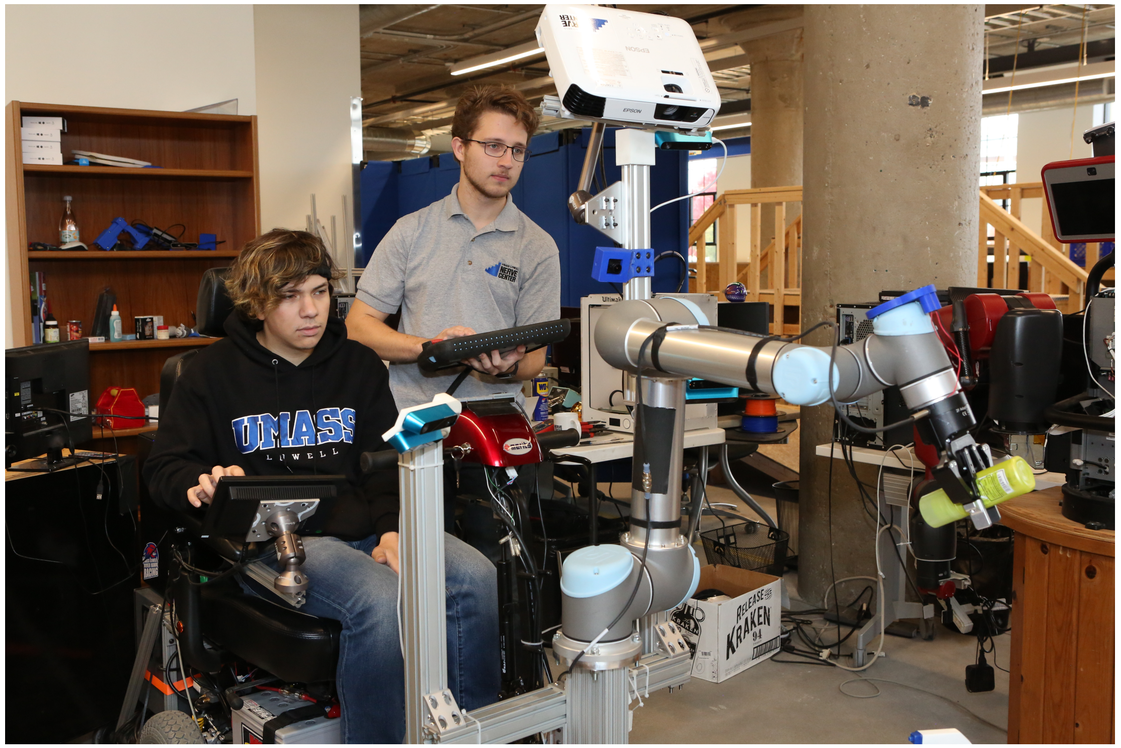

my.mo

Assistive Grasping of Unmodeled Objects in Clutter

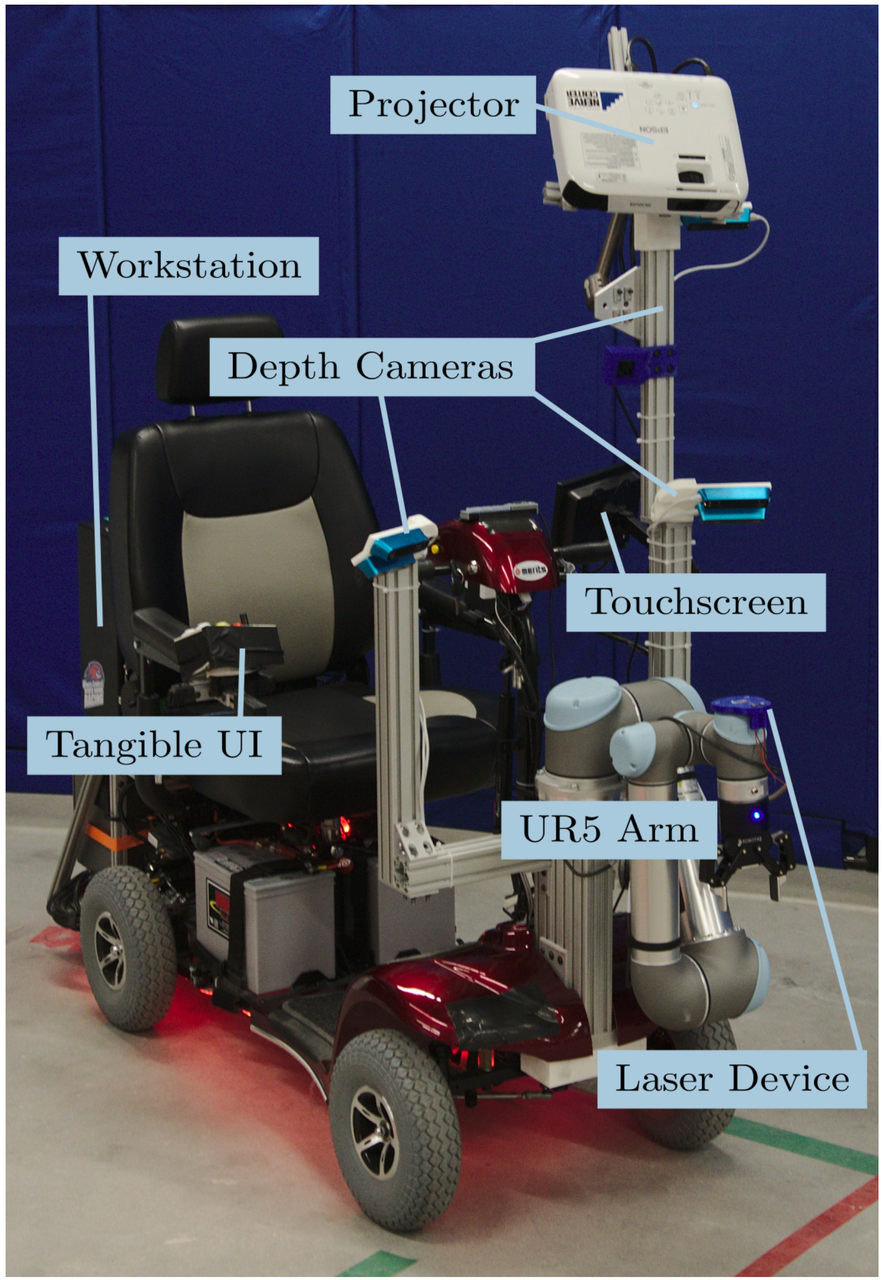
NSF
IIS-1426968
IIS-1763469

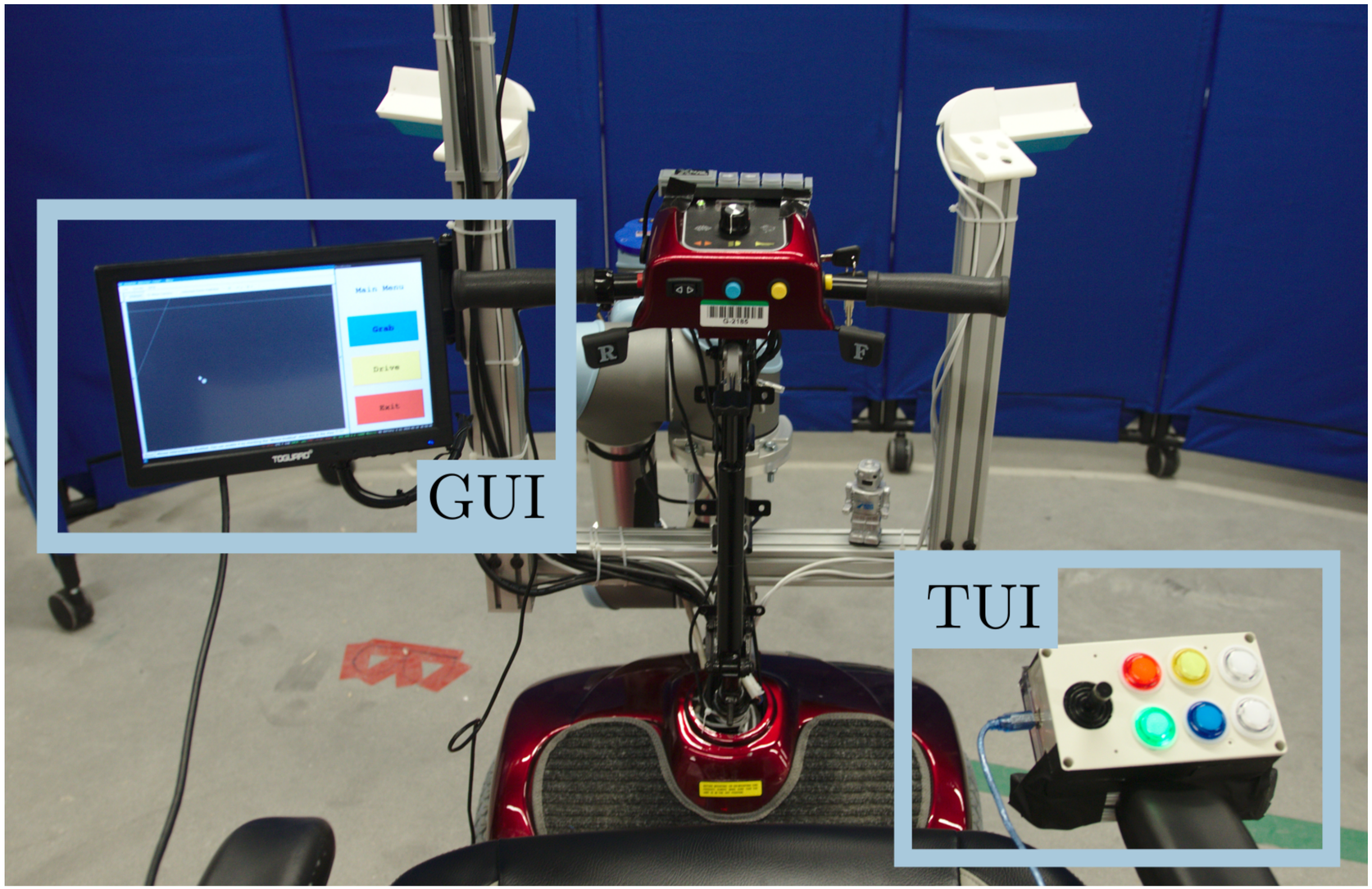
Turning the World into the Interface



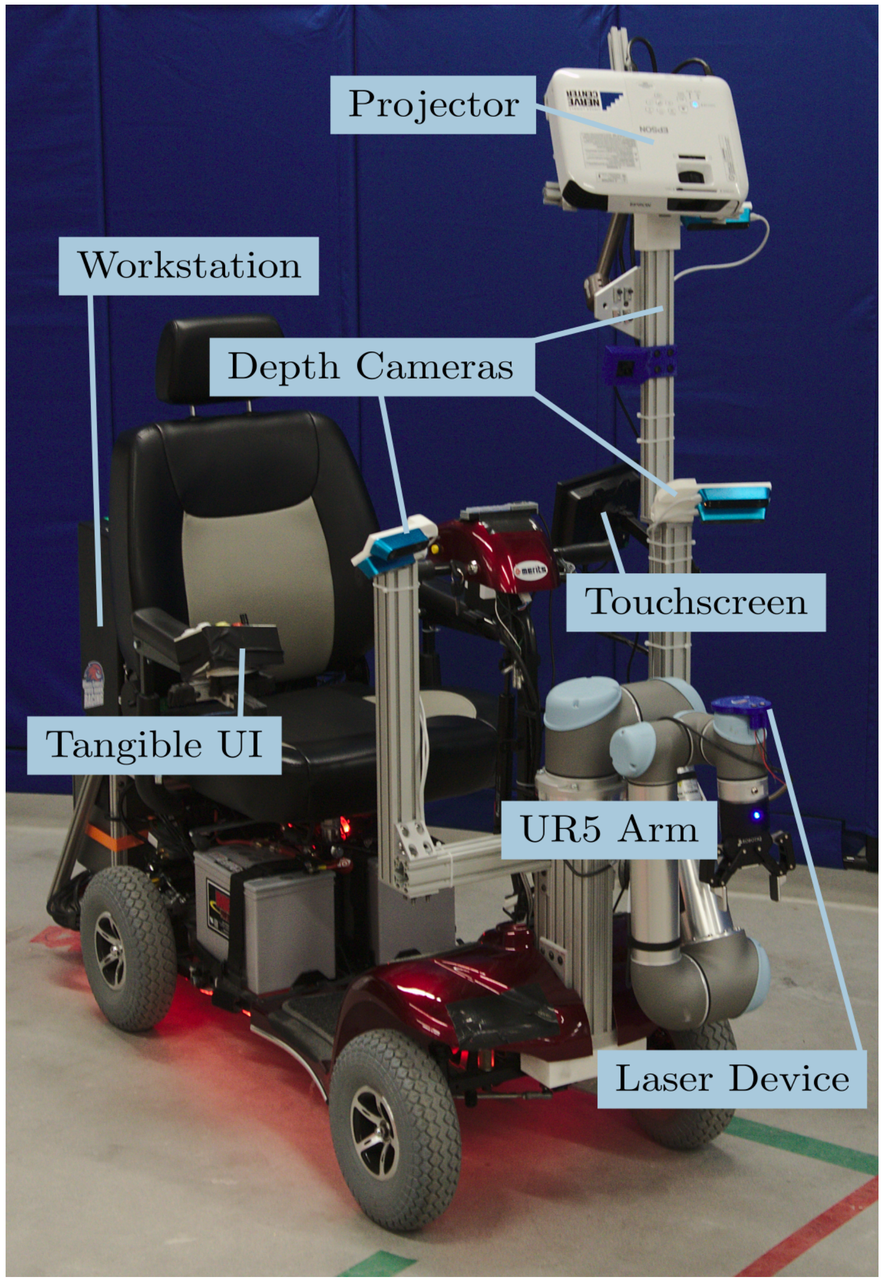


Dian Wang, Colin Kohler, Andreas ten Pas, Alexander Wilkinson, Maozhi Liu, Holly Yanco, and Robert Platt. “Towards Assistive Robotic Pick and Place in Open World Environments.” *Proceedings of the International Symposium on Robotics Research (ISRR)*, Hanoi, October 2019.

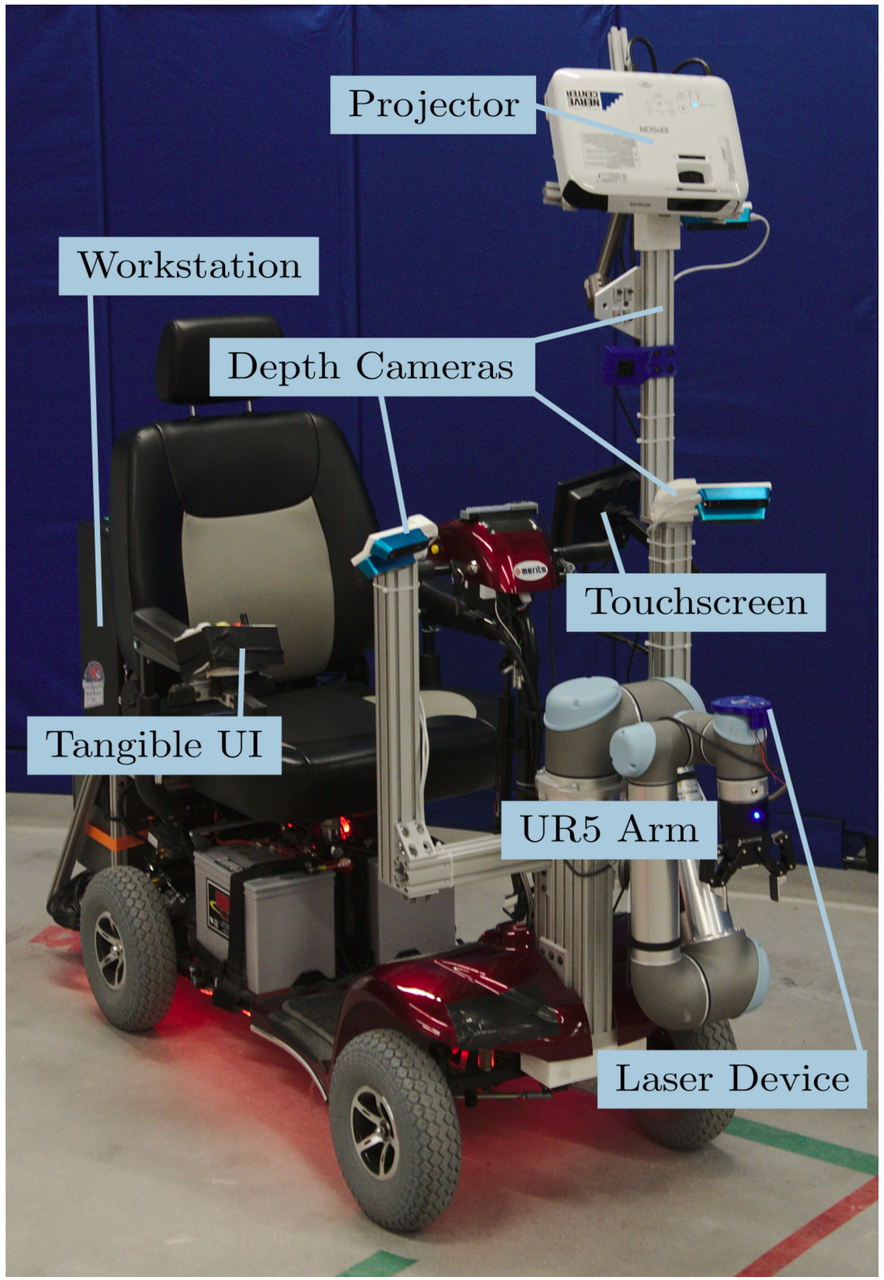




Alexander Wilkinson, Michael Gonzales, Patrick Hoey, David Kontak, Dian Wang, Noah Torname, Sam Laderoute, Zhao Han, Jordan Allspaw, Robert Platt, and Holly Yanco. “Design Guidelines for Human-Robot Interaction with Assistive Robot Manipulation Systems.” Paladyn, Journal of Behavioral Robotics, Vol. 12, No. 1, pp. 392-401, Sept 2021.


