Bi-Manual Articulated Robot Teleoperation *using an External RGB-D Range Sensor*

ICARCV 2018
November 18–21, 2018, Singapore

iit HHCM ISTITUTO ITALIANO DI TECNOLOGIA ADVANCED ROBOTICS
Humanoids & Human-Centred Mechatronics

Emily-Jane Rolley-Parnell, **Dimitrios Kanoulas**, Arturo Laurenzi, Brian Delhaisse, Leonel Rozo, Darwin G. Caldwell, Nikos G. Tsagarakis

contact: *Dimitrios.Kanoulas@iit.it*

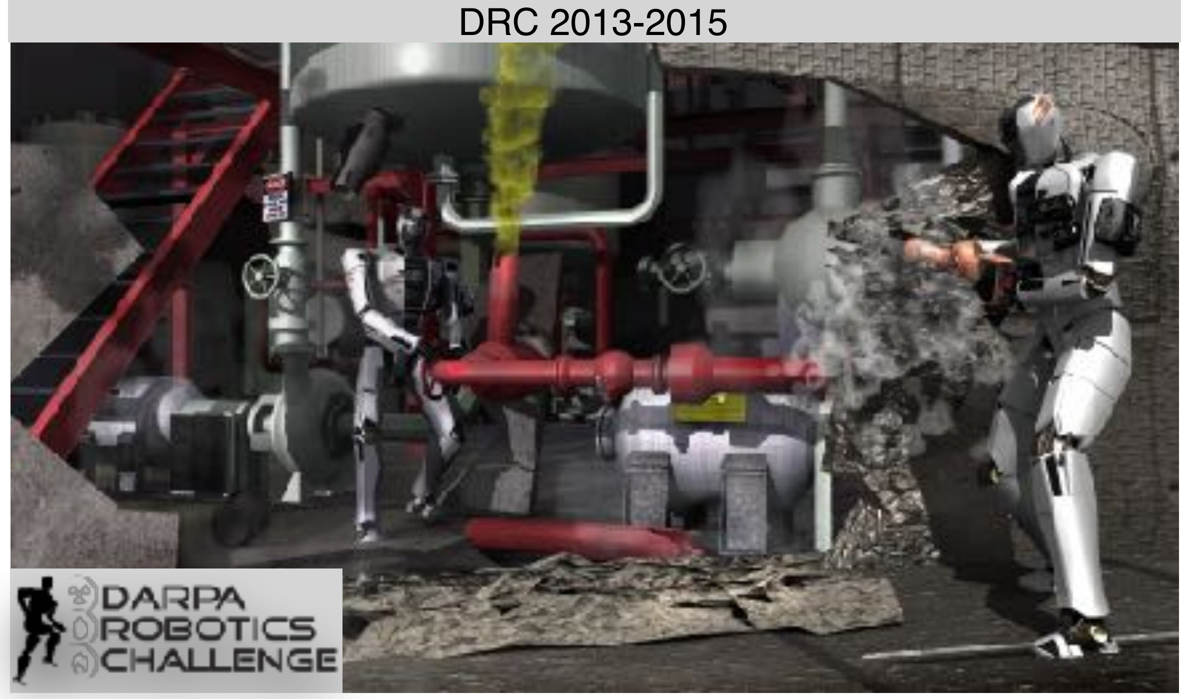
All Sourcecode Provided as Open-Sourced: *https://sites.google.com/view/telepose*

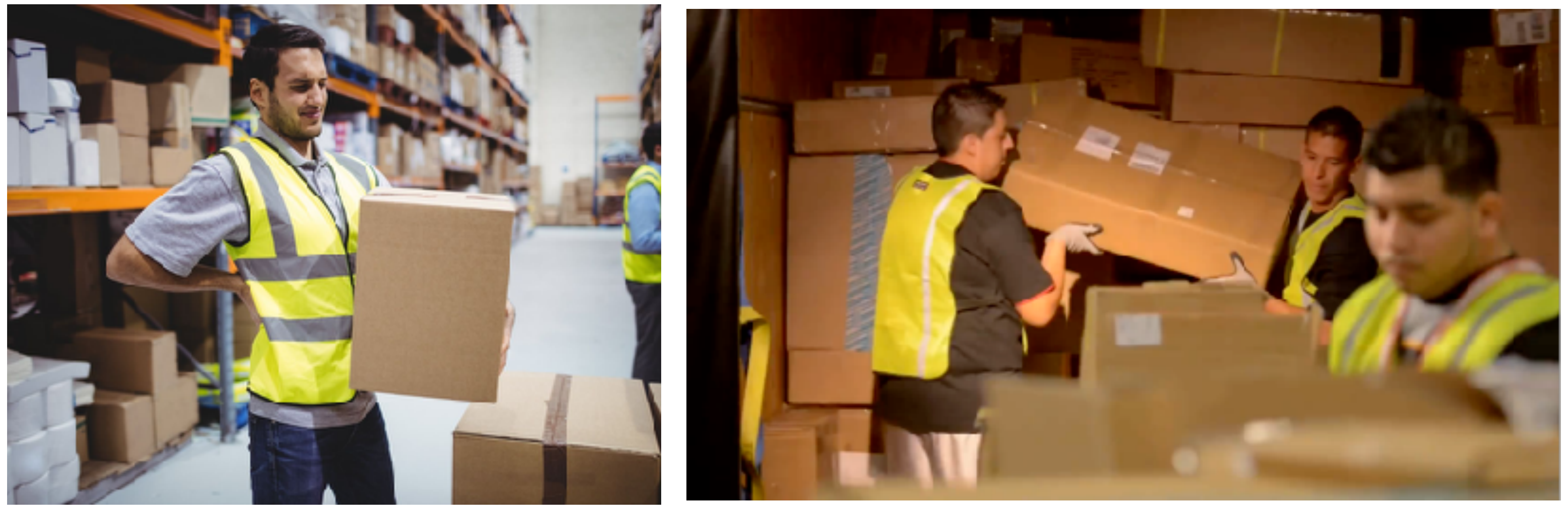
Intuition: limbed robots will aid humans by co-working either in *unstructured*, *uncertain*, or *complex* environments

Our Goal: achieve good manipulation results in a semi-autonomous way, through teleoperation

Tokyo Electric Power Co.'s tsunami-crippled Daiichi nuclear power plant's reactor building number 4, Fukushima, 5 July, 2012 [Reuters]

