H2020 RIA

CENTAURO

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

Sven Behnke
Autonomous Intelligent Systems
University of Bonn

CENTAURO Team

universität bonn | iit ISTITUTO ITALIANO DI TECNOLOGIA | Scuola Superiore Sant'Anna di Studi Universitari e di Perfezionamento | KTH VETENSKAP OCH KONST ROYAL INSTITUTE OF TECHNOLOGY | LINKÖPINGS UNIVERSITET | RWTH AACHEN UNIVERSITY | progenox | KHG

Motivation

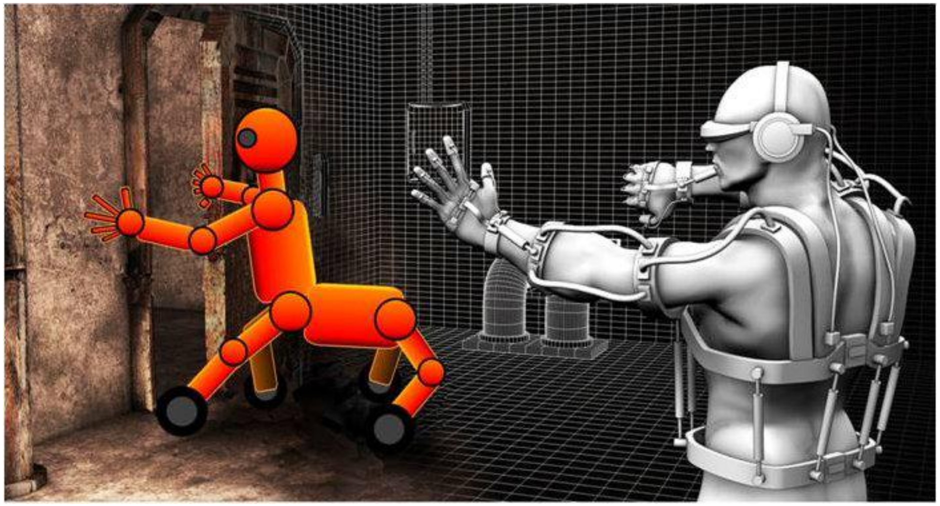
- Capabilities of disaster-response robots insufficient for providing effective support to rescue workers
  - Mobility: difficulties with uneven terrain, stairs, and debris
  - Manipulation: only a single actuator with simple end-effectors
  - User interface: requires extensive training, not intuitive,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

Fukushima disaster 2011, Image: Digital Globe CC 3.0.

iRobot PackBot in Plant, Image: Tepco.

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.



O1: Versatile CENTAURO Robot Platform

- The CENTAURO robot will be **flexible** and **highly articulated** to support different modes of locomotion and manipulation. **Compliant mechanics** and **hybrid leg design** are the key features that will permit CENTAURO to adapt to the environment and effectively operate in unstructured spaces.

O2: Robust Mobility

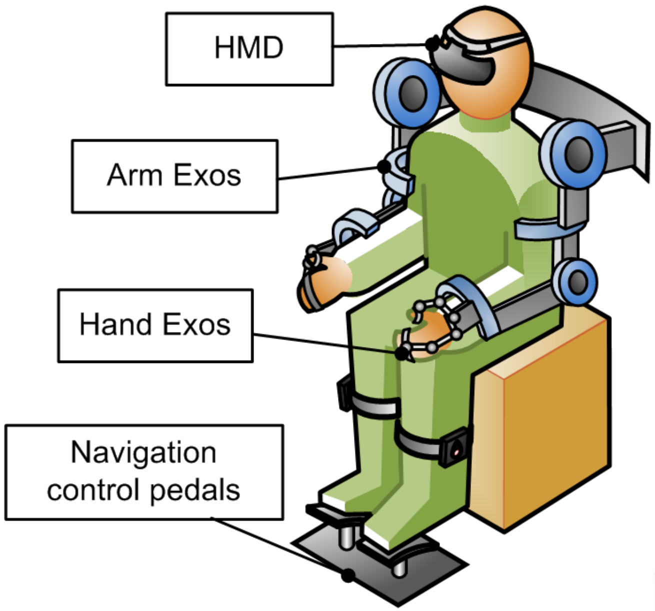
- The developed robot will be able to **navigate in affected man-made environments**, including the inside of buildings and stairs, which are cluttered with debris and partially collapsed. It will **combine advantages of legged and wheeled locomotion** and will select navigation actions mostly autonomously.

