NimbRo Humanoid Robots winning ANA Avatar XPRIZE and RoboCup AdultSize Soccer Competitions

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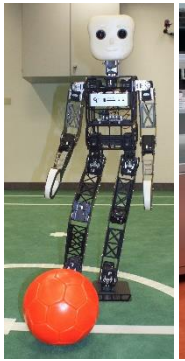
Developed many Humanoid Robots since 2004

- RoboCup Soccer

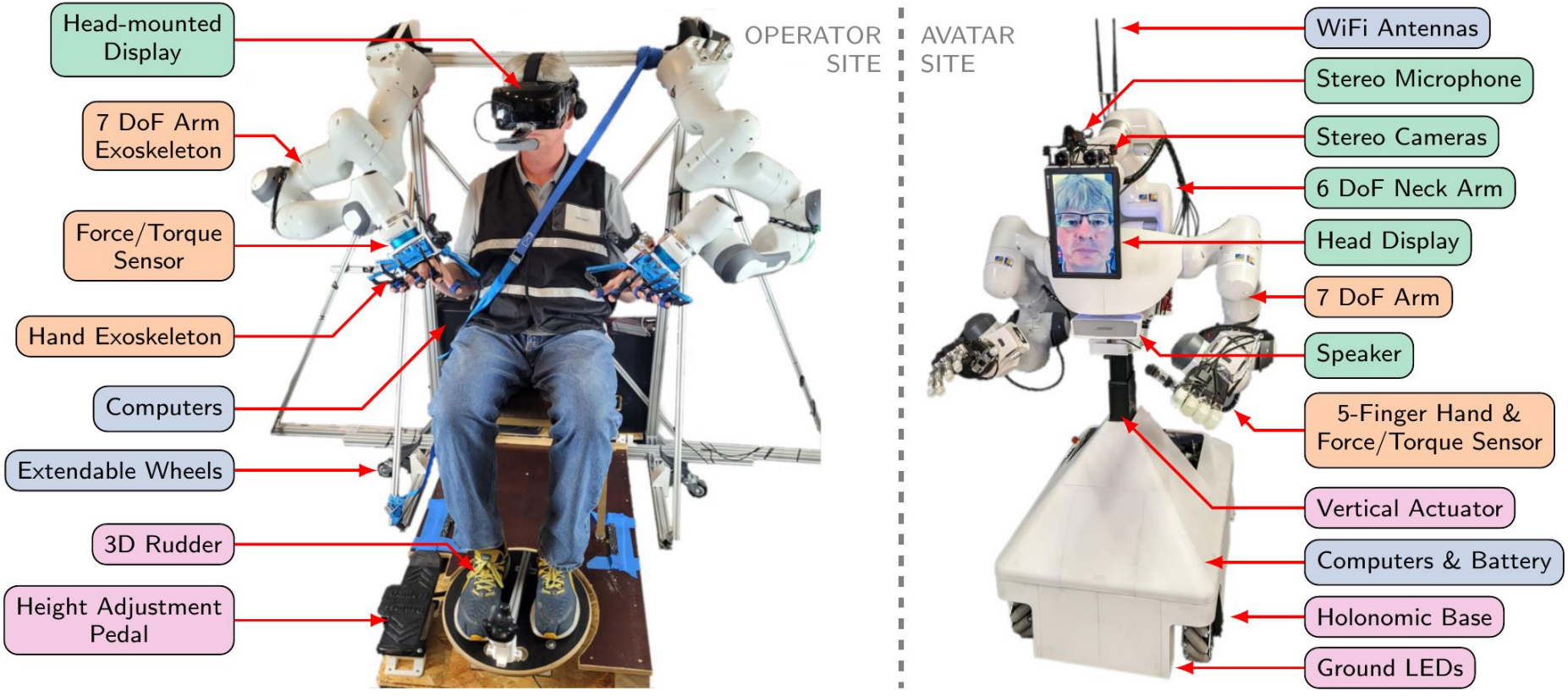



- Communication, RoboCup@Home, DARPA Robotics Challenge, Rescue, Avatar XPRIZE

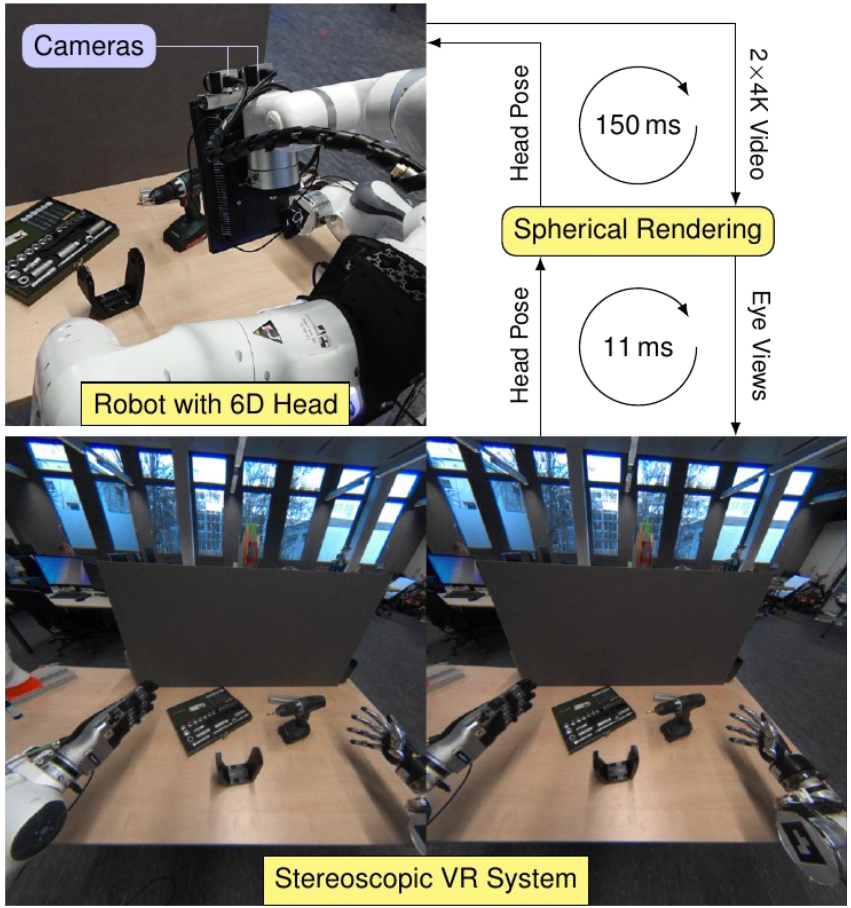

NimbRo Avatar System for ANA Avatar XPRIZE Finals

- Anthropomorphic telepresence robot and matching operator station

