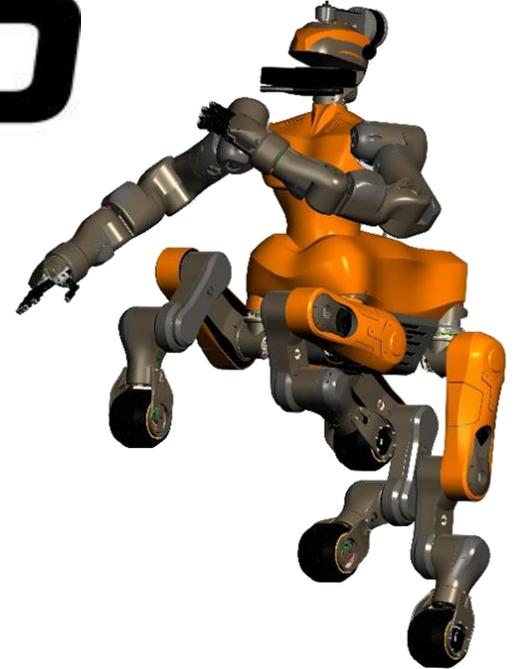


H2020 RIA



CENTAURO

**Robust Mobility and Dexterous Manipulation in
Disaster Response by Fullbody Telepresence in
a Centaur-like Robot**



Nikos Tsagarakis on behalf of Sven Behnke (Coordinator)
& CENTAURO Consortium



Motivation

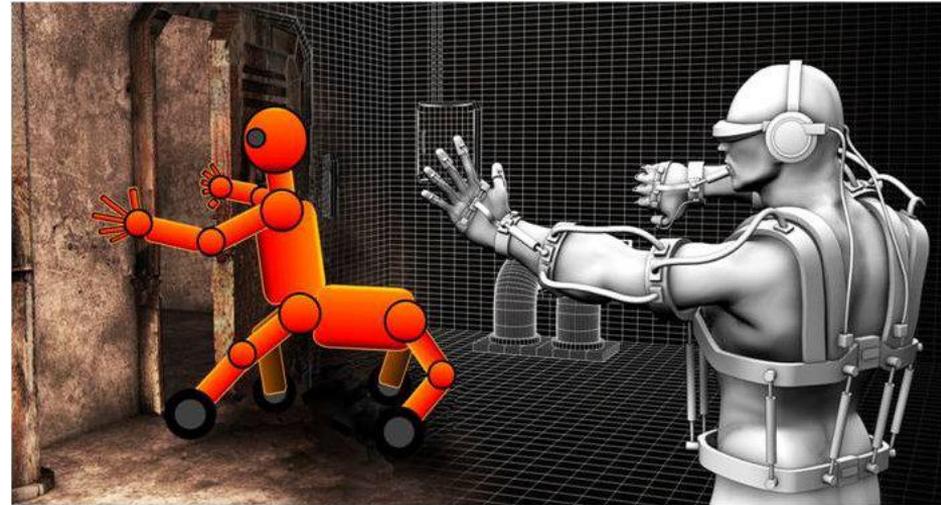
- Capabilities of disaster-response robots insufficient for providing effective support to rescue workers
 - Mobility: difficulties with uneven terrain, stairs, and debris
 - Manipulation: only a single actuator with simple end-effectors
 - User interface: requires extensive training, not intuitive, situation awareness problematic
- Task complexity tasks and execution speed limited



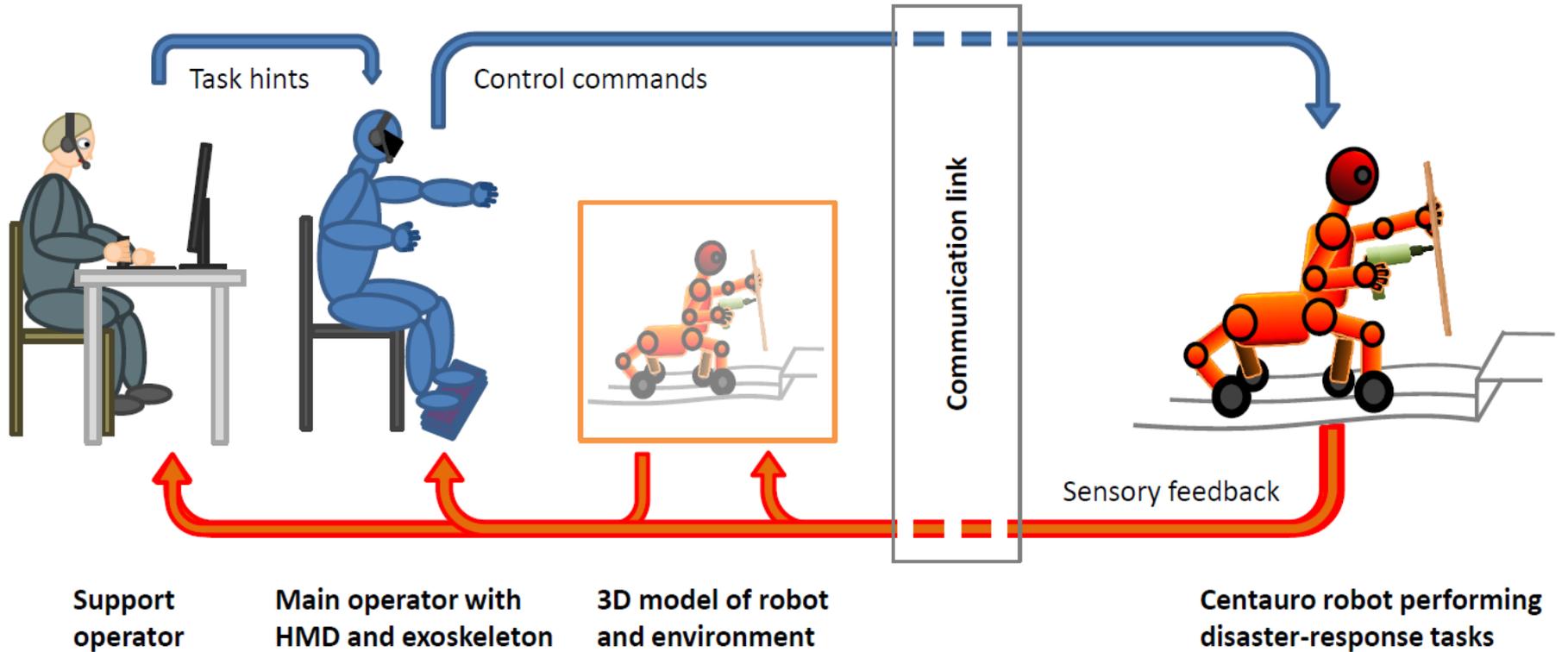
Fukushima disaster 2011, Image: Digital Globe CC 3.0.