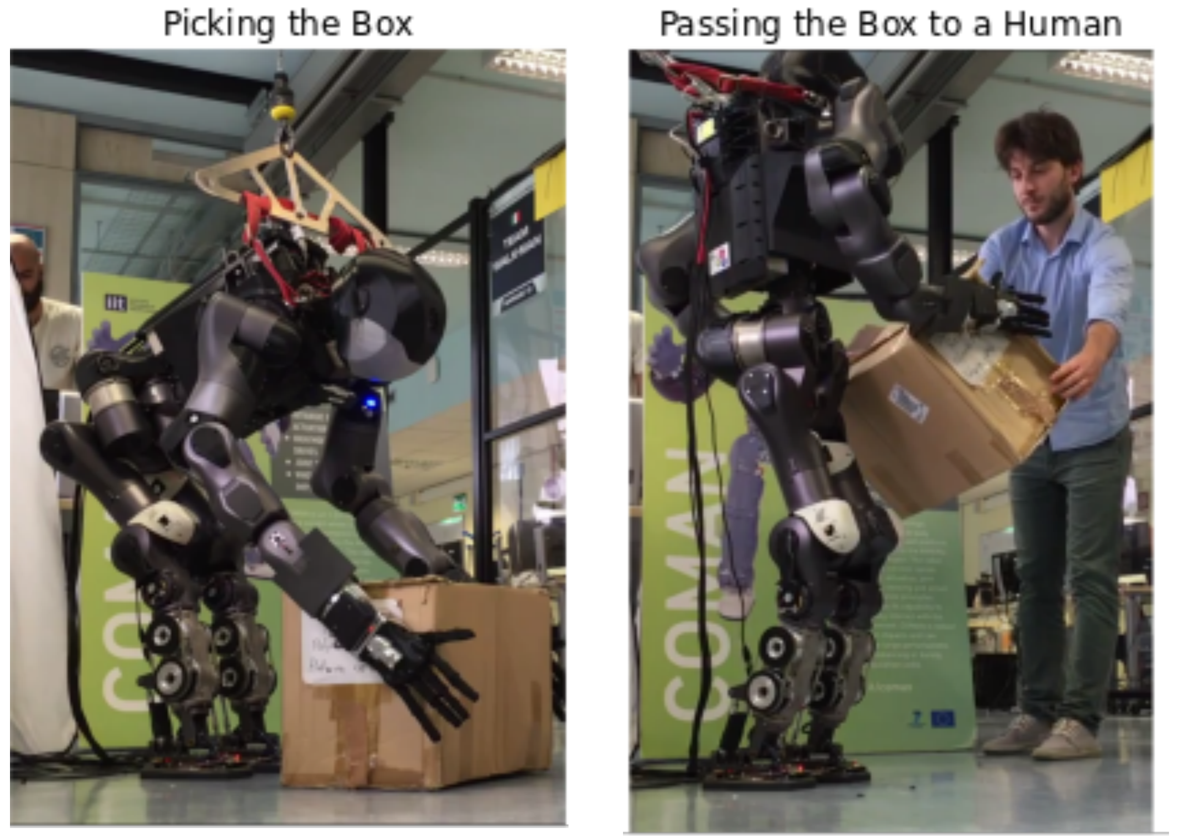
disaster intervention





Workers lifting heavy boxes daily in industrial environments

industry 4.0 intervention



IIT COMAN+ picking up boxes

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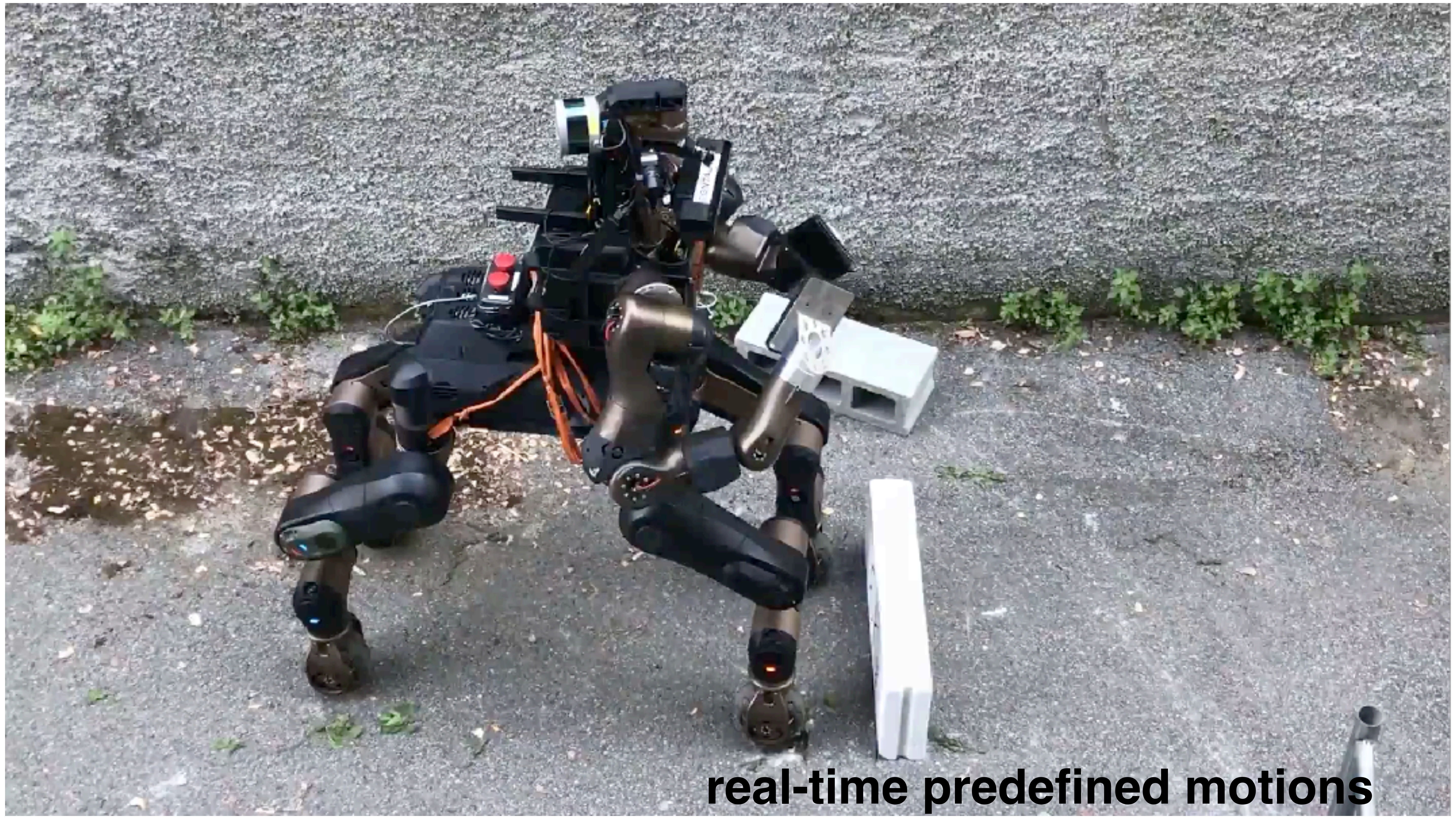

HalfMan/CENTAURO/Pholus

Centaur-like robot for 1) powerful manipulation
2) disaster scenarios

Height: 1.5m **Weight**: 93Kg
DoF: 42DoF 2DoF (hands)

Hardware: SEA
Joint Torques Sensors
4x6 F/T Sensors,
Lidar and RGB-D

Computing: 1 COM Express
2 i7 PC (GPUs)

Battery: 1.6KWh(2.5h)

Material: Aluminum, Titanium,
Magnesium Allow Plastics

Arm: Payload >10Kg
Payload/Weight Ratio >1.0
Joint Vel: 7rad/sec & 9rad/sec

EU H2020 Projects

HORIZON 2020

CENTAURO

CoGIMoN
Cognitive Interaction in Motion

WALK-MAN

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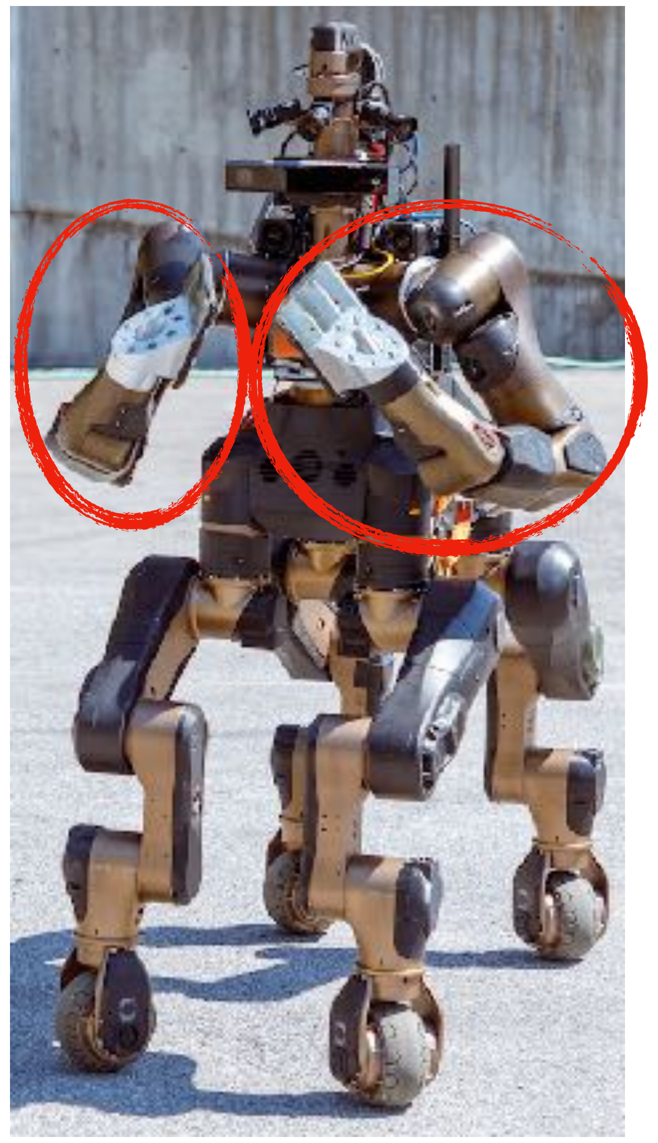
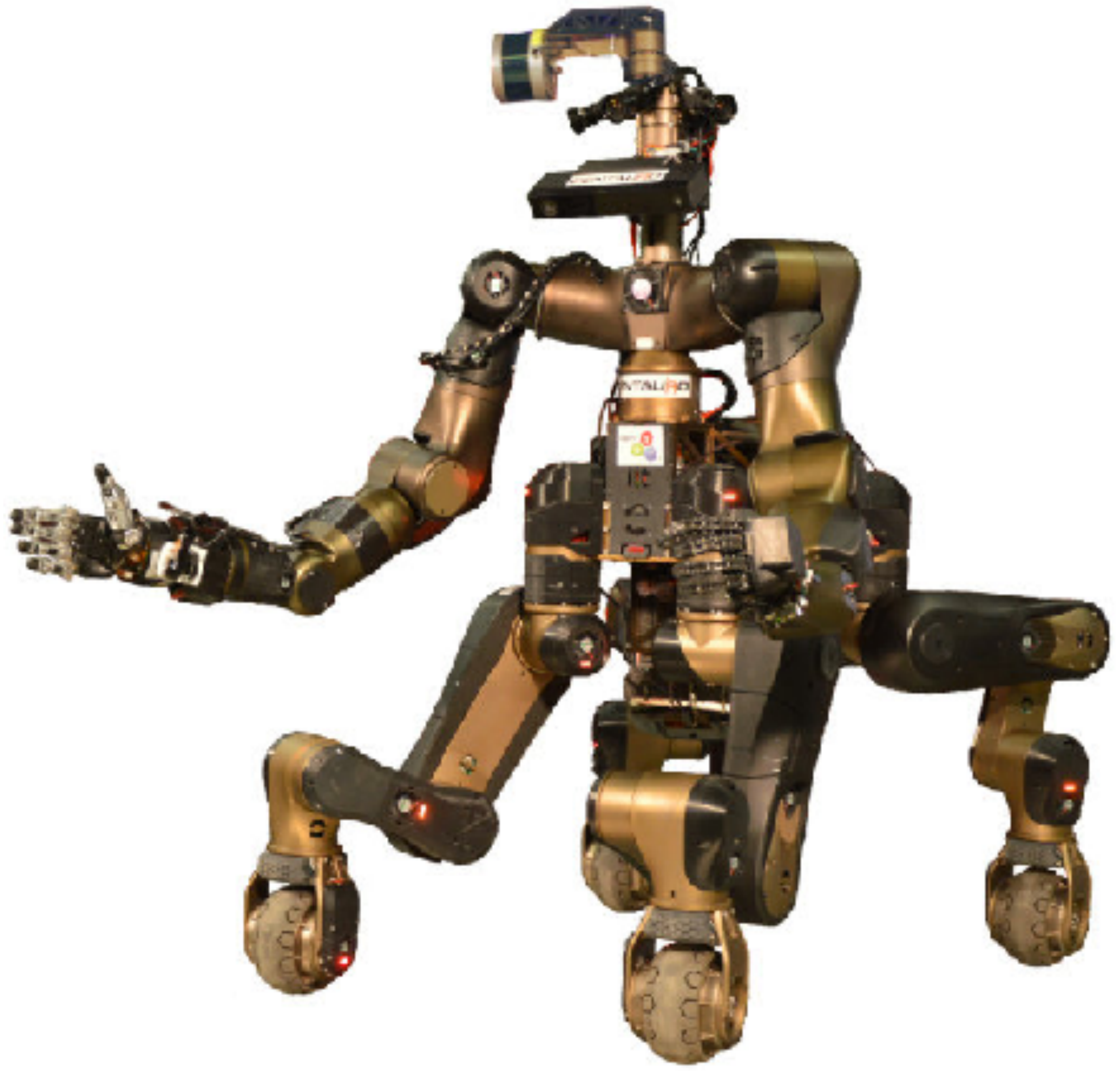
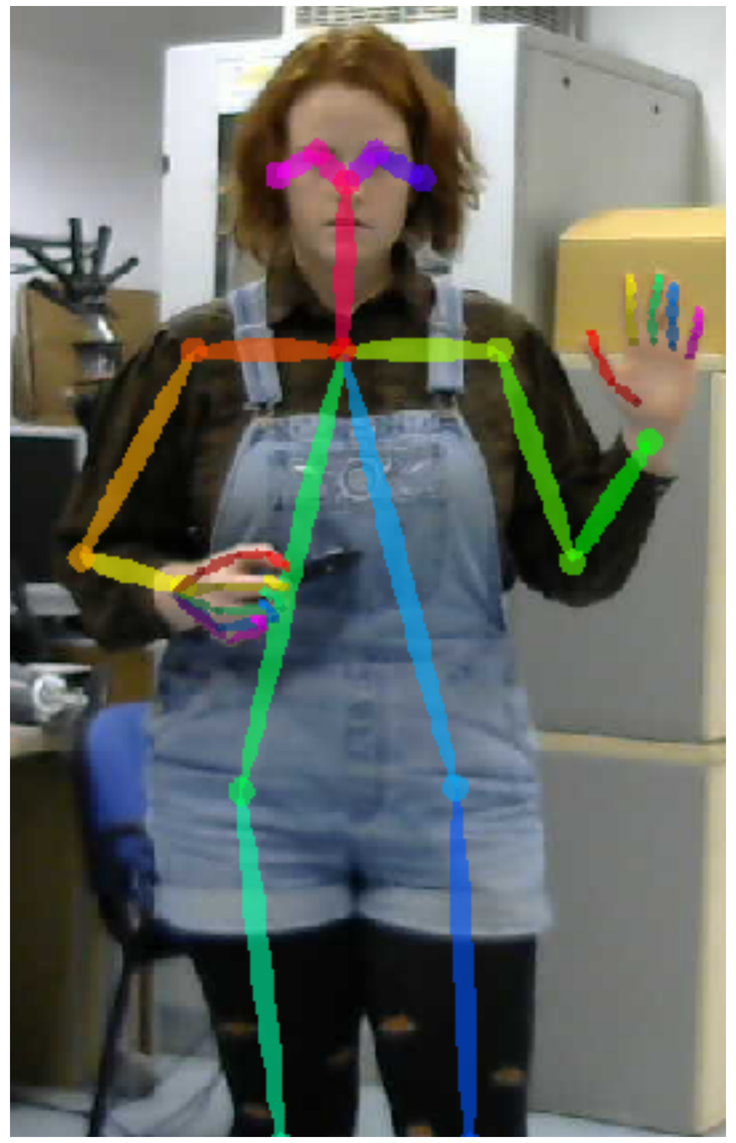
This Work's Goal

enable bi-manual articulated robot teleoperation using a cheap external RGB-D sensor







