AMERICAN UNIVERSITY OF BEIRUT

MAROUN SEMAAN FACULTY OF ENGINEERING & ARCHITECTURE

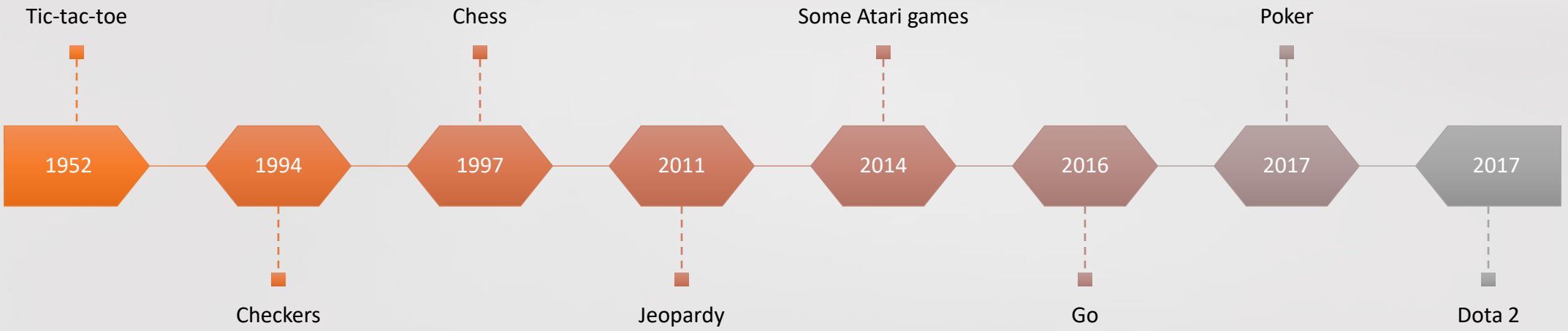
VISION & ROBOTICS LAB

EMBODIED AI EMBEDDED WITH HUMANS

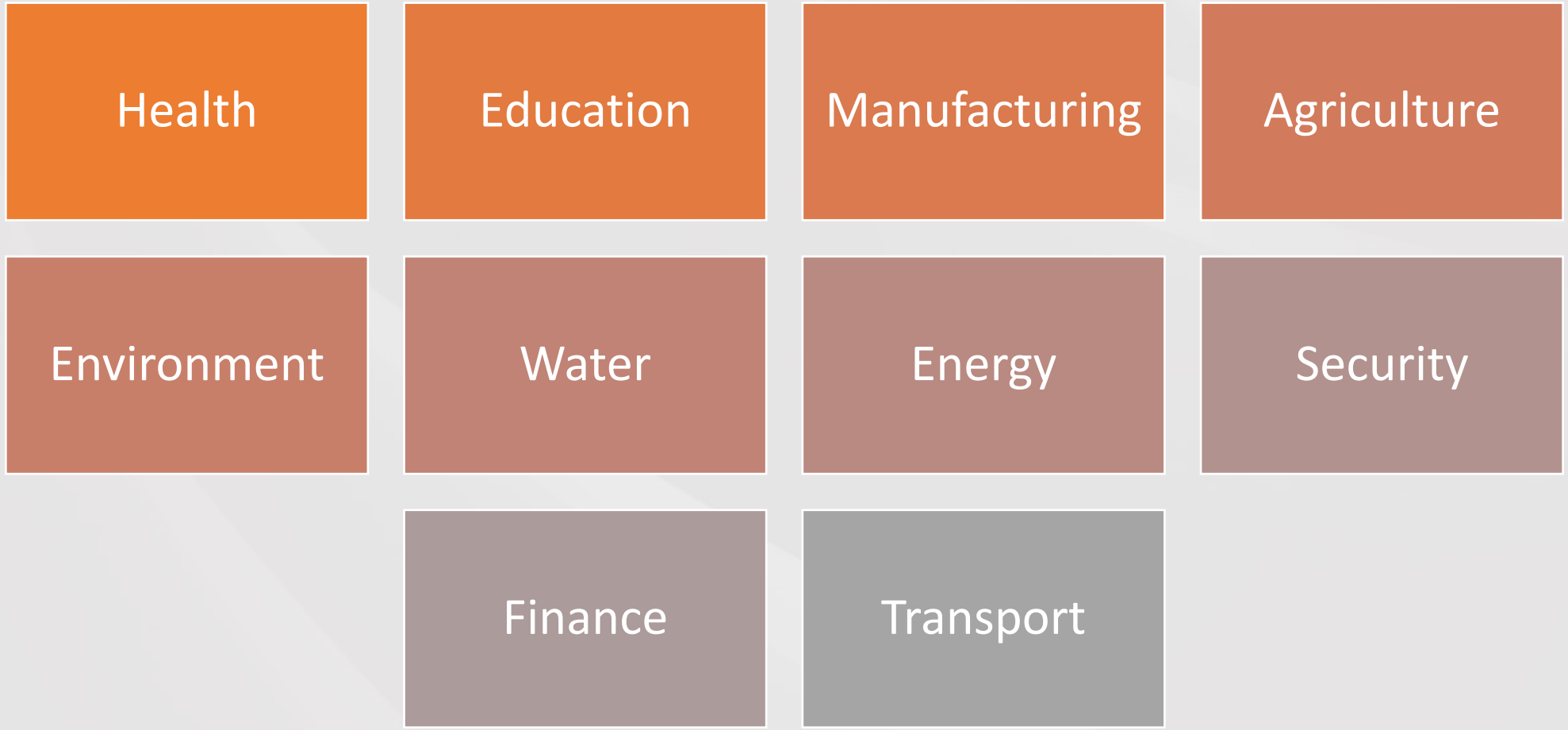
ITU WORKSHOP ON "EMBODIED AI AND MULTIMEDIA TECHNOLOGY STANDARDS"

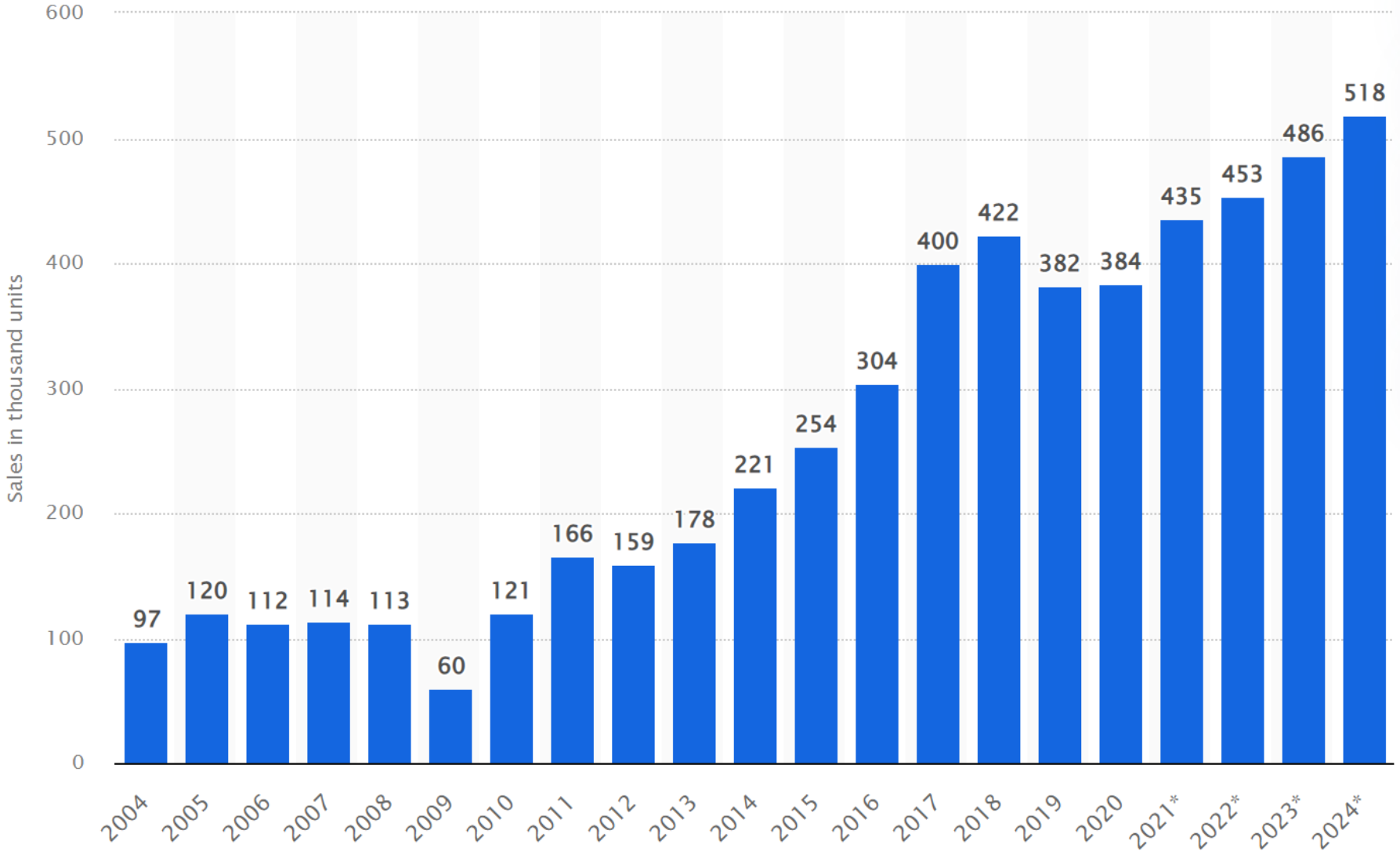
Imad H. Elhajj
Professor & Associate Dean
Maroun Semaan Faculty of Engineering
and Architecture

AI beating humans!



Scope


Health
Education
Manufacturing
Agriculture
Environment
Water
Energy
Security
Finance
Transport



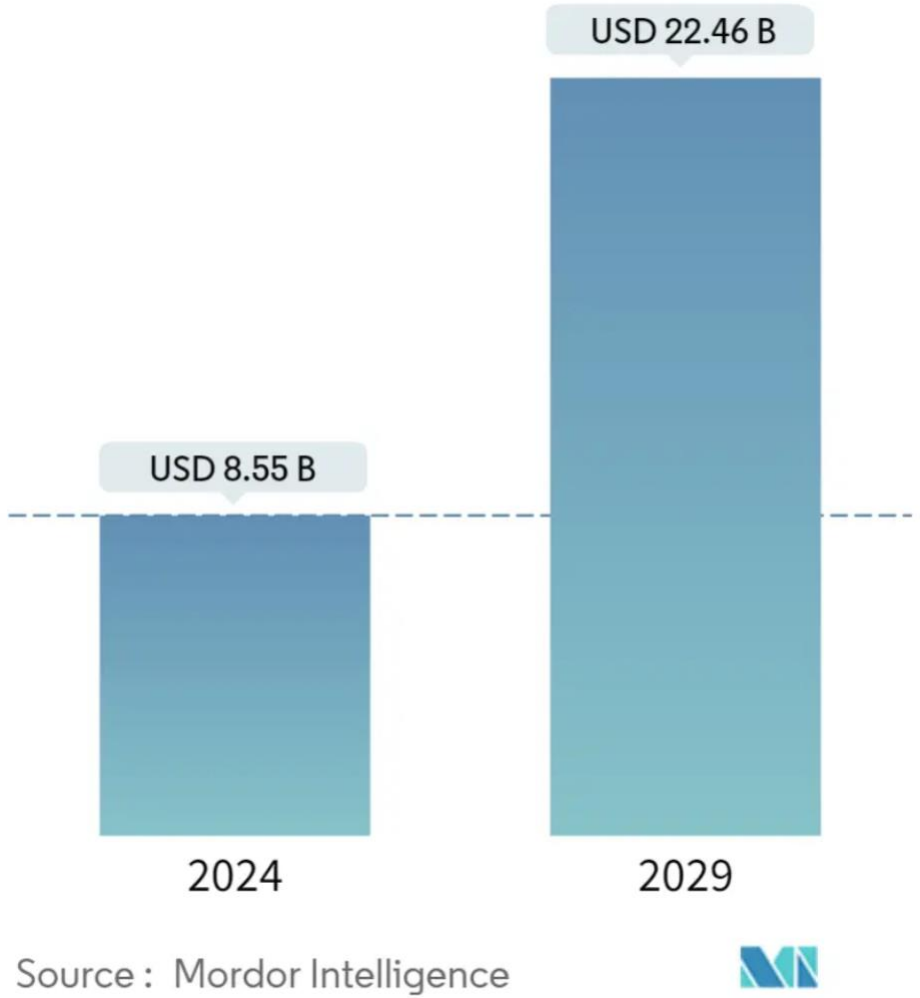
Worldwide installations of industrial robots