Overall Objective

- Development of a Human-robot system where a human operator is telepresent with its whole body in a Centaur-like robot, which is capable of robust locomotion and dexterous manipulation in the rough terrain and austere conditions characteristic of disasters.

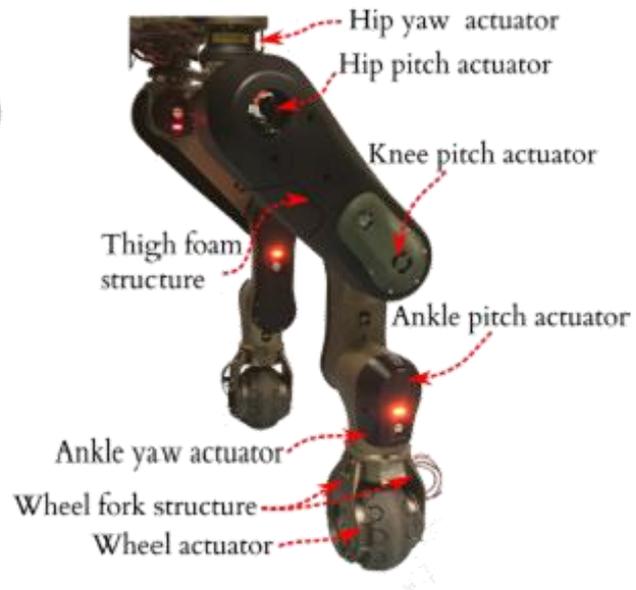
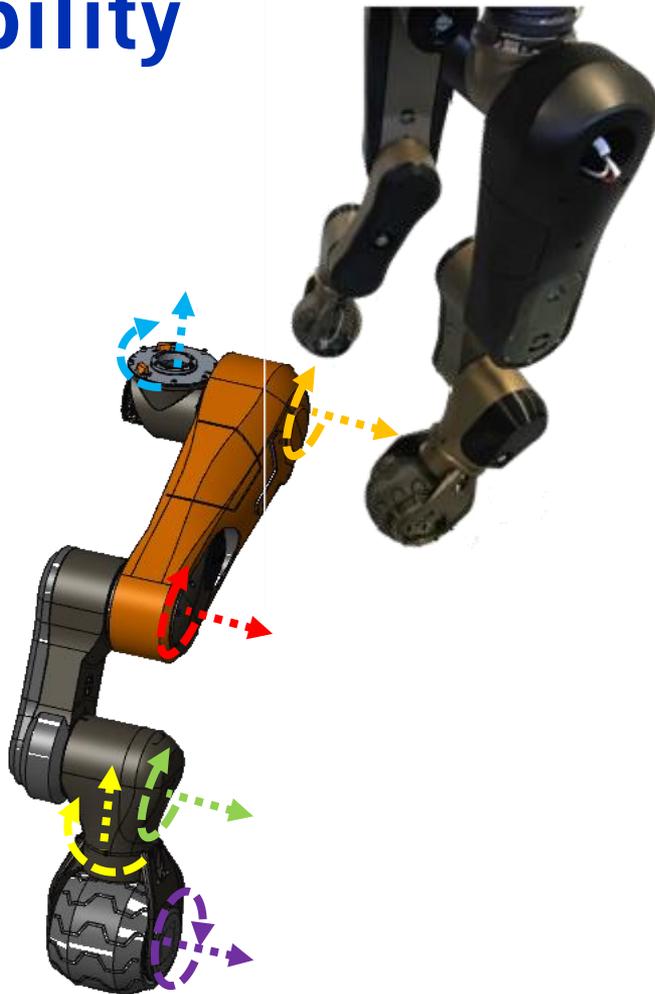


