Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

MIN Faculty
Department of Informatics

Enhancing Robotic UIs with Mixed Reality

Improving Interaction and Visual Communication

Dennis Krupke

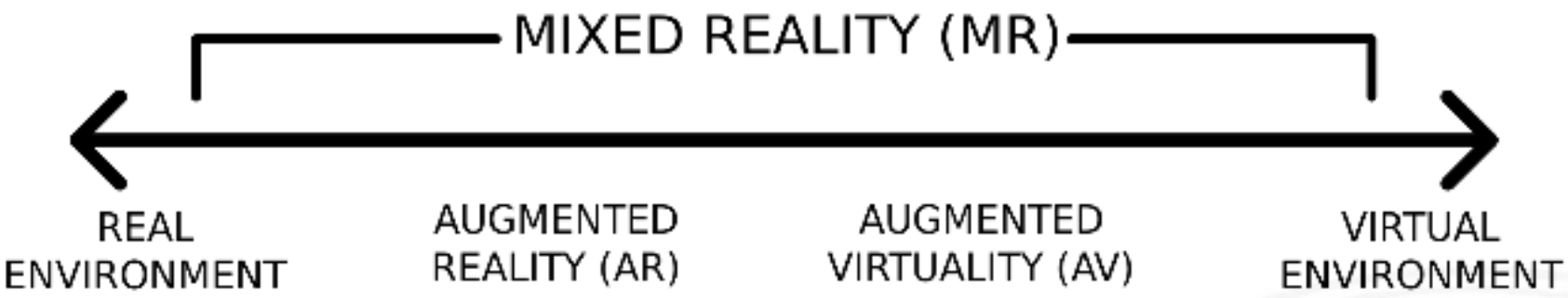
University of Hamburg
Faculty of Mathematics, Informatics and Natural Sciences
Department of Informatics

Technical Aspects of Multimodal Systems

21. May 2019

Table of Contents

Mixed Reality



A selection of achievable advantages:

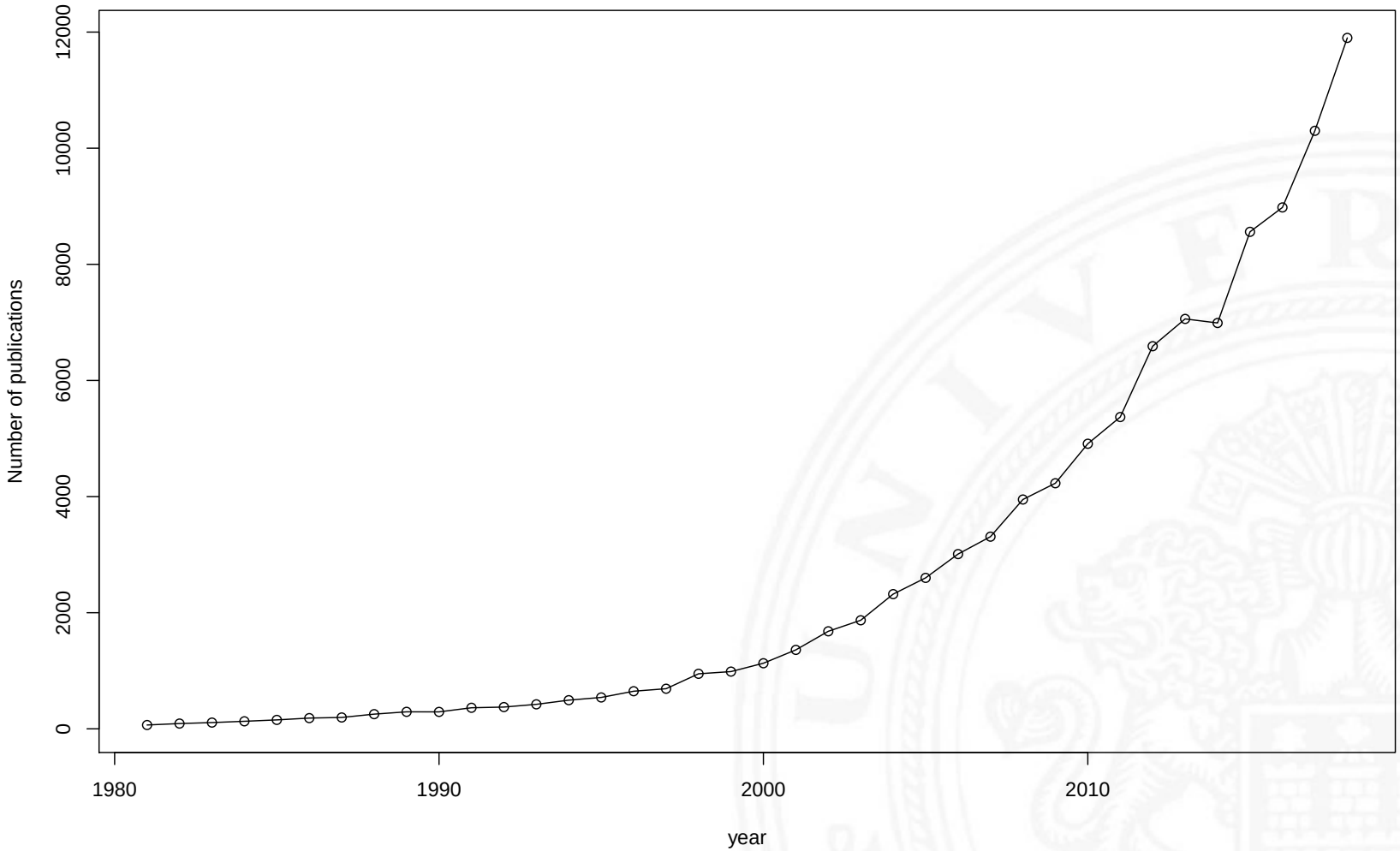
- sense of agency
- spatial/situational awareness
- depth perception
- immersion
- natural interaction

[Bur99] G. C. Burdea, *Invited review: the synergy between virtual reality and robotics*, IEEE Trans. Robot. Autom. **15** (1999), no. 3, 400–410.