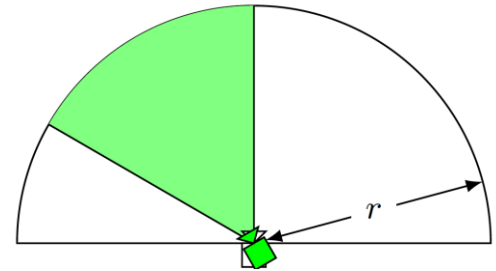


[Lenz, Schwarz et al. International Journal of Social Robotics 2023]

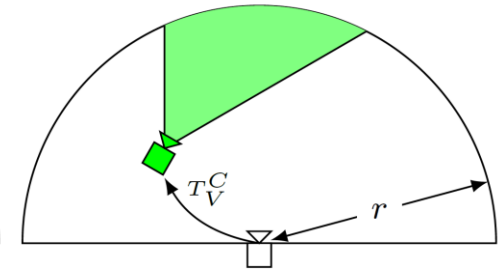
NimbRo Avatar: Immersive Visualization



- 4K wide-angle stereo video stream
- 6D neck allows full head movement
  - Very immersive
  - Good hand-eye coordination
- Spherical rendering technique hides movement latencies
  - Assumes constant depth



Exact for pure rotations

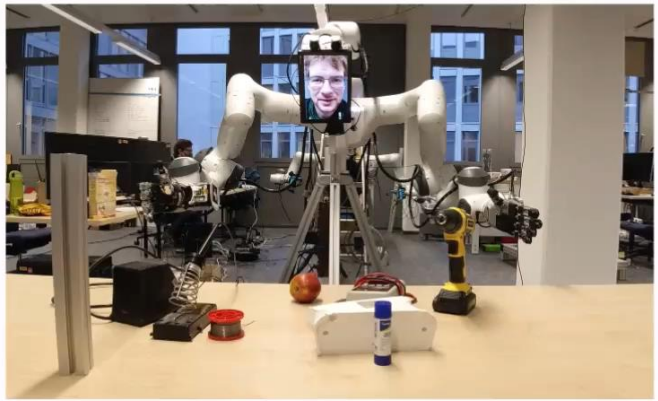


Distortions for translations

[Schwarz and Behnke Humanoids 2021]