O3: Dexterous Manipulation

- Through telemanipulation, the CENTAURO robot will be capable of using **unmodified human tools** for solving **complex bimanual manipulation tasks**, such as connecting a hose or opening a valve, in order to relieve the situation. It will be able to autonomously perform elementary manipulation tasks, such as grasping or placing an object.

O4: Intuitive Control

- A human operator will control the robot intuitively using a **full-body telepresence suit** that provides visual, auditory, and upper-body haptic feedback. A **support operator** will provide assistance to the main operator or specify navigation and manipu-lation goals for the robot from a third-person perspective.



O5: Situation Awareness

- Robot sensors will provide the remote human operators the necessary **awareness of the situation**. Robot plans and controls as well as semantic annotations will be displayed to the human operators within an **augmented virtual reality** of the robot’s environment.

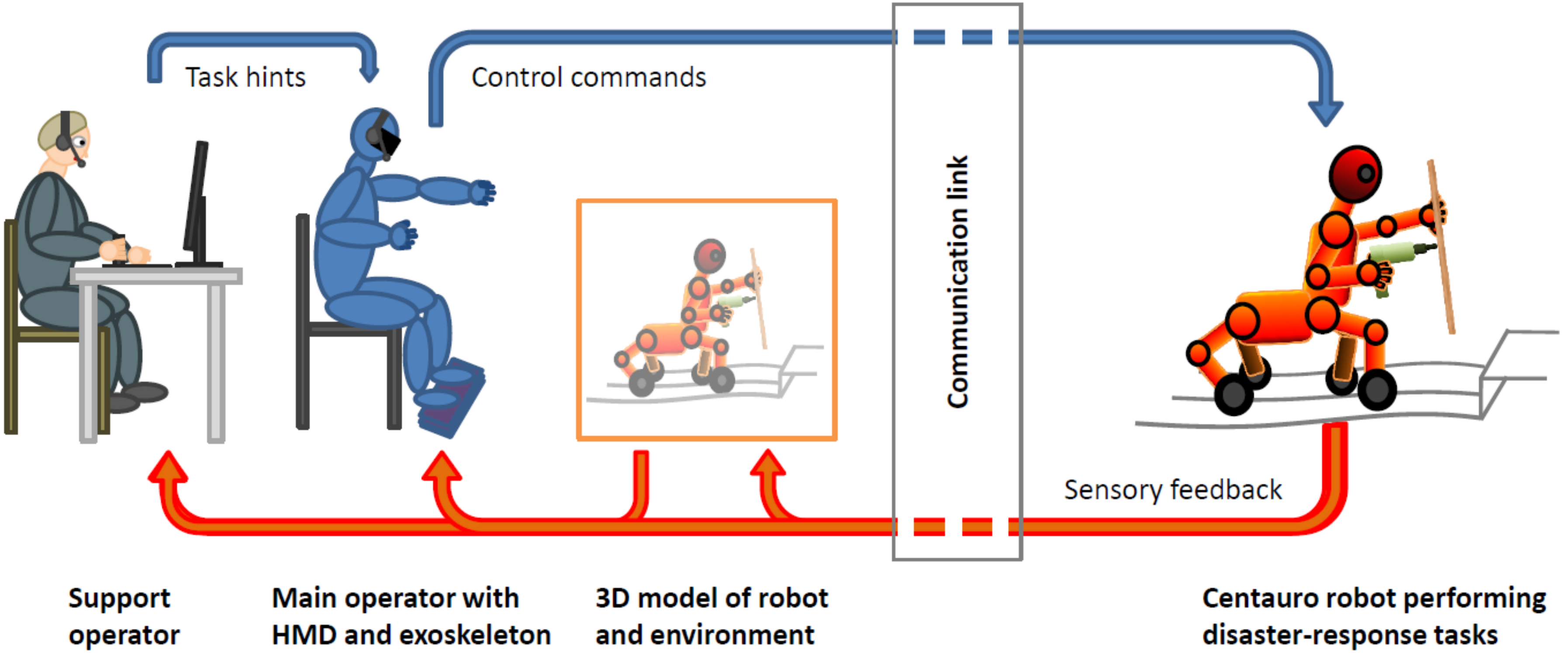
O6: Virtual Testbed

- A **physics-based simulation** of the robot and its environment will allow for specification and safe verification of robot navigation and manipulation plans. It will also serve as a virtual testbed for development of user interfaces integrating perception and control algorithms.

O7: Evaluation Methodologies

- Systematic **benchmark scenarios** and performance measures will be developed based on the input of end-users to assess the CENTAURO disaster-response system. The evaluation will be carried out in the virtual testbed as well as in **realistic training facilities** of professional rescue workers.