[MTUK95] Paul Milgram, Haruo Takemura, Akira Utsumi, and Fumio Kishino, *Augmented reality: A class of displays on the reality-virtuality continuum*, Telemanipulator and telepresence technologies, vol. 2351, International Society for Optics and Photonics, 1995, pp. 282–293.

Mixed Reality

Scientific Interest in MR and Robotics



Source: Google Scholar, 2019-03-13

Research Questions

- How can we *extend robotic systems* with mixed reality?
- What are appropriate *interaction methods* for robotic tasks?
- How is it possible to *enhance the communication* between the operator and the robot for increasing the *predictability* of the system?

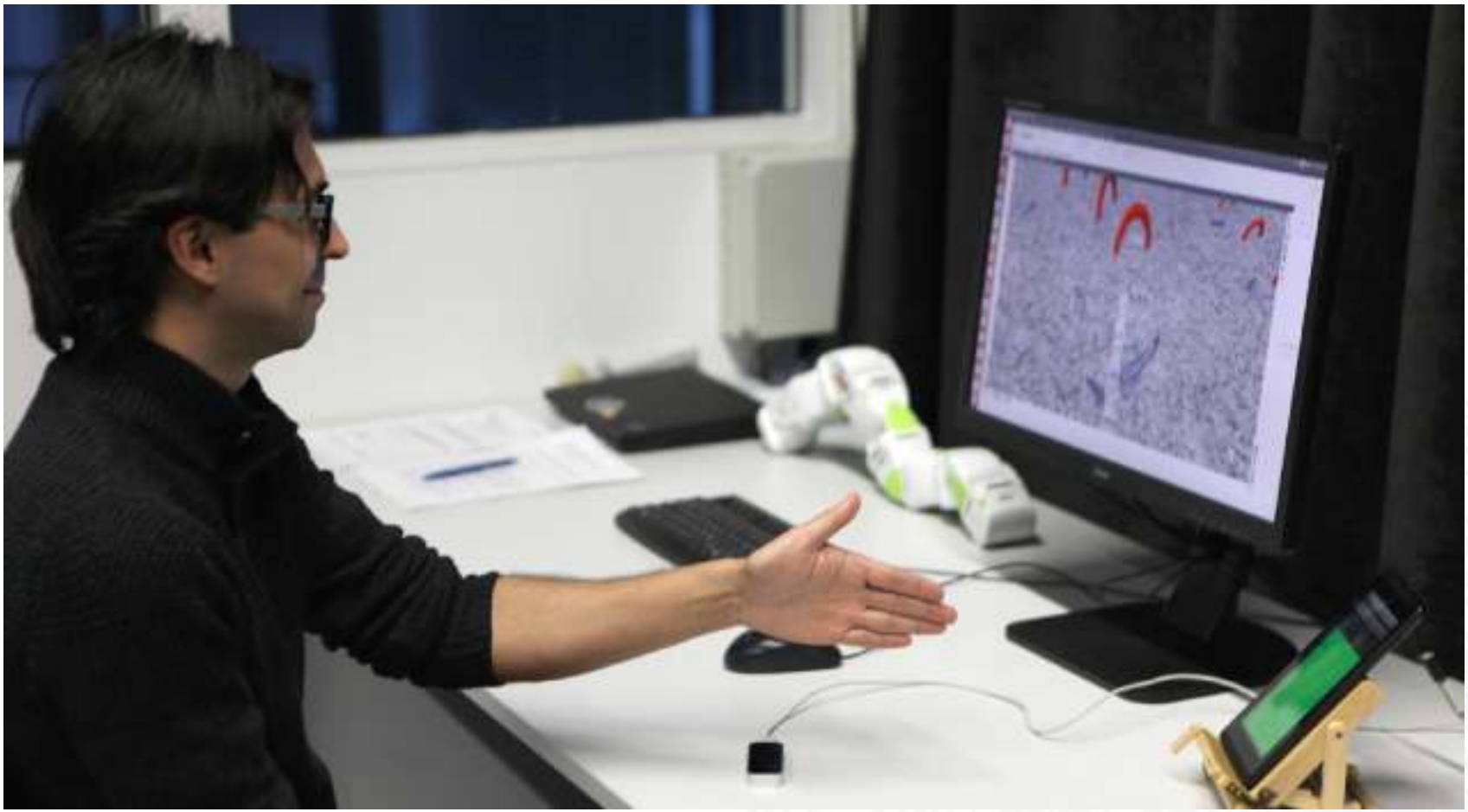
Research Questions

- How can we *extend robotic systems* with mixed reality?
- What are appropriate *interaction methods* for robotic tasks?
- How is it possible to *enhance the communication* between the operator and the robot for increasing the *predictability* of the system?

Research Questions

- How can we *extend robotic systems* with mixed reality?
- What are appropriate *interaction methods* for robotic tasks?
- How is it possible to *enhance the communication* between the operator and the robot for increasing the *predictability* of the system?

How not to achieve this!



- It was very cumbersome to extend OpenRAVE-based middleware with an Android device!
- Very static hand gestures are exhausting for operators!