https://www.statista.com/statistics/264084/worldwide-sales-of-industrial-robots/

Details: Worldwide; IFR; 2004 to 2020

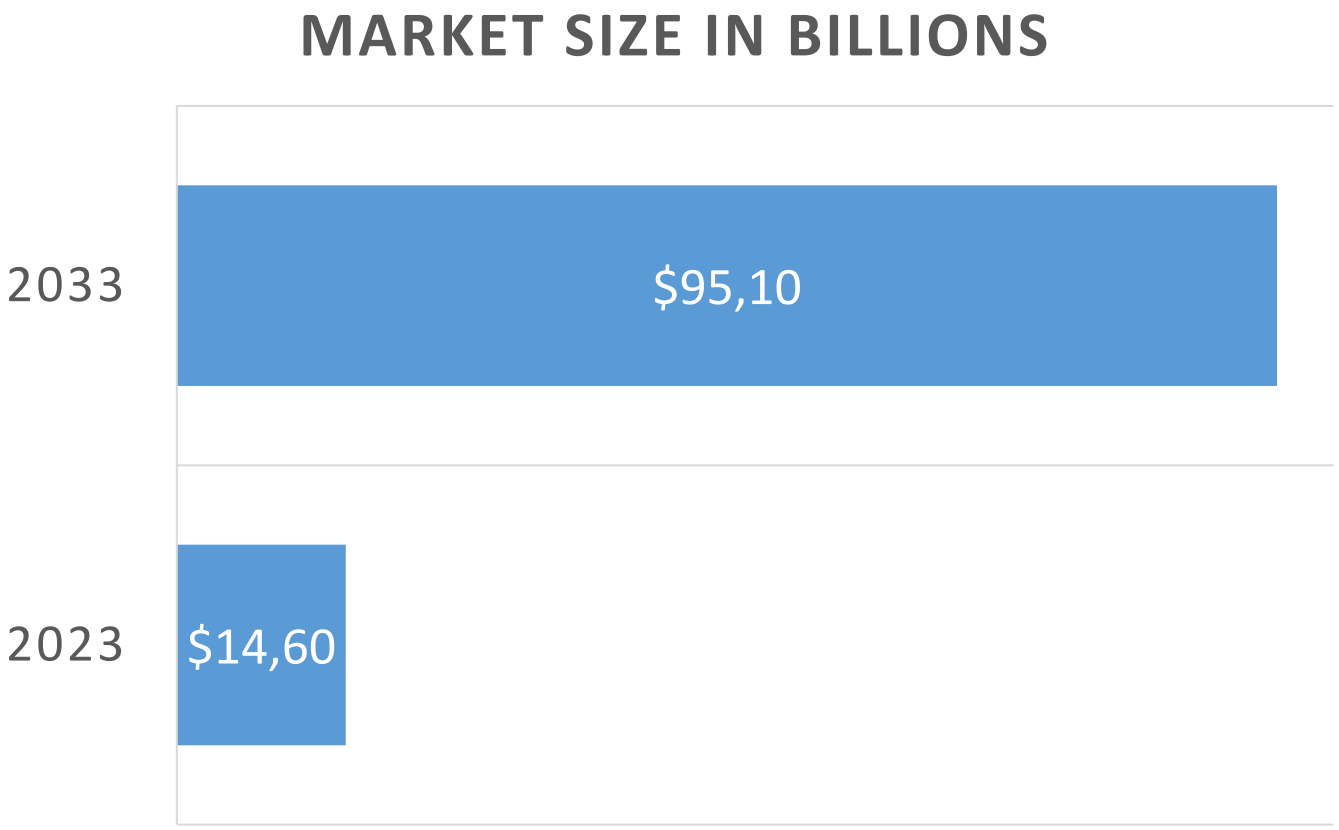
Why do we care?

Household Robots Market Size



Source: https://www.mordorintelligence.com/industry-reports/household-robots-market

Household Robots Market Size

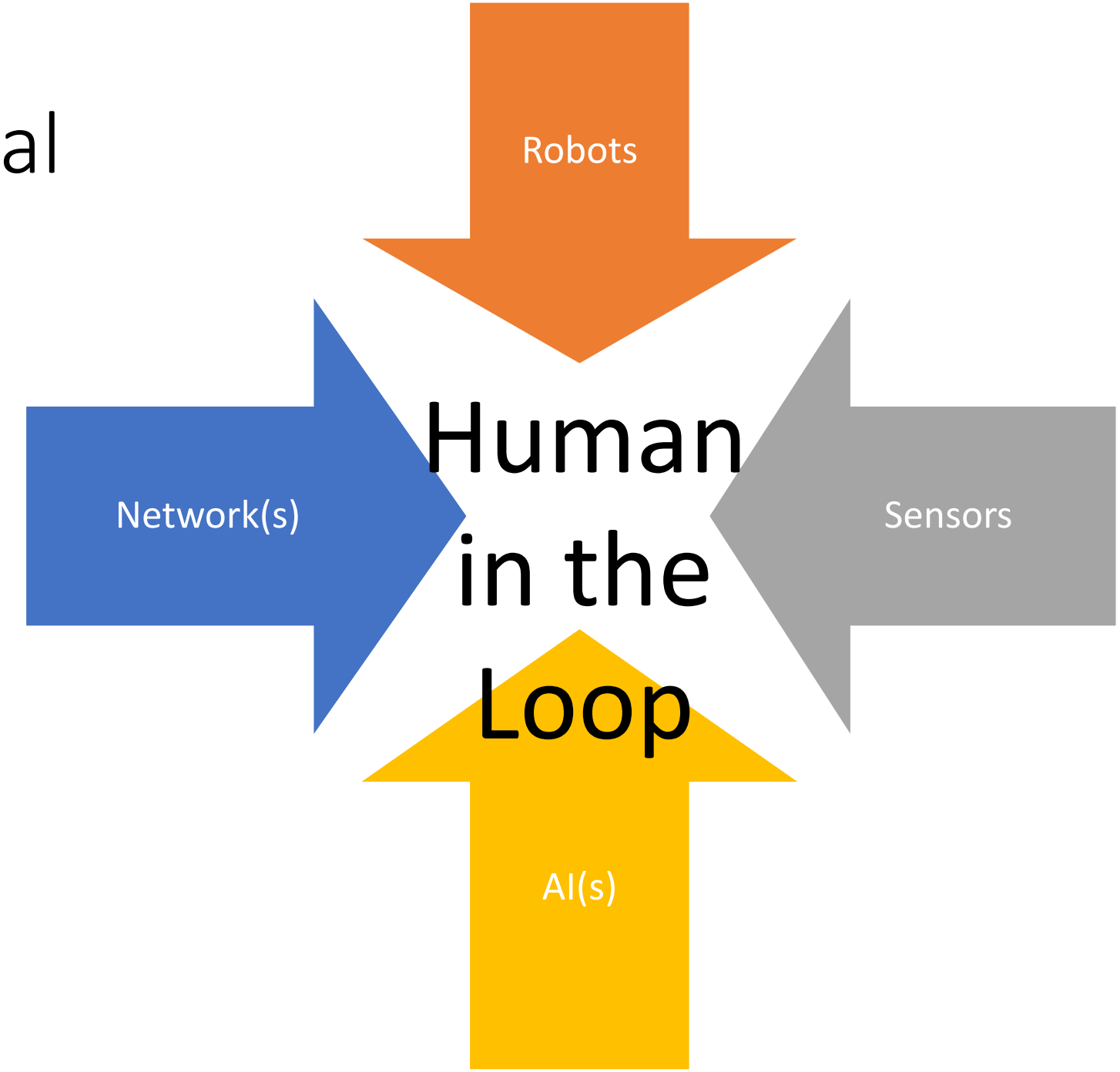


Source: https://www.factmr.com/report/household-robot-market

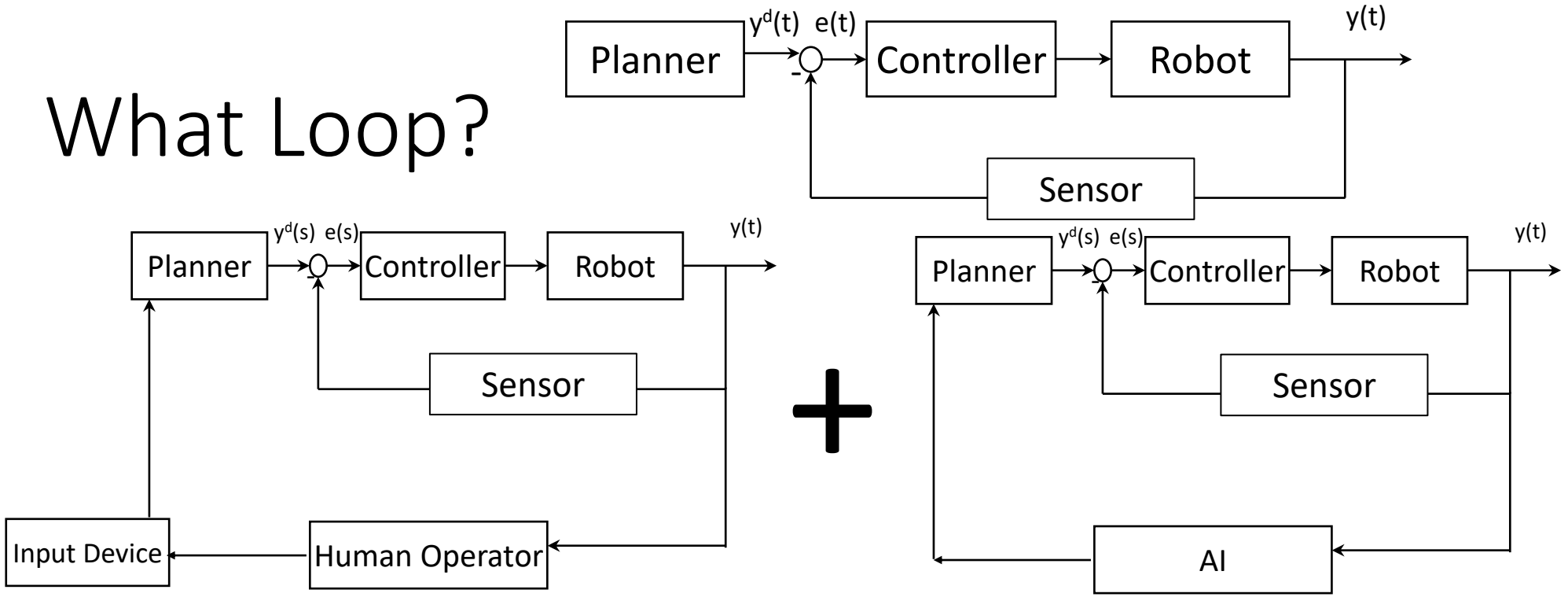
So?

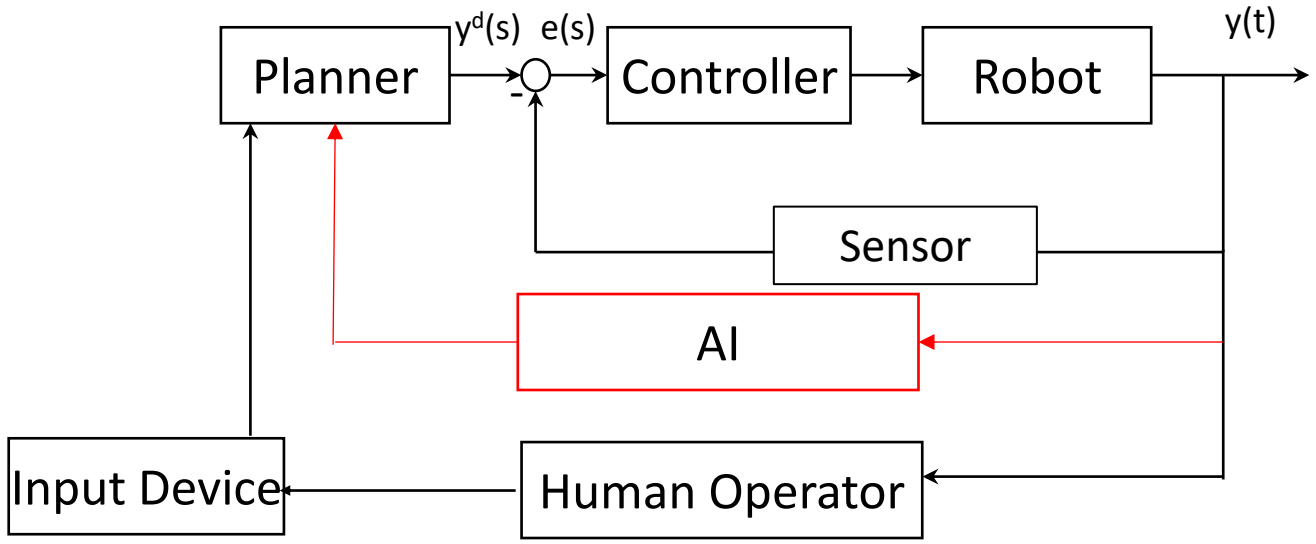
- Robots along side humans
- Trust
- Liabilities
- Mitigate technical failures & bias
- Unstructured environment
- Need high level intelligence
- “Supervised” learning

Proposal



What Loop?