CENTAURO Approach



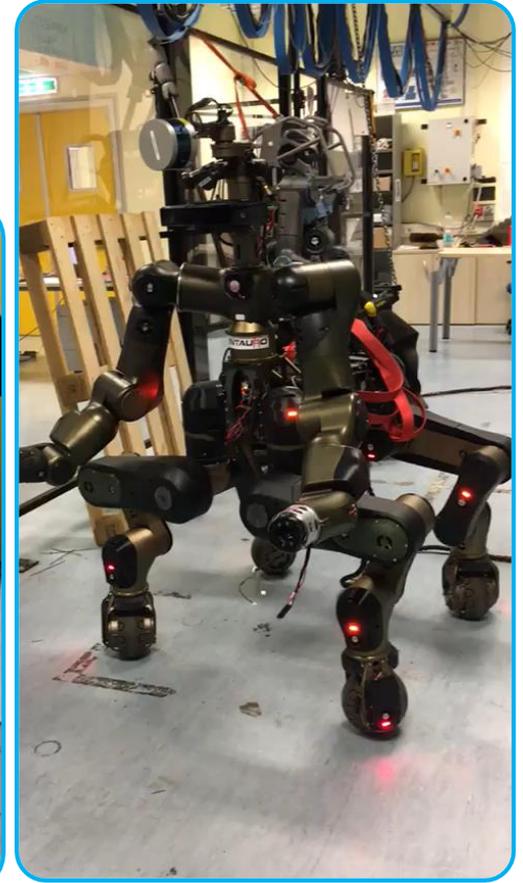
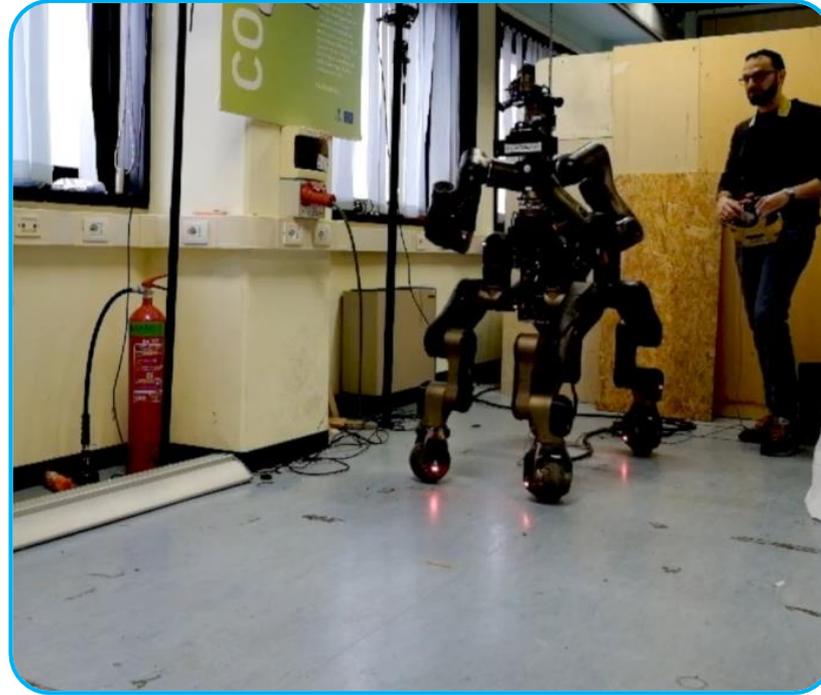
Centauro Mobility

- Leg Features
 - 6DOF
 - Hip yaw/roll
 - Knee pitch
 - Ankle pitch
 - Ankle yaw & wheel
 - Mixed compliant/stiff Actuation
 - Wide joint range of motion



Centauro Mobility

Hybrid Legged-wheeled locomotion



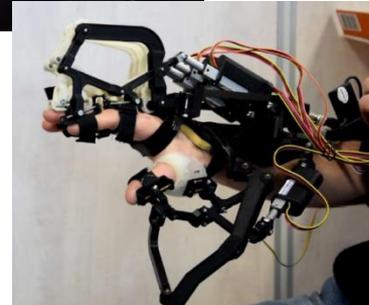
Centauro Interaction Control

Whole body Impedance Controller



Main Operator Telepresence Interface

- Tendon-driven dual-arm exoskeleton
- Active wrist with differential tendon transmission
- Underactuated hand exoskeleton
- Head-mounted display
- Foot pedals



Main Operator Control



Manipulation Tasks

- Surface
- Valve (lever)
- Valve (gate)
- Snap hook
- Fire hose
- 230V connector
- Cutting tool
- Driller
- Screw driver
- Grasping