NimbRo Avatar: Immersive Visualization

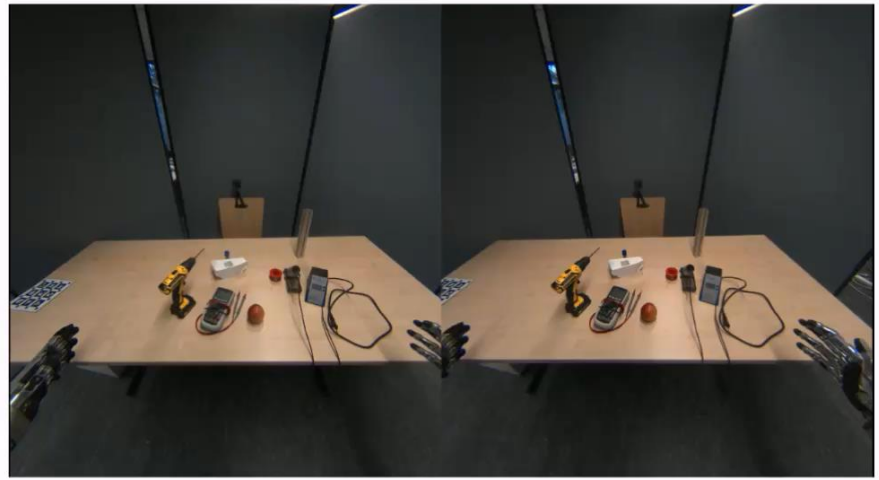
Avatar Robot



Wide-Angle Stereo

Operator

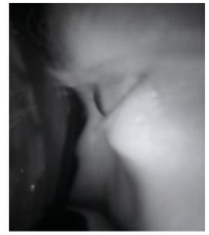
HMD View



[Schwarz and Behnke Humanoids 2021]

NimbRo Avatar: Operator Face Animation

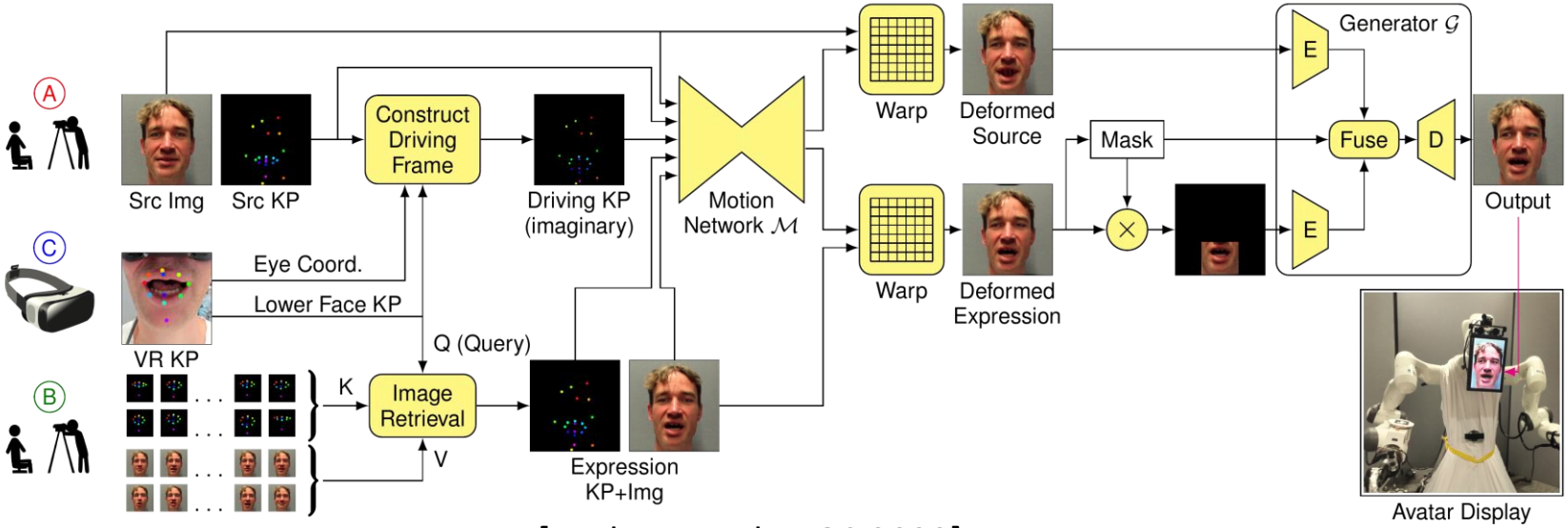
- Operator images without HMD
- Capture mouth and eyes
- Estimate gaze direction and facial keypoints