Planner
$y^d(t)$ e(t)
Controller
Robot
y(t)
Sensor
Planner
$y^d(s)$ e(s)
Controller
Robot
y(t)
Sensor
Input Device
Human Operator
Planner
$y^d(s)$ e(s)
Controller
Robot
y(t)
Sensor
AI


Planner
$y^d(s)$ e(s)
Controller
Robot
y(t)
Sensor
AI
Input Device
Human Operator


Opportunities

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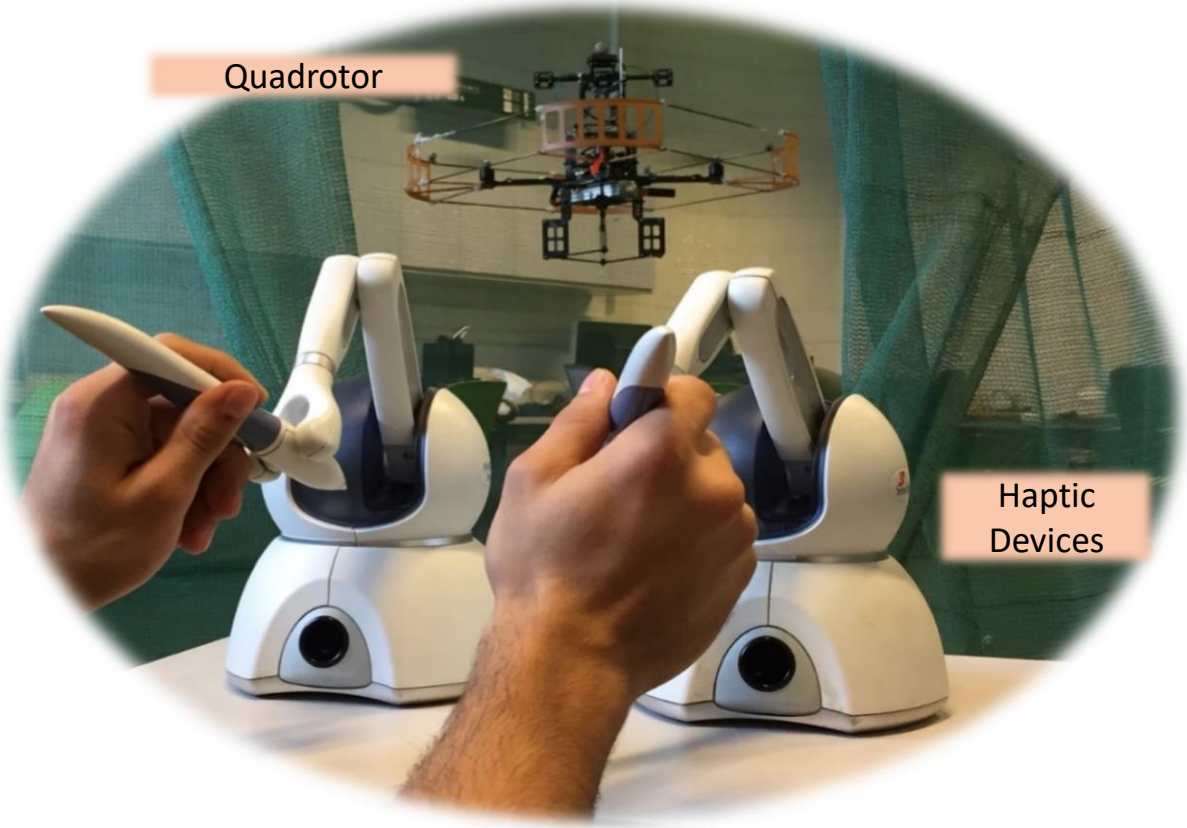
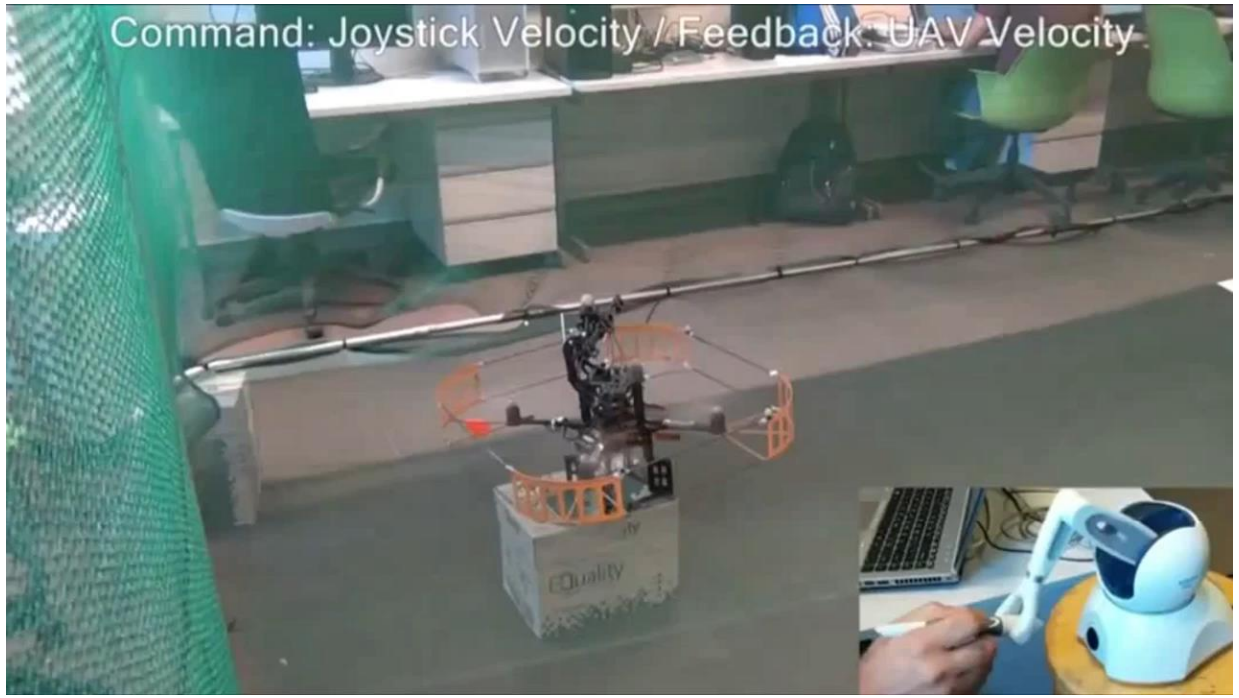
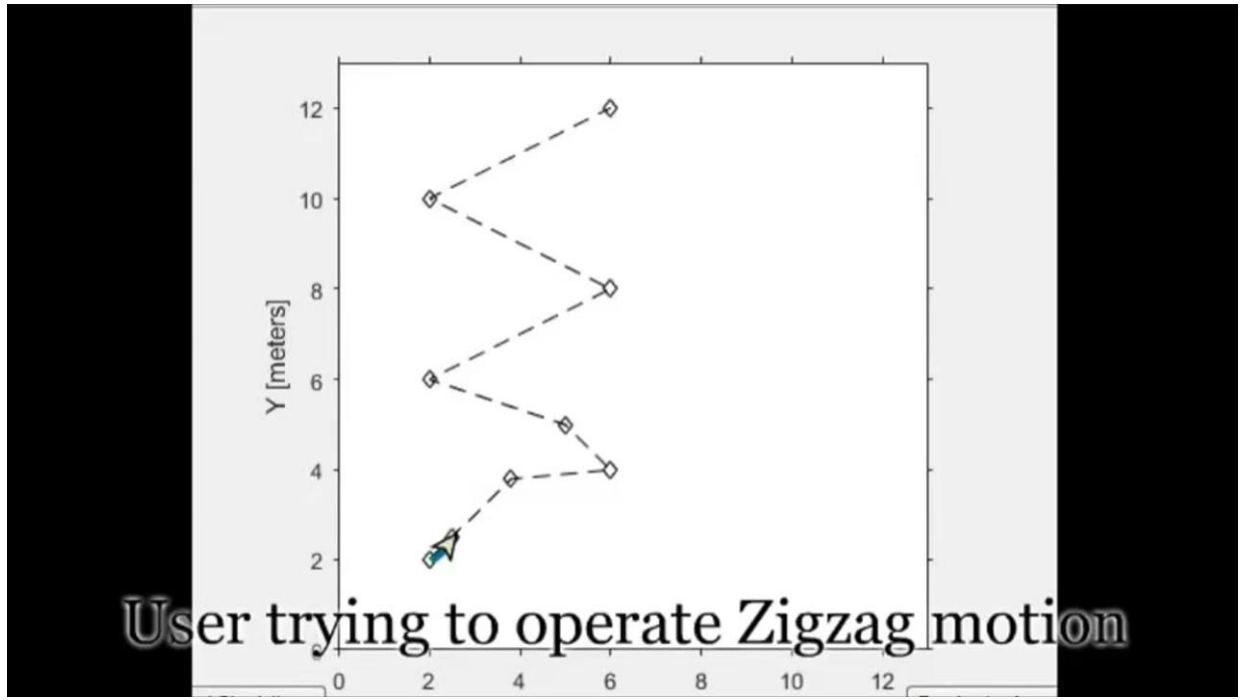
Intent Recognition for Teleoperation

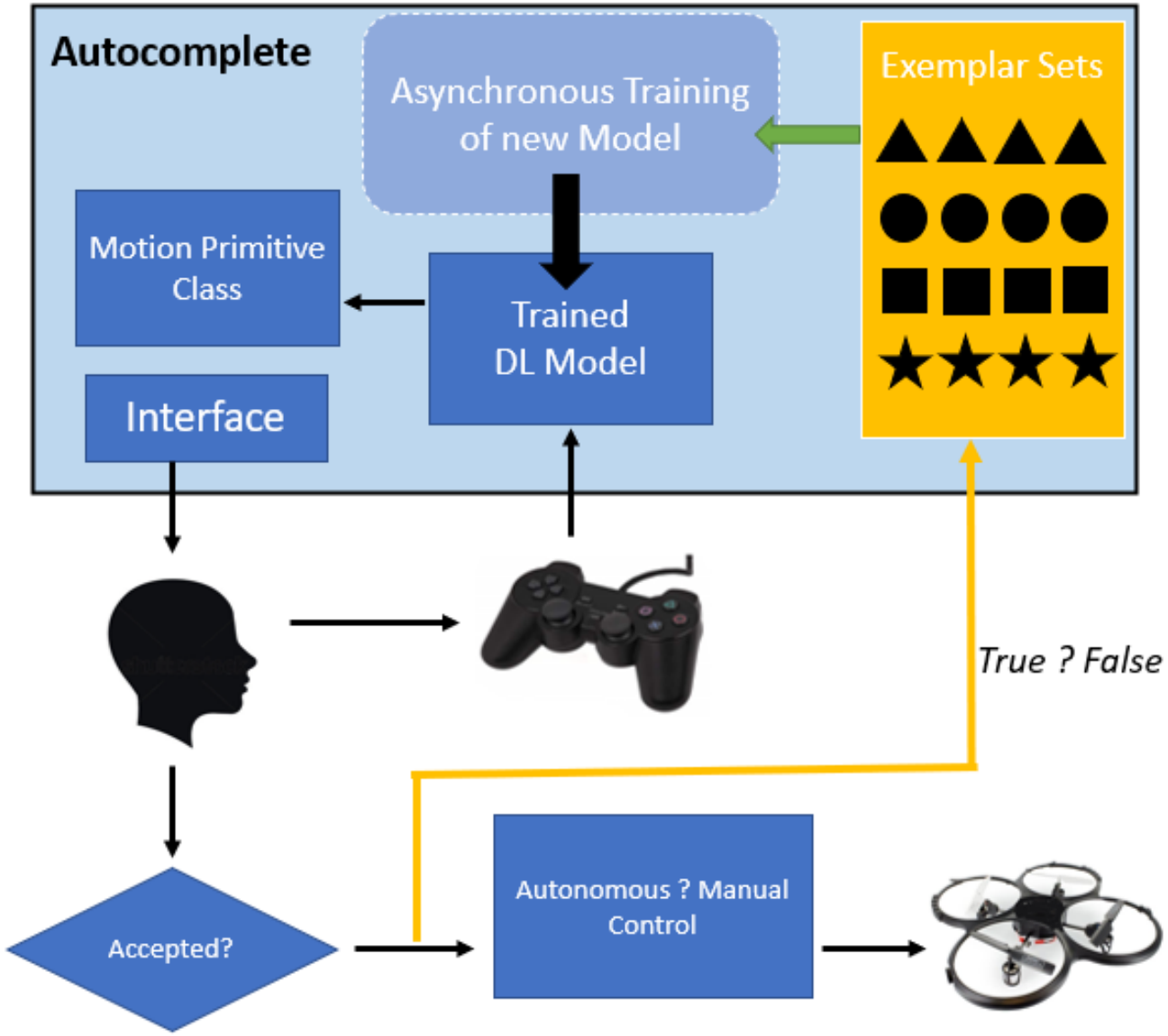
Mohammad Kassem Zein, Serge Moughabghab, Mohammad Haj Hussein, Batool Ibrahim, and Dr. Daniel Asmar