ASUS Xtion PRO

help humans with heavy, dangerous, or redundant tasks

valve turning

box lifting

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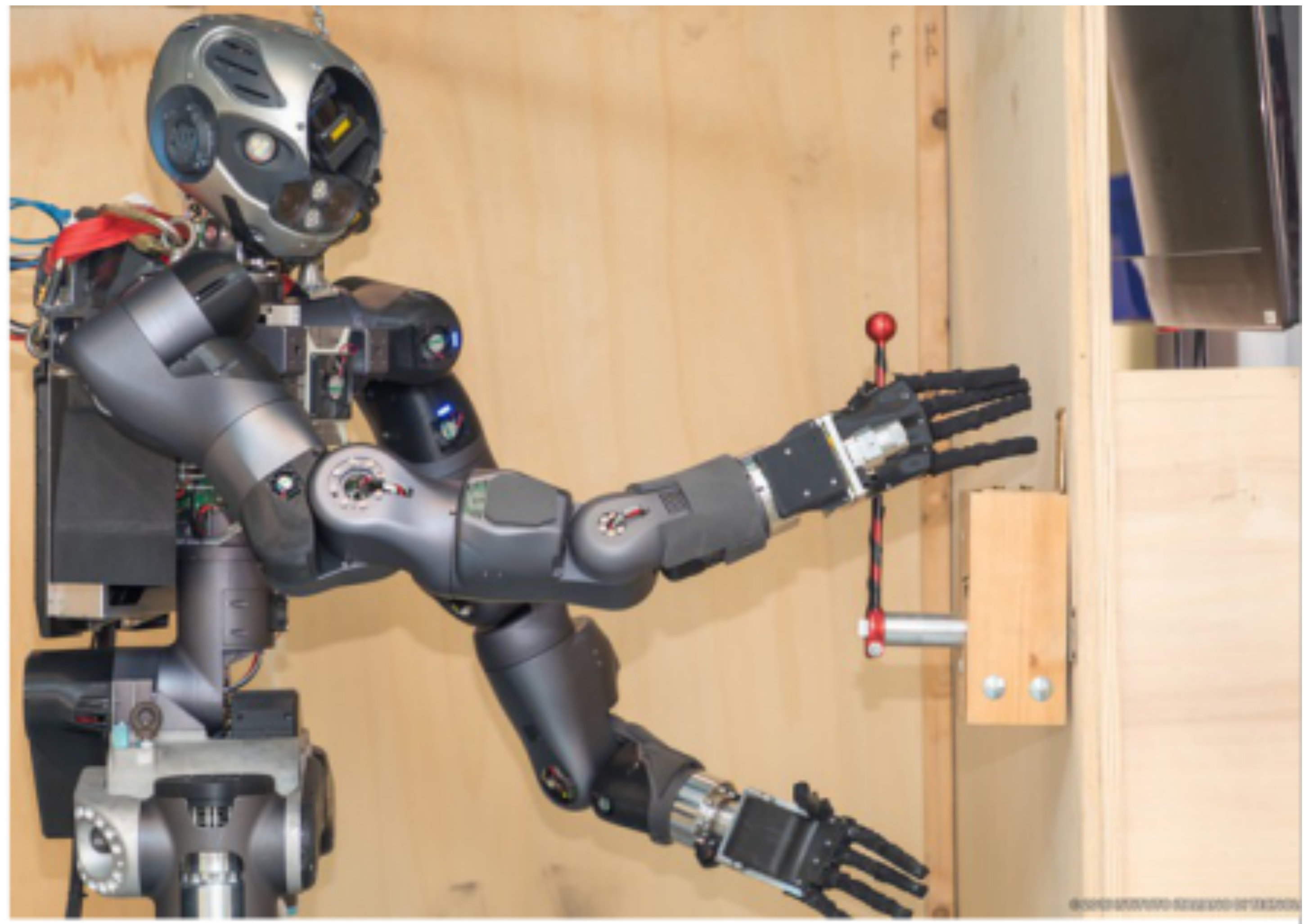
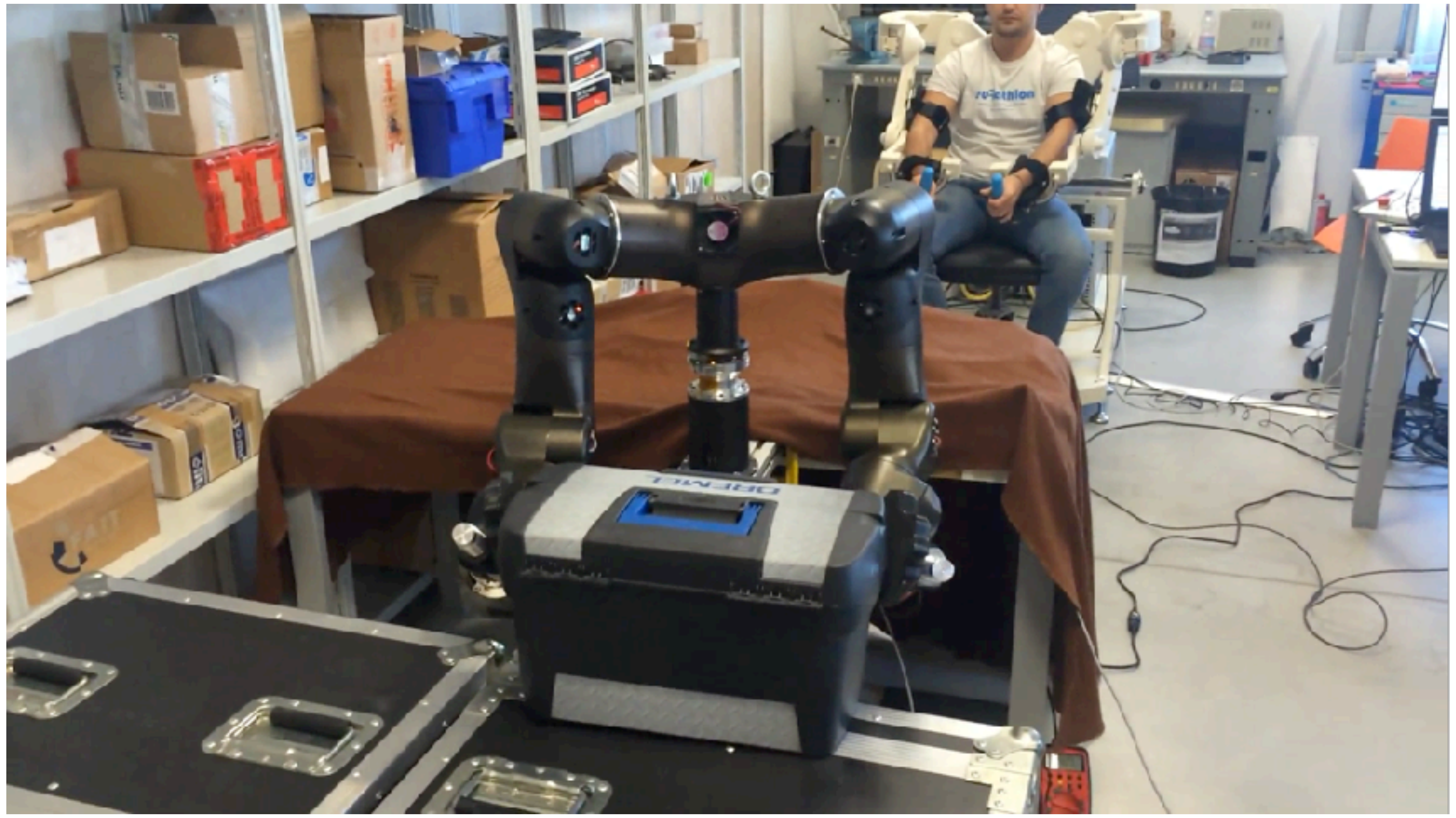


Previous Teleoperation Methods

1) body suits of IMU sensors
2) exoskeletons
3) motion-capture cameras or markers
4) GUIs or joystick-like tools

Issues

1) cost
2) speed
3) calibration
4) drifts



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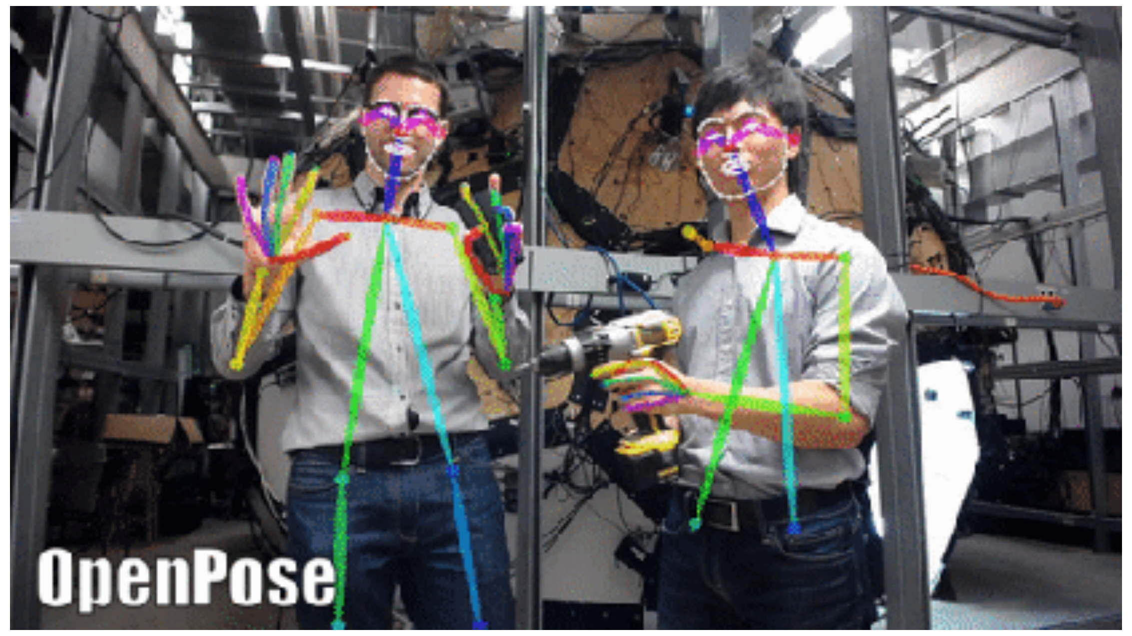
Method

- 3D human skeleton extraction, through RGB and range sensing
- Use of OpenPose (CNN) and map to the robot, through whole-body control