Left Eye


Mouth

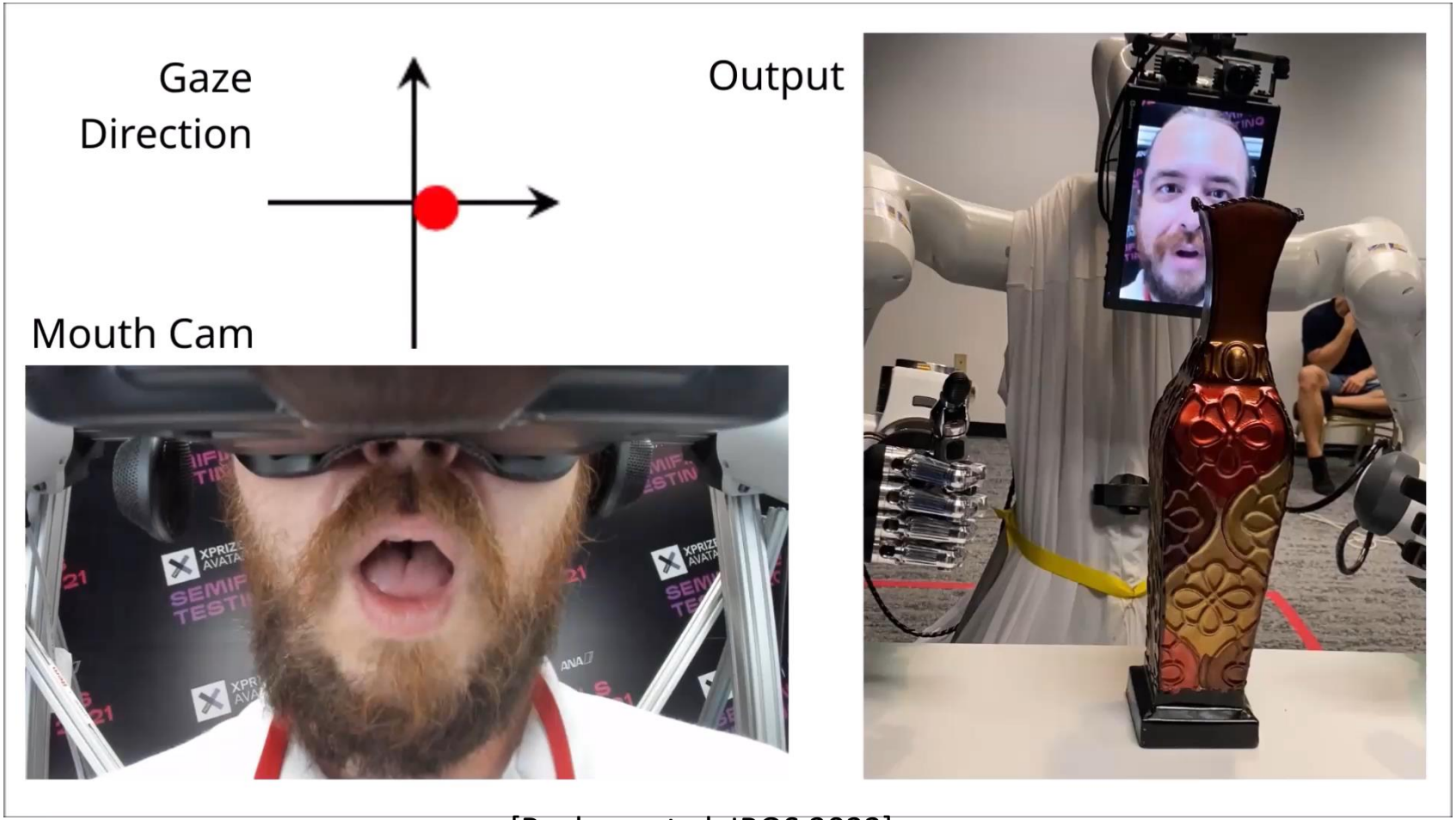

Right Eye

- Generate animated operator face using a warping neural network



[Rochow et al. IROS 2022]

NimbRo Avatar: Operator Face Animation



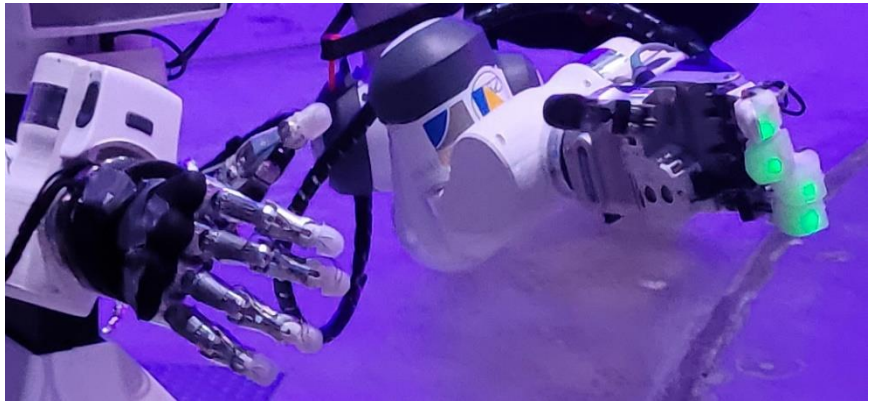
[Rochow et al. IROS 2022]