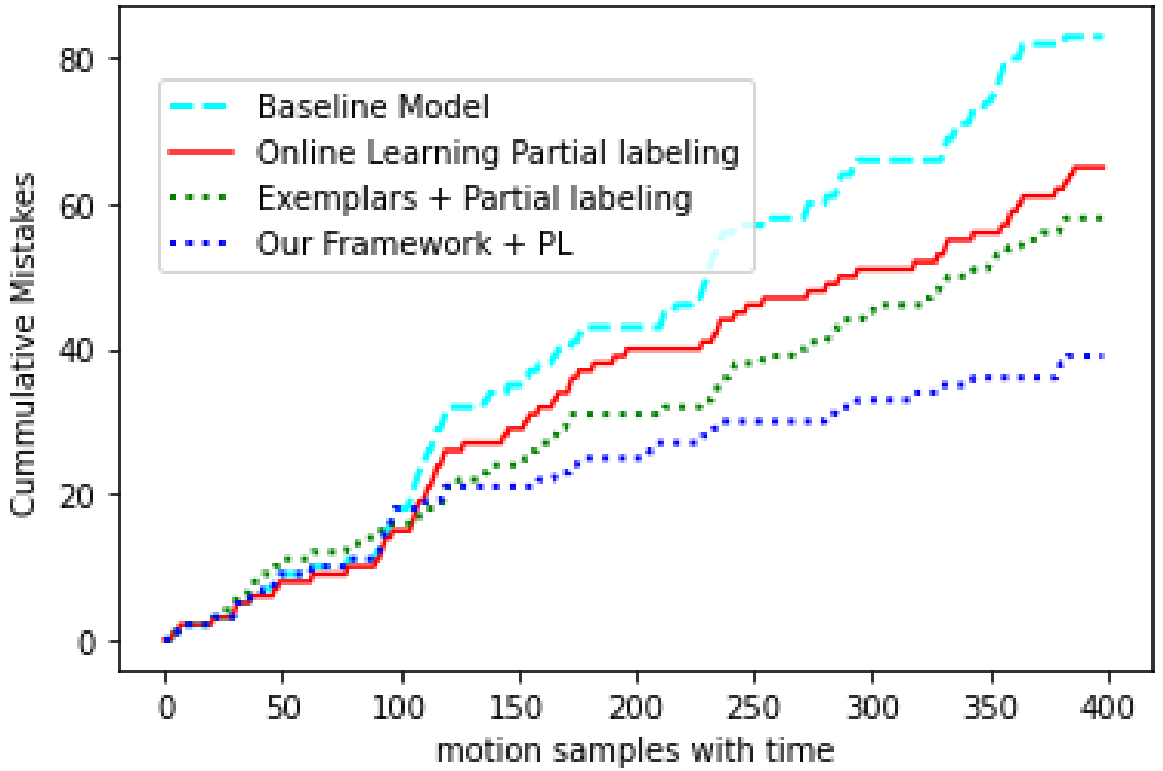






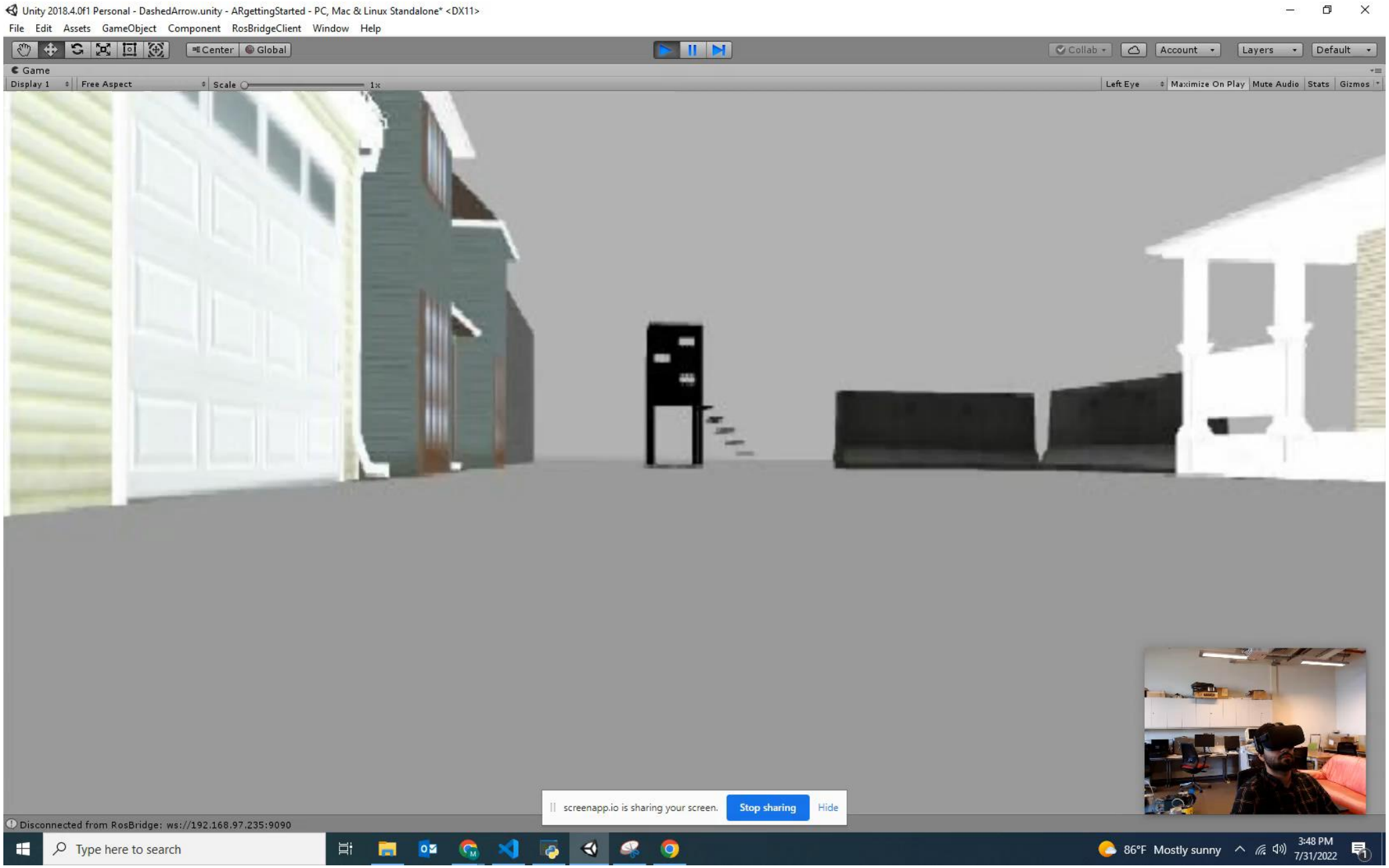
Serge Mghabghab, Imad H. Elhajj, Daniel Asmar, “Adaptive Gain Tuning for Teleoperation of Quadrotors,” IEEE International Multidisciplinary Conference on Engineering Technology, Beirut, Lebanon, 2-4 November 2016.

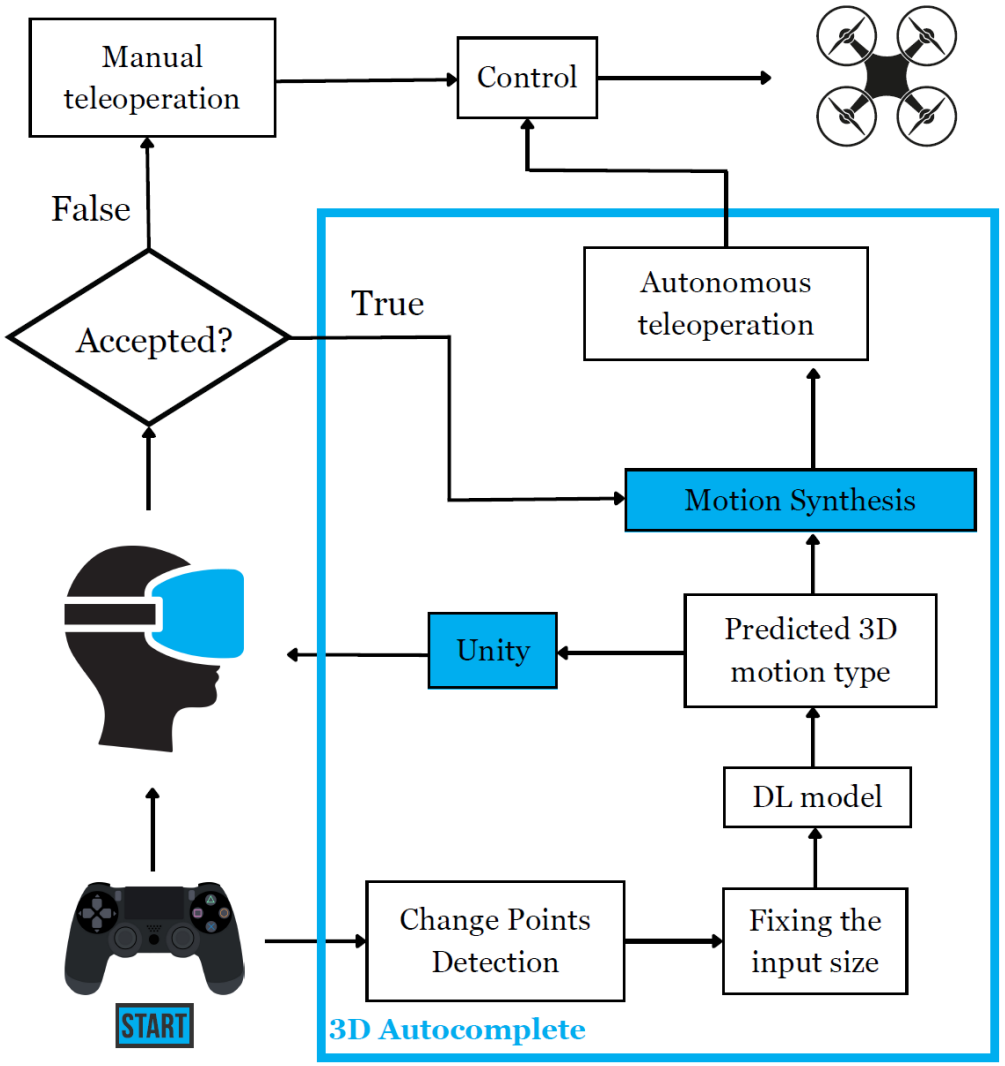


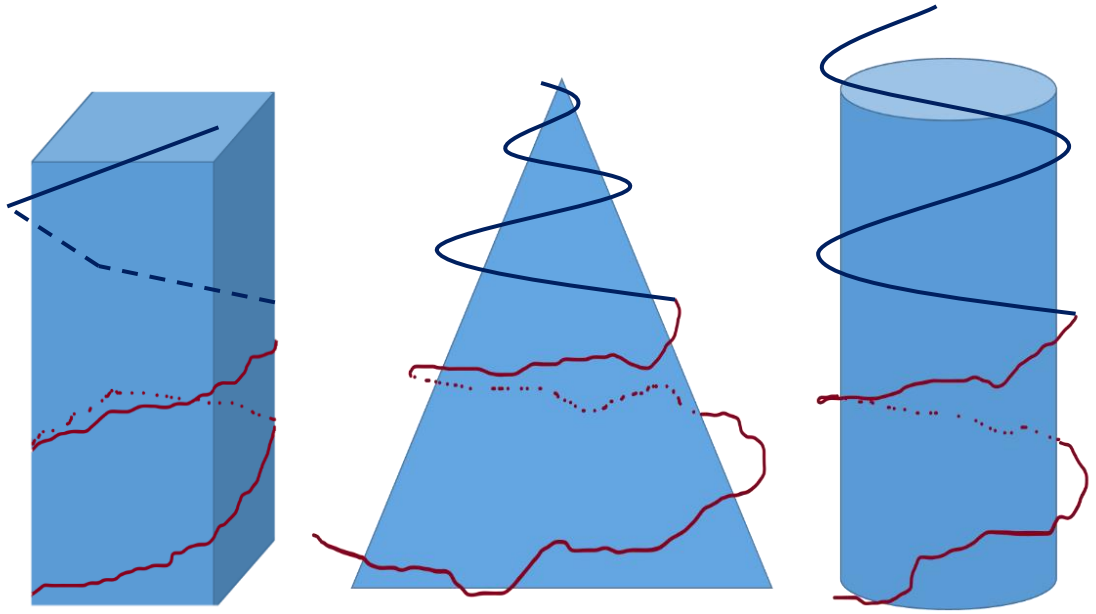


Mohammad Haj Hussein, Imad Elhajj and Daniel Asmar, “Personalized Autocomplete Teleoperation: Real-Time User Adaptation using Transfer Learning with Partial Feedback,” IEEE International Conference on CYBER Technology in Automation, Control, and Intelligent Systems, Jiaxing, China, July 27-31, 2021.

Mohammad Kassem Zein, Majd Al Aawar, Daniel Asmar and Imad Elhajj, “Deep Learning and Mixed Reality to Autocomplete Teleoperation,” IEEE International Conference on Robotics and Automation (ICRA), Xi'an, China, May 30 - June 5, 2021.


Unity 2018.4.0f1 Personal - DashedArrow.unity - ARgettingStarted - PC, Mac & Linux Standalone* <DX11>
File Edit Assets GameObject Component RosBridgeClient Window Help
Center Global
Collab Account Layers Default
Game
Display 1 Free Aspect Scale 1x
Left Eye Maximize On Play Mute Audio Stats Gizmos
screenapp.io is sharing your screen. Stop sharing Hide
Disconnected from RosBridge: ws://192.168.97.235:9090
Type here to search
86°F Mostly sunny
3:48 PM
7/31/2022