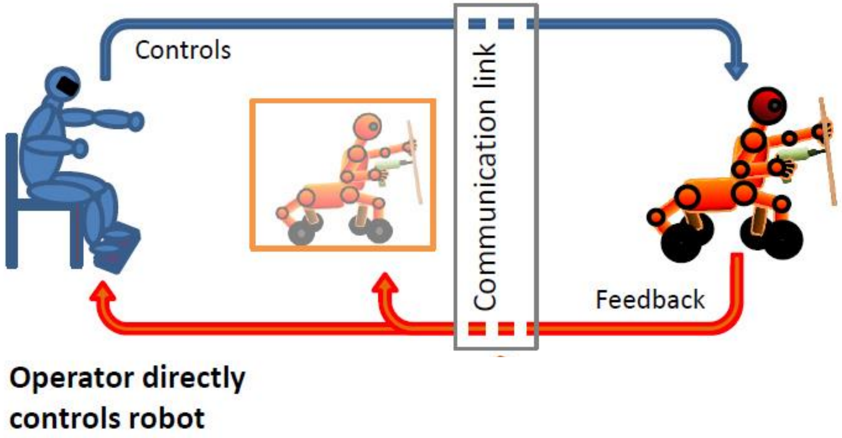
CENTAURO Approach



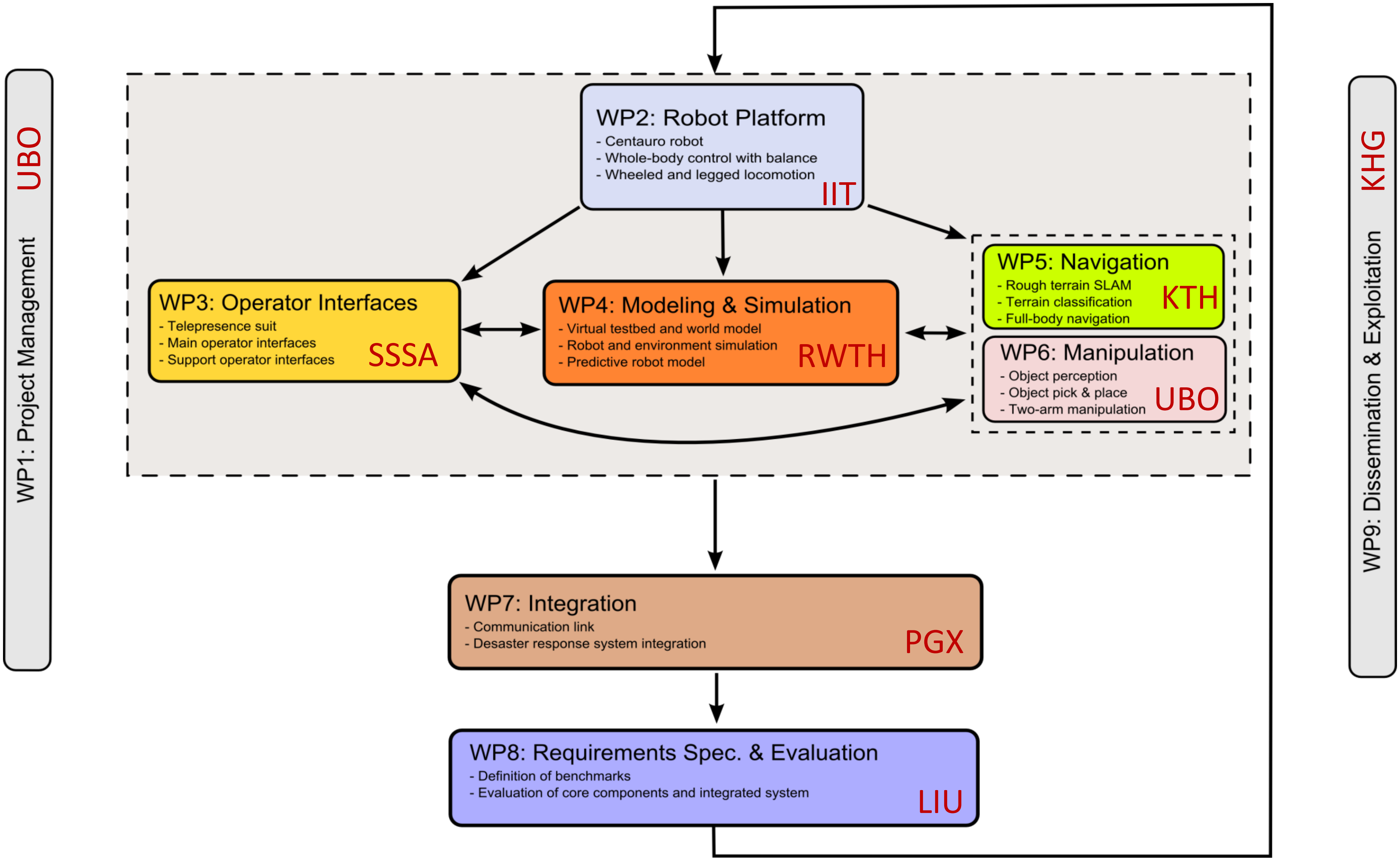
- Hybrid wheeled-legged base => Flexible locomotion
- Anthropomorphic upper body => Dexterous manipulation
- Telepresence suit => Situation awareness, intuitive control
- Predictive robot-environment model => Action planning
- Supervised autonomy => Effective human-robot teamwork

Predictive Robot-Environment Model

- Physics-based simulation of the robot in its environment, instantiated from the percepts and actions of the real robot
- Exploring mission alternatives without risk to the robot



Work Packages



Milestones

- **MS1 Critical Design Review (M6):** Concepts for hardware and software components have been designed. Requirements are identified from an integration perspective.
  Verification: Design Review Workshop
- **MS2 Core Components (M18):** First versions of core software and hardware components have been implemented and are evaluated. Requirements are identified for the development phase of the first integrated CENTAURO System.
  Verification: Evaluation of core components
- **MS3 First Integrated CENTAURO System (M30):** Components are integrated into a first version of the CENTAURO Disaster- Response System with partial functionality. The system is evaluated in simplified USAR scenarios. Requirements are identified for the final development phase.
  Verification: Evaluation of first integrated CENTAURO system
- **MS4 Final Integrated CENTAURO System (M42):** Components are integrated into the final CENTAURO Disaster-Response System with full functionality. The system is evaluated in realistic USAR scenarios.
  Verification: Evaluation of final integrated CENTAURO system.