Projector
Workstation
Depth Cameras
Touchscreen
Tangible UI
UR5 Arm
Laser Device


Begin
TOGUARD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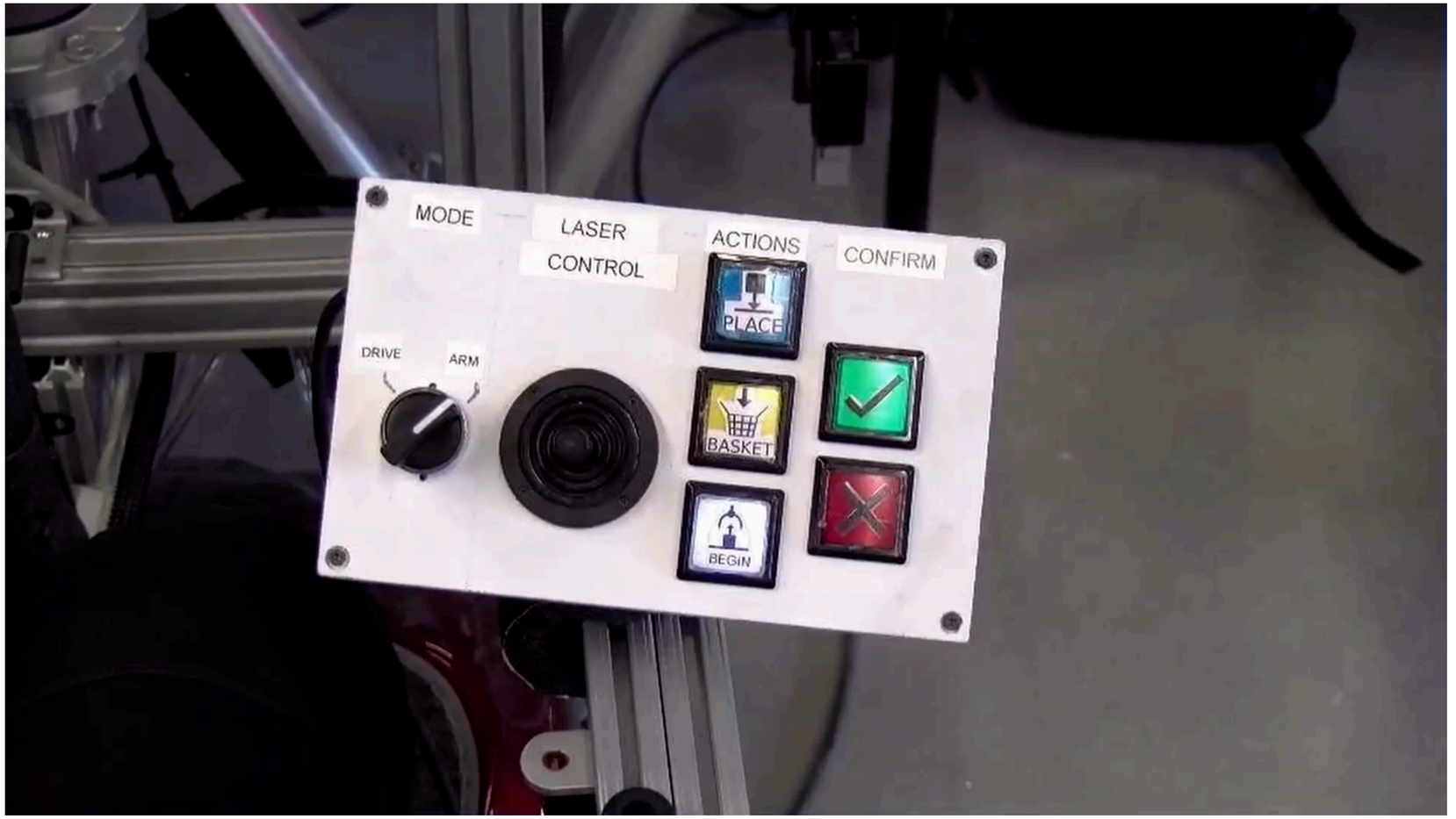
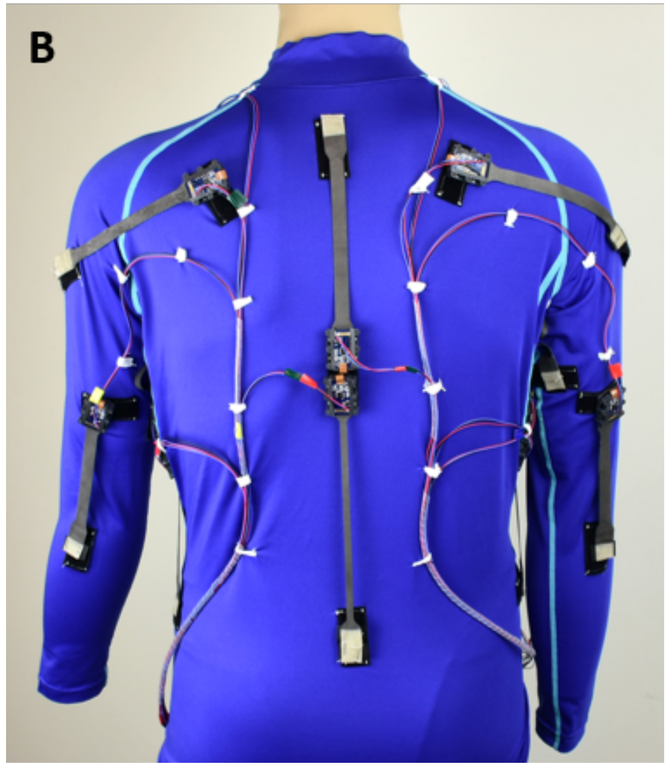

MODE
LASER CONTROL
ACTIONS
CONFIRM
DRIVE
ARM
PLACE
BASKET
BEGIN

Yi-Ning Wu, Adam Norton, Michael R. Zielinski, Pei-Chun Kao, Andrew Stanwicks, Patrick Pang, Charles H. Cring, Brian Flynn, and Holly A. Yanco. “Characterizing the Effects of Explosive Ordnance Disposal Operations on the Human Body While Wearing Heavy Personal Protective Equipment.” Human Factors: The Journal of the Human Factors and Ergonomic Society, February 2021.

Adaptive Exoskeletons



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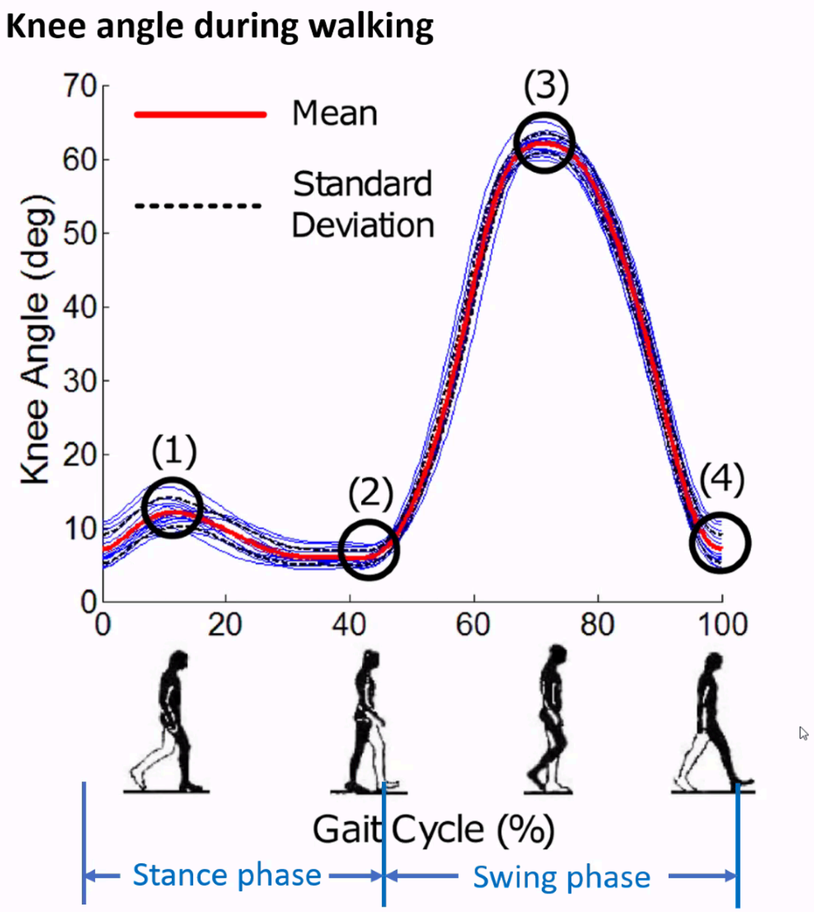
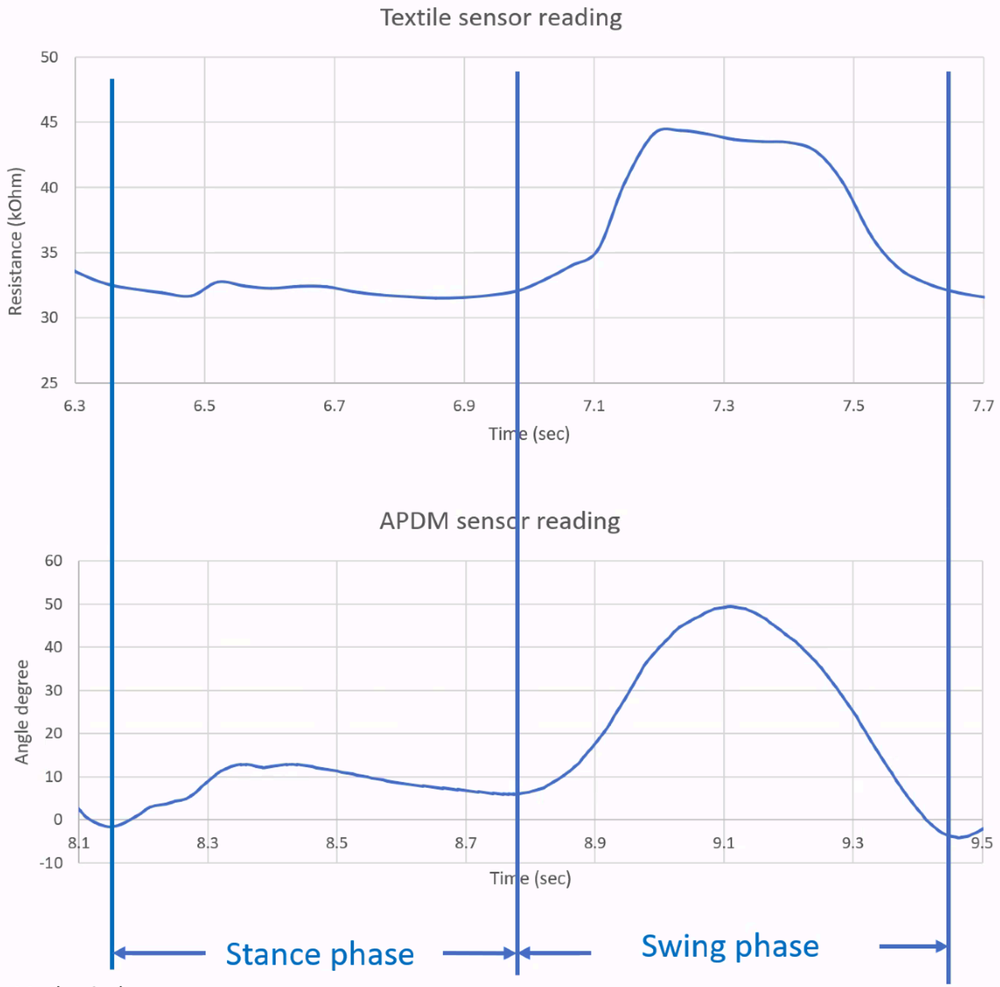




Ahn, Jooeun & Hogan, Neville. (2012). Walking Is Not Like Reaching: Evidence from Periodic Mechanical Perturbations. PloS one. 7. e31767. 10.1371/journal.pone.0031767.

Attitudes towards robot autonomy

- You park your car manually
- Another driver manually parks their car next to your car
- Another car automatically parks itself next to your car
- Your car automatically parks itself (and you cannot override it)
- Your car automatically parks itself (and you can override it)
- You take a taxi and the taxi driver parks the taxi.

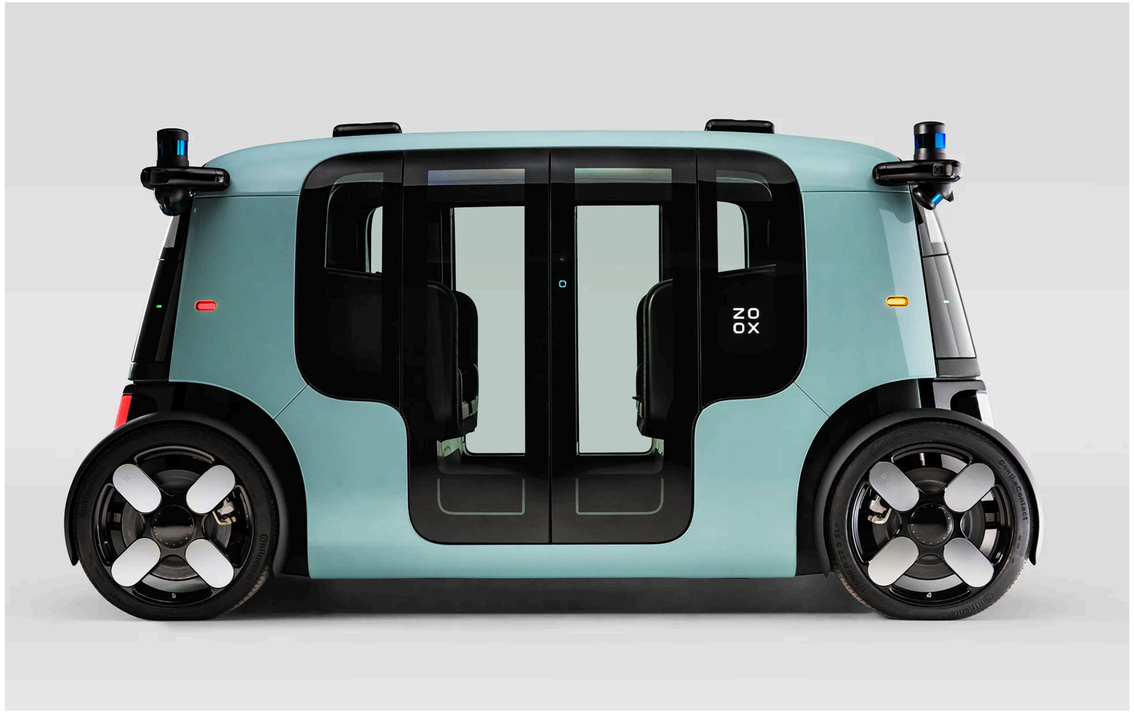
- Survey conducted using Mechanical Turk: 176 responses
- 69.3% females, 30.1% males, and 0.6% unreported
- 22% 18-25, 36% 26-36, 22% 36-45, 18% 46 and over
- 97.7% reported having prior experience driving a car