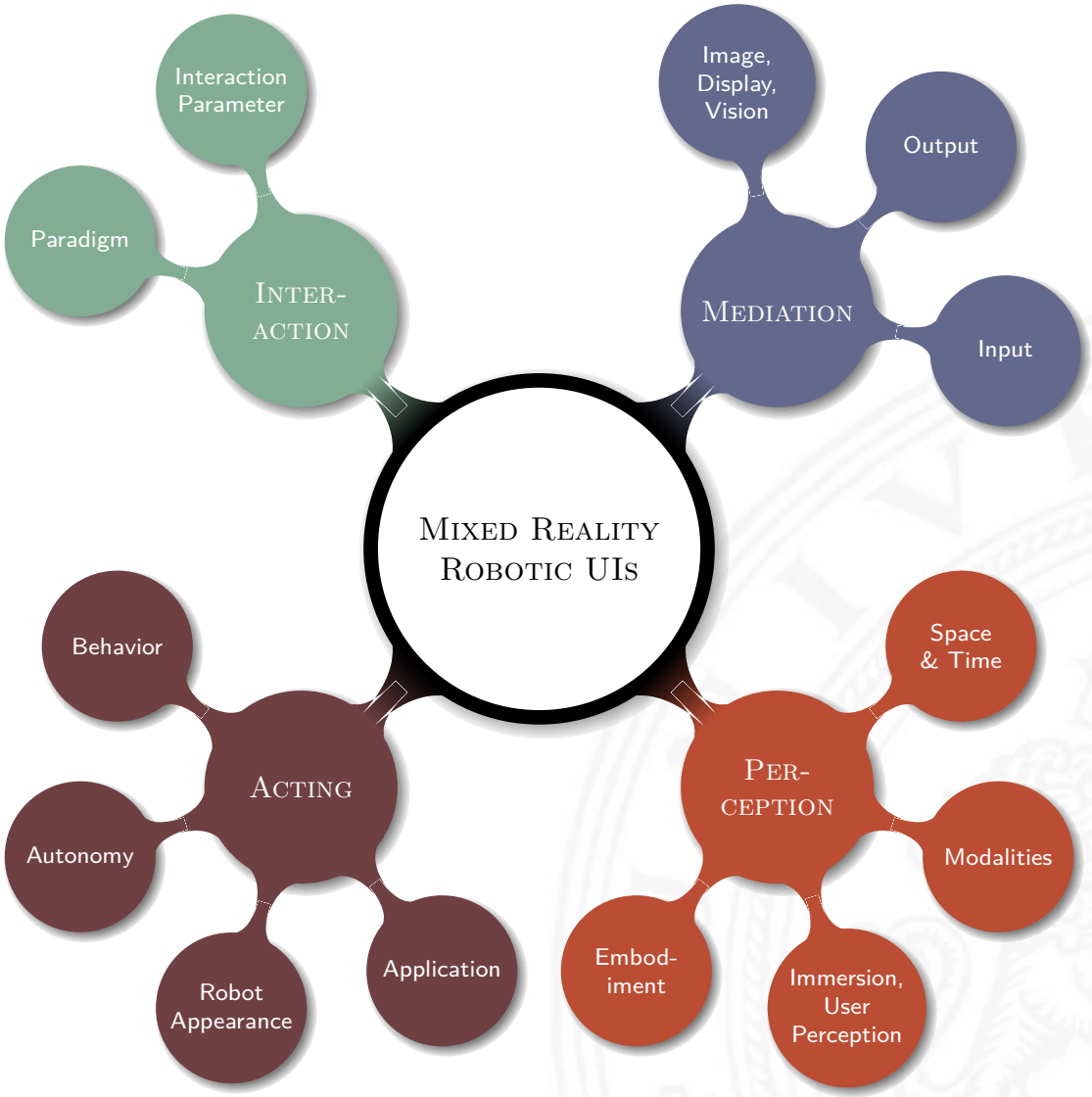
How not to achieve this!

- This causes strong simulator sickness!

Mixed Reality Robotic User Interfaces (MRRUI)

- What is potentially possible with MR?
- What factors can be influenced during the system design phase?
- What has already been done by other researchers?

Mixed Reality Robotic User Interfaces (MRRUI)
IMPAct Framework for Classification

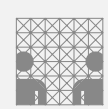


[KZS19] Dennis Krupke, Jianwei Zhang, and Frank Steinicke, *Impact: A holistic framework for mixed reality robotic user interface classification and design*, Multimodal Technologies and Interaction **3** (2019), no. 2.

Category	Group	Factor	Value
Interaction	Interaction Parameters	Action Type	discrete
		AFR Interaction Level	Type D
		Control Alignment	[illegible]
		Control Order	0
		Directness	almost isomorph
		DoF	5
		Interaction Plasticity	virtual
		Interaction Type	selection
		Mapping Relationship	position
		Parameter Manipulation Type	direct
		Sensing Mode	[illegible]
		Structure of Interaction	SU,SR,ST
	Paradigm	Human-Robot Communication	two monologues
		Intelligent Robot Control Paradigm	hierarchical at user level
		Robot Control Concept	feedback control loop
		Role of Interaction	supervisor & manager
		RUI-Type	interactive
		UI-Type	[illegible]
Mediation	[illegible]	Display Centricity	egocentric
		Display Class (Milgram)	class 4
		(Display) Space	registered
		Image Scaling	1:1
		Vividness	mid-to-low
	Input	Action Measurement Type	[illegible]
		Directness of Sensation	partially directly viewed
		DoF	3+1
		Gesture Type	static posture
		Sensor Type	IMU, structured light IR camera, [illegible], joint encoder, current measurement
	Output	Actuator Type	robot arm & gripper
		Display Type	see-through HMD
Perception	[illegible]	Extent of Body Matching	no VB
		Extent of Proprioceptive Matching	virtual cursor and viewing direction
	[illegible]	Extent of Presence Metaphor	strong tendency towards real-time imaging
		Integration of VR	almost completely integrated
		Level of MR	AR with tendency to [illegible]
		Reproduction Fidelity	stereoscopic realtime rendering but with simple shaders
	Modalities	Causality of Modalities	partially transmitted and simulated
		[illegible]	only vision
		[illegible]	almost none
		Model of Modality-Source	computed
		Superposition of Modalities	merged
		User Experience	mixture of transmitted, simulated and supervised robot
	Space & Time	Extent of World Knowledge	objects of interest are modeled with normal to high accuracy
		Location	in loco
		Realtime Level	delayed up to half a second
		Surrounding	only [illegible] FoV
		System Extent	network-based in one room
		Time (interaction)	[illegible]
		Time (purpose)	realtime
Action	Autonomy	Level of Capabilities	generate trajectories, self localize
		Level of Intelligence	collision avoidance, contact grasp points
		Plan	virtual robot shows probable solution
		Refined LOA	[illegible]
		Initiative	fixed at the human
		JIRA Intelligence Level of the Robot	class 3
		Timely Aspects	static
	Behavior	Robot Behavior Level	remote controlled
		Robot Communication Capability	reactive
		Transparency of System State	visible
	RA	Level of Robot Anthropomorphism	very low
	[illegible]	Robot Purpose	tool
		Robot Type	industrial