Used control interfaces



Joystick



Exos



6D



Keyframes

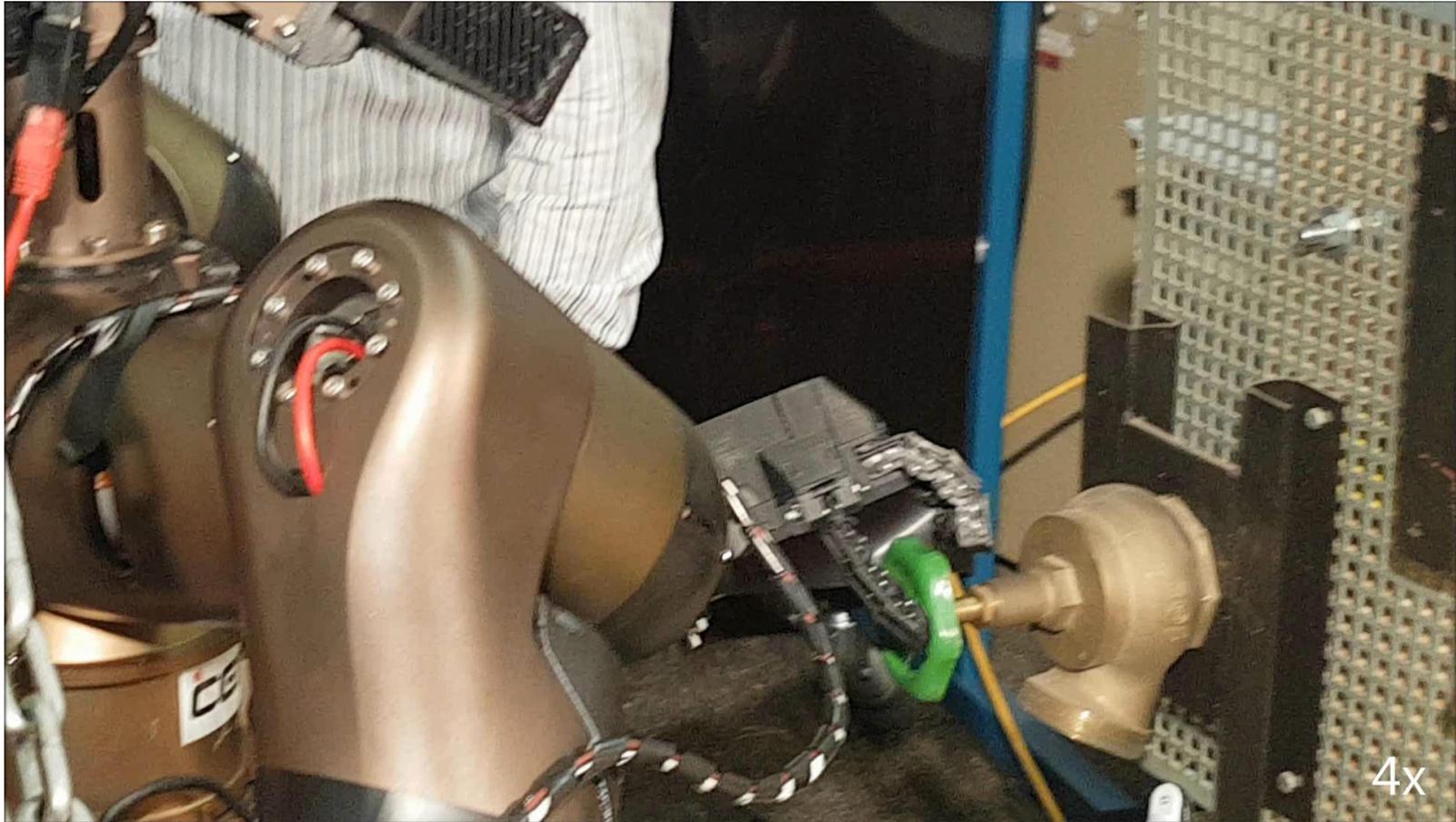


Stepping



Autonomous

Turning a Valve



Connecting a Plug



Manipulation Tasks

- Surface
- Valve (lever)
- Valve (gate)
- Snap hook
- Fire hose
- 230V connector
- Cutting tool
- Driller
- Screw driver
- Grasping