Attitudes towards robot autonomy

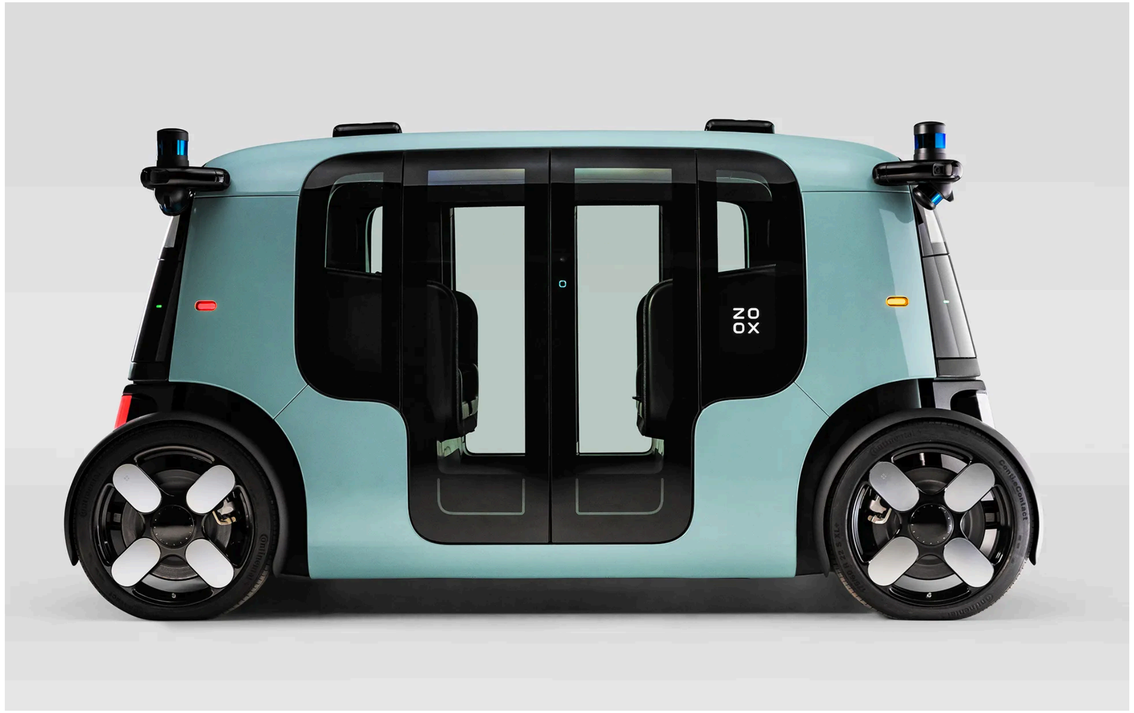
- Nomura et al. demonstrated empirically that negative attitudes towards robots affect interactions with robots [IEEE T-RO 2008]

Scenario	Mean Rank	Mode Rank	Participants at Mode
Self: Manual	1.74	1	65.3%
Another Driver: Manual	3.31	2	38.6%
Taxi	3.36	3	27.3%
Self: Auto: Override	3.19	4	27.3%
Another Driver: Auto	4.36	5	36.4%
Self: Auto: No Override	5.04	6	55.1%

Munjal Desai, Kristen Stubbs, Aaron Steinfeld, and Holly Yanco. “Creating Trustworthy Robots: Lessons and Inspirations from Automated Systems.” Proceedings of the AISB Workshop on New Frontiers in Human-Robot Interaction, 2009.



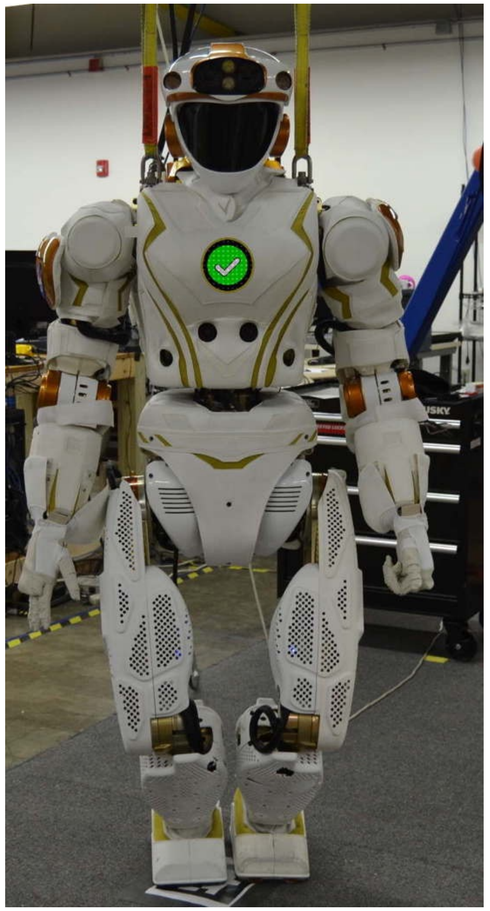
Zoox



https://www.edmonton.ca/transportation/cycling_walking/pedestrian-safety

Zoox

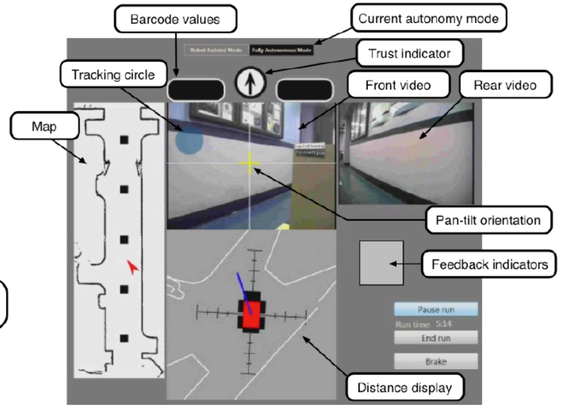
Bystander Feedback

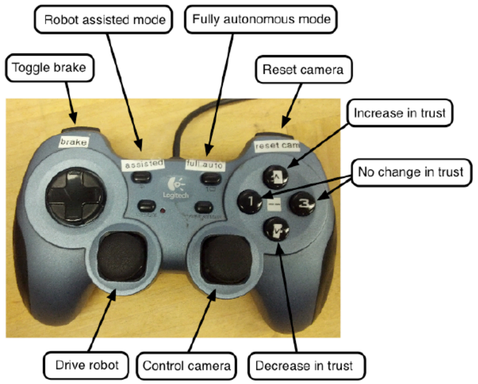


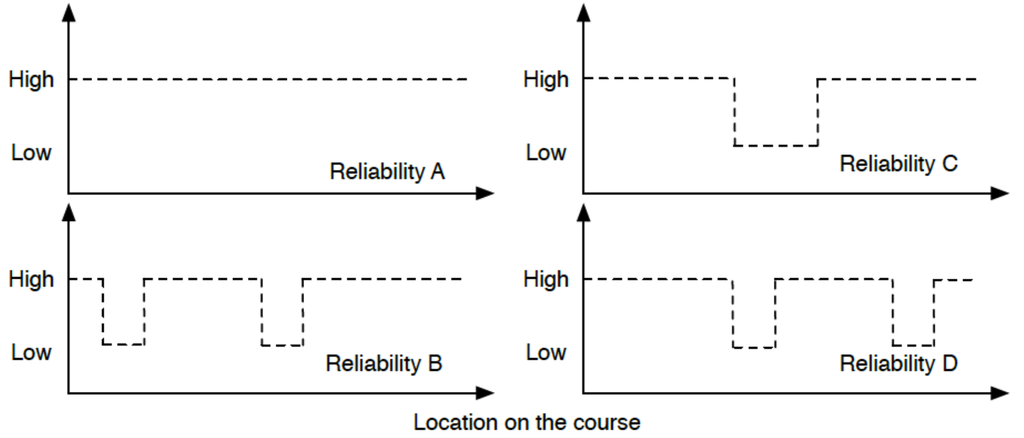
Daniel J. Brooks, Dalton J. Curtin, James T. Kuczynski, Joshua J. Rodriguez, Aaron Steinfeld, and Holly A. Yanco. "A Communication Paradigm for Human-Robot Interaction During Robot Failure Scenarios." Human-Machine Shared Contexts, Eds: William Lawless, Ranjeev Mittu, and Don Sofge, Elsevier: Academic Press, pp. 277-306, 2020.

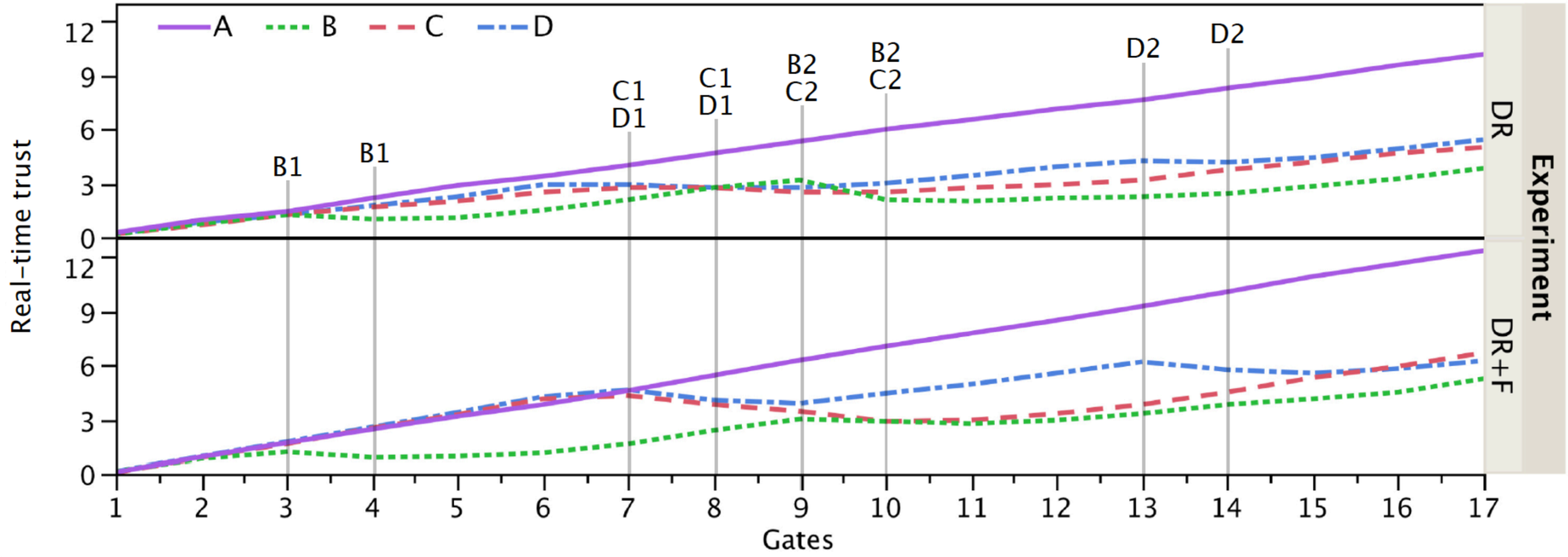
IIS-1552228

Trust in Human-Robot Interaction









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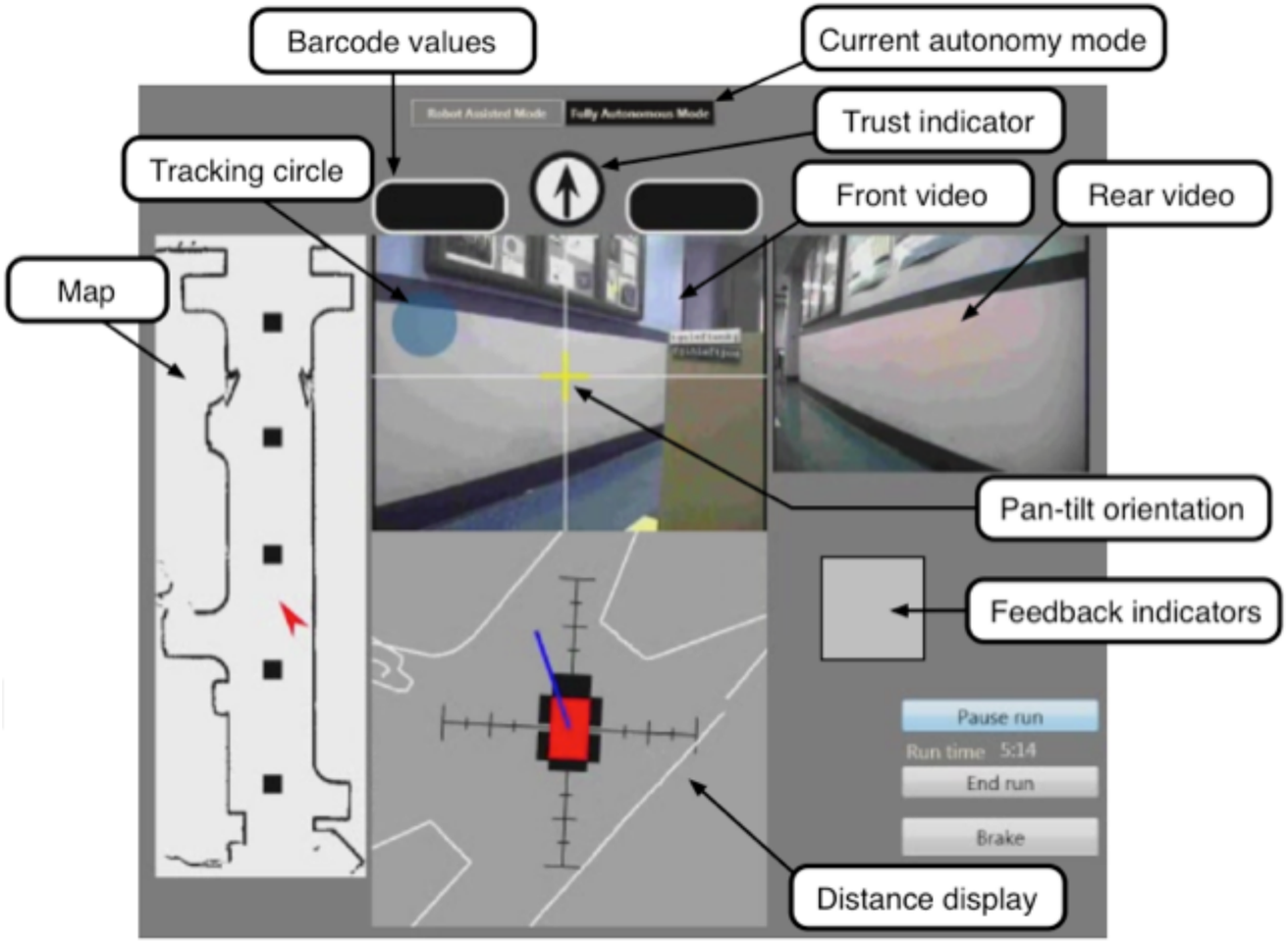
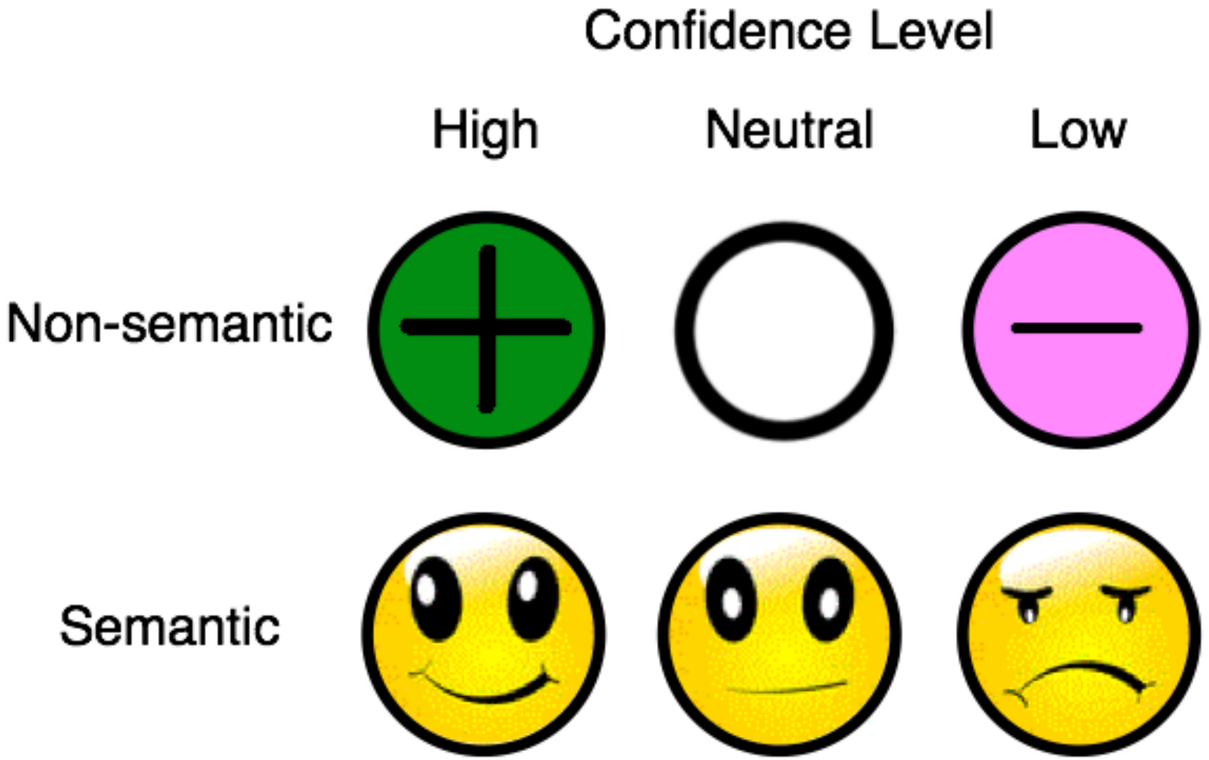
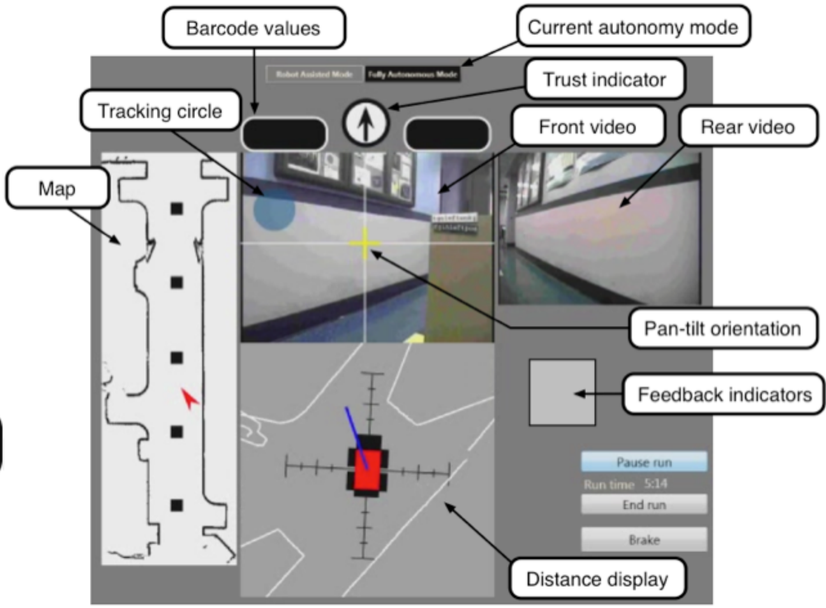
Feedback indicators