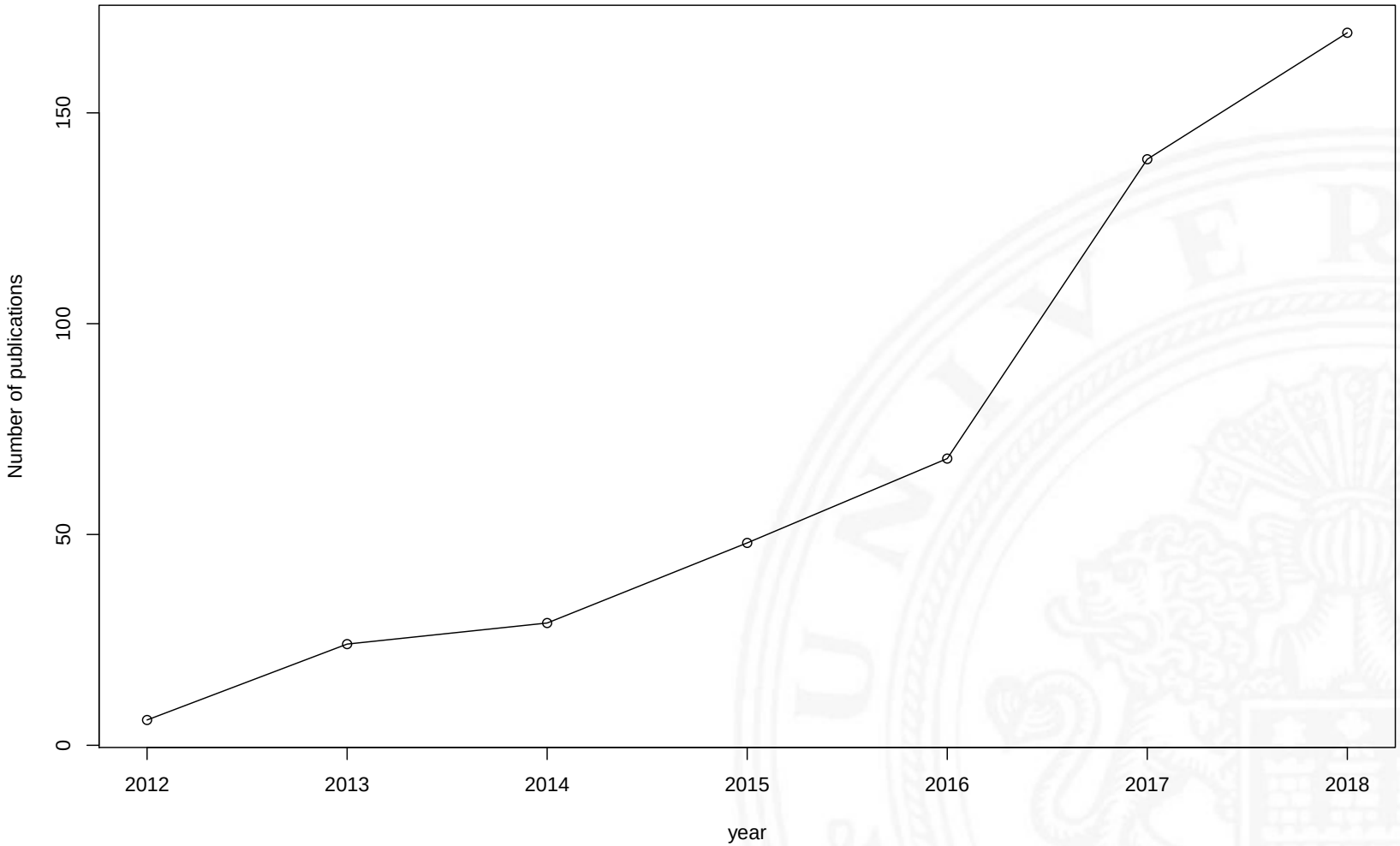
Why ROS and Unity3D?

- widely accepted frameworks
- strong communities
- (at least tendencies to) professional use
- modular and extendable
- effective and efficient
- support of state-of-the-art hard- and software



Why ROS and Unity3D?

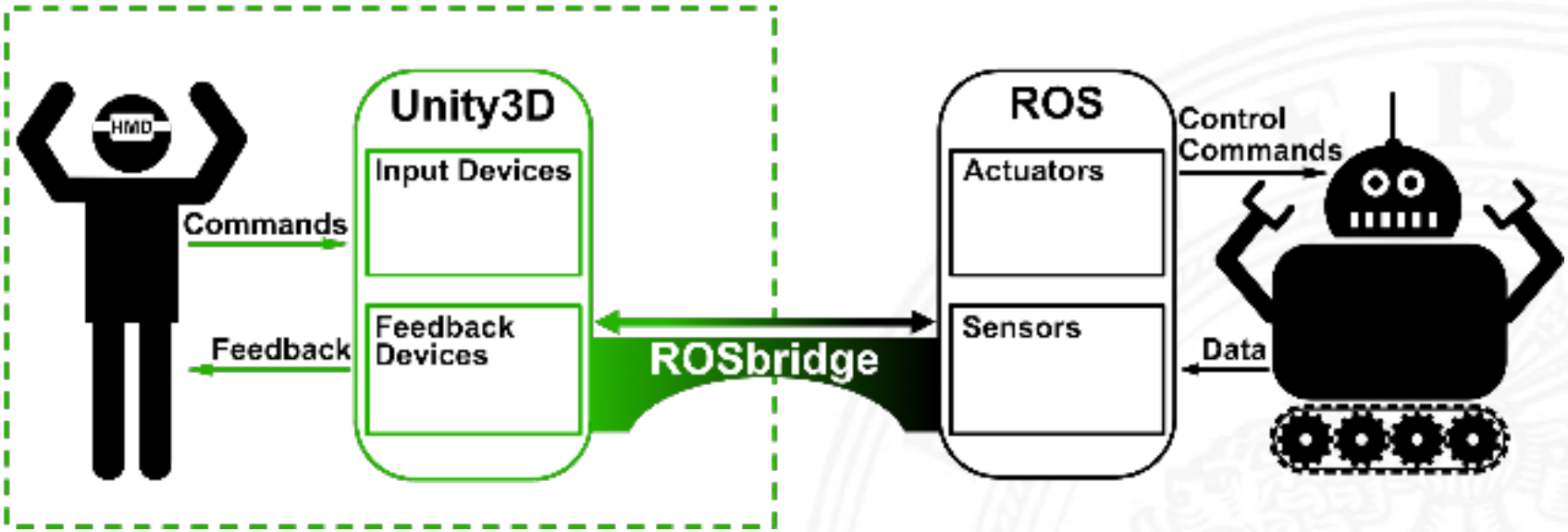
Scientific Publications on Google Scholar