Used control interfaces



Joystick



Exos



6D



Keyframes

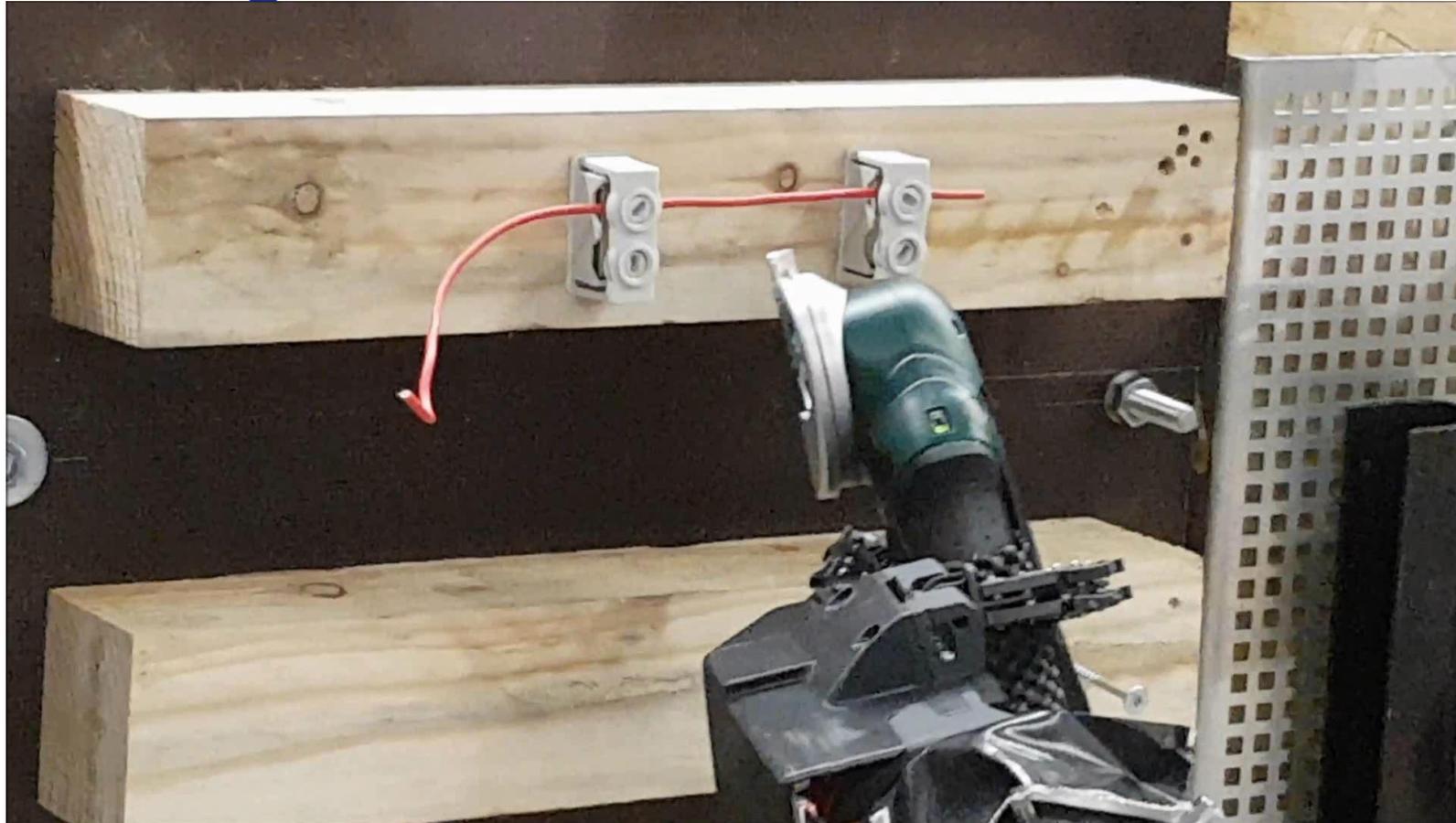


Stepping



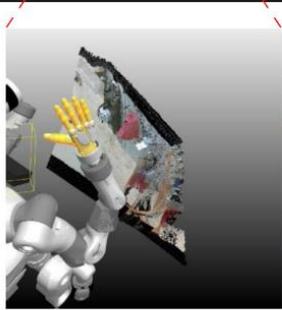
Autonomous

Cutting a Wire

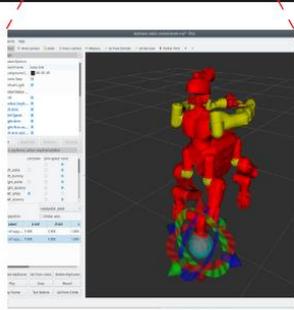


Support Operator Interfaces

3D VEROSIM
visualization



Robot state &
Keyframe editor



Foot
cameras



Panoramic view &
RGB Kinect image

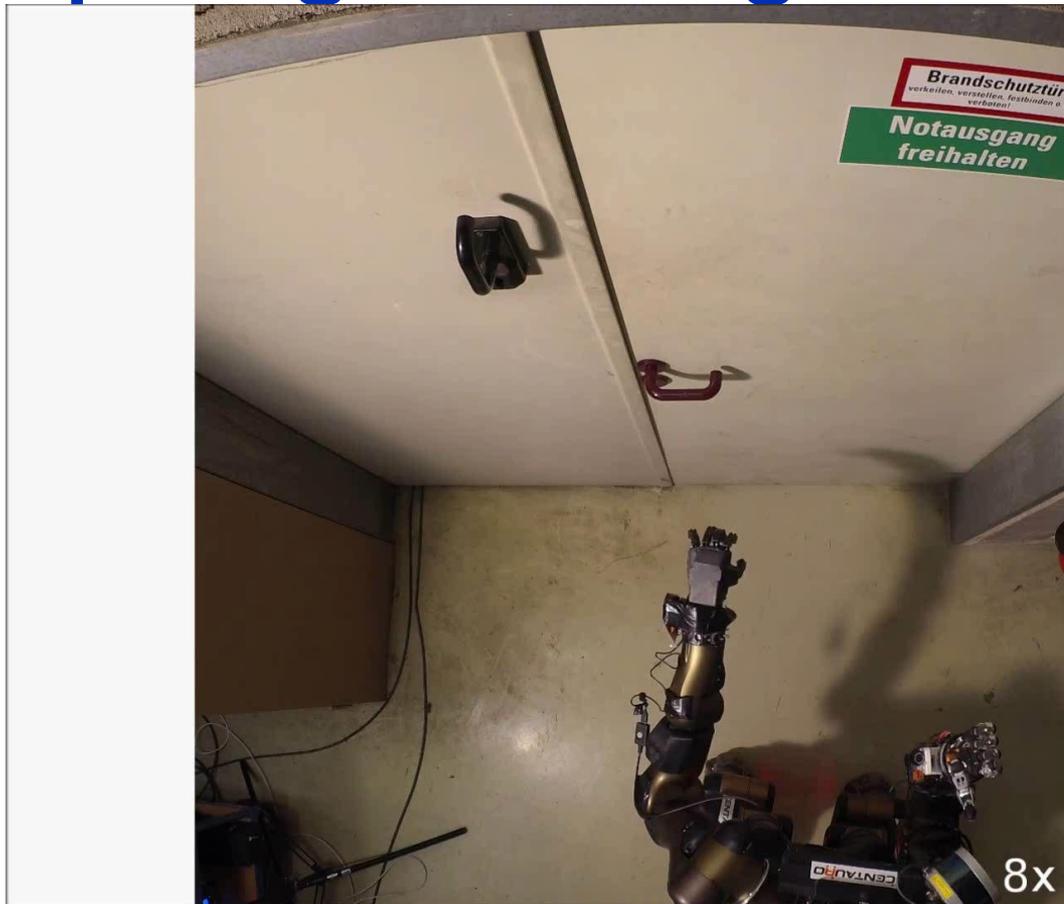
Task specific
GUI



Pointcloud, ground
contact & COM markers



Opening and Going Through a Door



Locomotion Tasks

- Ramp
- Small door
- Regular door
- Gap
- Step field
- Stairs

Used control interfaces



Joystick



Exus



6D



Keyframes

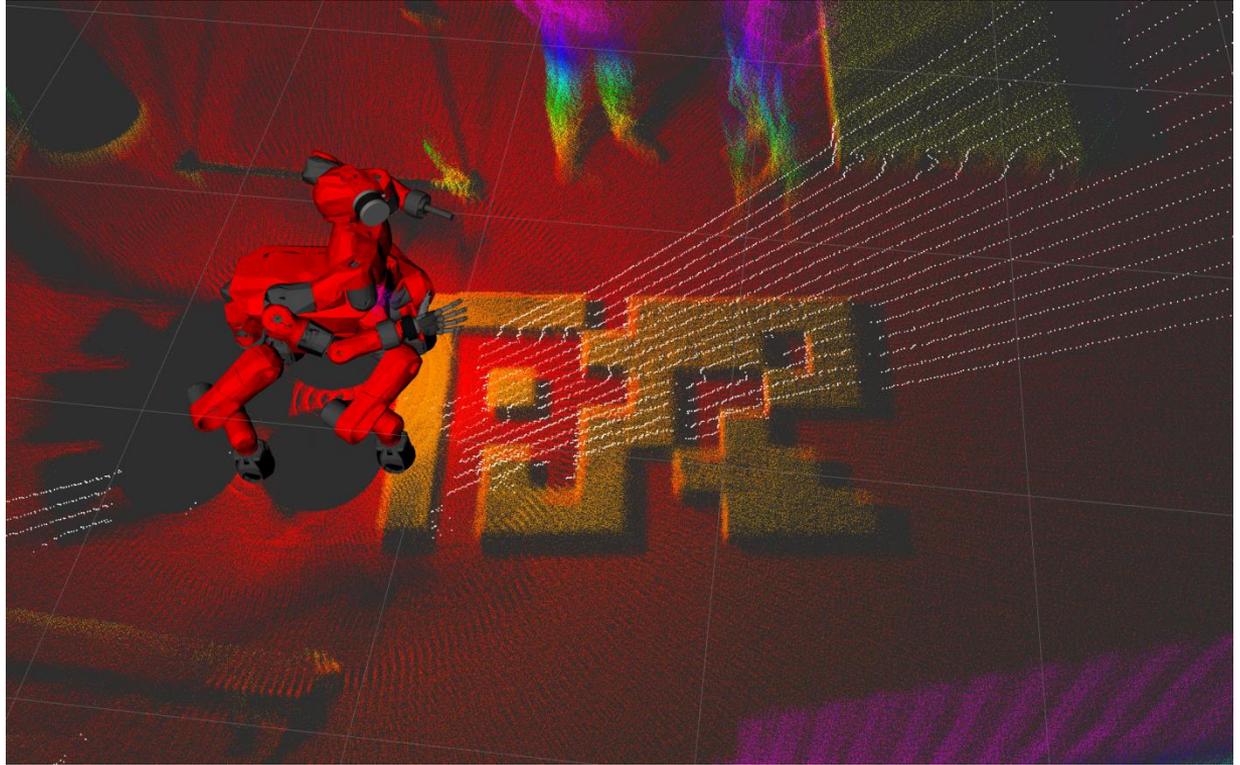