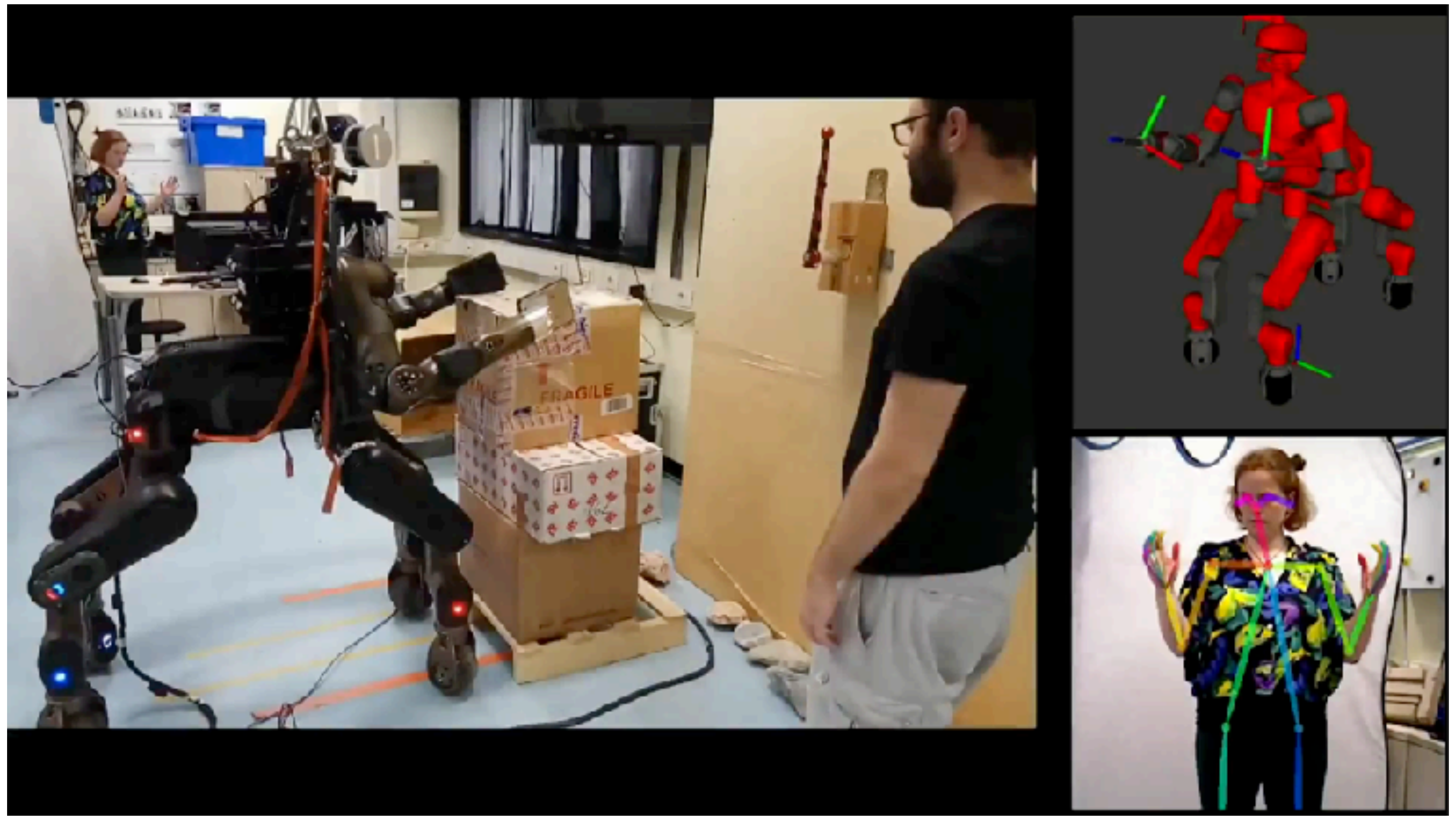


OpenPose [Z. Can et. al, CVPR'17]

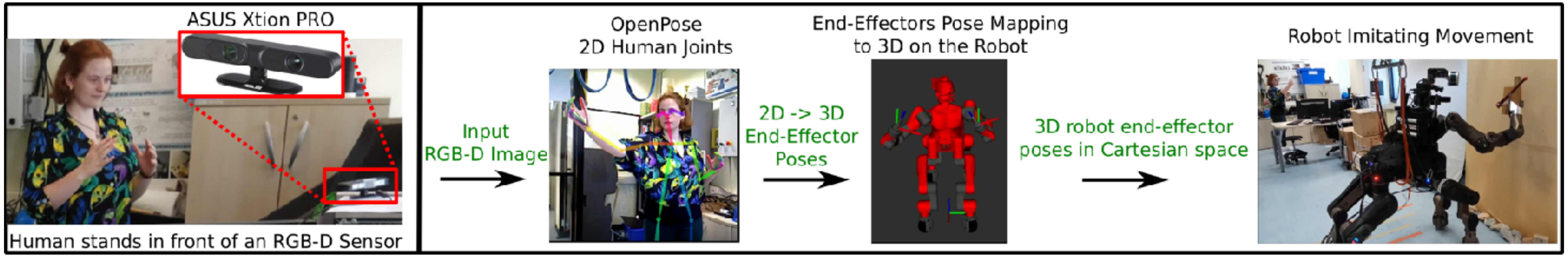
\+

Whole-Body Cartesian IK SoT

Help Humans for Heavy Tasks: *Box Lift Task*



Steps



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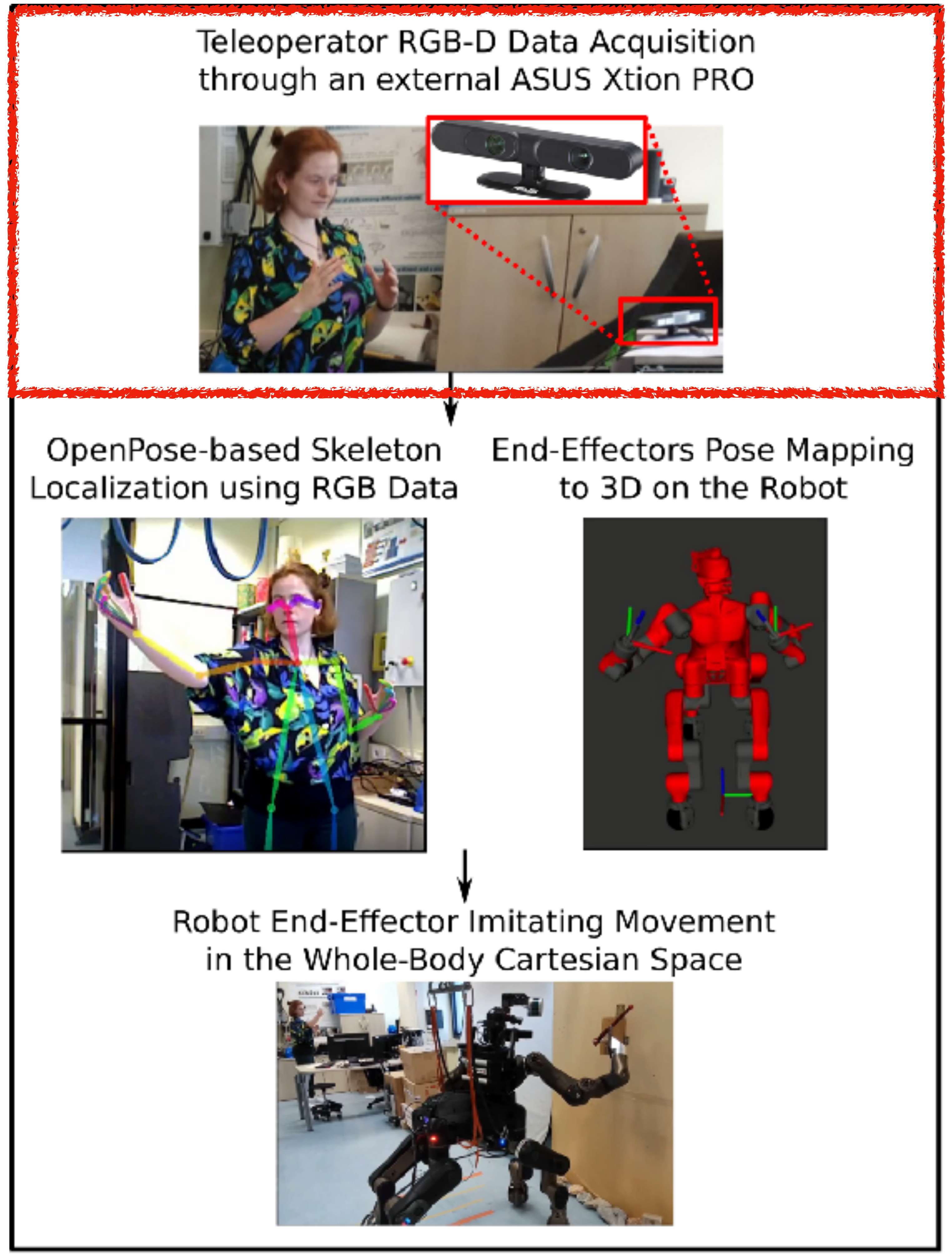
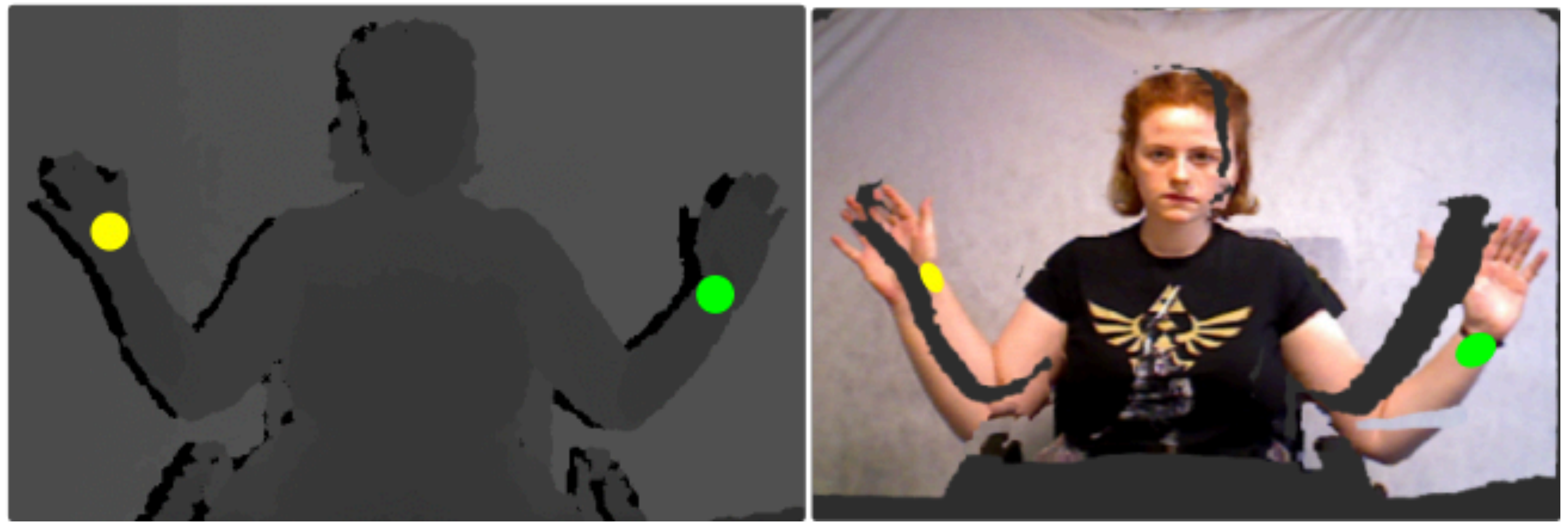