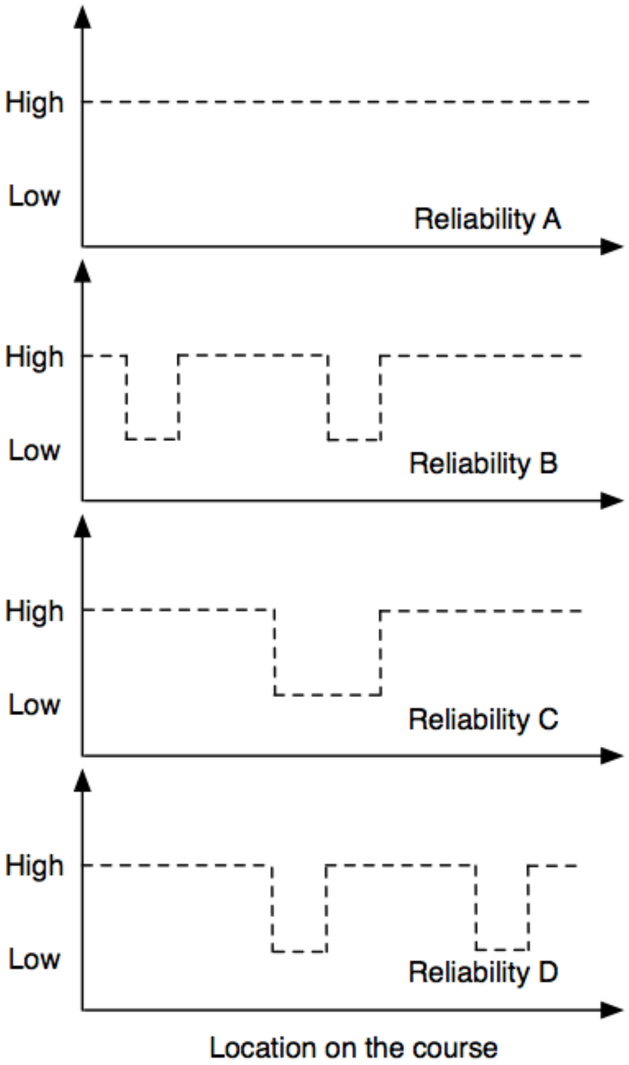
Operator tasks

- Follow the correct path
- Perform the secondary tasks
  - Trust measurements
  - Camera placement task
- Avoid hitting objects
- Finish as quickly as possible



- Compensation based upon performance measures including time, number of hits, incorrect turns, and secondary task completion

Experiments



Dynamic Reliability (DR)

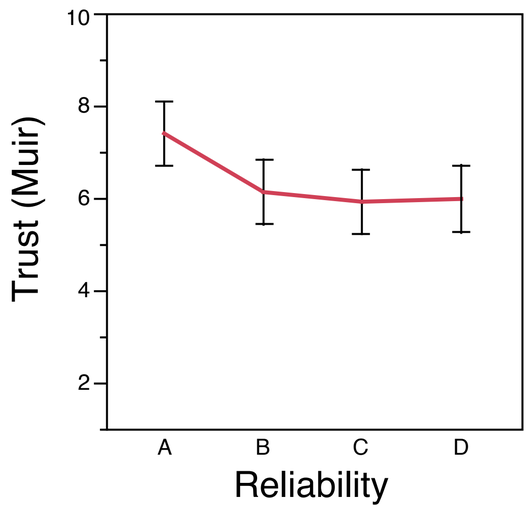
- 12 participants (6 male, 6 female)
- Mean age: 37.4 (16.3)

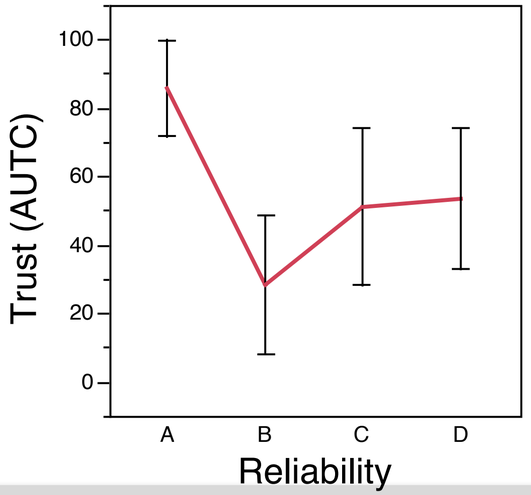
Dynamic Reliability + Feedback (DR+F)

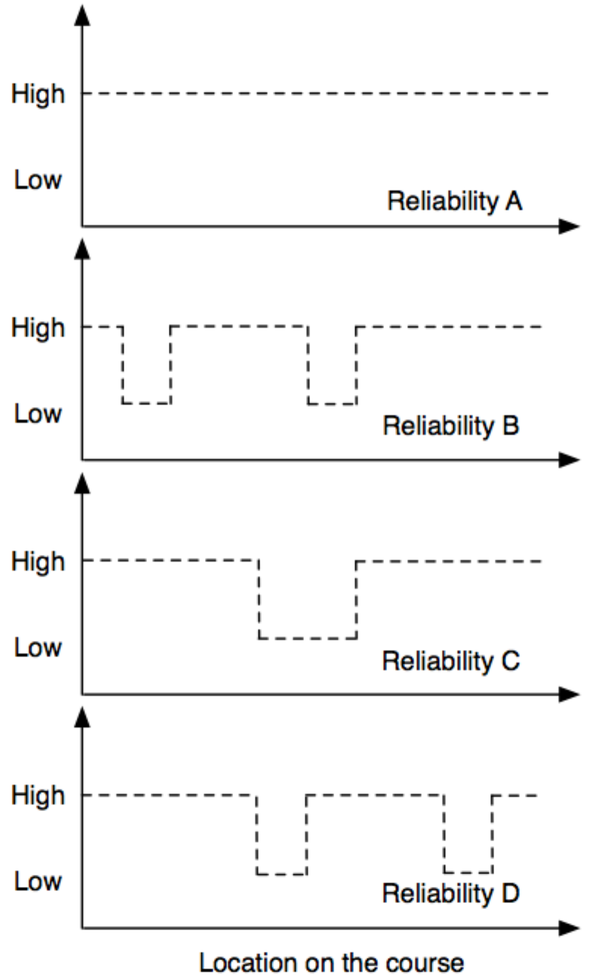
- 16 participants (8 male, 8 female)
- Mean age: 22.2 (4.0)
- Split into two groups of 8: Semantic Feedback (DR+F:S) and Non-Semantic Feedback (DR+F:NS)

How does the timing of periods of low reliability impact real-time trust?

- Traditional post-run survey approaches can be masked by primary-recently bias
- Real-time trust results demonstrate that early drops in reliability negatively impact real-time trust differently than middle or late drops





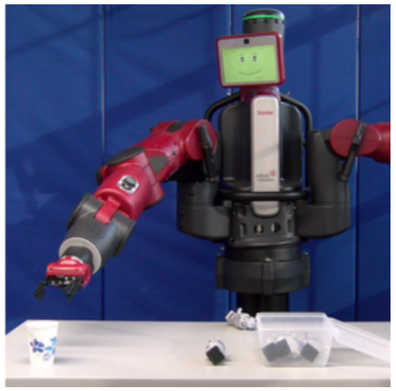


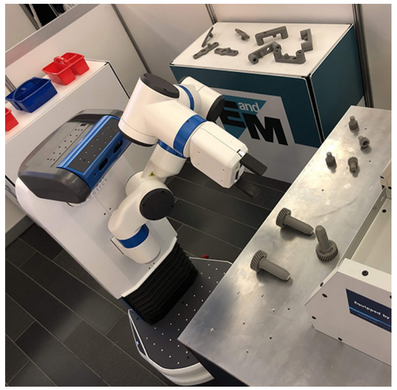
Should we provide feedback to robot operators?

- Feedback results
  - \+ No difference in trust
  - \+ Better control allocation strategy
  - \- Increased workload
  - \- Increased mode switching
- Provide feedback only when robot is failing, not when it is working properly

Munjal Desai, Poornima Kaniarasu, Mikhail Medvedev, Aaron Steinfeld, and Holly Yanco. “Impact of Robot Failures and Feedback on Real-Time Trust.” Proceedings of the 8th Annual ACM/IEEE International Conference on Human-Robot Interaction, Tokyo, Japan, March 2013. Nominated for best paper.

SUCCESS: Self-assessment and Understanding of Competence and Conditions to Ensure System Success





Basic science research that develops new knowledge and techniques for **machine self-assessment of proficiency**

… over multiple time-scales and complexities

- Assessment of past, current, and future performance
- Range from simple binary responses to reflective explanations

… using multiple techniques

- Use human methods as inspiration for AI systems
- Use AI-specific ideas even if there's no human analog

… with an integrated, multi-institution team

- Cross-cutting research topics to connect research threads
- Joint development and testing

Carnegie Mellon University

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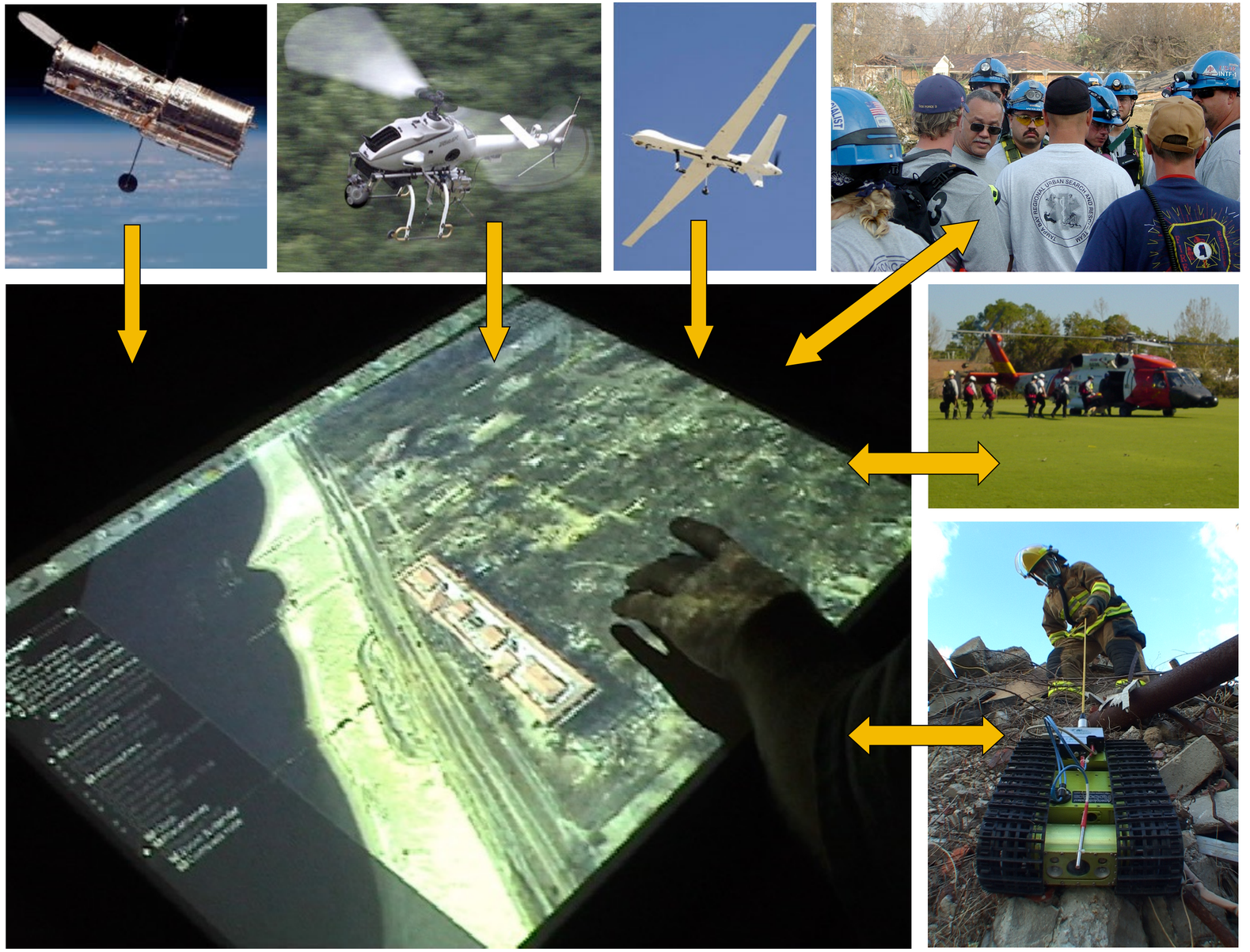
Tufts UNIVERSITY

BRIGHAM YOUNG UNIVERSITY · FOUNDED BYU 1875 · PROVO, UTAH

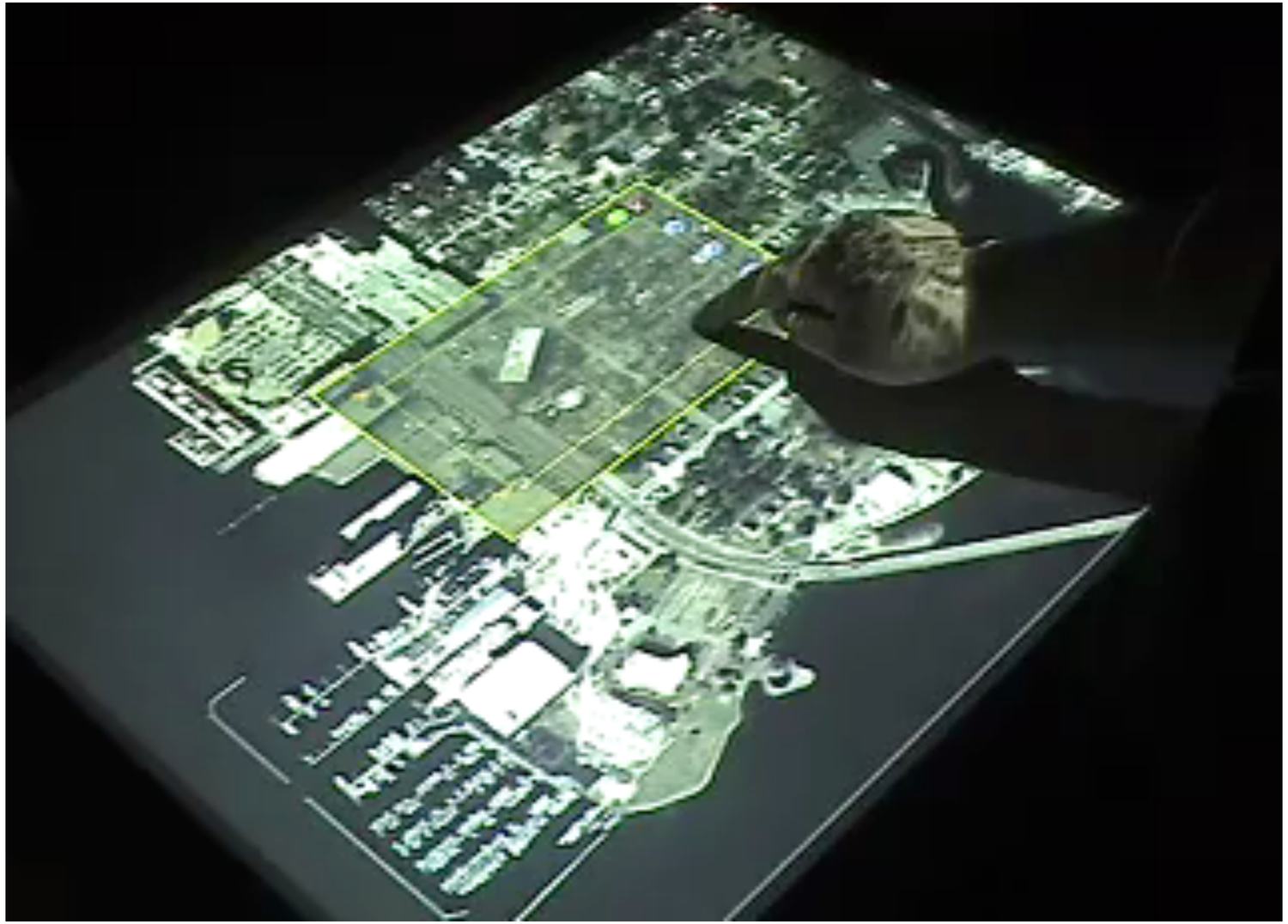
Which object will the robot grasp?