Finals Test Run Day 1

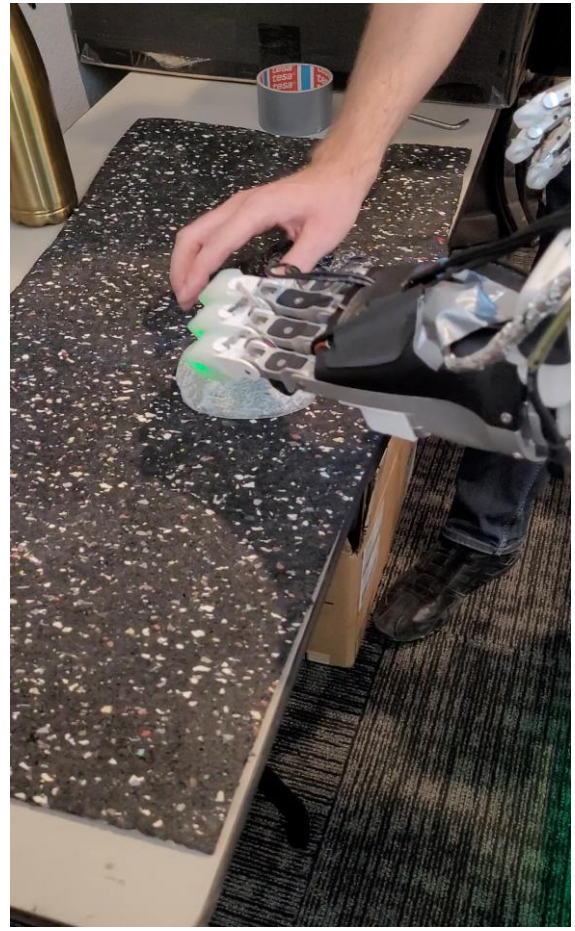
[Lenz, Schwarz et al. SORO 2023]

Haptic Perception

- Sensors in the finger tips

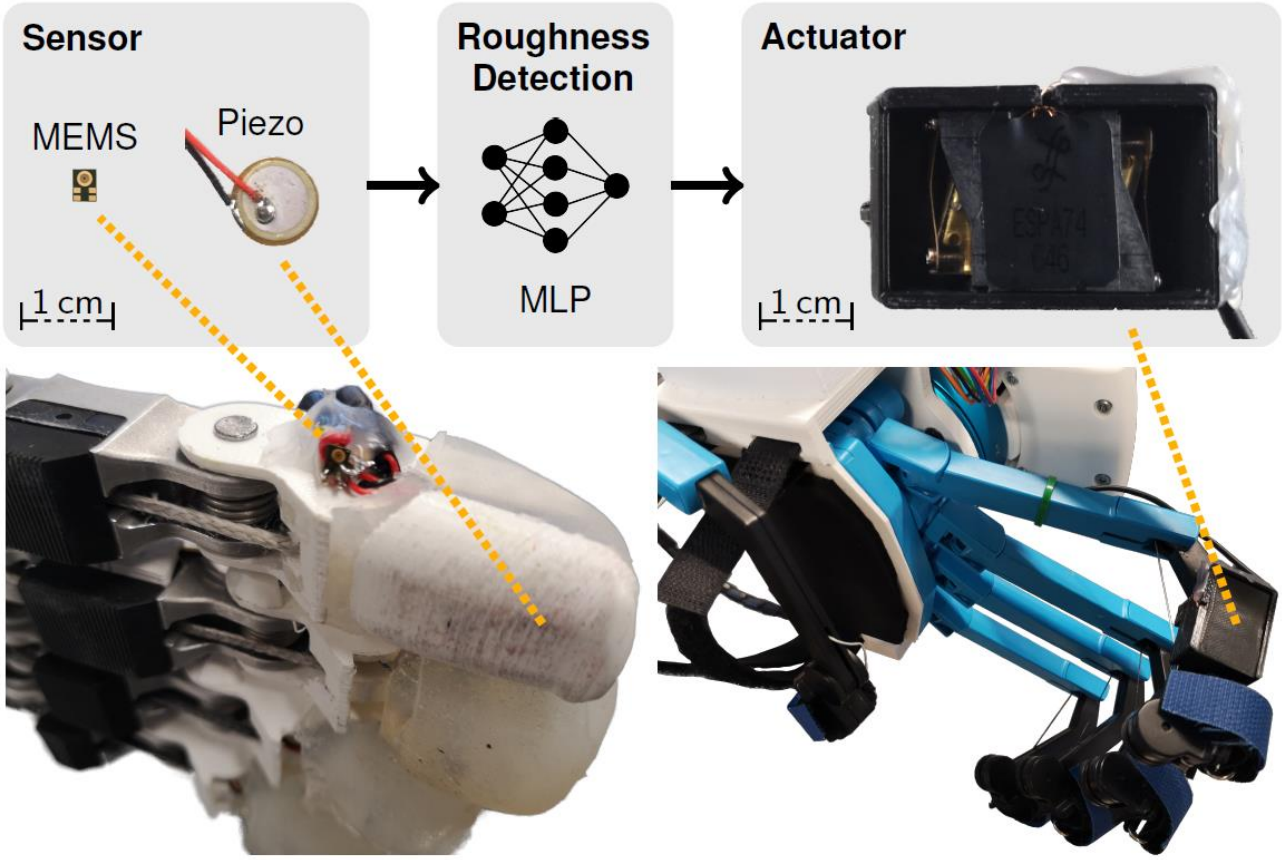


- Actuators on the hand exoskeleton



[Pätzold et al. SMC 2023]