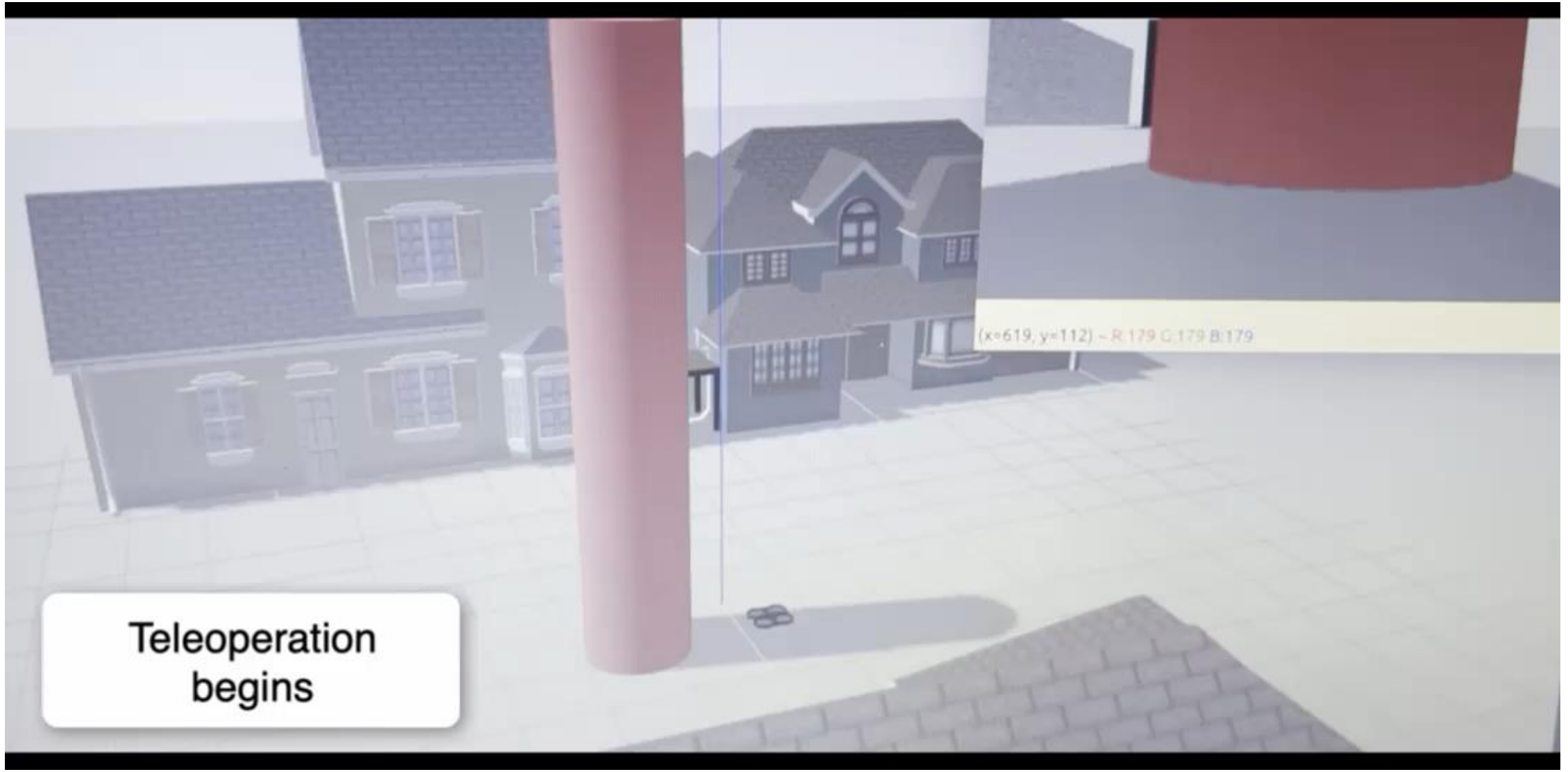




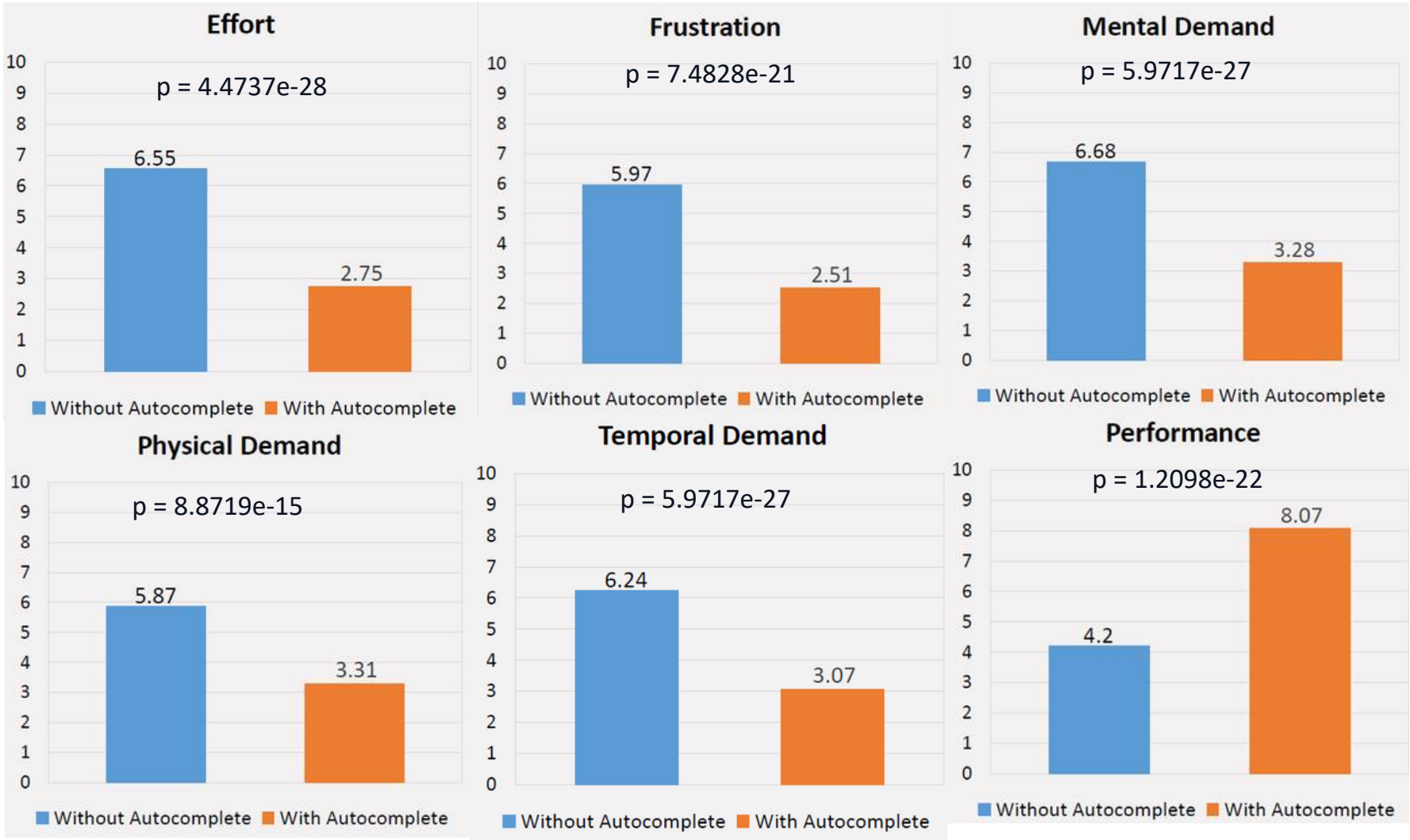
Batool Ibrahim, Mohammad Haj Hussein, Imad H. Elhajj, Daniel Asmar, "Autocomplete of 3D Motions for UAV Teleoperation," IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Detroit, Michigan, USA, October 1-5, 2023.

Batool Ibrahim, Imad H. Elhajj, Daniel Asmar, "3D Autocomplete: Enhancing UAV Teleoperation with AI in the Loop," IEEE International Conference on Robotics and Automation (ICRA), Yokohama, Japan, May 13-17, 2024.

Sample run:



Qualitative Results



Quantitative Results

	Average time (s)		Average distance (m)		Average smoothness (rad)	
	Manual	**Auto**	Manual	**Auto**	Manual	**Auto**
Cylinders 	39.1	**25.1**	29.6	**20.7**	6450	**3134**
Cones 	36.6	**23.9**	30.6	**20.6**	5010	**2920**
Boxes 	36.7	**22.5**	27.4	**16.5**	6137	**3126**

35% less time to complete a task

30% reduction in distance travelled

50% improvement in trajectory smoothness

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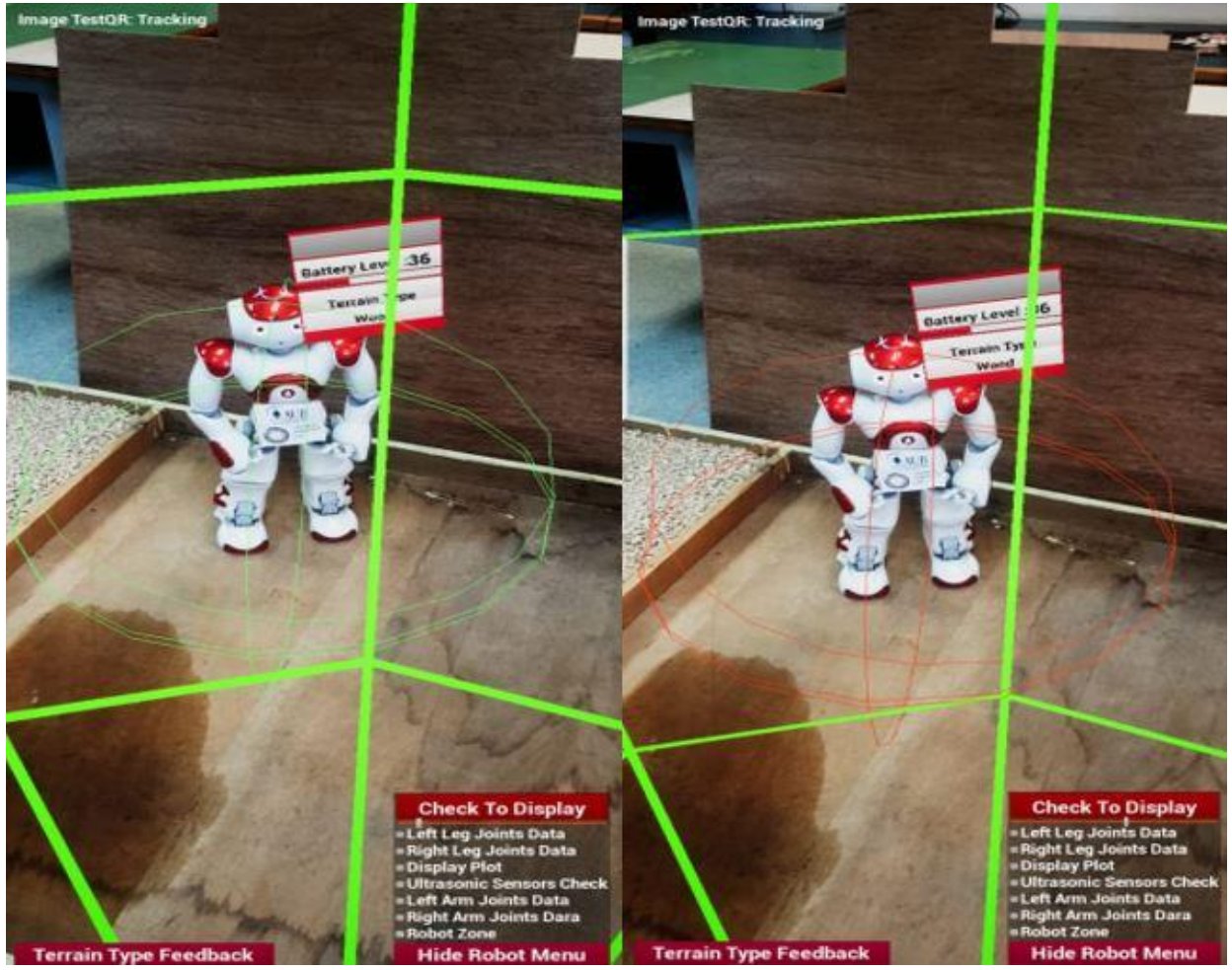
Human-Aided Online Terrain Classification for Bipedal Robots Using AR

Zahraa Awad, Celine Chibani, and Dr. Noel Maalouf



Zahraa Awad, Celine Chibani, Noel Maalouf, Imad Elhajj, "Human-Aided Online Terrain Classification for Bipedal Robots Using Augmented Reality," IEEE International Conference on Robotics and Biomimetics (ROBIO), Xishuangbanna, China, December 5-9, 2022.

Human Aided Digital Twins

Dr. Daniel Asmar

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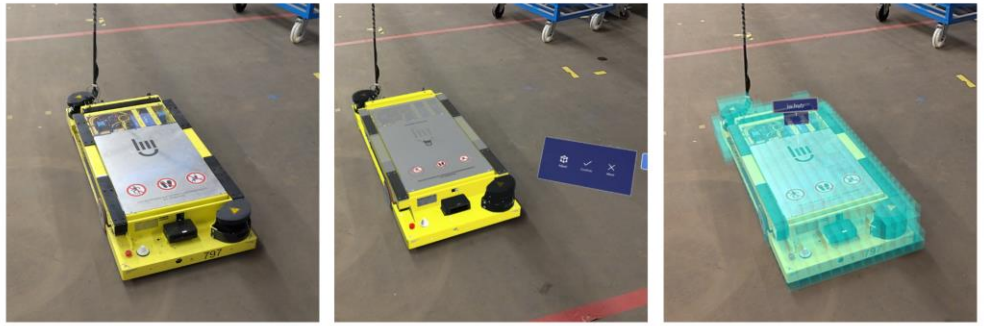
Karim Yassine, Malak Sayour, Adam Manasfi, Maya Hachach, Nadim Dib, Imad Elhajj, Elie Khoury, Boulos Asmar, Daniel Asmar, “Human-Robot Collaborative SLAM-XR,” IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Hangzhou, China, 19 – 25 October, 2025.

Malak Sayour, Mohammad Karim Yassine, Nadim Dib, Imad H. Elhajj, Boulos Asmar, Elie Khoury, Daniel Asmar “HAC-SLAM: Human Assisted Collaborative 3D-SLAM Through Augmented Reality,” IEEE International Conference on Robotics and Automation (ICRA), Yokohama, Japan, May 13-17, 2024

Abbas Sidaoui, Imad H. Elhajj, Daniel Asmar, “Collaborative Human Augmented Mapping,” IEEE/RSJ International Conference on Intelligent Robots and Systems, Macau, China, November 4-8, 2019.