Are the objects detected?

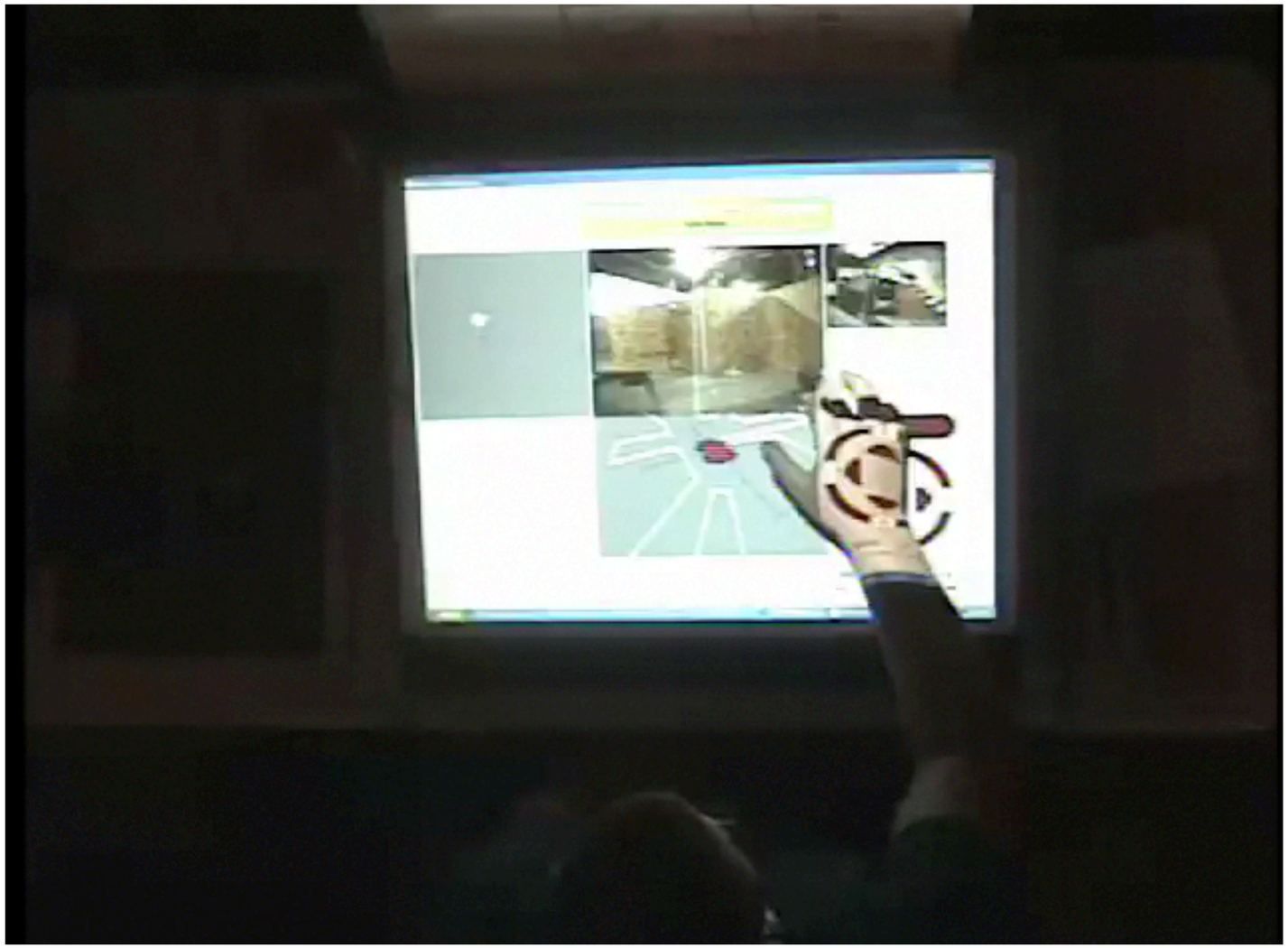

ON
OFF
CAUTION
WET
FLOOR



Multi-touch damage assessment

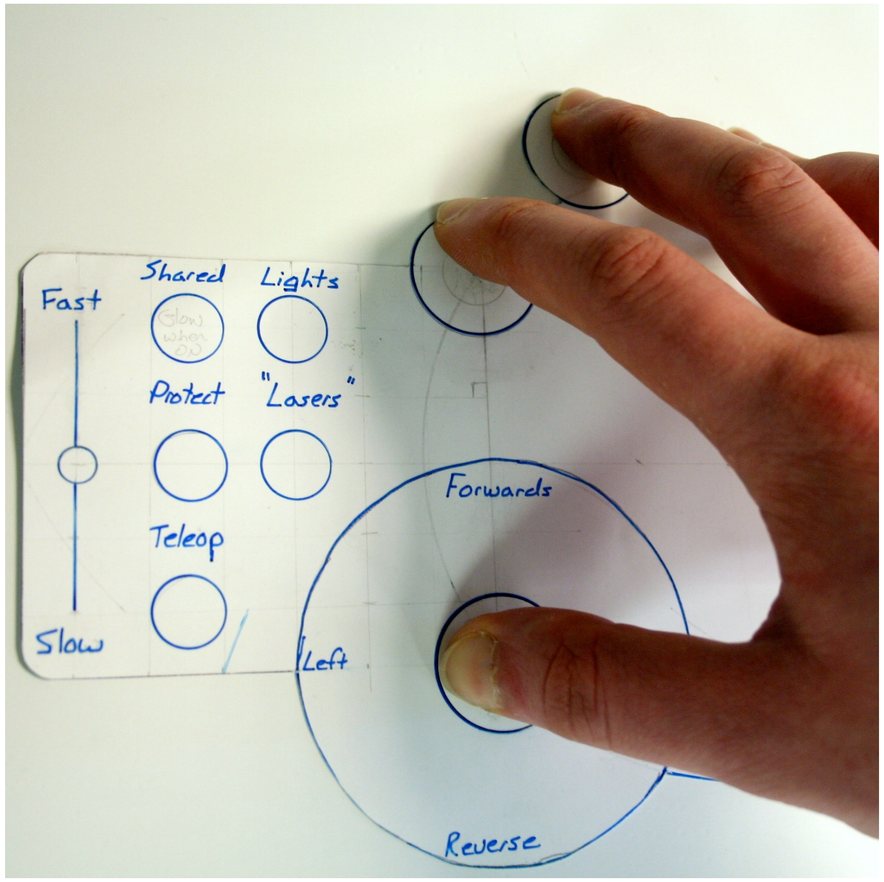


Multi-touch single robot search and rescue interface

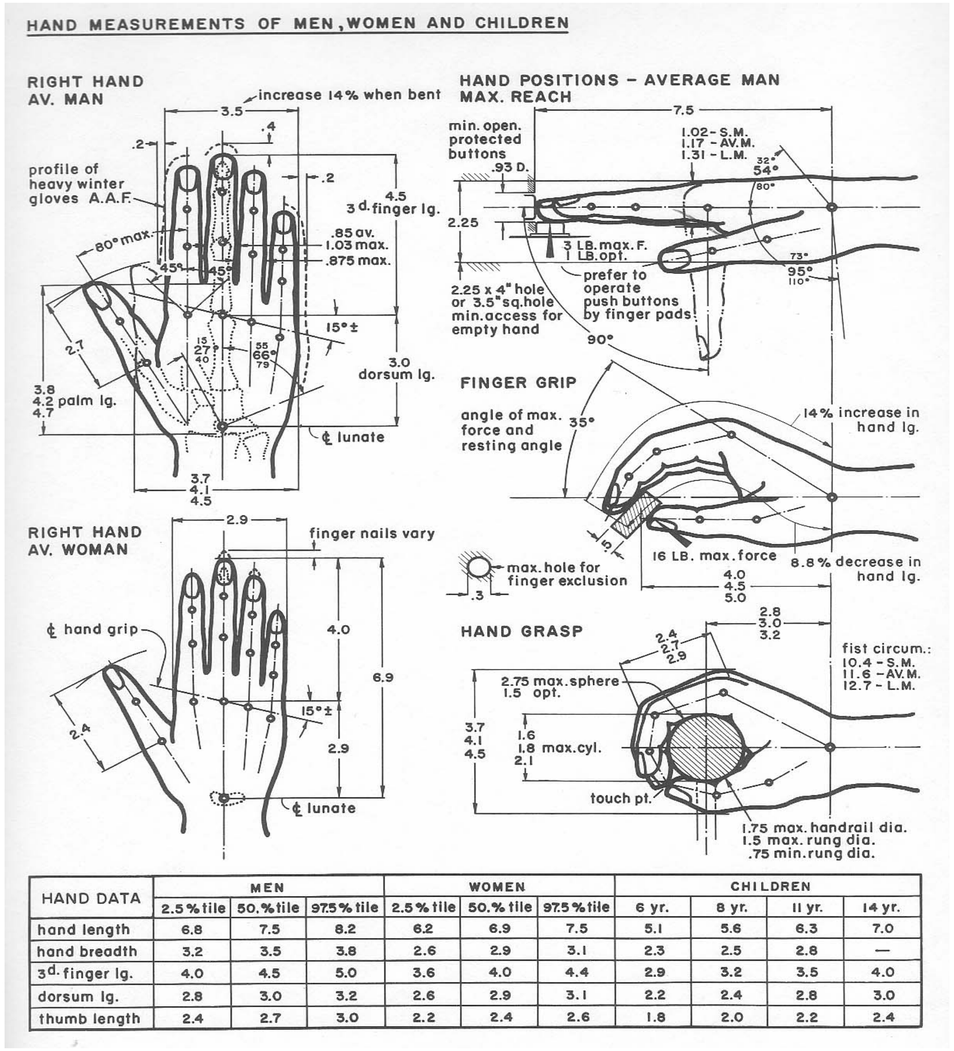


Mark Micire, Jill L. Drury, Brenden Keyes, and Holly Yanco. “Multi-Touch Interaction for Robot Control.” International Conference on Intelligent User Interfaces (IUI), Sanibel Island, Florida, February 8–11, 2009.

Inspiration: Video games



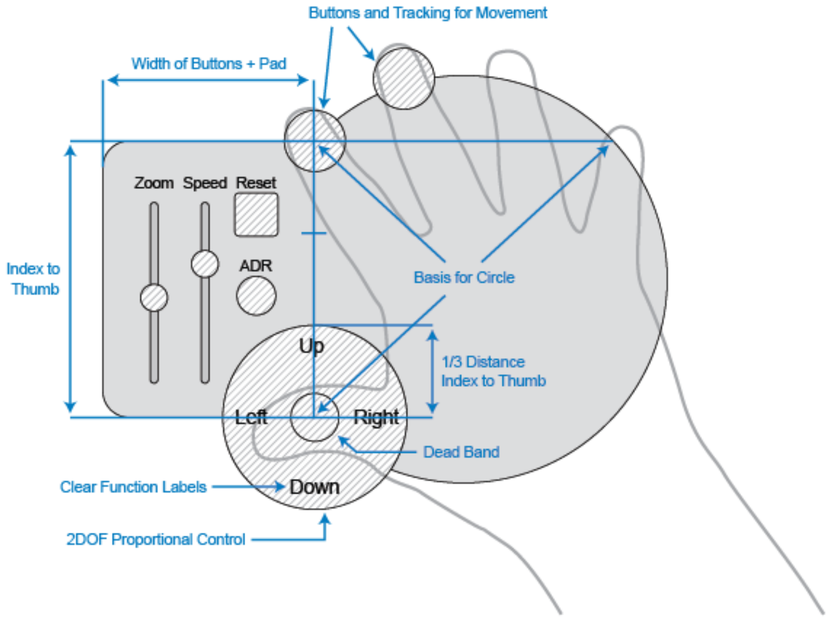
Inspiration: Ergonomics

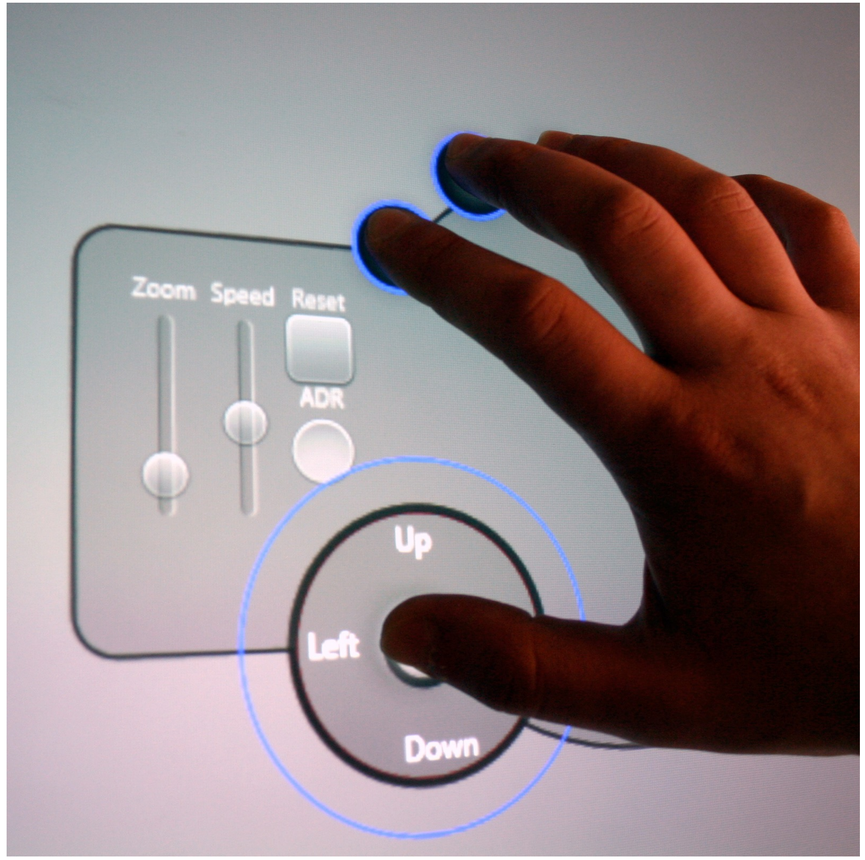


HAND DATA	MEN			WOMEN			CHILDREN			
	2.5% tile	50.% tile	97.5% tile	2.5% tile	50.% tile	97.5% tile	6 yr.	8 yr.	11 yr.	14 yr.
hand length	6.8	7.5	8.2	6.2	6.9	7.5	5.1	5.6	6.3	7.0
hand breadth	3.2	3.5	3.8	2.6	2.9	3.1	2.3	2.5	2.8	—
3d. finger lg.	4.0	4.5	5.0	3.6	4.0	4.4	2.9	3.2	3.5	4.0
dorsum lg.	2.8	3.0	3.2	2.6	2.9	3.1	2.2	2.4	2.8	3.0
thumb length	2.4	2.7	3.0	2.2	2.4	2.6	1.8	2.0	2.2	2.4

From Henry Dreyfuss, “Designing for People,” 1955. Courtesy Allworth Press.