Roughness Perception



Data set of
rough and smooth objects

[Pätzold et al. SMC 2023]

Finals Day 2 Testing

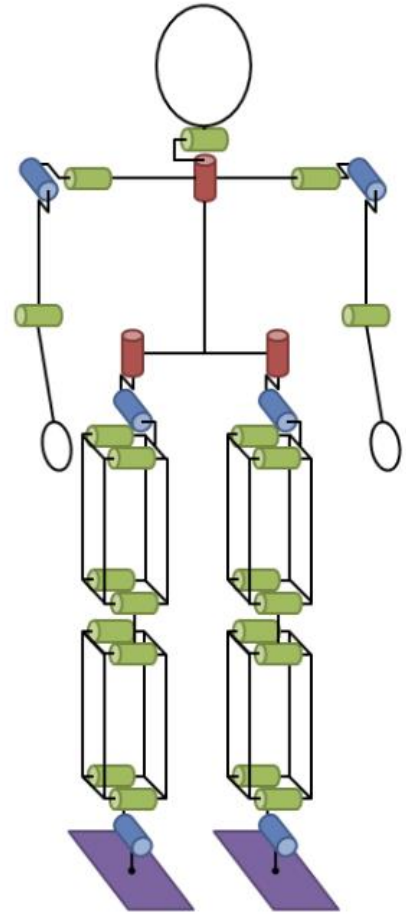
[Lenz, Schwarz et al. SORO 2023]

Team NimbRo

[Lenz, Schwarz et al. SORO 2023]

NimbRo-OP2X

- 135 cm, 19 kg
- 18 DoF
  - 5 per leg (parallel kinematics)
  - 3 per arm
  - 2 in the neck
- 34 Dynamixel XH540 actuators
- Mini-ITX PC
- Nvidia SFF GPU
- Fisheye camera
- LiPo battery (14.8 V, 8 Ah)