WP8 Requirement Specification

- Requirement Specification Workshop @KHG

- Manipulation

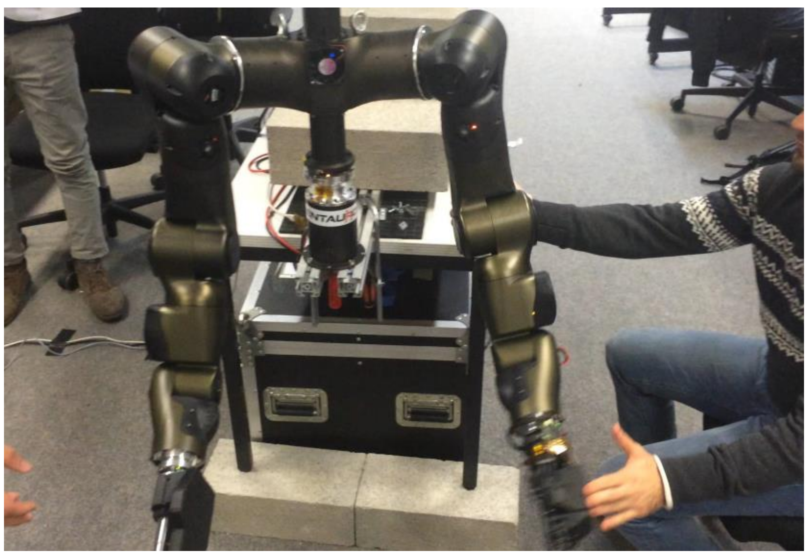
Tasks	[M30]	[M42]
Turn valve	Different locations, different diameters	Put uneven ground in front of it
Pipe Stars		Inspection, direction, extraction and insertion
Fire hose connection	Connect mobile hose to stationary part	Connect two hoses (both mobile)
Power connection	Connect plug to stationary part 230V	Connect plug to a part (both mobile) 230V, 400V
Take a sample	Follow a surface with a sensor	Smear test
Fix a cable	Snap hook	Shackle
Use a power screw driver	Screw is already partially in the wood	Attach a piece of wood to some static wood
Use a drill	Single-handed	Two -handed larger version
Cut max 20 mm diameter cable or pipe	Use a cutting tool	Secure the part that is being cut off with the second hand

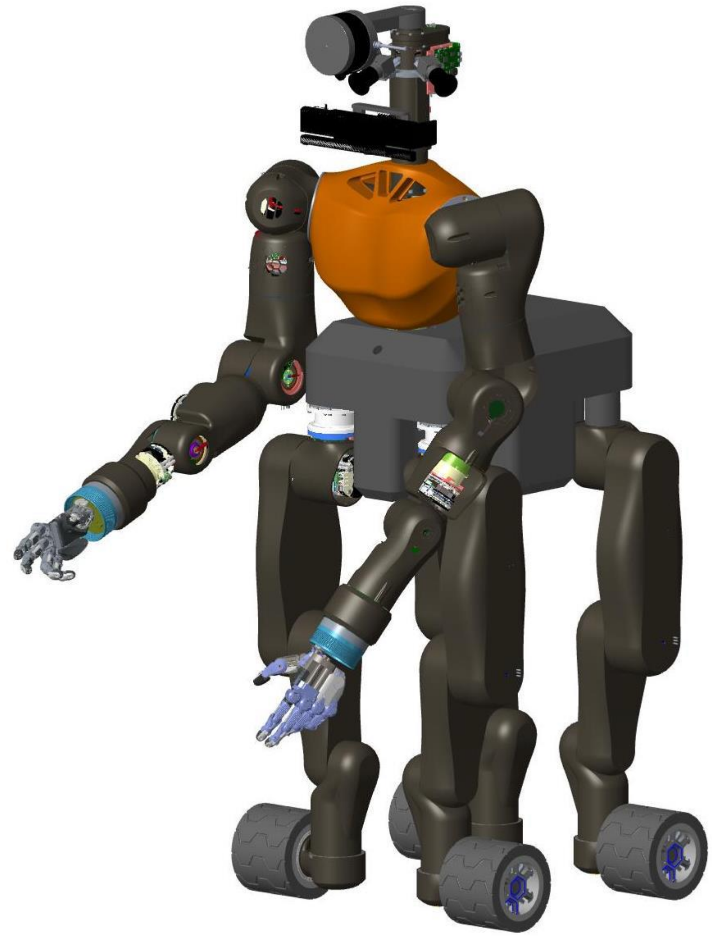
- Locomotion

Taks	[M30]	[M42]
Door	"Regular door" opening and going through a regular door with a handle, unlocked	Add closing mechanism and use key to unlock
Obstacles	RoboCup Rescue 3D step field	Add debris on the field
Stairs	Regular stairs, straight, change direction when landing at the top	Add debris on the stairs
Ramp	30 degrees	45 degrees
Gap	30 cm	60 cm