1. RGB-D Sensing

Depth Image Input   RGB-D PointCloud Input



ASUS Xtion PRO

Input: 640x480 grid-organized RGB-D data in 30Hz

Issues: mismatch between color and depth data due to calibration errors (pixels around depth discontinuities)

Solution: use point's nearest neighborhood of organized point clouds

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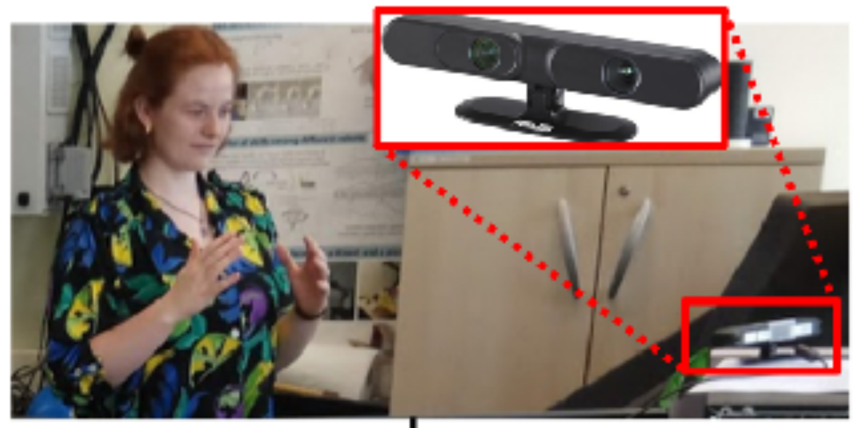
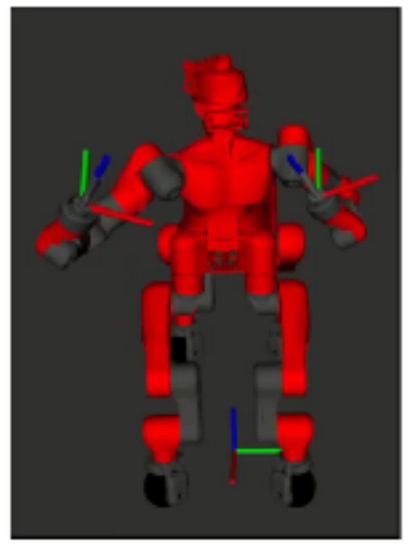
Teleoperator RGB-D Data Acquisition through an external ASUS Xtion PRO



OpenPose-based Skeleton Localization using RGB Data

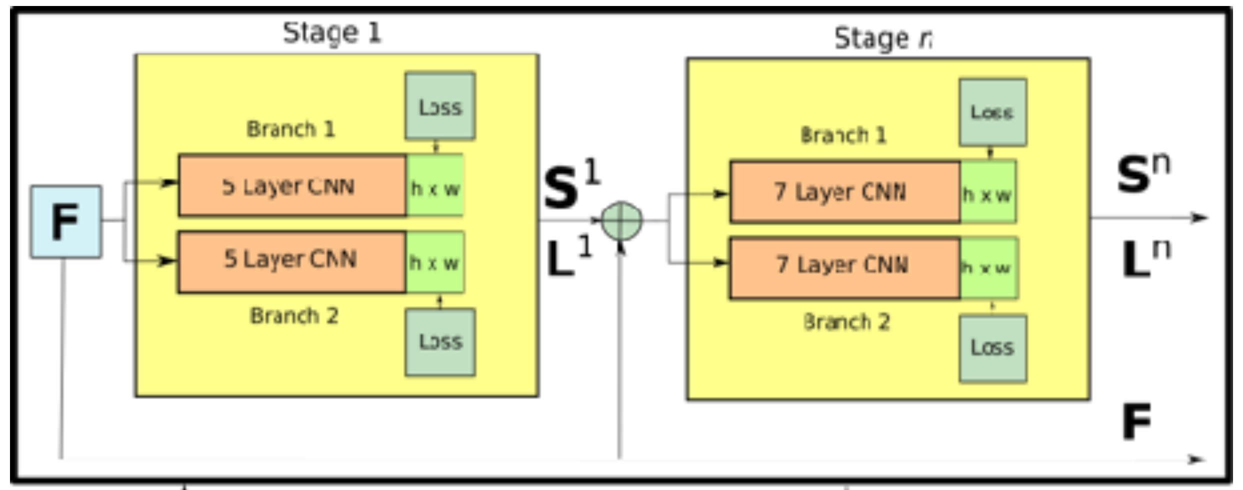
End-Effectors Pose Mapping to 3D on the Robot

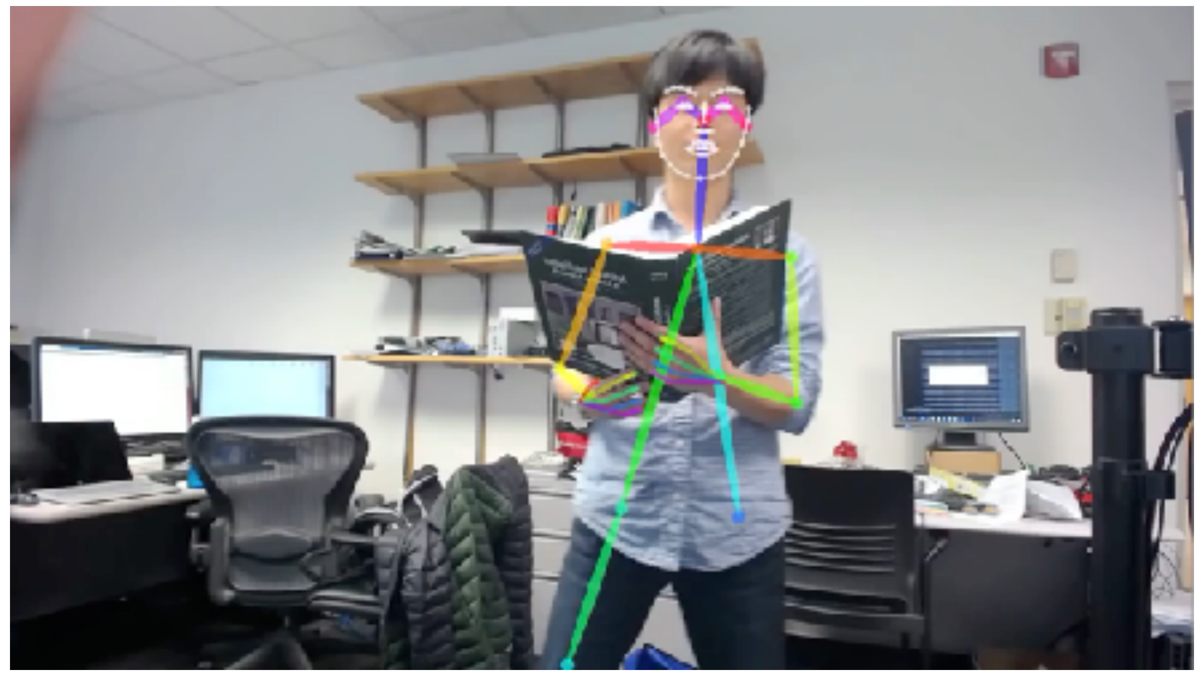


Robot End-Effector Imitating Movement in the Whole-Body Cartesian Space

2. Extracting 2D Human Positions with OpenPose

OpenPose feed-forward deep CNN Architecture [Z. Can et. al, CVPR'17]:





- **part confidence maps S^n**
  a set of 2D confidence maps of body part locations
- **part affinity fields L^n**
  encode the location and orientation of limbs over the image domain

Results:

- robust tracking of both body and hands parts of humans in 2D
- reliable in preventing occlusions & misidentification by proximity

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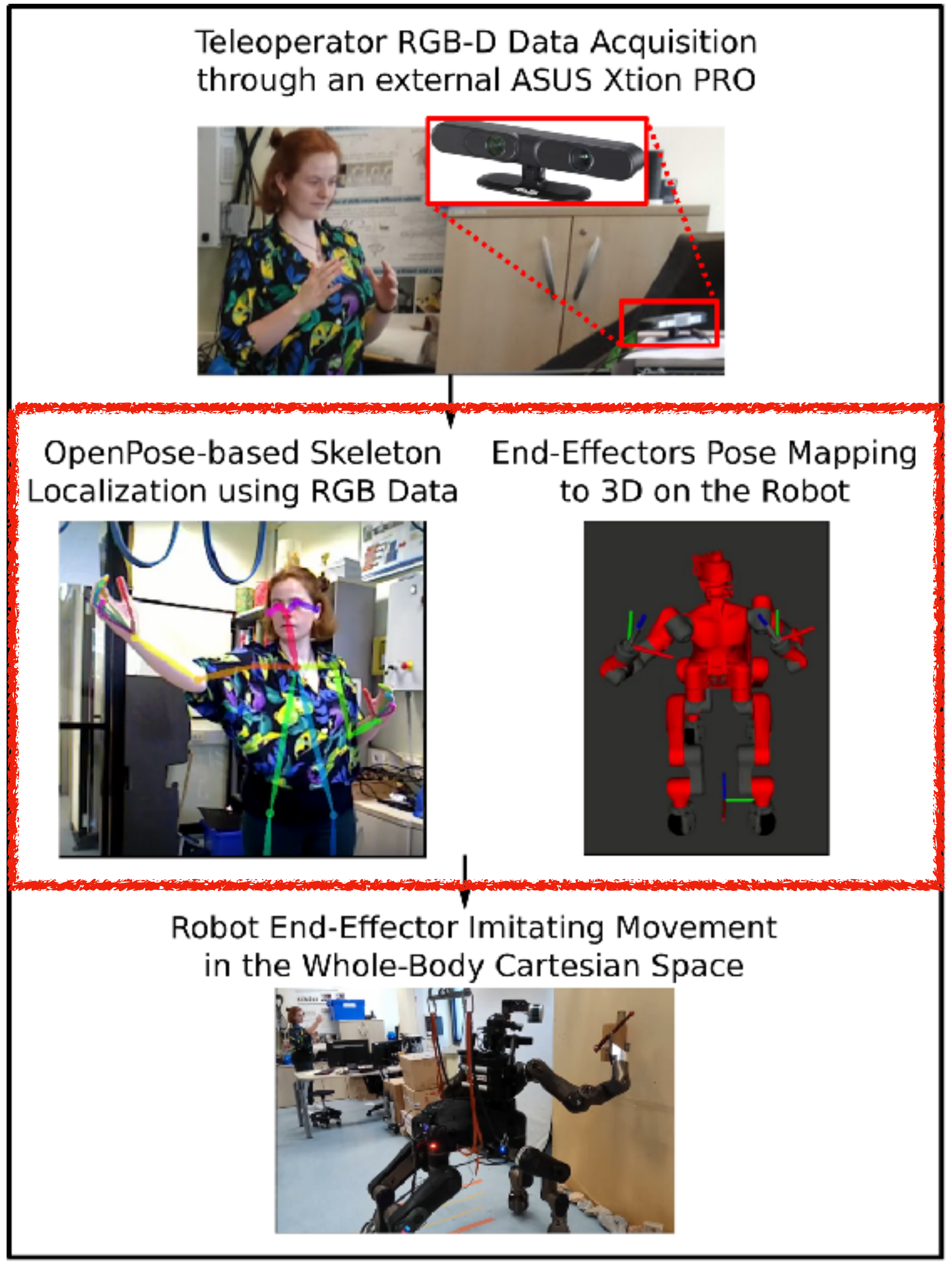