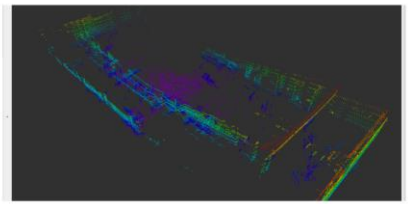
XR Agent and Human-in-the-Loop Features

- Voxel grid mapping
- Automatic labeler (6D pose)
- Agent localization
- Path visualization and editing
- Asset Injection

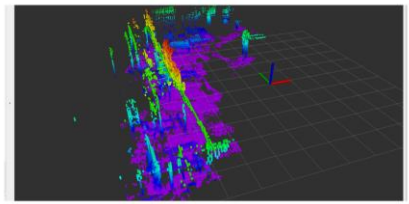


Automatic labeling of a robot

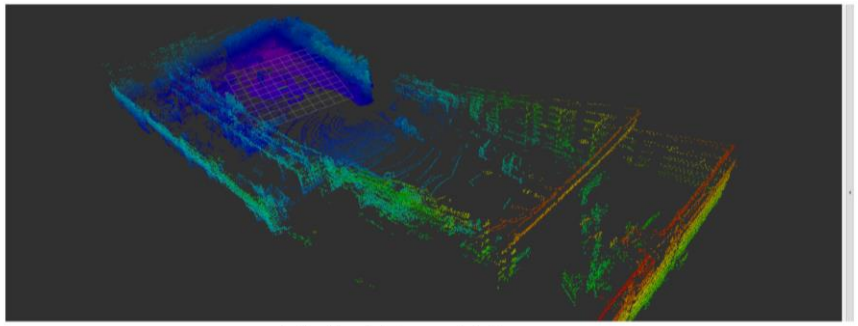
Path visualization



Robot 1 Map - LIDAR



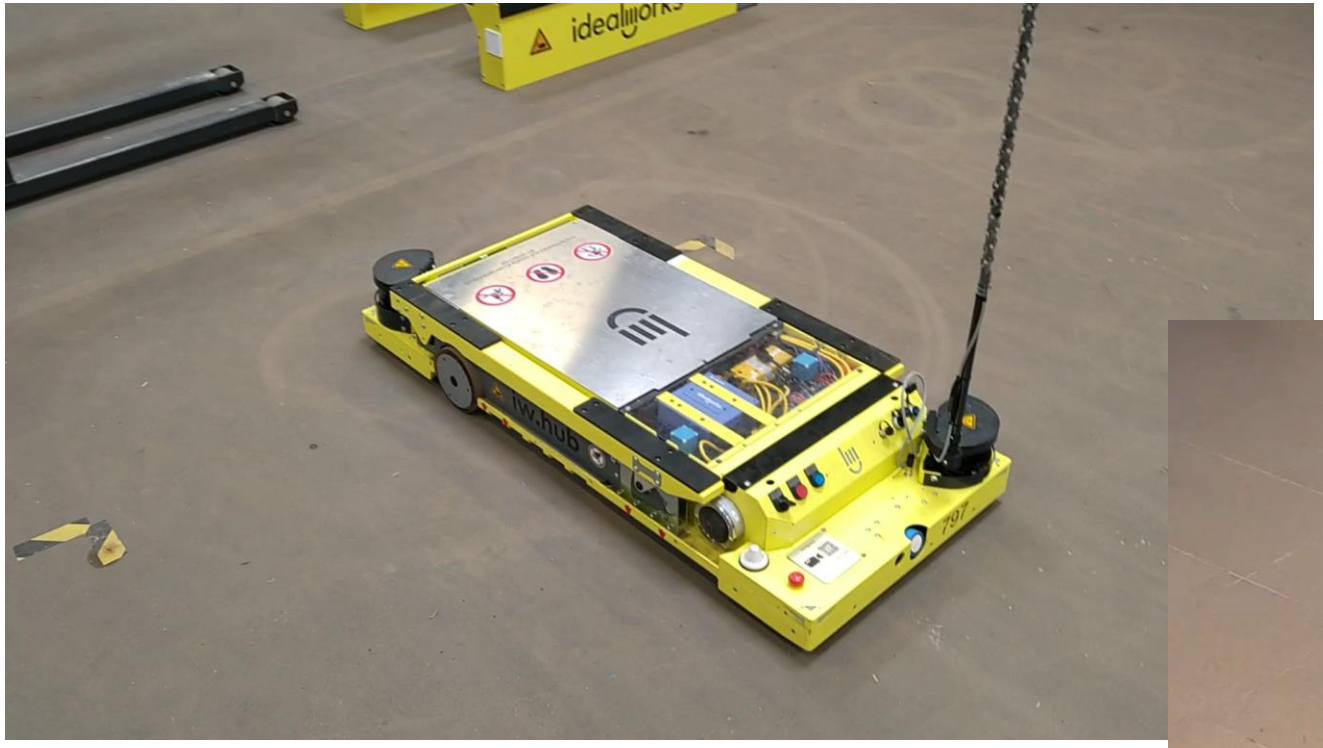
Hololens Map

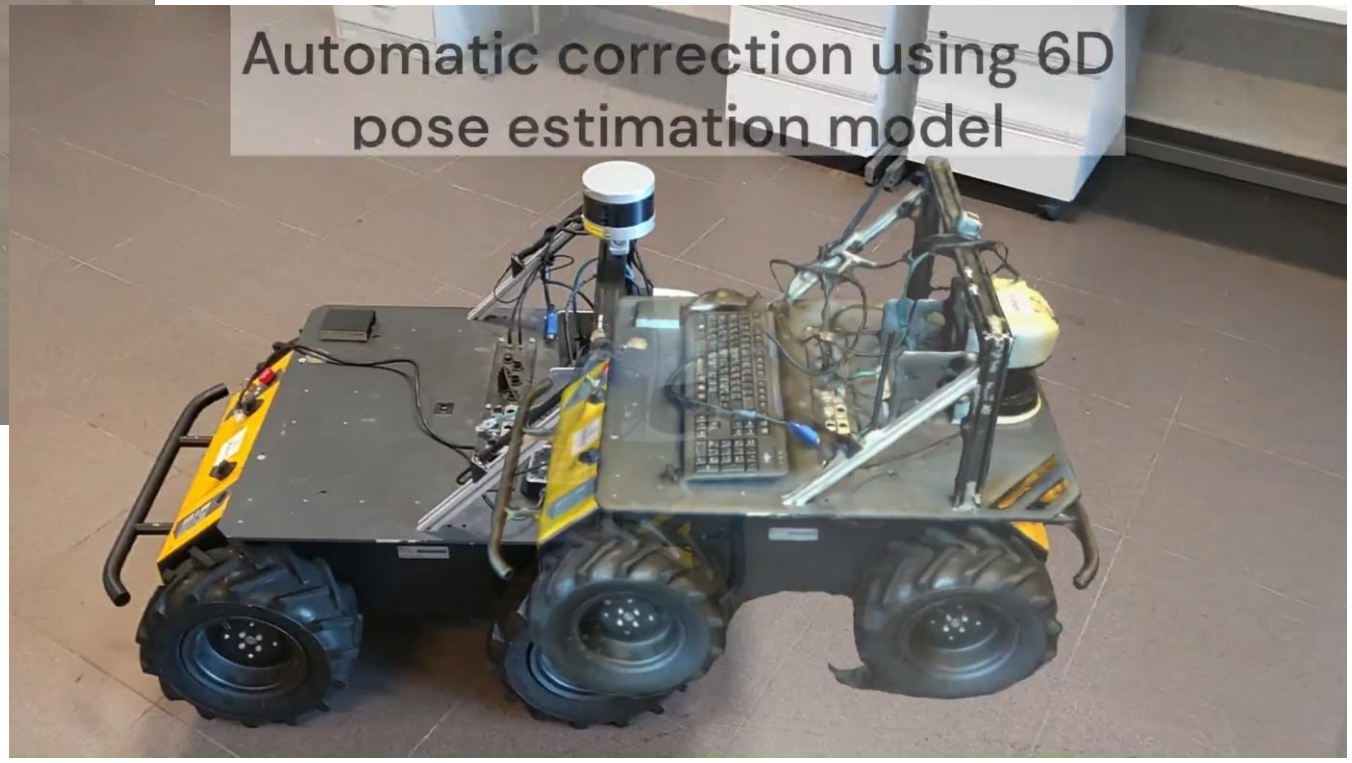


Global Fused Map

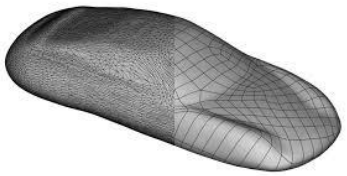
Real-Time Digital Twin Update

6D object pose estimation model

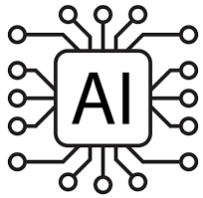




6D object pose estimation model pipeline



Prepare 3D CAD or scan of an object



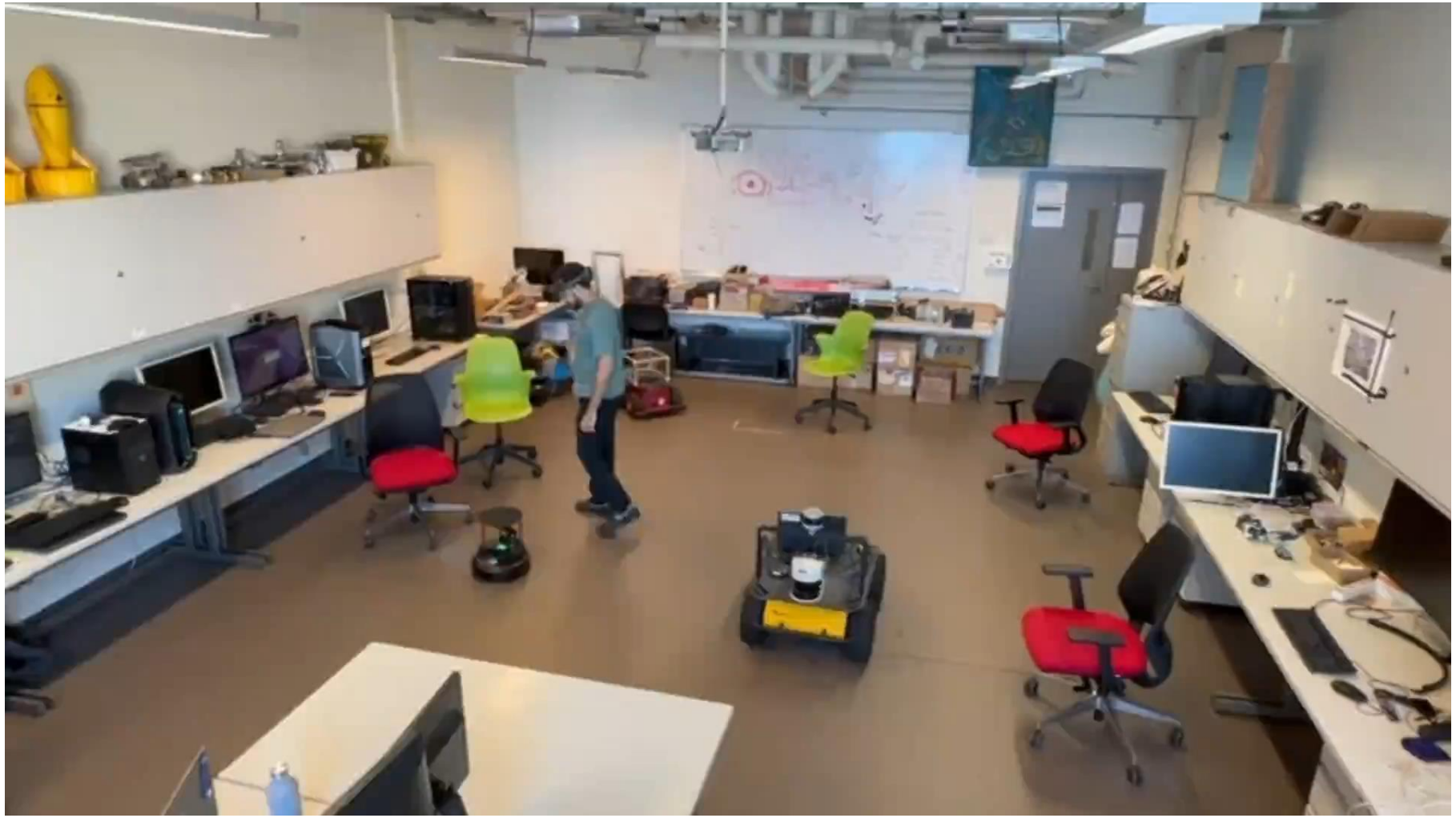
Train object pose estimation model on the file

Unity

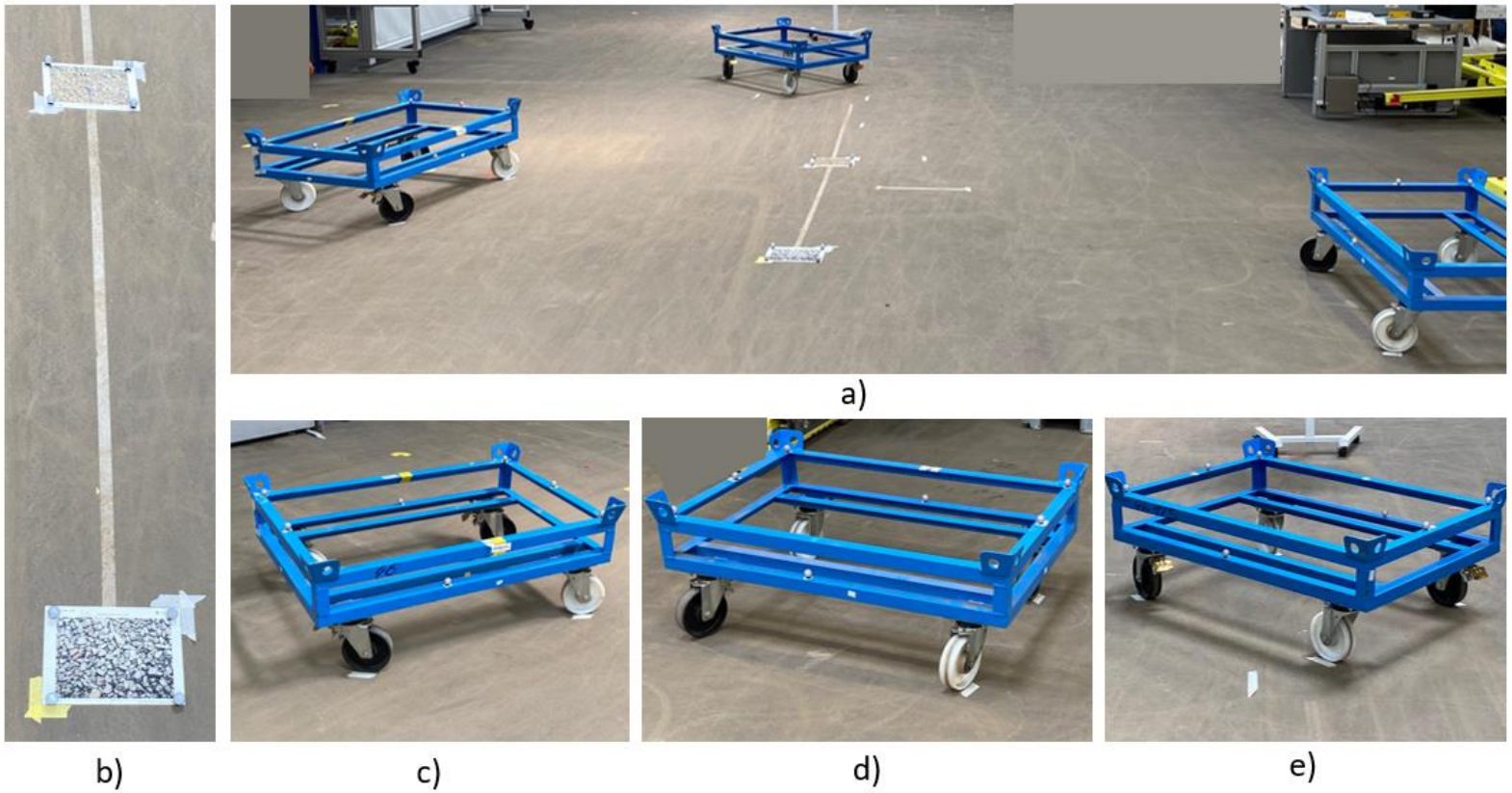
Input the trained model into Unity to trigger events upon detection

Deploy to XR device

Temporal Playback



Experiment Objective Results



Experimental setup in the industrial environment. (a) Full view of the setup. (b) QR anchor utilized by the XR system for localization. (c–e) The three dollies used in the experiments.