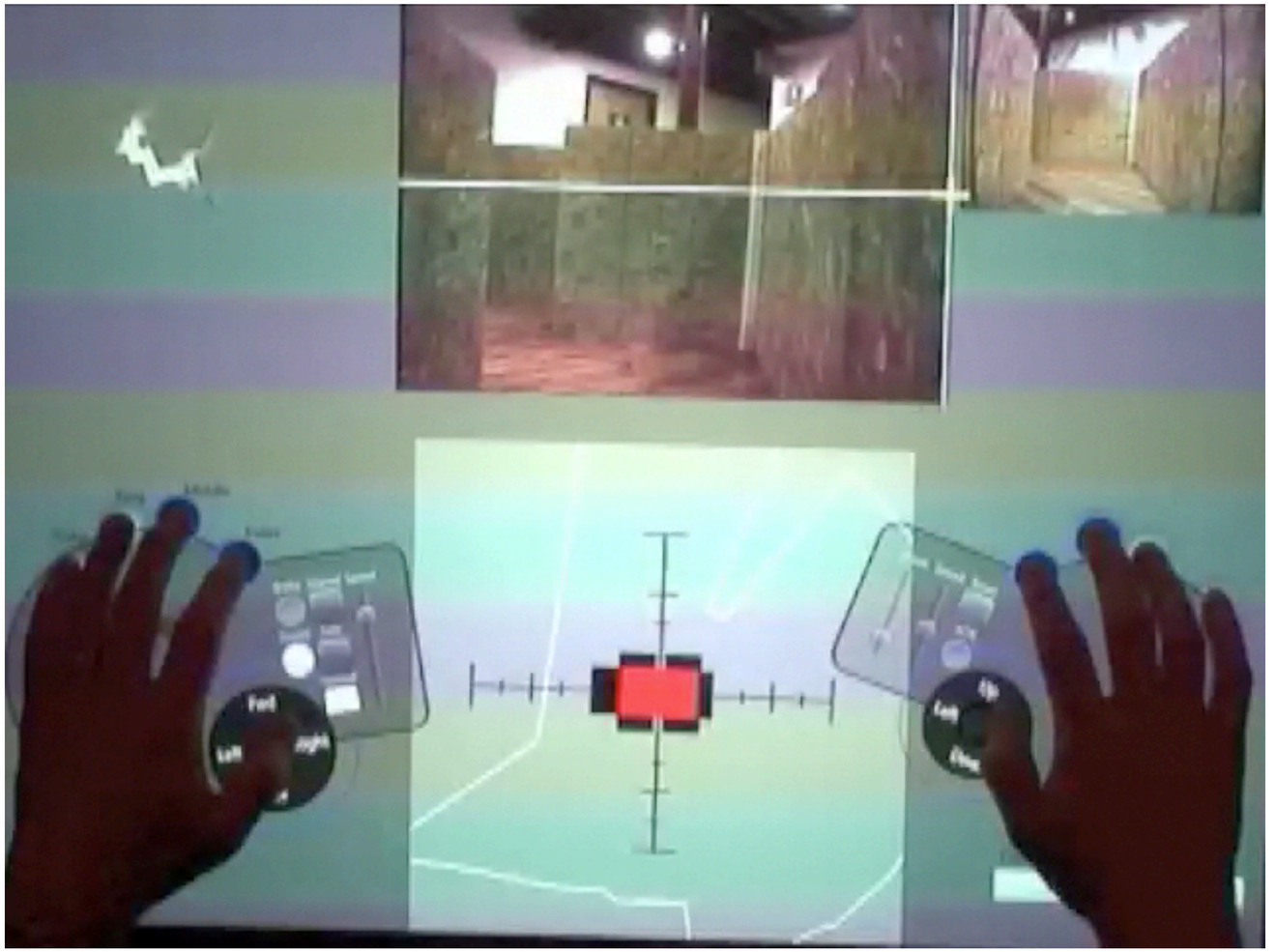
DREAM Controller





Mark Micire, Munjal Desai, Jill L. Drury, Eric McCann, Adam Norton, Katherine M. Tsui, and Holly A. Yanco. “Design and Validation of Two-Handed Multi-Touch Tabletop Controllers for Robot Teleoperation.” Proceedings of the International Conference on Intelligent User Interfaces, Palo Alto, CA, February 13-16, 2011.

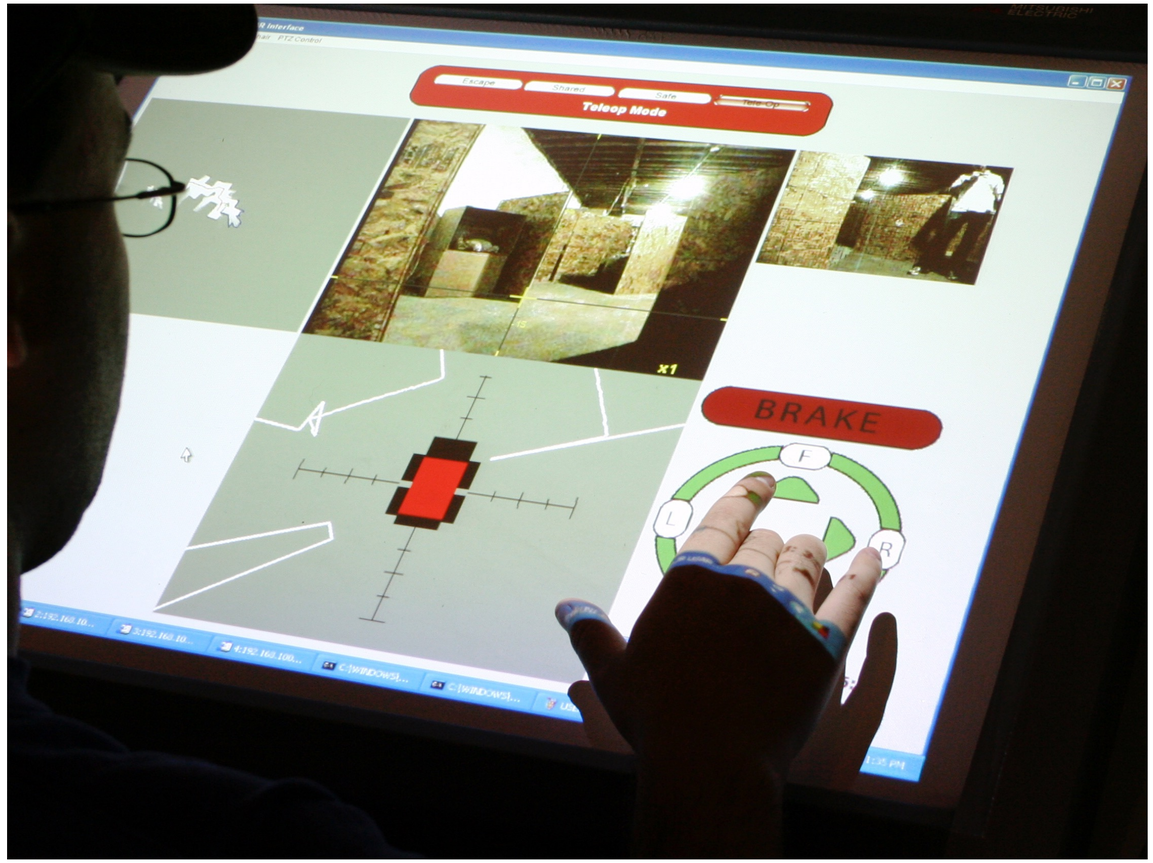
Single robot control



Controlling multiple robots

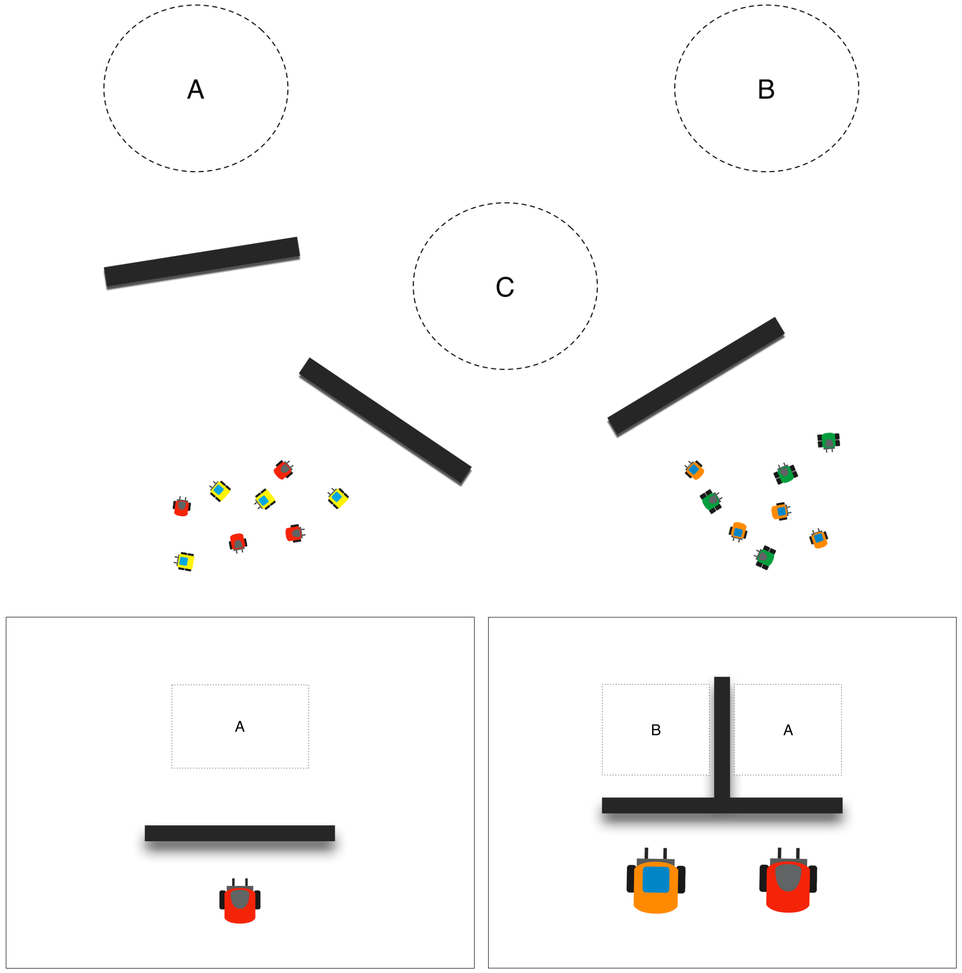
- Demographics for command and operations personnel necessitate the maximization of learnability

- Designed an experiment to elicit the gestures that people would use naturally for controlling robots



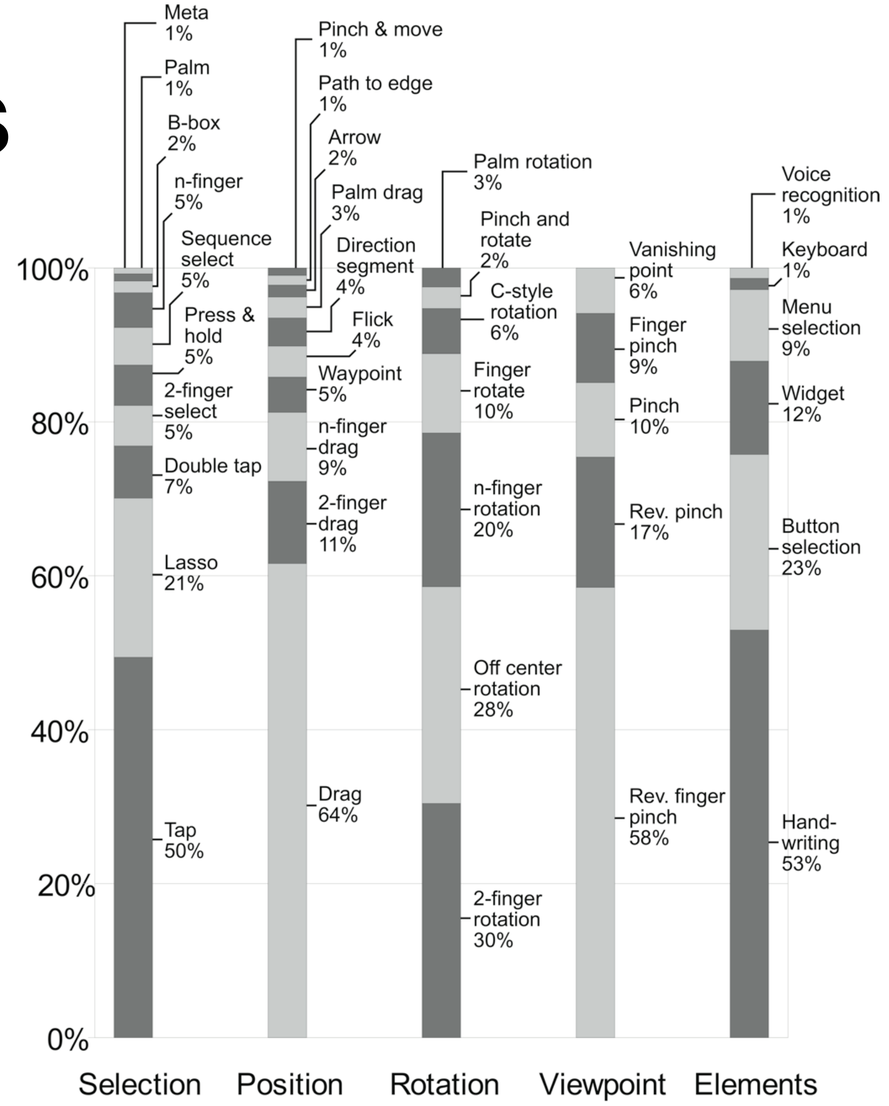
User-defined gesture sets

- 26 tasks presented to 31 users (average age = 27.5, SD=10.1)
- 39 gesture primitives in 5 categories:
  - Selection
  - Position
  - Rotation
  - Viewpoint
  - Elements
- 3197 coded gestures



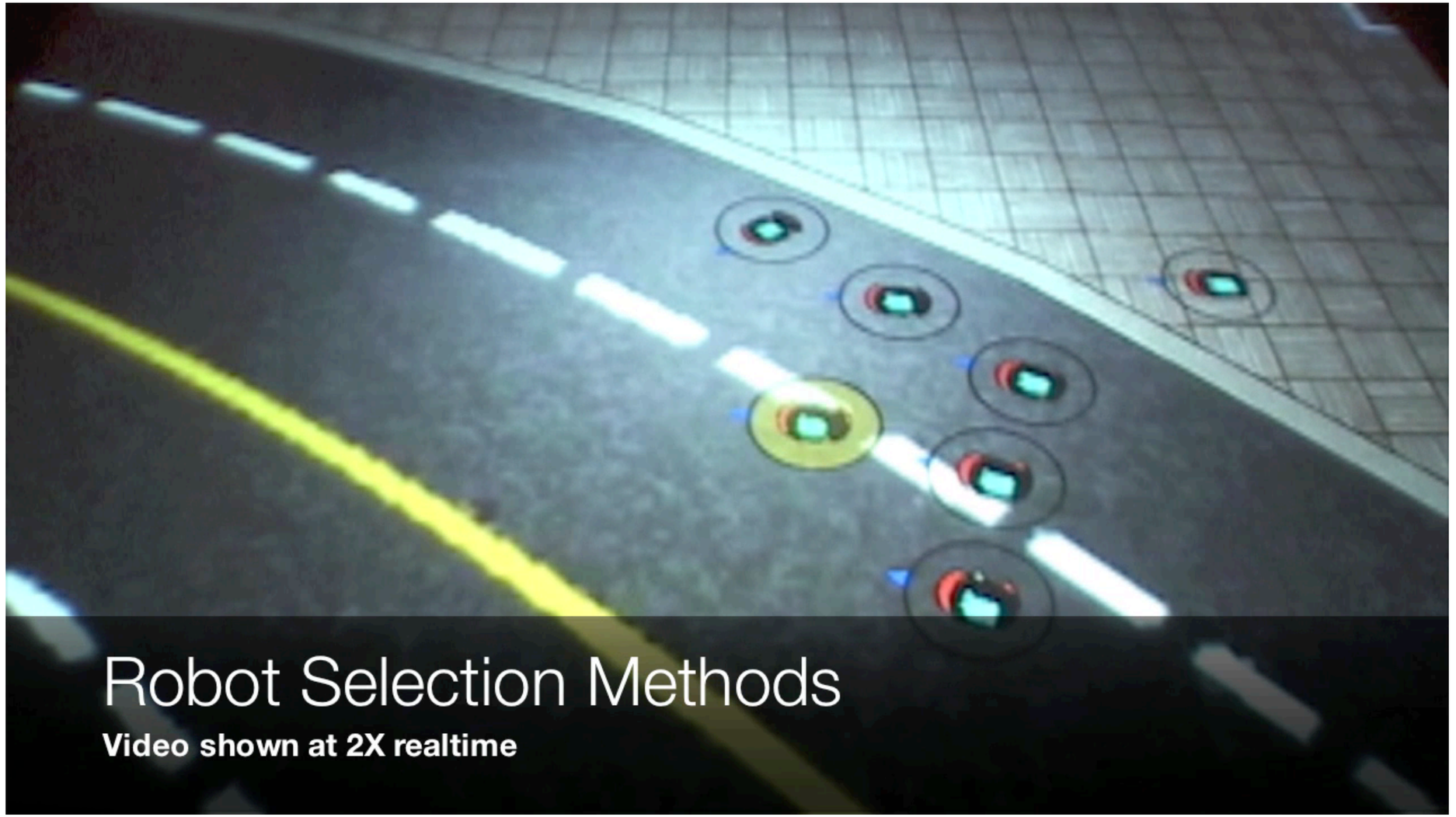
Study results

- Half of selection gestures: taps
  - Not surprising given ubiquity of mouse driven interfaces
- 1, 2 or n finger drags were 84% of position gestures
  - Lack of significance with number of fingers also found by Wobbrock, Morris and Wilson (CHI-09)
- All used a two handed gesture
- 90% used gestures with more than one finger from same hand
- Gesture differences: RTS players, iPhone