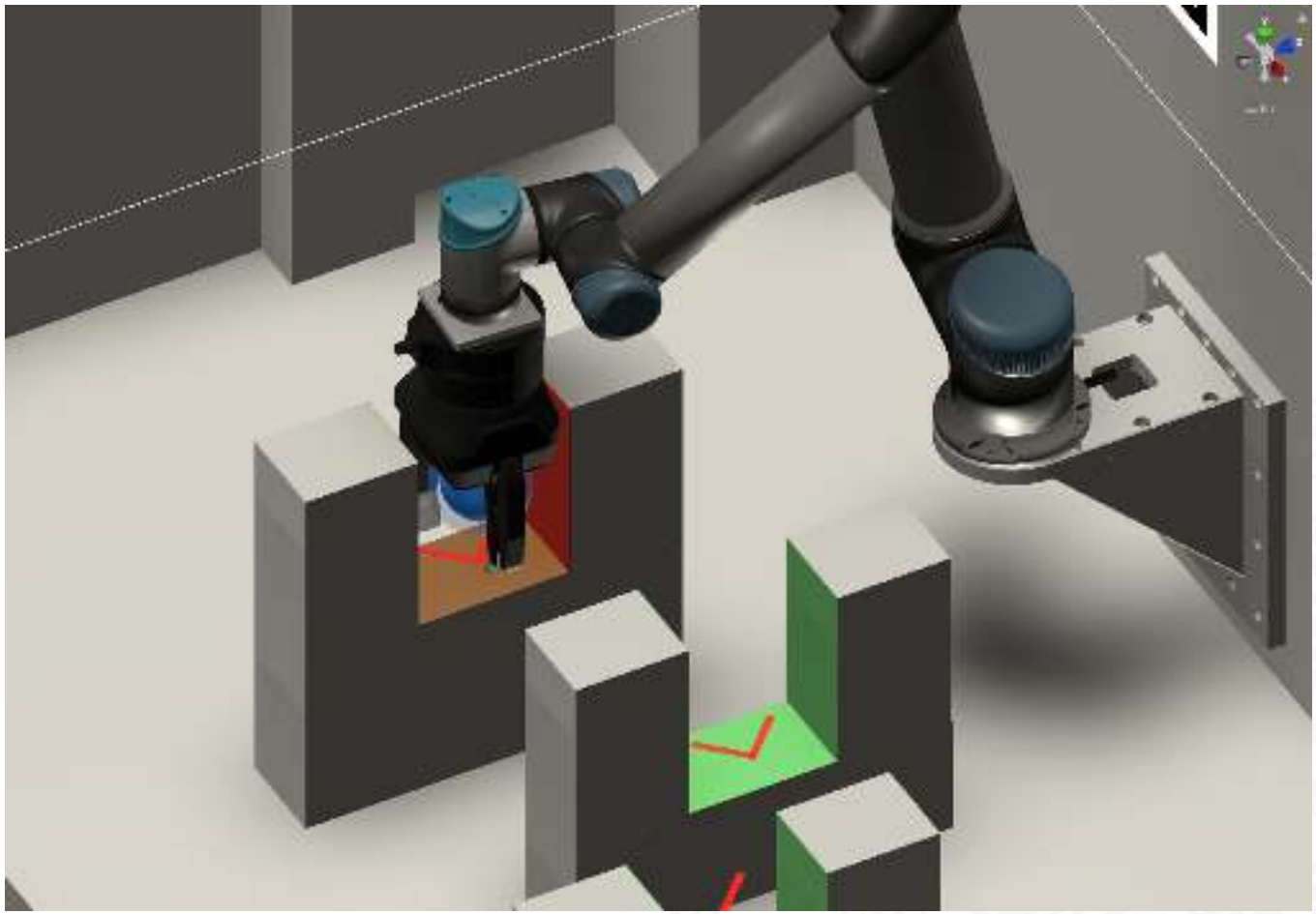
Source: Google Scholar, 2019-03-13

Concept

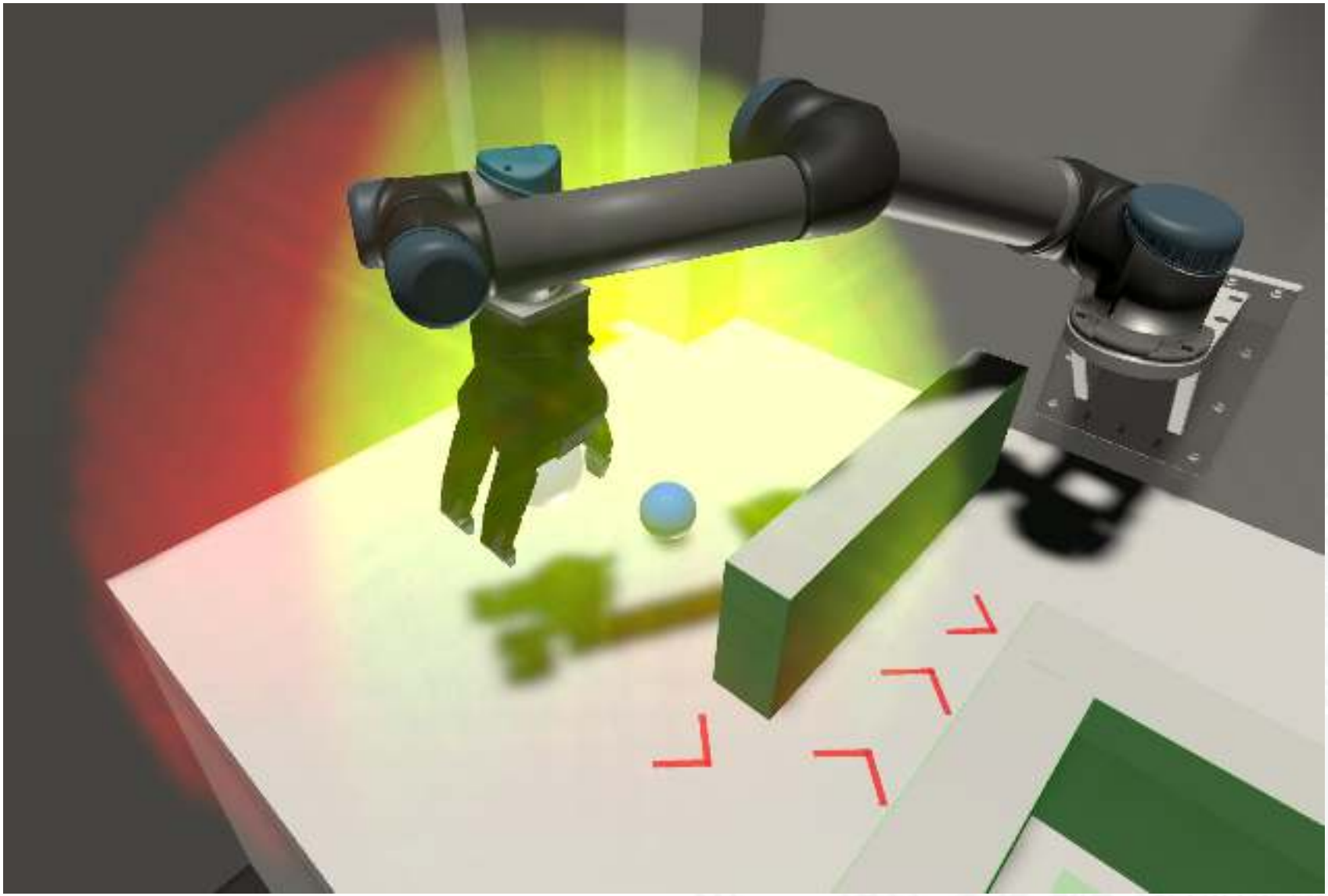
- URDF importer
- local IK solver
- bi-directional communication
- state machine
- tools (coordinate conversion, reliable (marker) tracking, . . .)



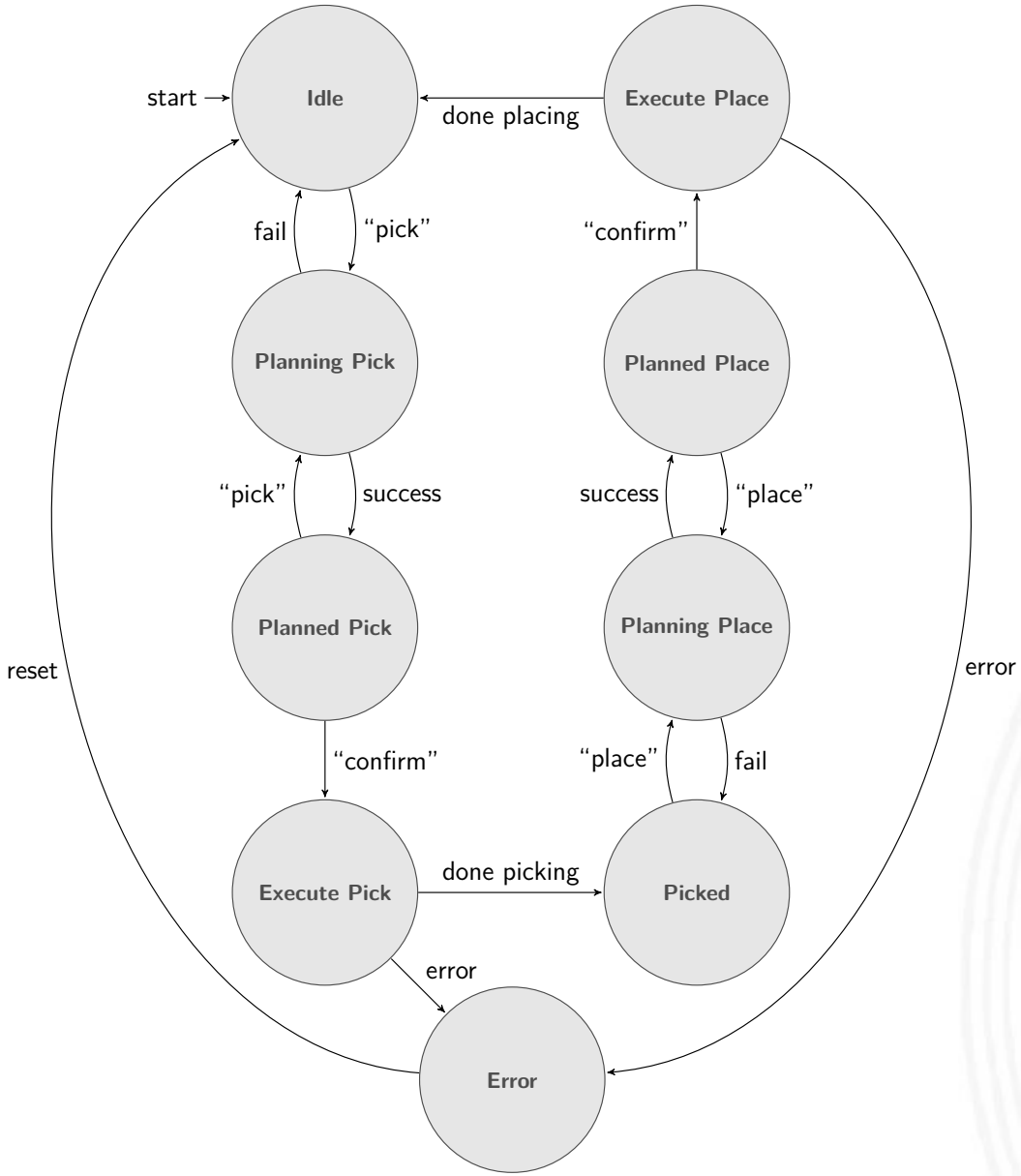
[KSE+17] Dennis Krupke, Sebastian Starke, Lasse Einig, Frank Steinicke, and Jianwei Zhang, *Prototyping of Immersive HRI Scenarios*, Human-Centric Robotics (Mohammad O. Tokhi Benedita Malheiro Pedro Guedes Manual F. Silva, Gurvinder S. Virk and Paulo Ferreira, eds.), Proceedings of CLAWAR 2017: 20th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, CLAWAR Association, World Scientific, sep 2017, pp. 537–544.