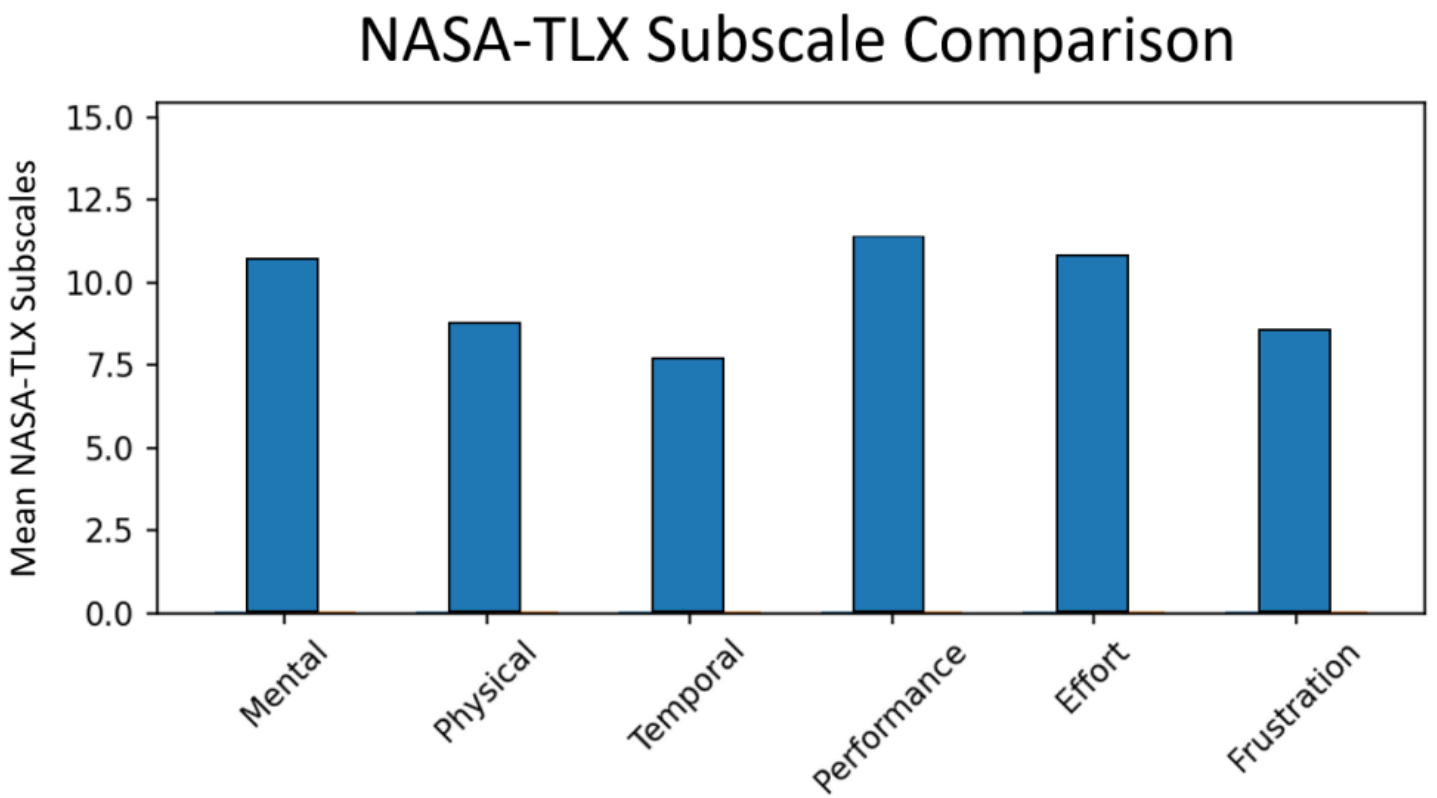
Quantity	Mean	Std
Time (sec)	58.78	18.12
Position (m)	0.052	0.037
Angle (deg)	0.710	0.339

Descriptive analysis for completion time, position, and angular errors from 37 users

Experiment Subjective Results

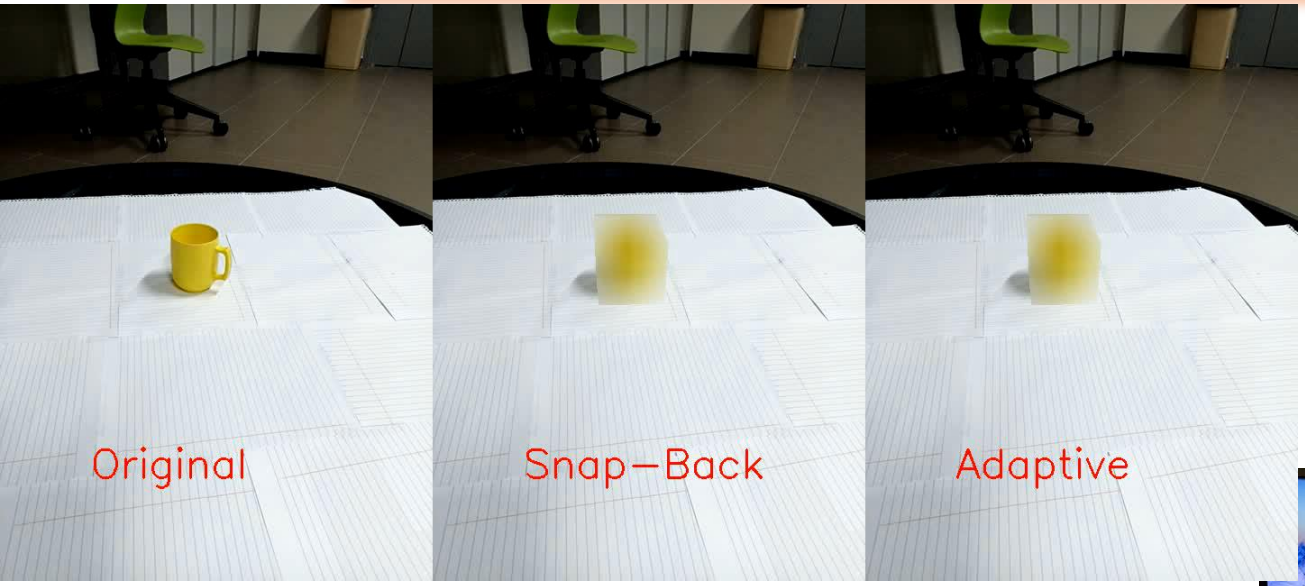
Metric	Mean	Std
Mental	4.00	2.65
Physical	4.62	3.75
Temporal	3.84	3.17
Performance	17.43	3.50
Effort	3.486	2.231
Frustration	2.92	2.36
Total	30.25	8.04

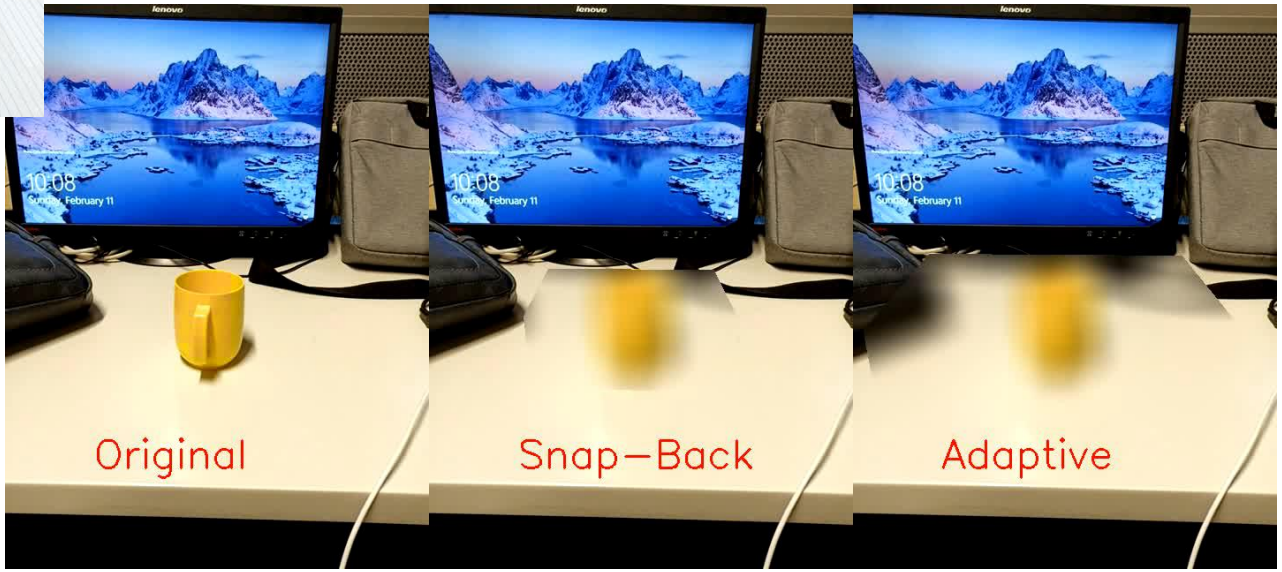
Descriptive analysis for NASA-TLX subscale and composite scores from participants.



NASA-TLX subscale ratings across all 37 participants, illustrating perceived workload in terms of mental demand, physical demand, temporal demand, performance, effort, and frustration.

Diminished Reality
Salam Tabet and Dr. Ayman Kayssi

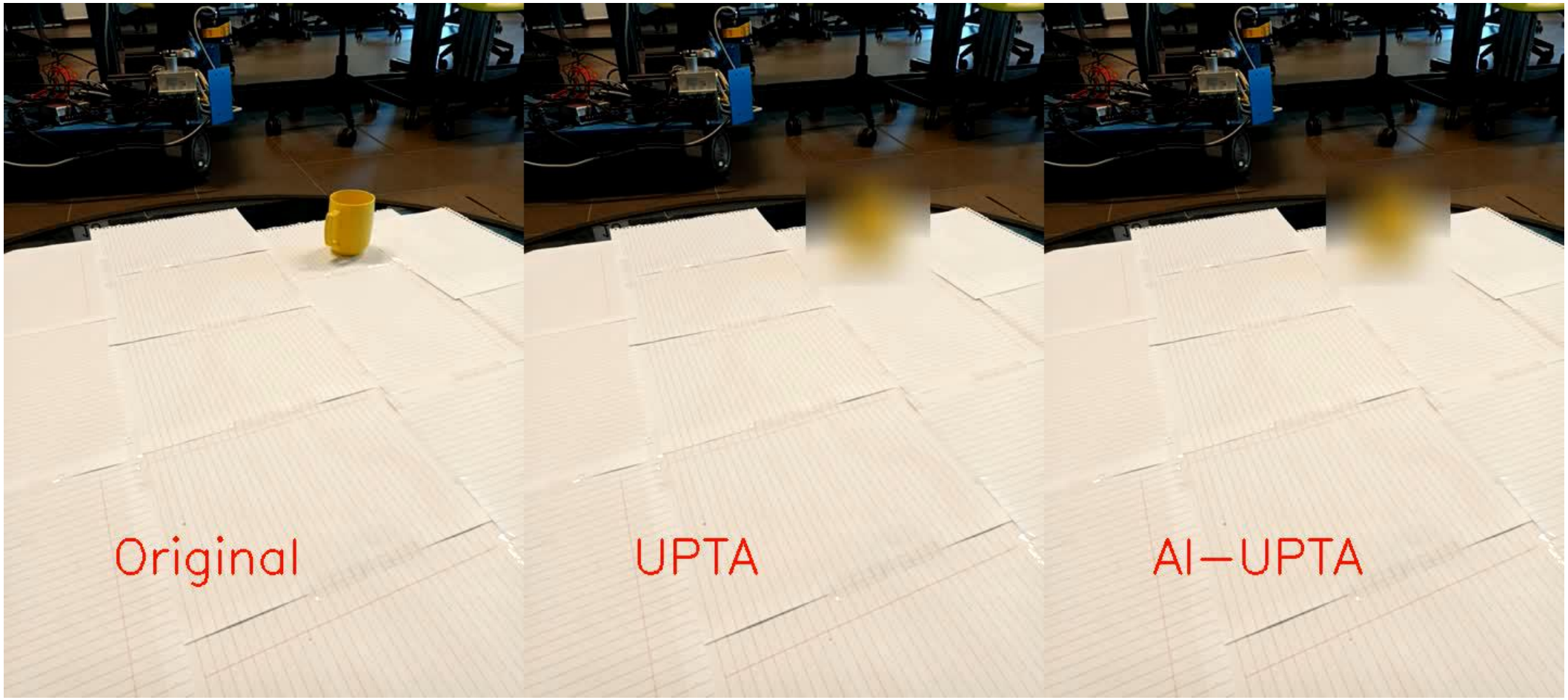




Salam Tabet, Ayman Kayssi and Imad H. Elhajj, “Mobile Diminished Reality for Preserving 3D Visual Privacy,” International Conference on Intelligent Metaverse Technologies & Applications (iMETA), Tartu, Estonia, 18-20 September 2023.