Stepping



Autonomous

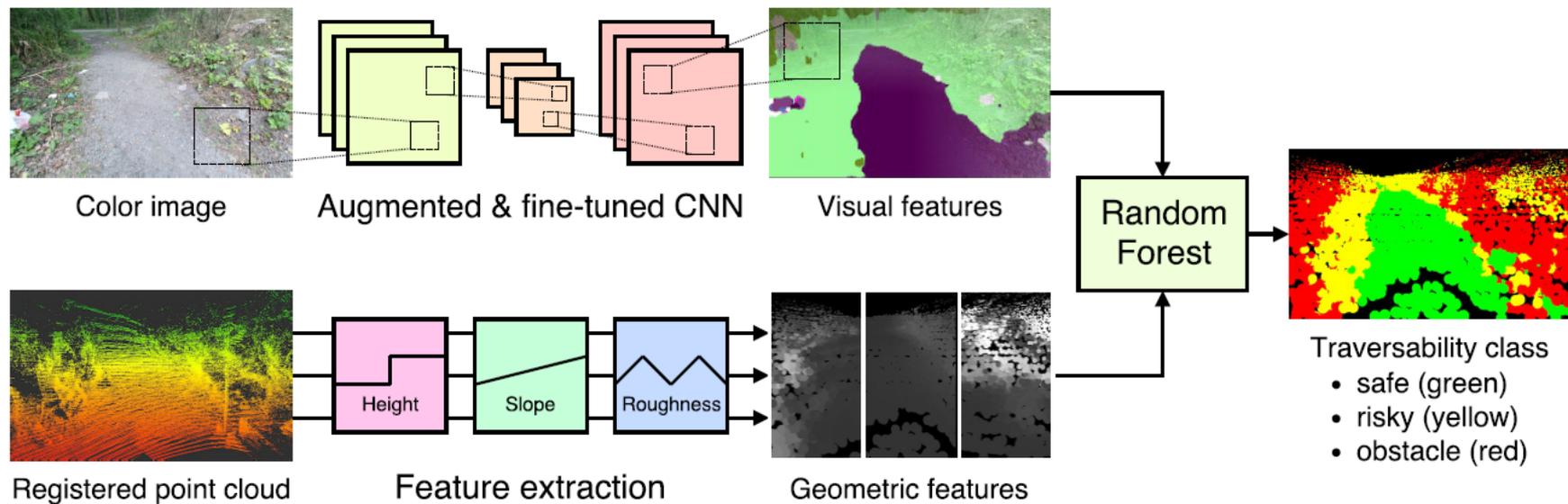
3D Mapping and Localization



Walking over a Step Field

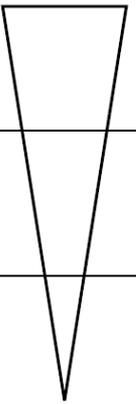
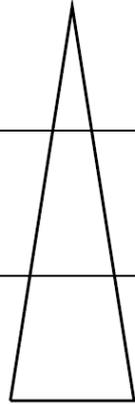
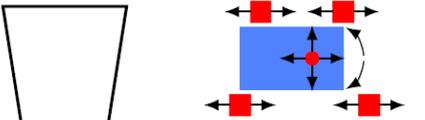
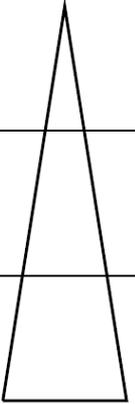
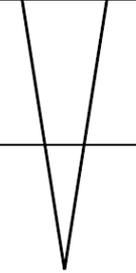
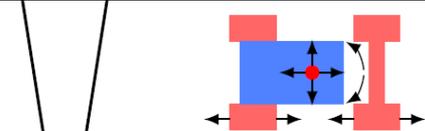
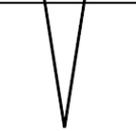
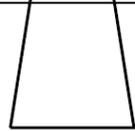
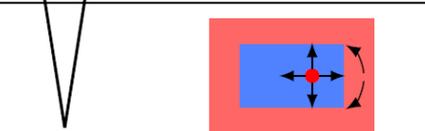
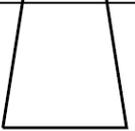


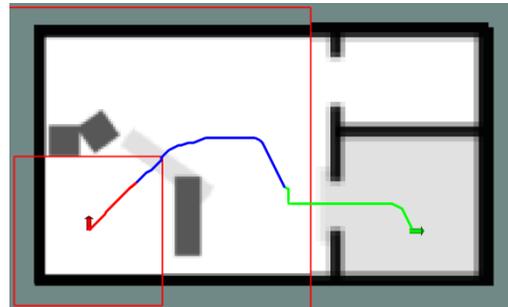
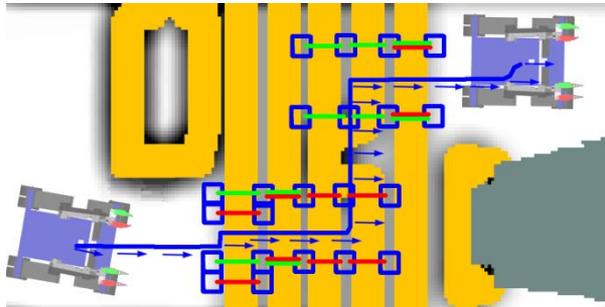
Terrain Classification



[Schilling et al., IROS 2017]

Hybrid Driving-Stepping Locomotion Planning

Level	Map Resolution	Map Features	Robot Representation	Action Semantics
1	 <ul style="list-style-type: none"> • 2.5 cm • 64 orient. 	 <ul style="list-style-type: none"> • Height 		 <ul style="list-style-type: none"> • Individual Foot Actions
2	 <ul style="list-style-type: none"> • 5.0 cm • 32 orient. 	 <ul style="list-style-type: none"> • Height • Height Difference 		 <ul style="list-style-type: none"> • Foot Pair Actions
3	 <ul style="list-style-type: none"> • 10 cm • 16 orient. 	 <ul style="list-style-type: none"> • Height • Height Difference • Terrain Class 		 <ul style="list-style-type: none"> • Whole Robot Actions



[Klamt and Behnke,
IROS 2017, ICRA 2018]