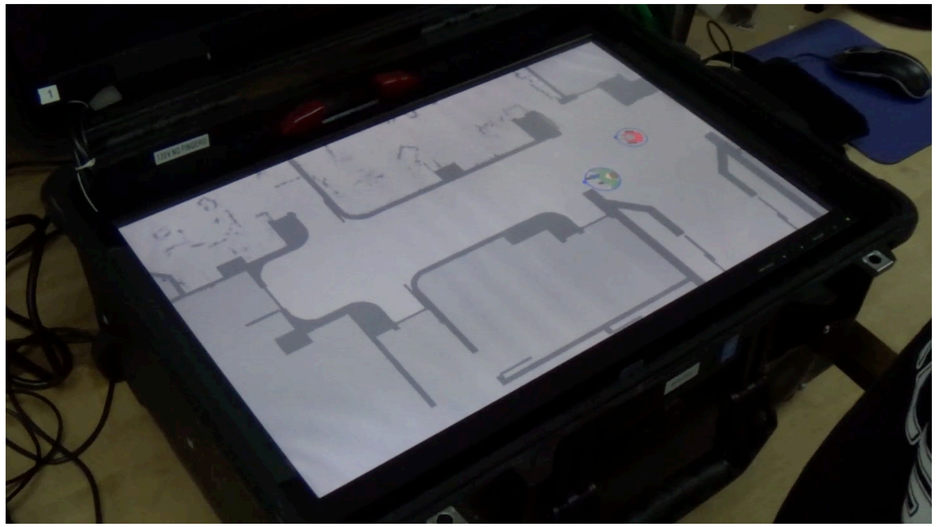


Mark Micire, Munjal Desai, Amanda Courtemanche, Katherine M. Tsui, and Holly A. Yanco. “Analysis of Natural Gestures for Controlling Robot Teams on Multi-touch Tabletop Surfaces.” ACM International Conference on Interactive Tabletops and Surfaces, Banff, Alberta, November 23–25, 2009.

Multi-robot control

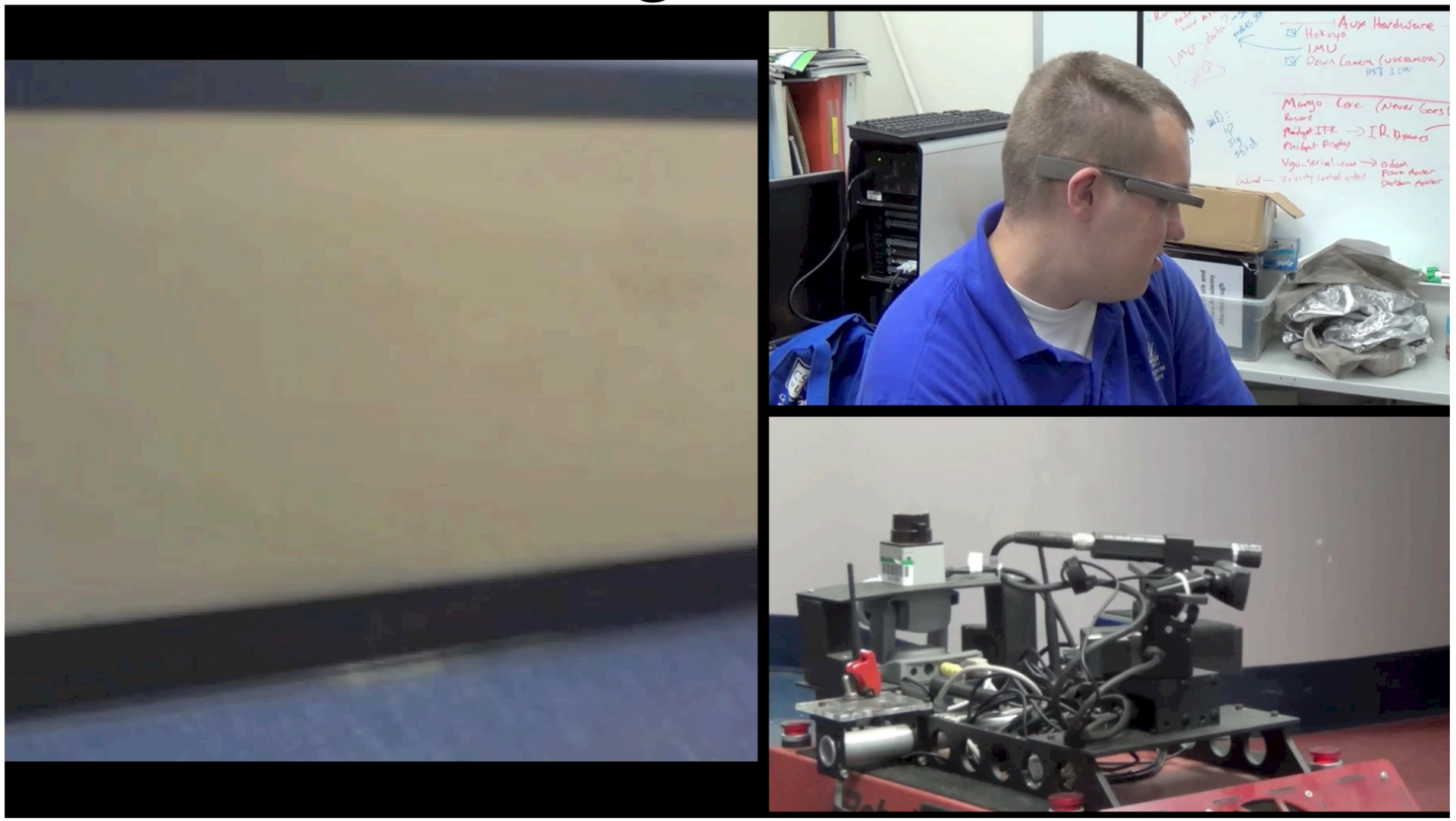


Instrumenting people



Carlos Ibarra Lopez, James Kuczynski, Holly A. Yanco. “Unified Human and Robot Command for Disaster Recovery Situations.” IEEE Symposium on Technologies for Homeland Security (HST '17), 25-26 April 2017.

Google Glass



Design Principles for Human-Robot Interaction with Humanoid Robots

DARPA ROBOTICS CHALLENGE 2013 TRIALS

DARPA ROBOTICS CHALLENGE FINALS 2015

BOSTON ENGINEERING™

AnthroTronix
Human Inspired. Technology Driven.

DARPA

W31P4Q-13-C-0136
W31P4Q-12-C-0216

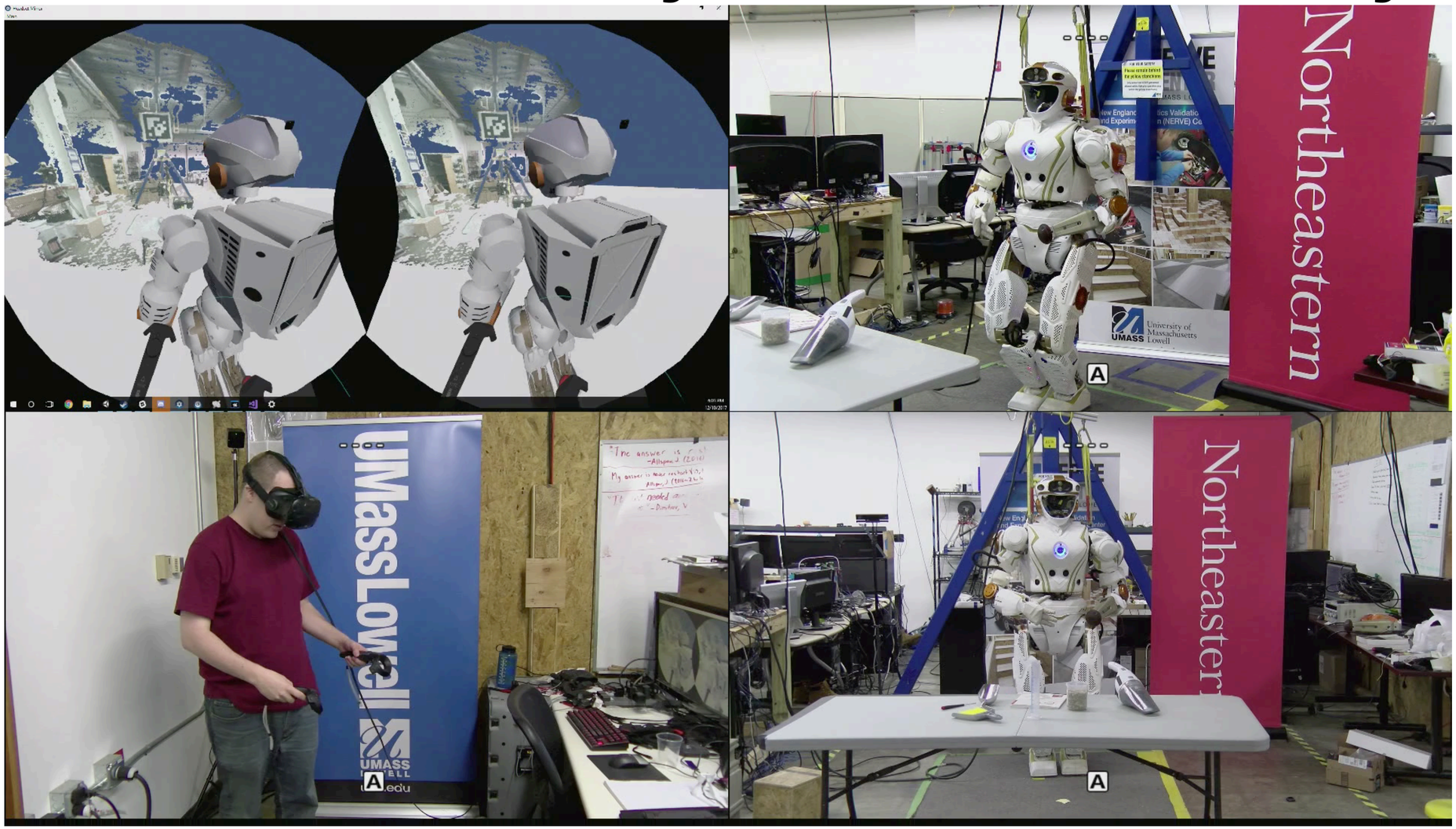
A. Norton, W. Ober, L. Baraniecki, E. McCann, J. Scholtz, D. Shane, A. Skinner, R. Watson, and H. Yanco. “Analysis of Human-Robot Interaction at the DARPA Robotics Challenge Finals.” *International Journal of Robotics Research*, 36(5-7): 483-513, June 2017.

H.A. Yanco, A. Norton, W. Ober, D. Shane, A. Skinner, and J. Vice. “Analysis of Human-Robot Interaction at the DARPA Robotics Challenge Trials.” *Journal of Field Robotics*, 32(3): 420-444, May 2015.

New Control Strategies for Humanoid Robots: Contact with Objects and VR

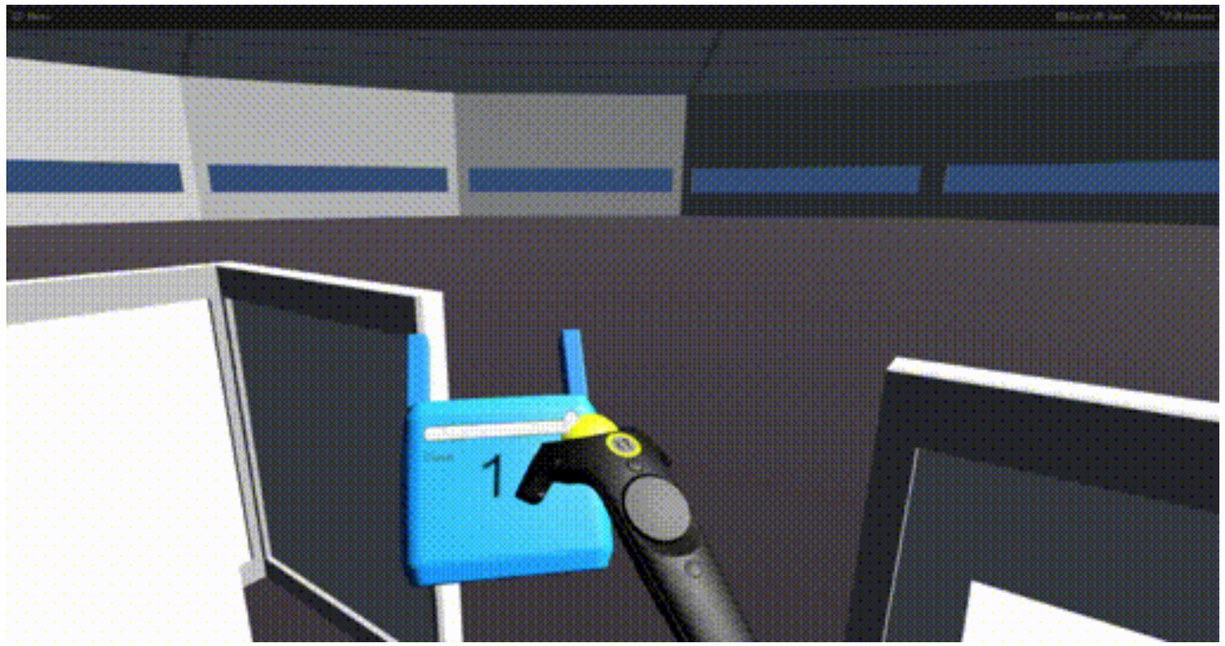
NASA NNX16AC48A, IIS-1451427,
DE-EM0004482 through NRI, IIS-1944584

Valkyrie: Virtual Reality

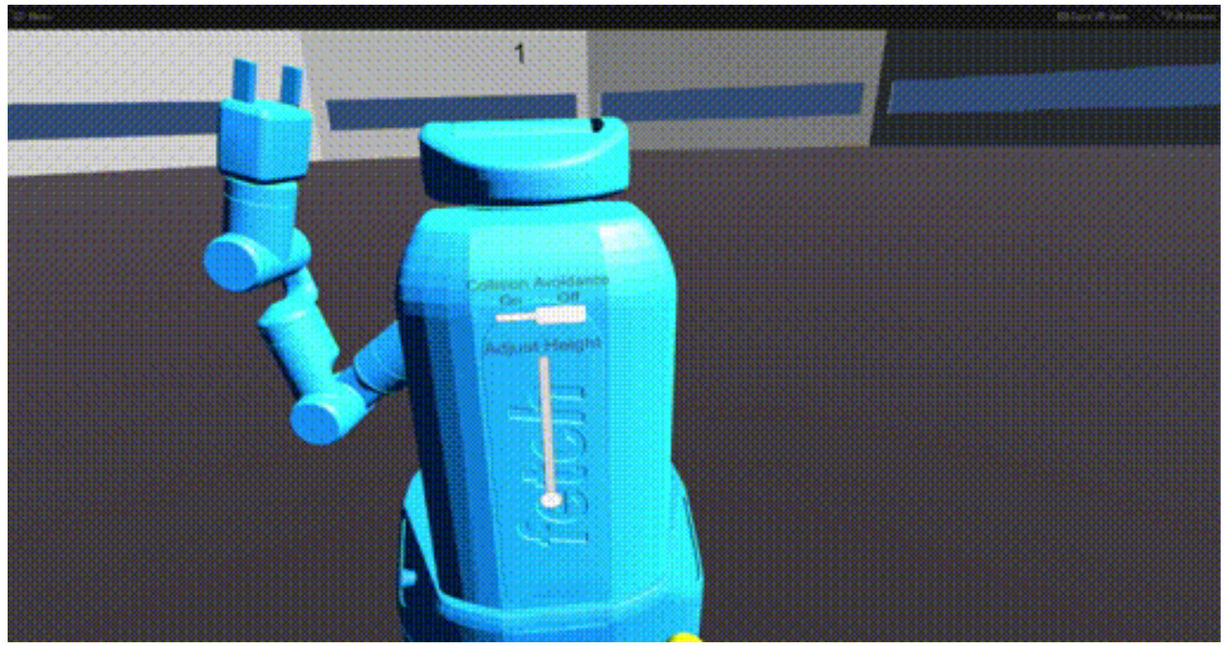


Jordan Allspaw, Gregory LeMasurier, and Holly Yanco. “Implementing Virtual Reality for Teleoperation of a Humanoid Robot.” ACM/IEEE HRI 2020 Workshop on Virtual, Augmented, and Mixed Reality for Human-Robot Interactions (VAM-HRI), March 2020.