[KZS18] Dennis Krupke, Jianwei Zhang, and Frank Steinicke, *Virtual Fixtures in VR - Perceptual Overlays for Assisted Teleoperation, Teleprogramming and Learning*, Proceedings of the ICAT-EGVE (International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments) 2018 (Gerd Bruder, Shunsuke Yoshimoto, and Sue Cobb, eds.), The Eurographics Association, The Eurographics Association, nov 2018.



Visual Aids
State-Machine



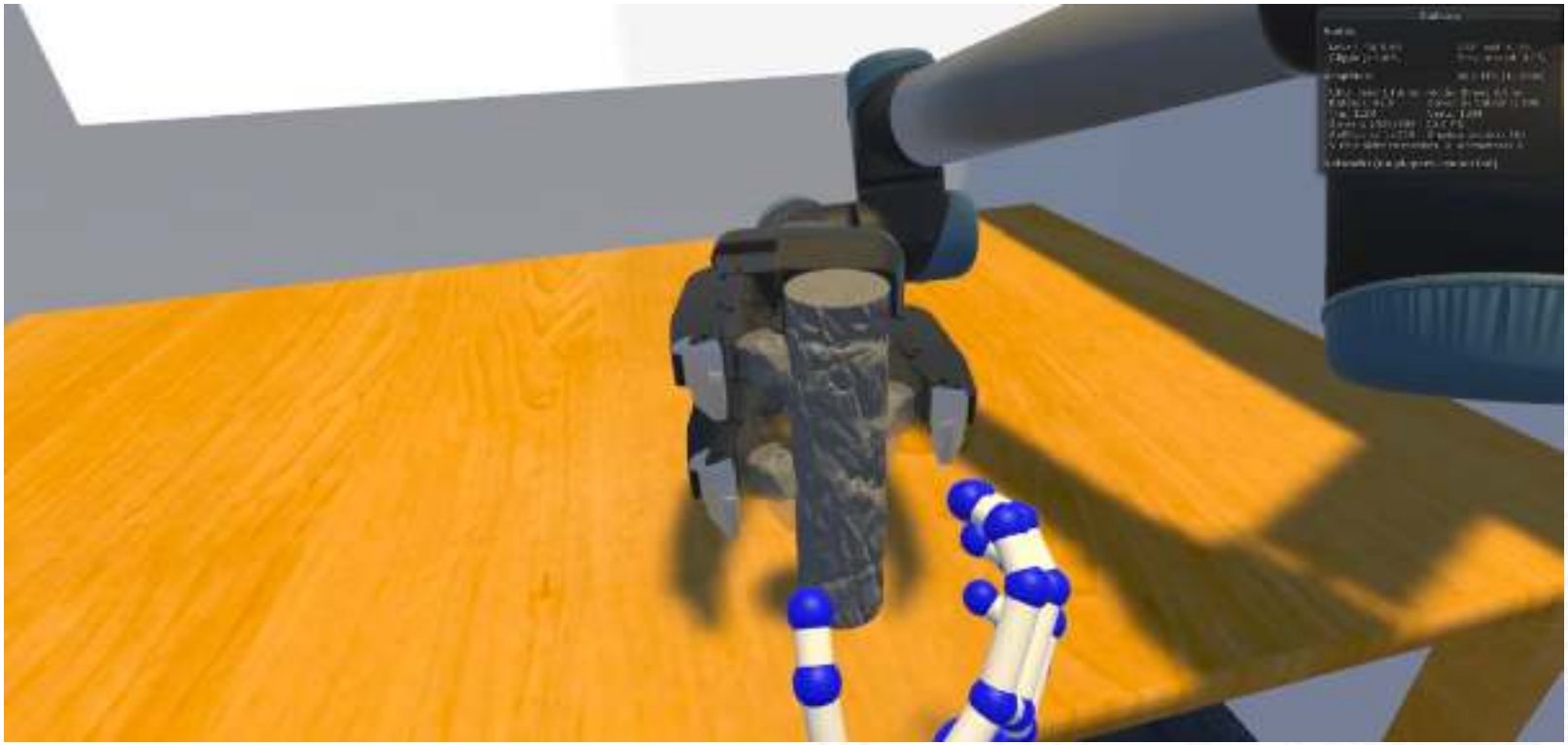
- basis for head-up display (HUD)
- (necessary for a robust system)