Transfer of Manipulation Skills



Knowledge
Transfer

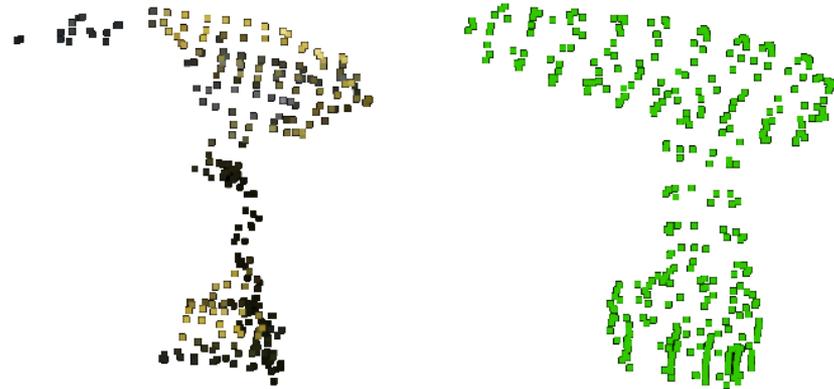


Object Perception

- Semantic segmentation



- Shape-aware non-rigid registration



[Rodriguez et al. ICRA 2018]

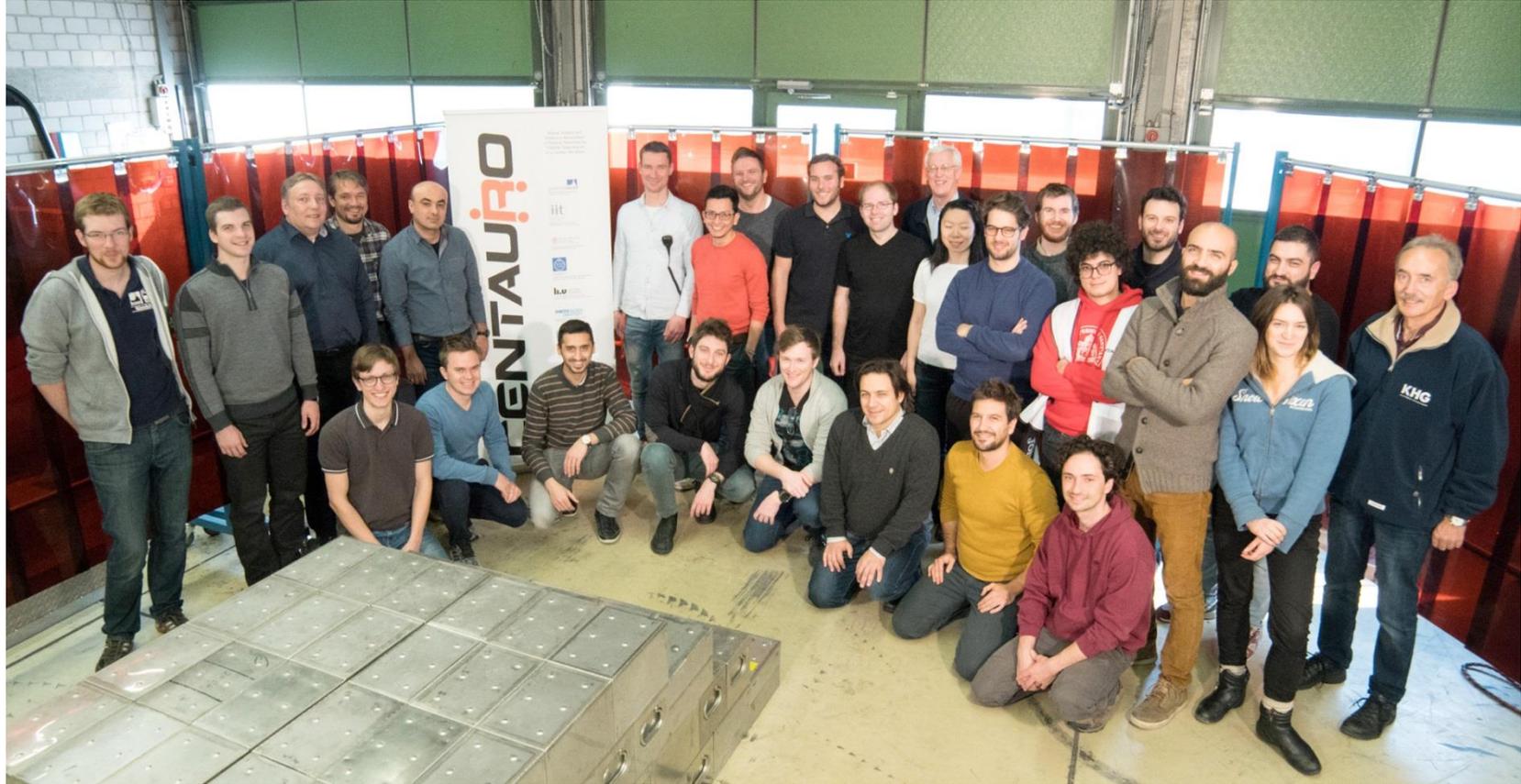
Grasping an Unknown Power Drill



Fastening a Screw



CENTAURO Team



Conclusions

- Centauro robot versatile and capable platform for mobile manipulation
- Full-body telepresence suite and autonomous assistance functions
- Demonstrated a large variety of manipulation and locomotion tasks
- Valuable insights for further development
- Plan to demonstrate integrated disaster-response missions



Thank you very much for your attention !