3. Mapping 3D Human Positions & Hand Orientation

to control the robot end-effectors -> map human 2D hand positions in 3D

Issues:

1. Inaccurate depth errors due to calibration

2. Body occlusions

Solution: use point's nearest neighborhood of organized point clouds

Solution: no mapping and control accordingly the robot

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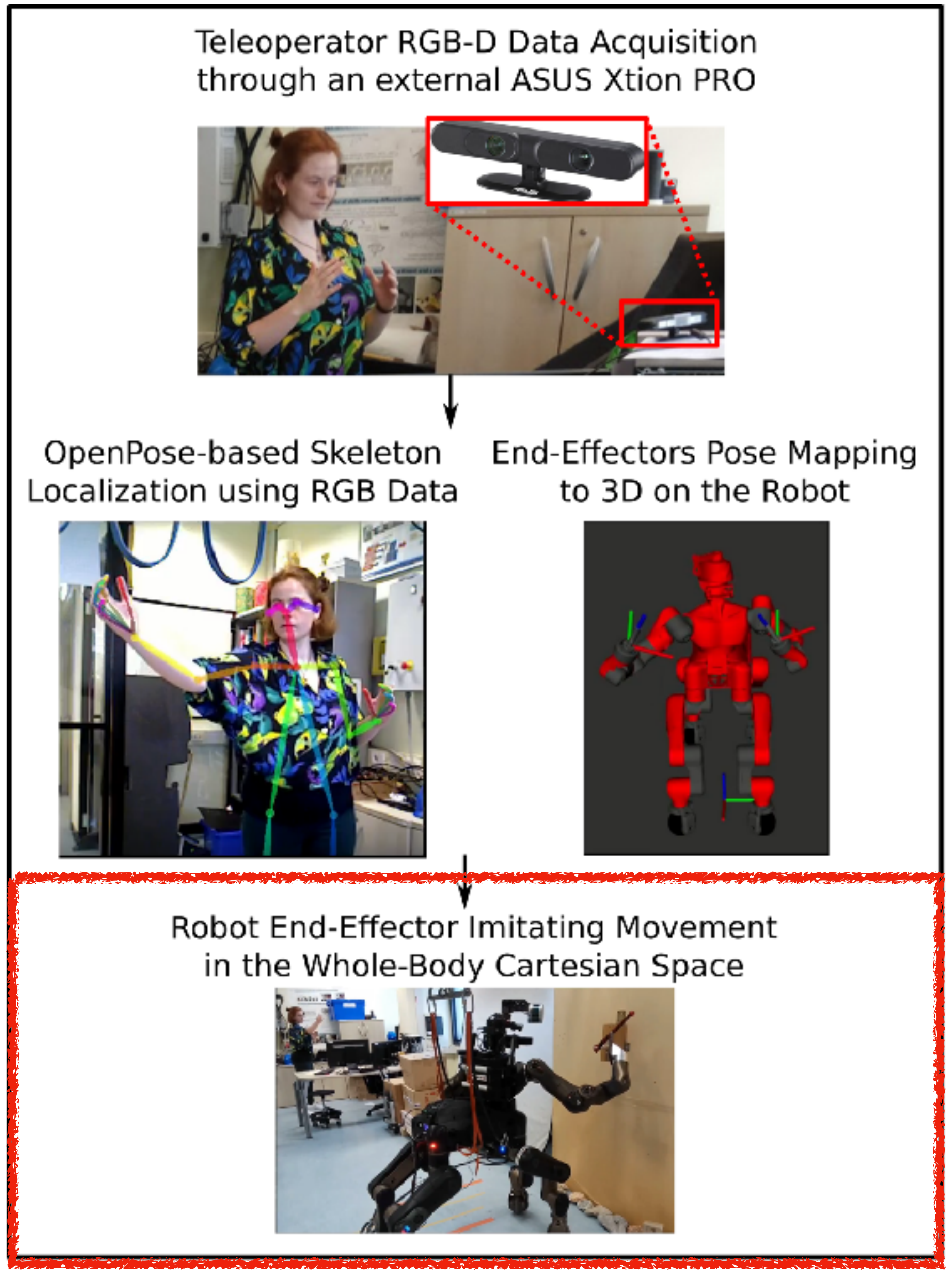
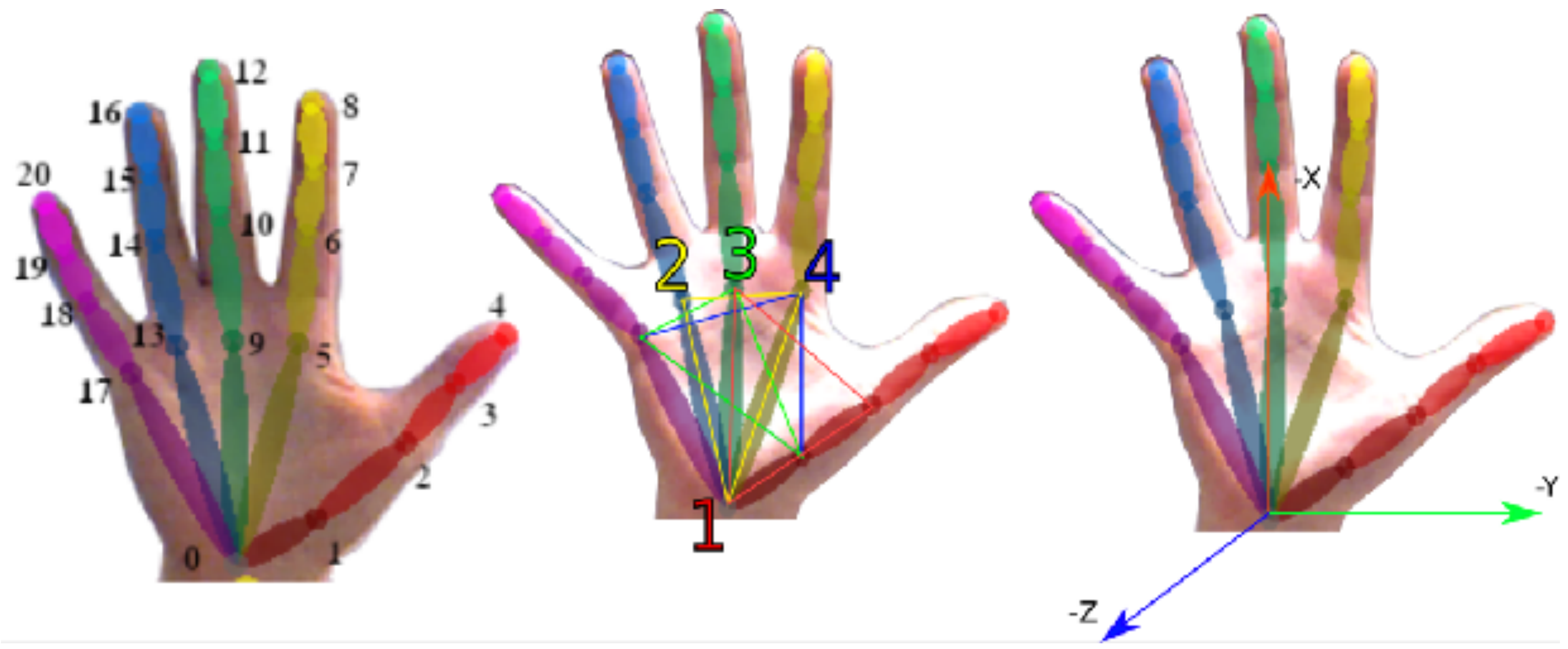


4. Robotic Hand 6-DoF Pose Control

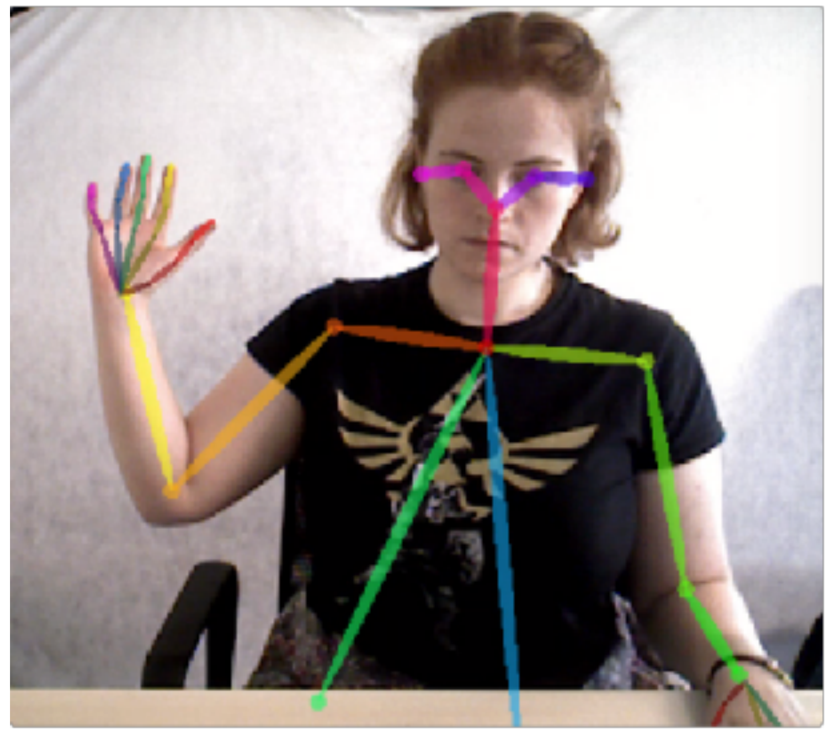
4.1 Robotic Hand Position: at every frame move the robot's end-effector as much as human's, measured from the previous frame.