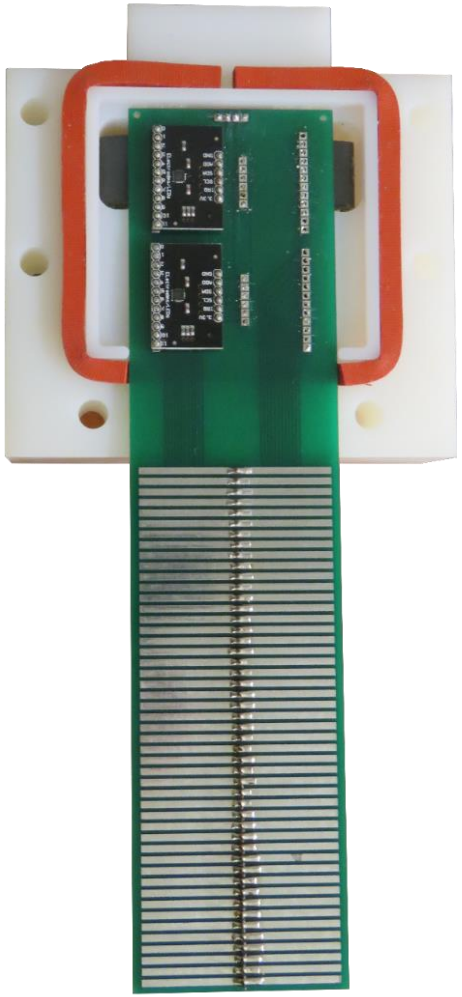
Salam Tabet, Ayman Kayssi and Imad H. Elhajj, “Utility-Privacy Aware Mobile Diminished Reality Framework for 3D Visual Privacy,” IEEE International Conference on Trust, Privacy and Security in Intelligent Systems, and Applications (TPS), Washington, D.C., USA, 28-30 October 2024.

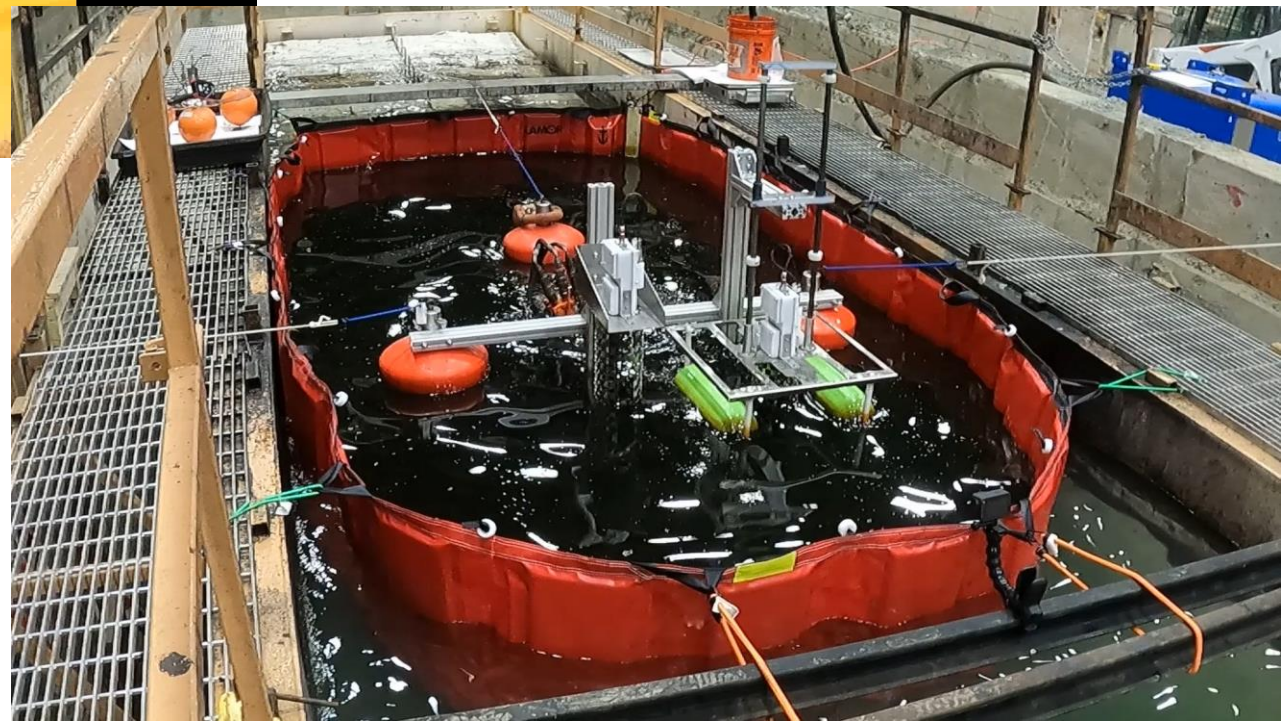
AI Watching AI

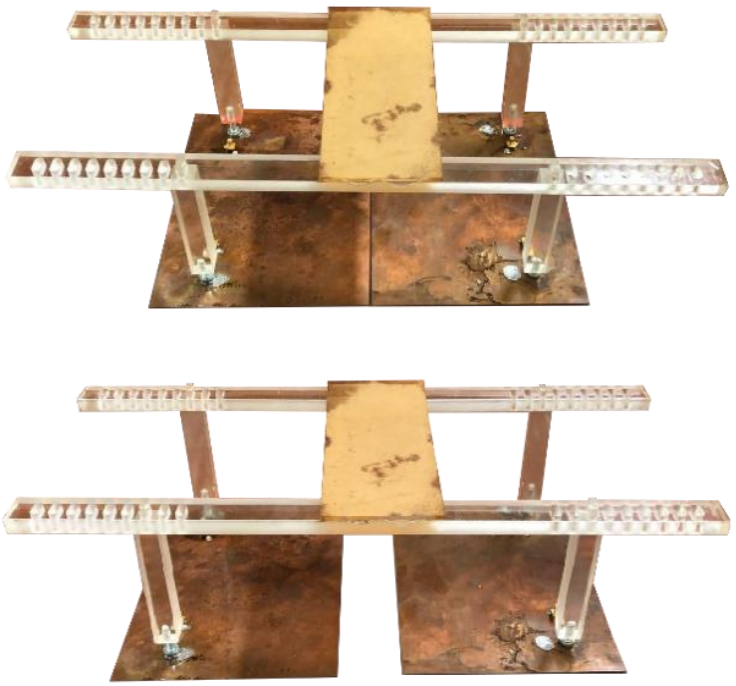


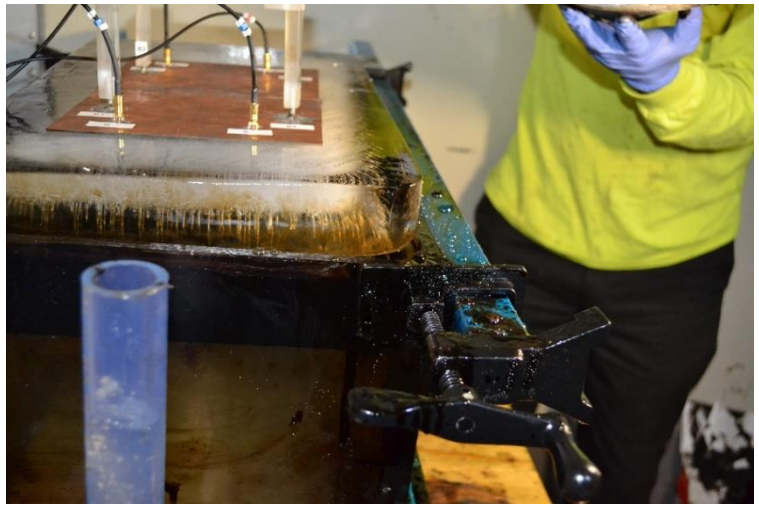
Salam Tabet, Ayman Kayssi, Imad H. Elhajj, “AI-Enhanced Mobile Diminished Reality Framework for Preserving 3D Visual Privacy,” International Conference on Intelligent Metaverse Technologies & Applications (iMETA), Dubai, UAE, 26-29 November 2024.

Beyond Robotics: AI Powered Oil Detection and Thickness Estimation Sensors





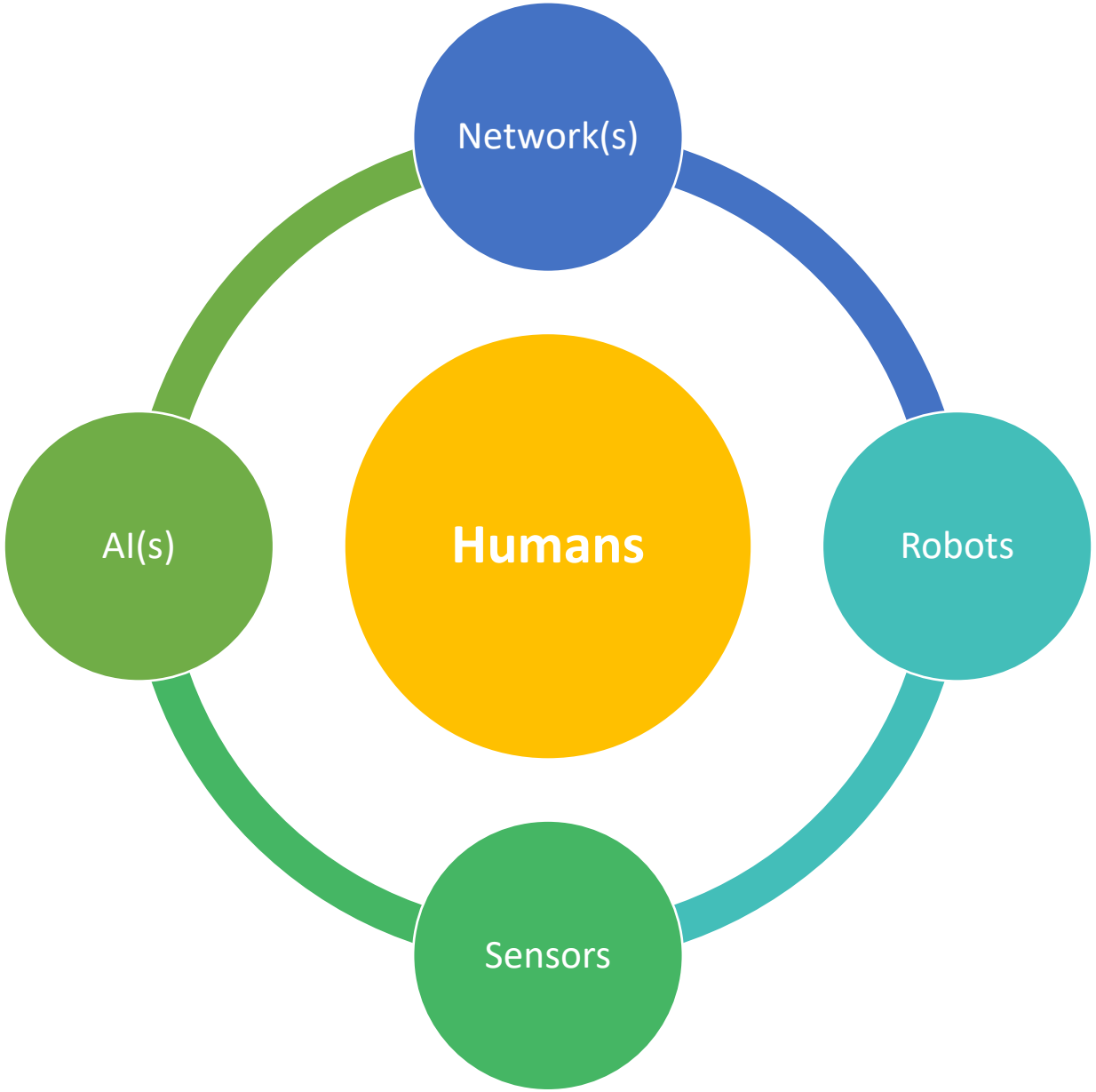




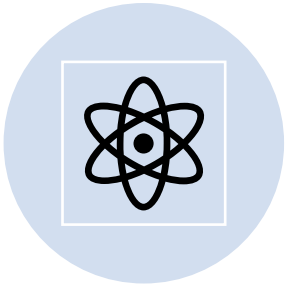
Mahmoud Altrabolsi, Mahdi Saleh, Imad H. Elhajj, Daniel Asmar, “A Planar Capacitive Sensor for Detecting and Measuring Thickness and Depth of Oil Under Ice,” Measurement Science and Technology, Volume 36, Number 1, 2025. 10.1088/1361-6501/ad99ee

Mahdi Saleh, Ali Rida Tabikh, Imad H. Elhajj, Kristi McKinney, Daniel Asmar, "Dual-Modality Capacitive-Ultrasonic Sensing for Measuring Floating Oil Spill Thickness" IEEE Transactions on Instrumentation & Measurement, Vol.71, 2022. 10.1109/TIM.2022.3212108

Mahdi Saleh, Ghassan Oueidat, Imad H. Elhajj, and Daniel Asmar, “In-situ Measurement of Oil Slick Thickness,” IEEE Transactions on Instrumentation and Measurement, Vol. 68, No. 7, pp. 2635-2647, July 2019. DOI: 10.1109/TIM.2018.2866745


Network(s)
AI(s)
Humans
Robots
Sensors

Current Questions



Physics (Knowledge)

Human Factors & Human Like

Context

LLM/VLM

Human Behavior

- How to test?
- Cultural differences?
- Personal preferences?
- Explainable?

Communication Challenges

Key Takeaways

- There is significant potential for humans, AI and “Physics” sharing the loop
- Does not compete with autonomy
- Might be the bridge needed to market acceptance
- Similar good old challenges