Functional Waypoints for VR

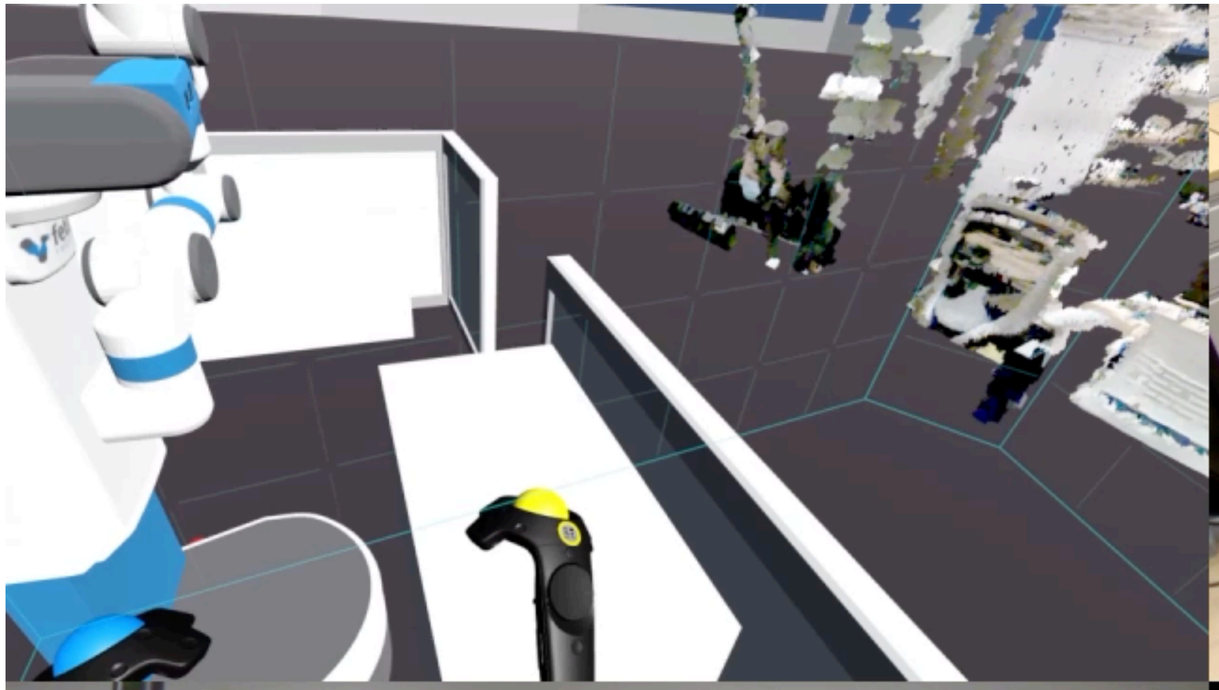


Manipulation



Navigation

Gregory LeMasurier, Jordan Allspaw, and Holly A. Yanco. “Semi-Autonomous Planning and Visualization in Virtual Reality.” ACM/IEEE HRI 2021 Workshop on Virtual, Augmented, and Mixed Reality for Human-Robot Interactions (VAM-HRI), March 2021.



Motion Planning in Virtual Reality

UMass Lowell Human-Robot Interaction Lab
robotics.cs.uml.edu

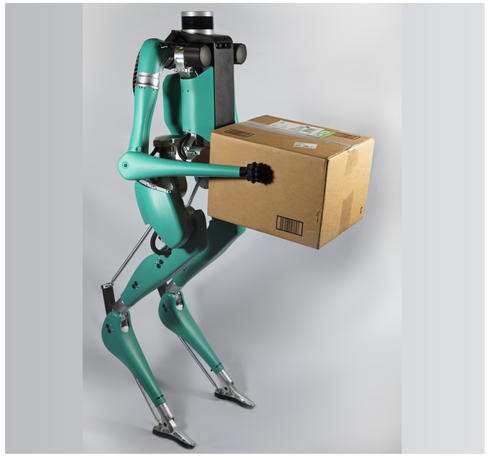
University of Massachusetts Lowell
www.uml.edu

University of Massachusetts Lowell

New England Robotics Validation and Experimentation (NERVE) Center

Exoskeletons and Wearable Robots

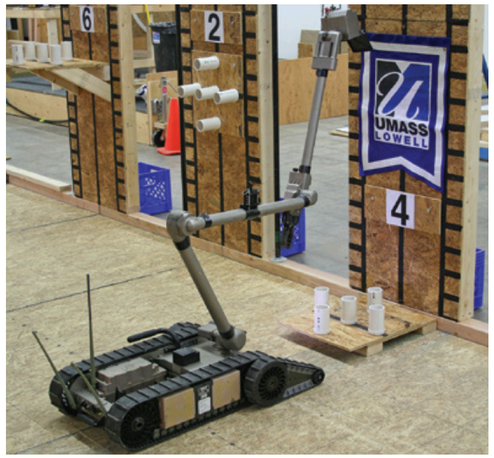
Human Performance



Legged Locomotion

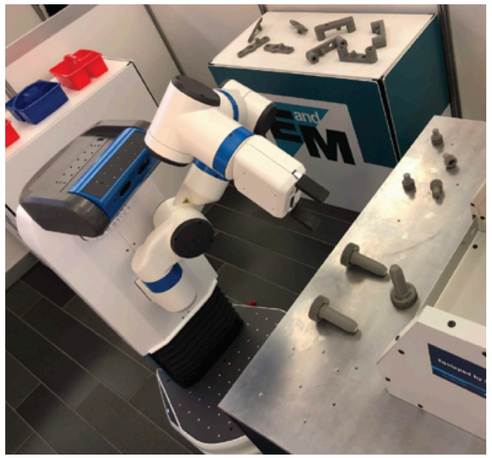
Human-Robot Teaming

Unmanned Aerial Systems



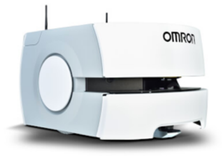
Unmanned Ground Vehicles

Industrial Mobile Robots



Grasping and Manipulation

ARMada Manipulation and Automation Testbed



Omron LD90

ABB YuMi

Agility Robotics Digit

Fetch Mobile Manipulator

Kinova Gen3

Kinova JACO²

KUKA LBR iiwa

Rethink Robotics Sawyer

Universal Robots UR5e

Yaskawa Motoman GP7

Omron TM700

OnRobot RG2-FT

Rethink Robotics Vacuum Gripper

RightHand Robotics ReFlex TakkTile 2

Robotiq Epick

Robotiq 2-Finger Adaptive Gripper

Robotiq 3-Finger Adaptive Gripper

SAKE EZGripper Gen2

Schunk 2-Finger Grippers

Schunk 3-Finger Grippers

Soft Robotics Gripper

Vaccon Vacuum Grippers

Wonik Robotics Allegro Hand

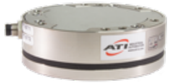
Cognex Camera

Asus Xtion Pro

Intel RealSense

OptiTrack V120:Trio

OptiTrack Prime 17w



ATI 6-axis F/T Sensor

Robotiq F/T Sensor

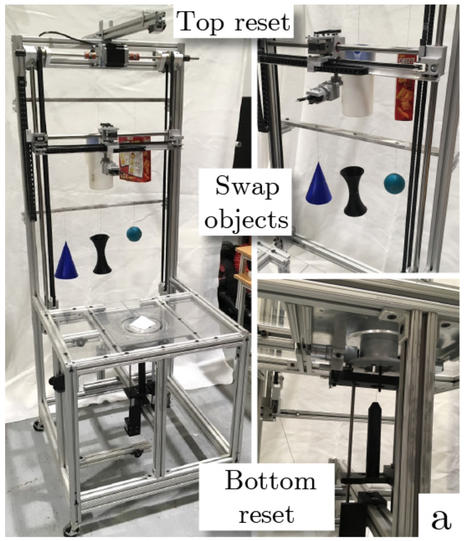
OptoForce OMD-20-SE-40N

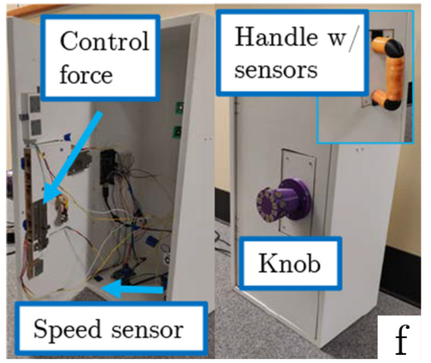
Fusion3 F410

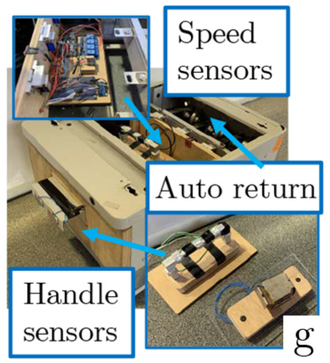
Computer Stations

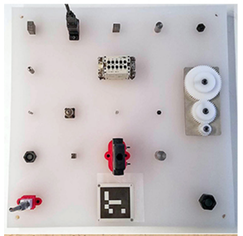
Remote Experimentation of Manipulation for Online Test and Evaluation (REMOTE) Testbed

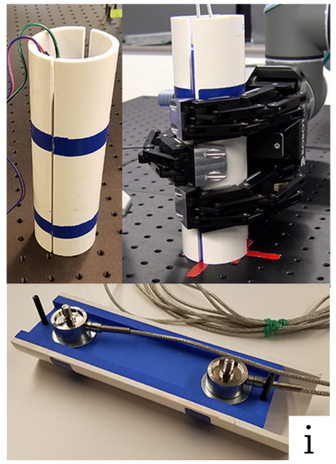
Oregon State University











- Infrastructure to support remote experimentation of robotic manipulation and benchmarking
- Set of arms and grippers available and a set of test stations for performing repeatable, measurable tasks
- All test stations sensorized for ground truth measurements and high-fidelity playback of activities

NSF

CNS-1925604

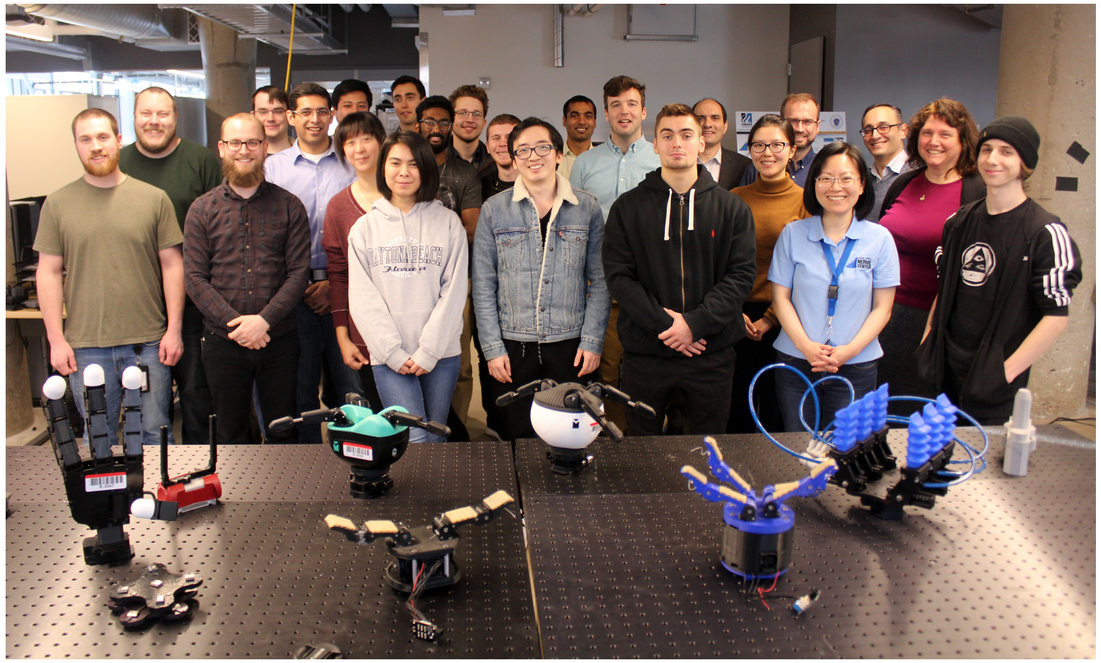
HRI = Robotics

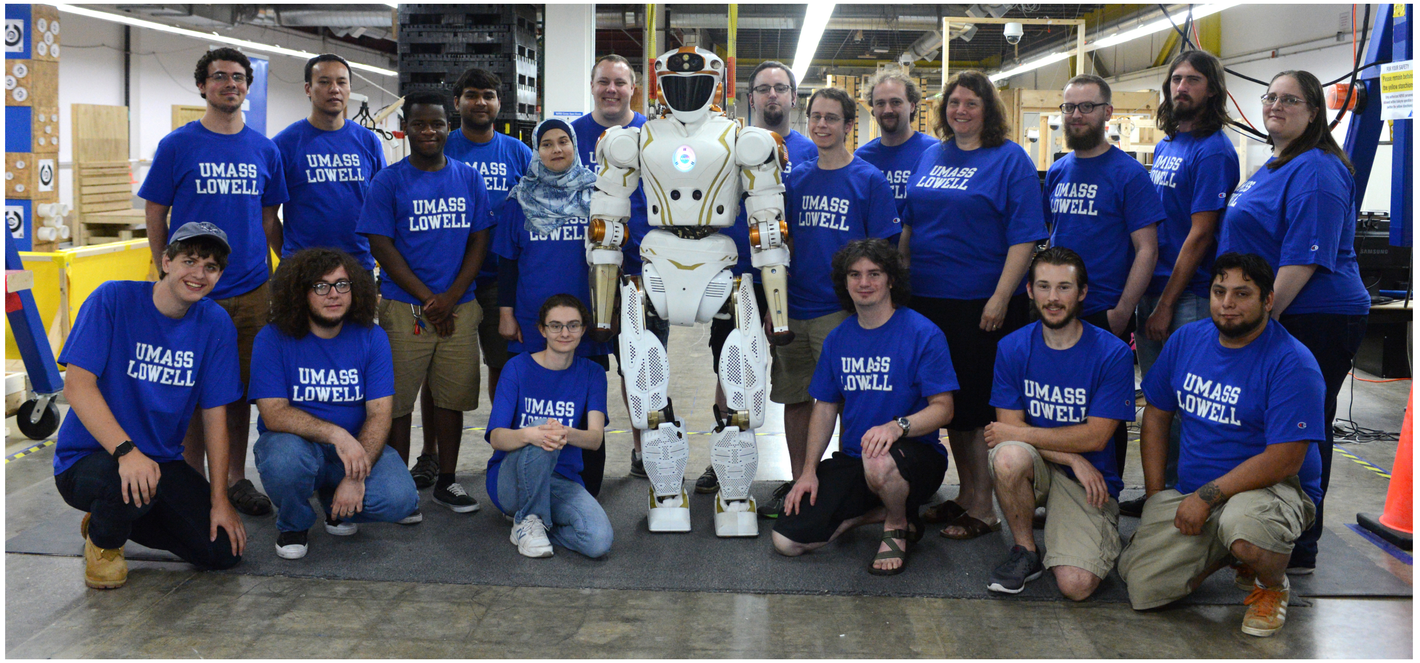
HRI = Robotics - ε

Some Open Questions in HRI

- How will HRI change as systems become more capable/autonomous? Will HRI designs always need to adapt, or is there a steady-state that we could achieve?
- How do we account for people's experience with other robots and technology when designing systems?
- Can we develop robot systems that can vouch for the capabilities of other robots or people in order to improve teaming?
- Can we use results from prior human subjects studies over many application domains to develop methods to evaluate HRI designs computationally?

Collaborators





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holly@cs.uml.edu