Results: simple & maintains reasonable accuracy by preventing drifts

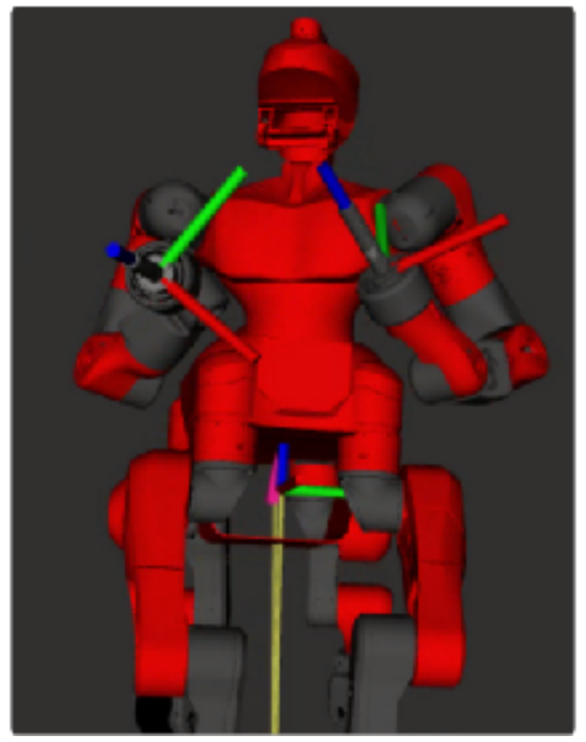
4.2 Robotic Hand Orientation: generate triangles on the human's hand.



OpenPose Pose Visualisation



Centauro Simulation



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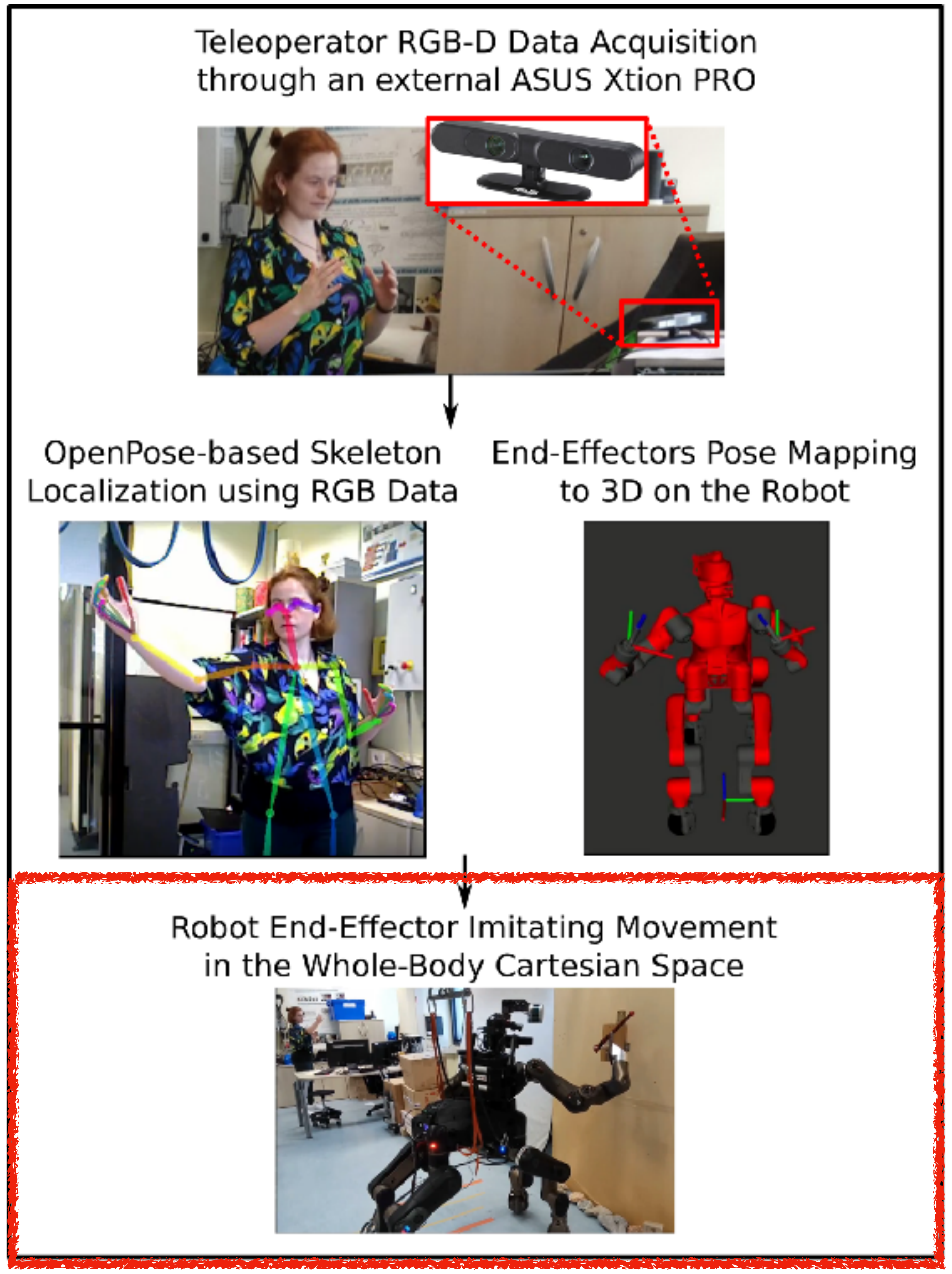


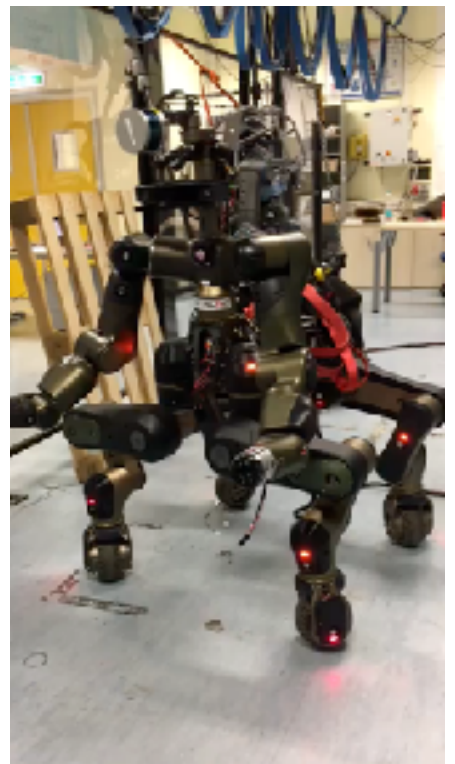
4. Robotic Hand 6-DoF Pose Control

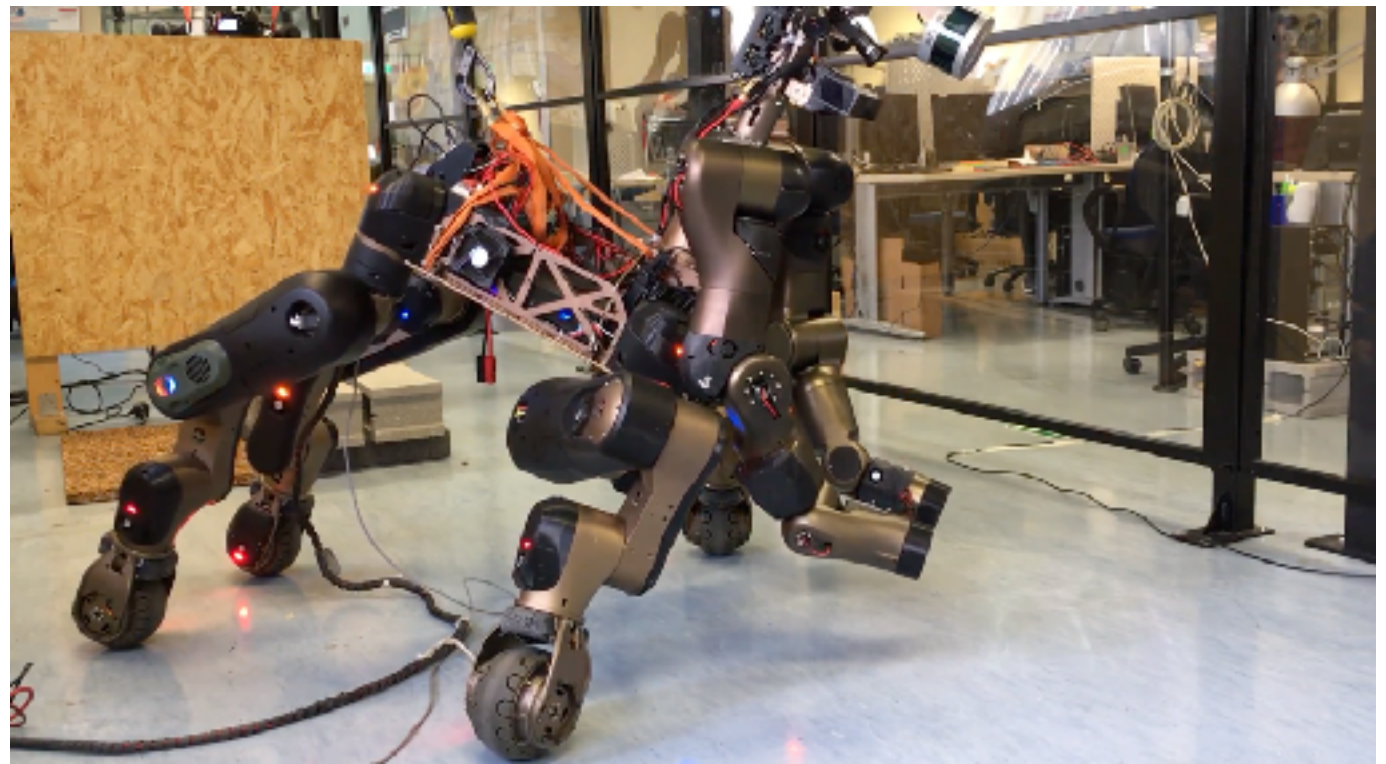
4.3 Cartesian Interface on the CENTAURO Robot: hard real-time control of the robot in the Cartesian space.

OpenSoT (hierarchical whole-body control): *the kinematic solver updates the joints accordingly.*

Cartesian Interface: *smoothing and interpolating the path of hand end-effectors*

Task Solutions Constraints: *1) joint limits, 2) self-collisions, 3) joint velocities 4) Cartesian constraints, 5) CoM-based balancing*