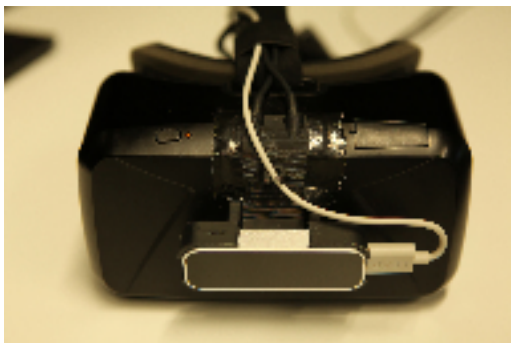
(Natural) Control Methods
"Real" Walking

- 6-DoF tracking of the operator's head is applied to the robot's floor pose

[ZLK+18] Jingxin Zhang, Eike Langbehn, Dennis Krupke, Nicholas Katzakis, and Frank Steinicke, *Detection Thresholds for Rotation and Translation Gains in 360° Video-based Telepresence System*, IEEE Transactions on Visualization and Computer Graphics (TVCG), Special Issue on IEEE Virtual Reality (VR) **24** (2018), no. 4, 1671 – 1680.

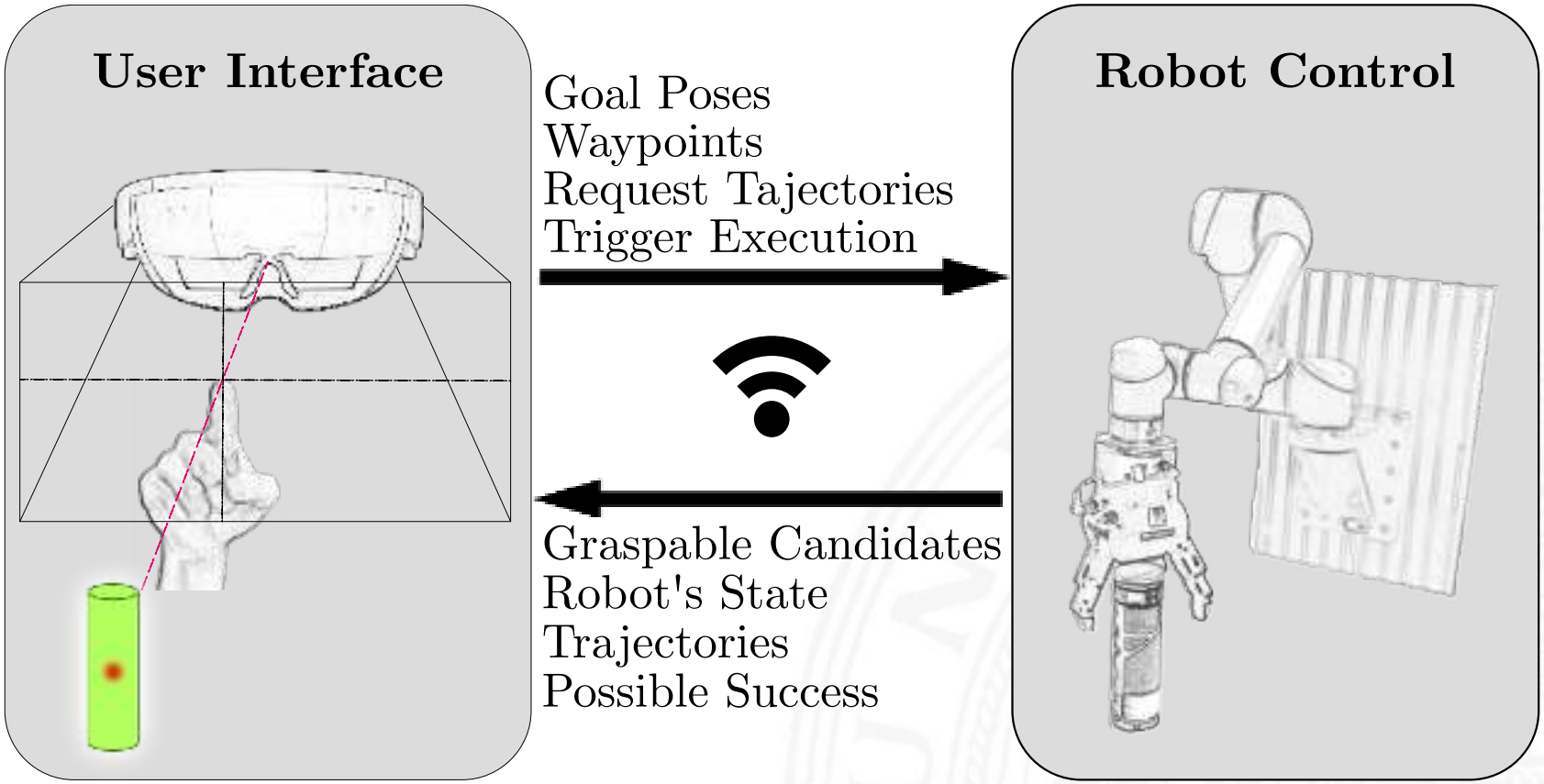
(Natural) Control Methods
"Natural" Grasping





- hand tracking is applied to gripper control

(Natural) Control Methods
Selection by Raycast



[KSL+18] D. Krupke, F. Steinicke, P. Lubos, Y. Jonetzko, M. Görner, and J. Zhang, *Comparison of Multimodal Heading and Pointing Gestures for Co-Located Mixed Reality Human-Robot Interaction*, 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Oct 2018, pp. 1–9.

Summary

Achieved Results:

- Development of a Theoretical Framework for MRRUI Classification.
- Implementation of Unity3D Assets for Prototyping Robotic Use-Cases.
- Evaluation of Control and Visual Communication Concepts.

- `https://github.com/denniskrupke/ros2unity`
- `https://github.com/denniskrupke/virtualFixturesExperiment`
- `https://github.com/denniskrupke/holoROS`
- `https://github.com/TAMS-Group/hololens_grasp`

`mailto:krupke.dennis@gmail.com`

Thank You!