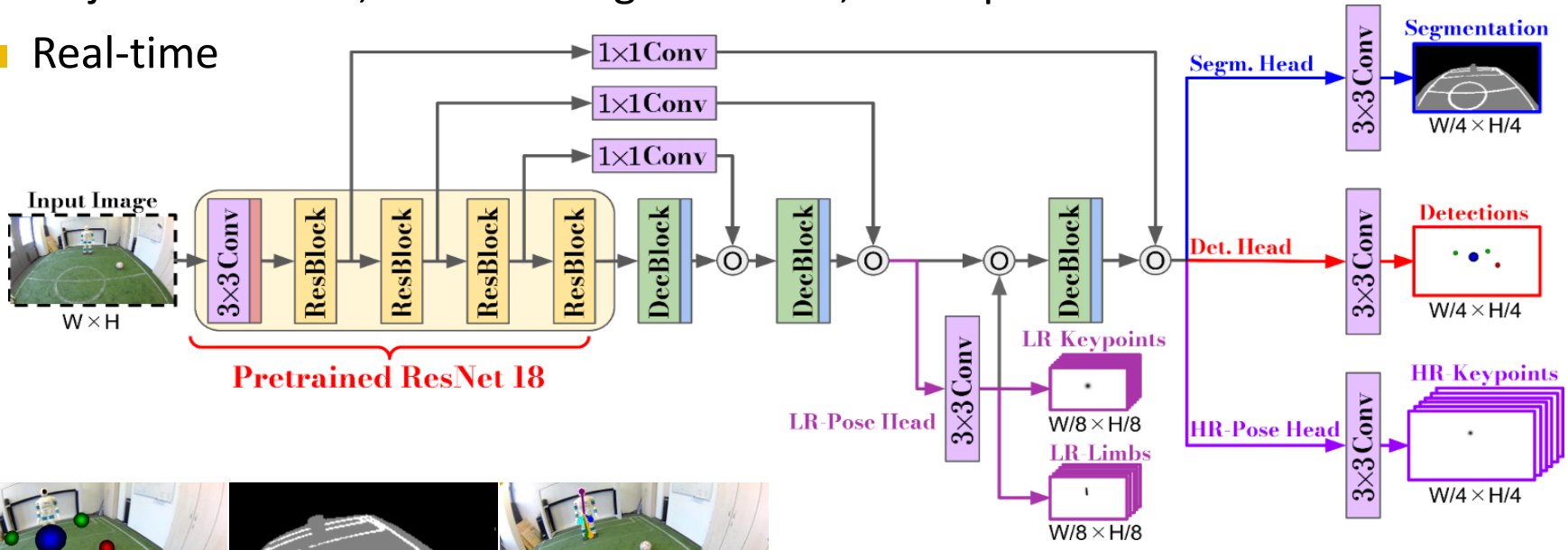


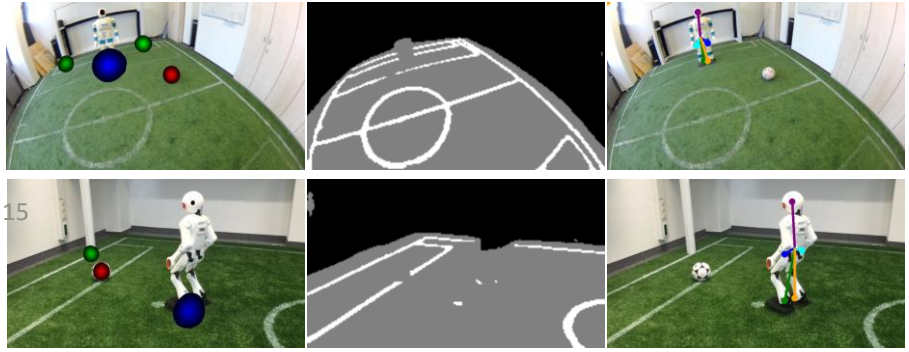
[Ficht et al. IJHR 2020]

RoboCup 2023 Humanoid AdultSize Final

Visual Perception for Soccer

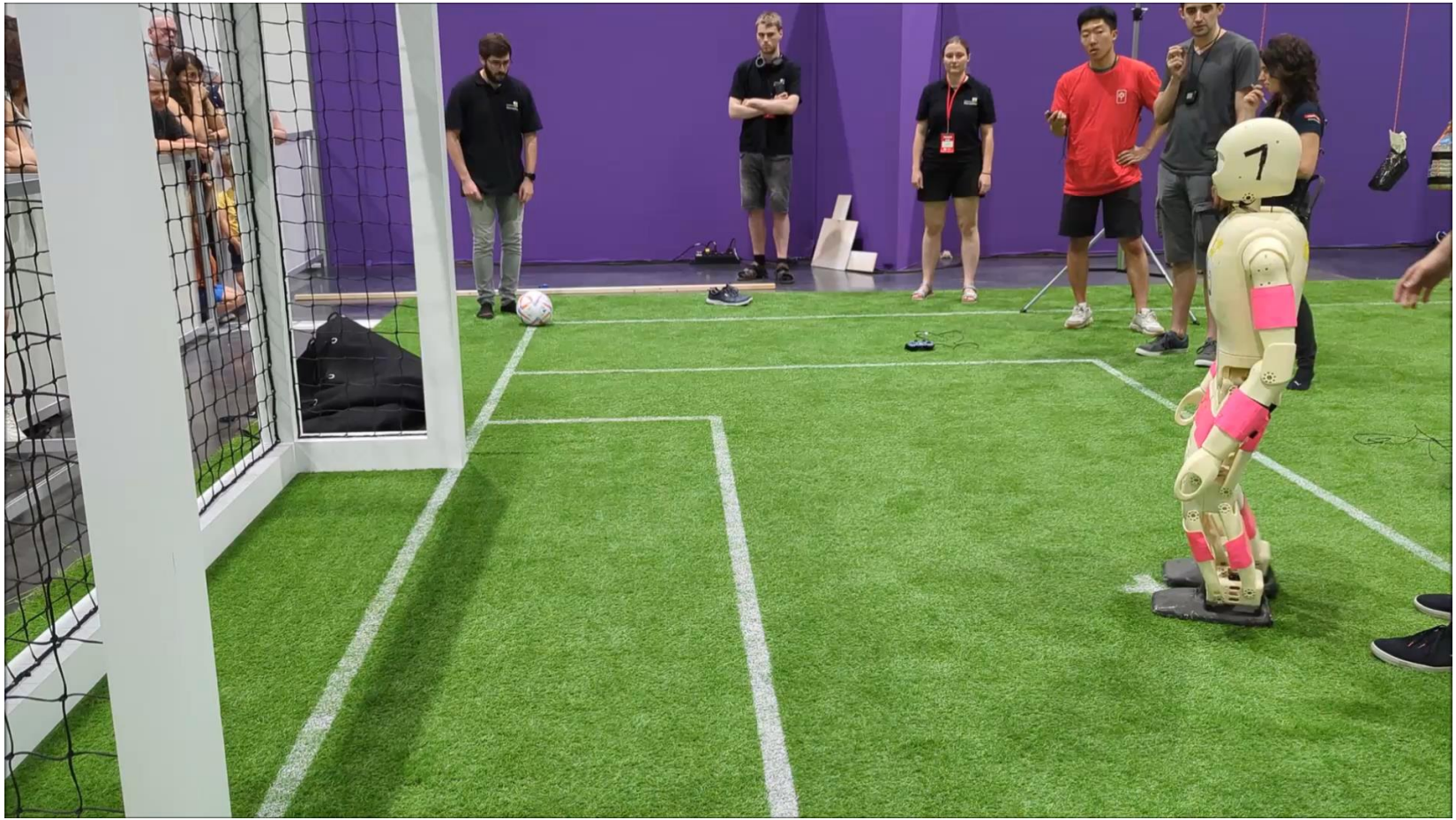
- Object detection, semantic segmentation, robot pose estimation
- Real-time