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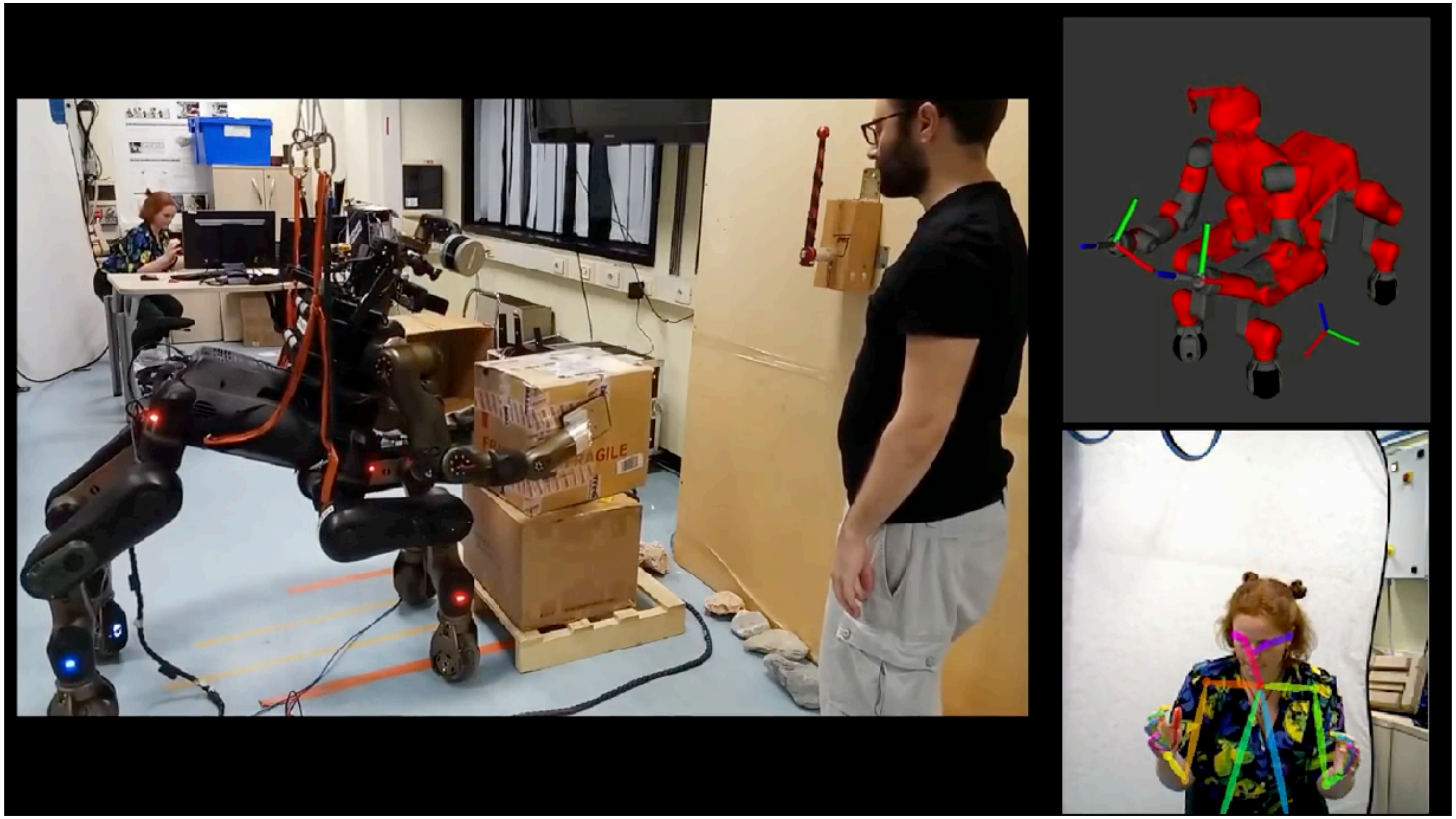
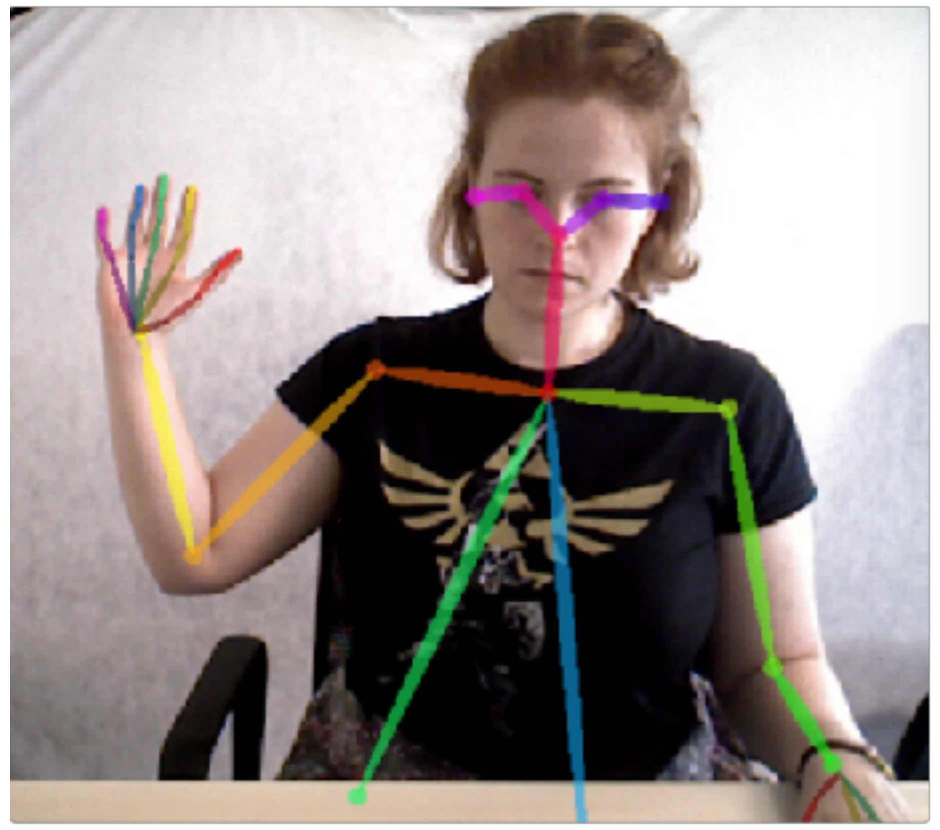
Experimental Results: 1) Box Push, 2) Lever Move, 3) Box Lift

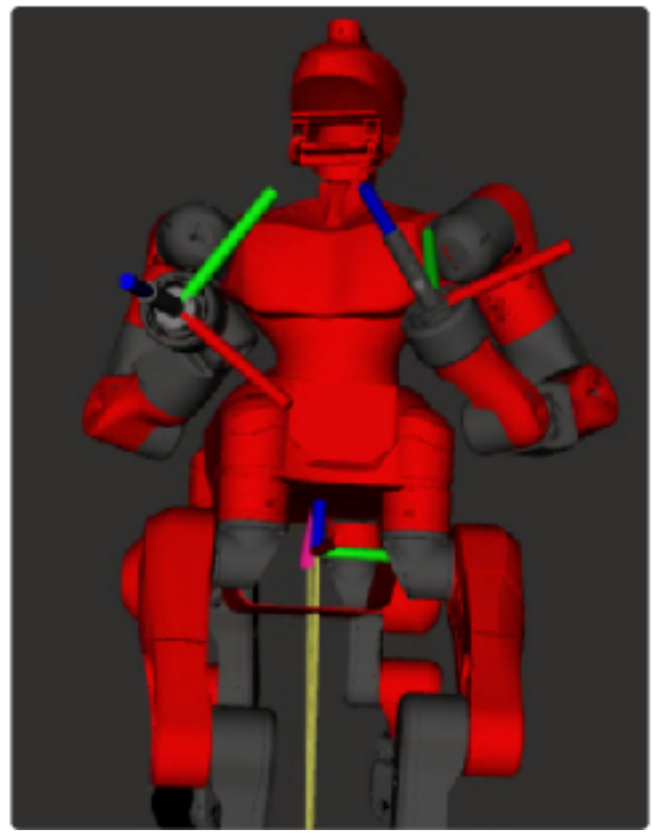


Experimental Results in Simulation (Gazebo)

OpenPose Pose Visualisation

Centauro Simulation





Euclidian distance error: ~0.10m for 1.00m tracking

Frequencies

Frequency of Message Published						
Stage	**OpenNI2**		**OP**	**OPToROS**		**Pt2Xbot**
ROS Msg	I_R	PCL2	keypts	r_hand	r_arm	r_robot
Freq (Hz)	29.82	29.98	8.07	6.65	6.75	7.13

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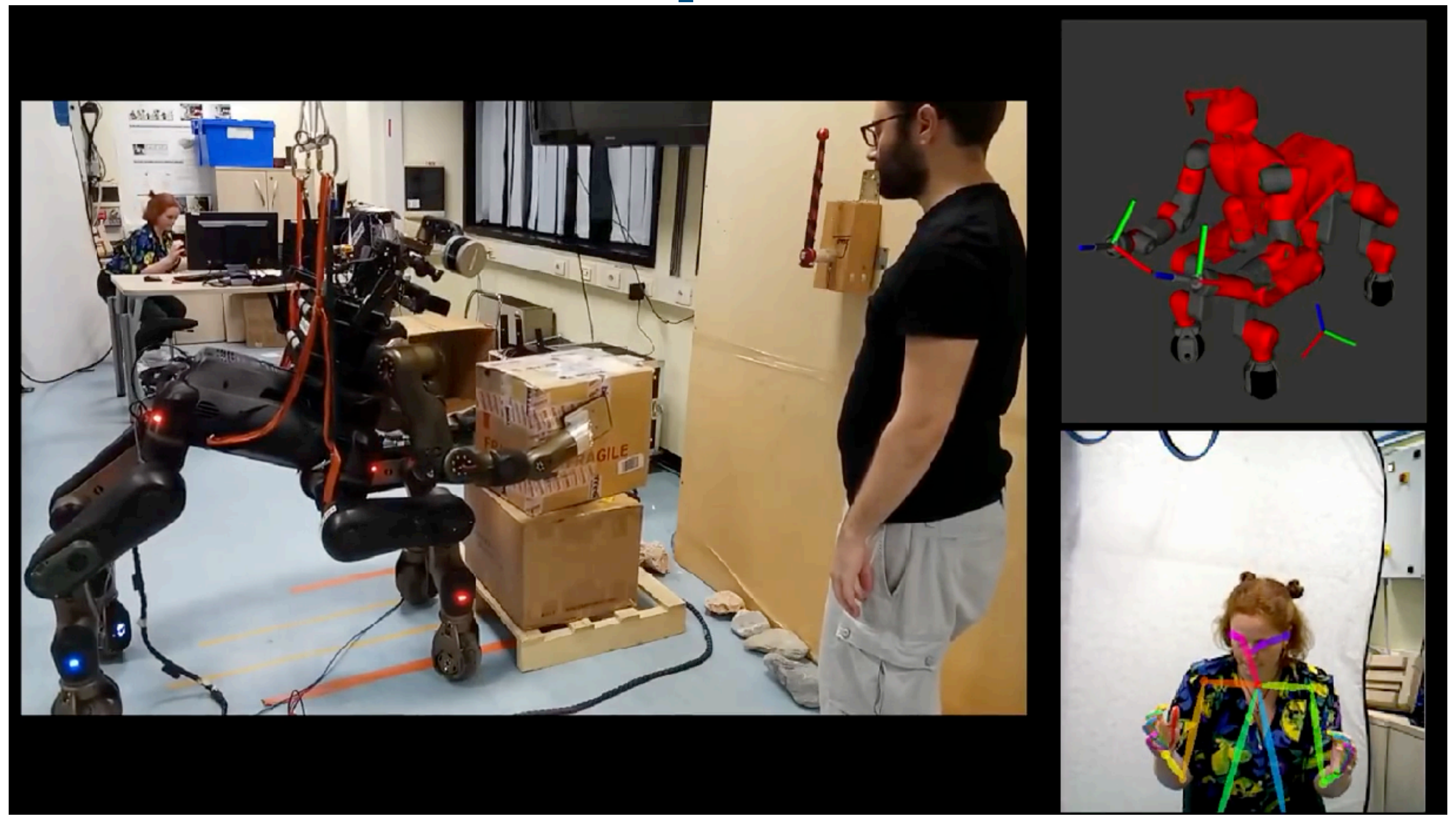
Future Work

Moving from Predefined Motions to Teleoperation to Fully Autonomy

Predefined Motions

Teleoperation



Fully Autonomy