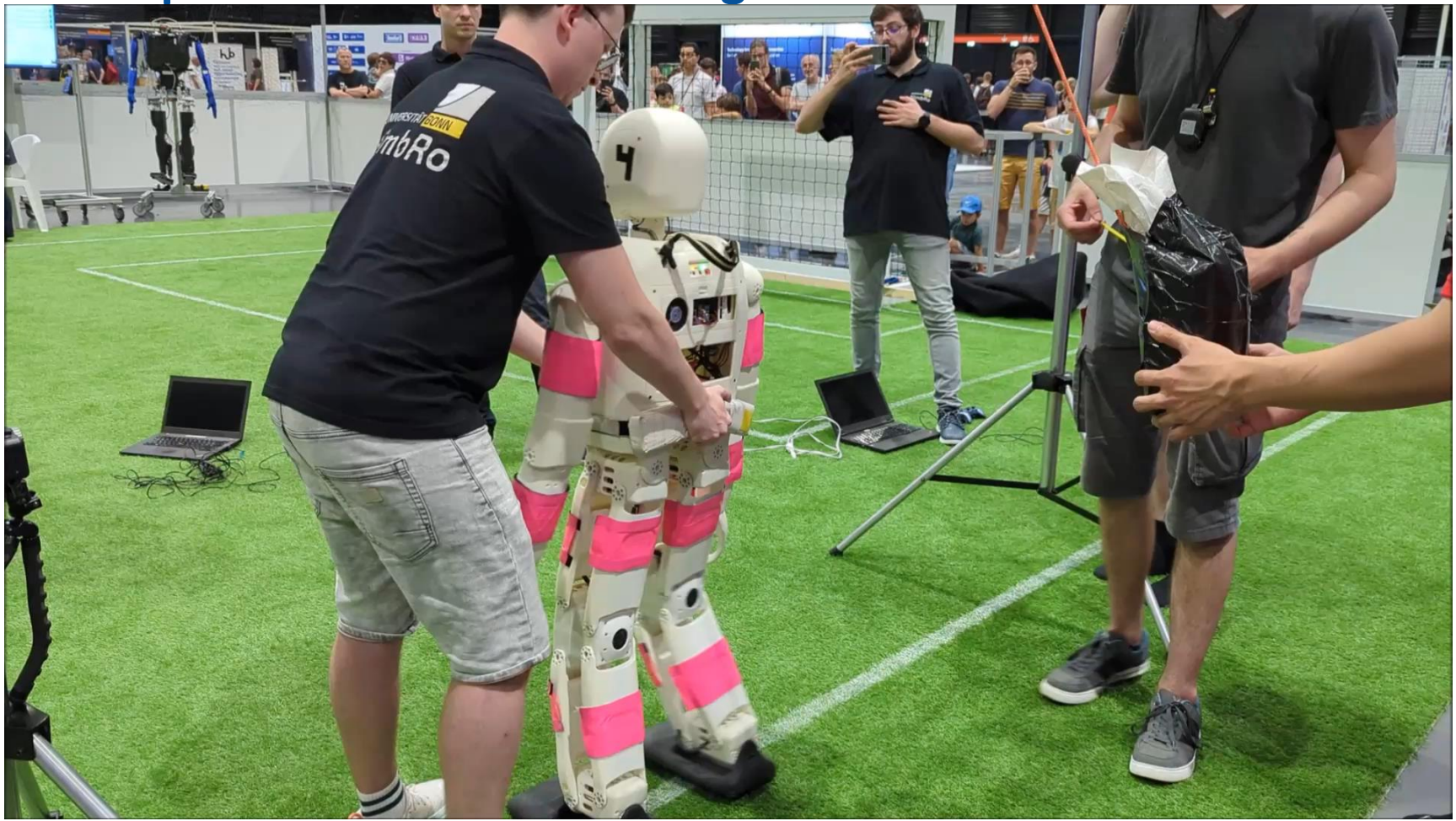
[Pavlichenko et al. RoboCup 2023]

RoboCup 2023 Passing Challenge



[Pavlichenko et al. RoboCup 2023]

RoboCup 2023: Technical Challenges



[Pavlichenko et al. RoboCup 2023]

Team NimbRo @ RoboCup 2023

[Pavlichenko et al. RoboCup 2023]

Conclusions

- Developed capable robotic systems for challenging scenarios
  - Telepresence
  - Humanoid soccer
- Challenges include
  - Mechatronic design
  - 4D semantic perception
  - High-dimensional motion planning
- Promising approaches
  - Prior knowledge (pretrained models, inductive bias)
  - Shared experience (fleet learning)
  - Shared autonomy (human-robot)
  - Instrumented environments