WP2 Robot Platform

- Design of robot platform
- Series elastic actuators
- Upper body realized



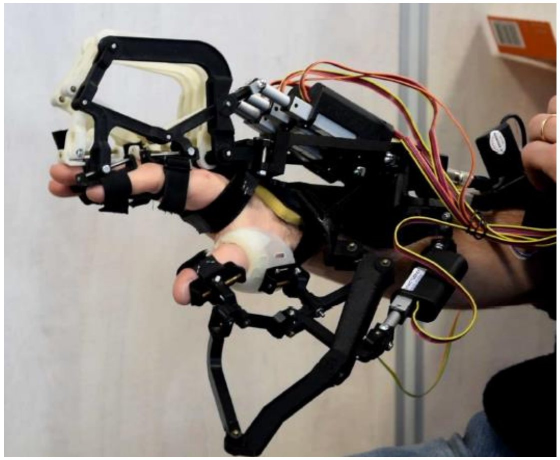


WP3 Operator Interfaces

- Tendon-driven dual-arm exoskeleton

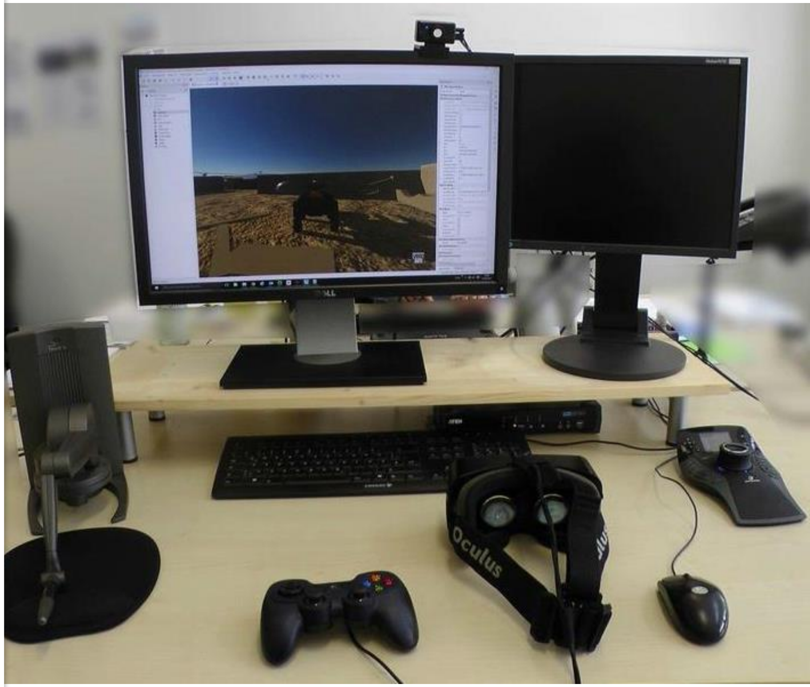
- Active wrist with differential tendon transmission

- Underactuated hand exoskeleton



WP4 Modeling and Simulation

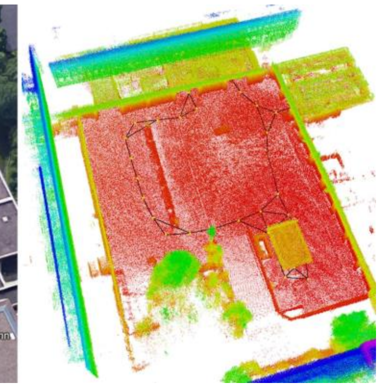
- Multiple robot models, sensors
- Immersive visualization, force feedback

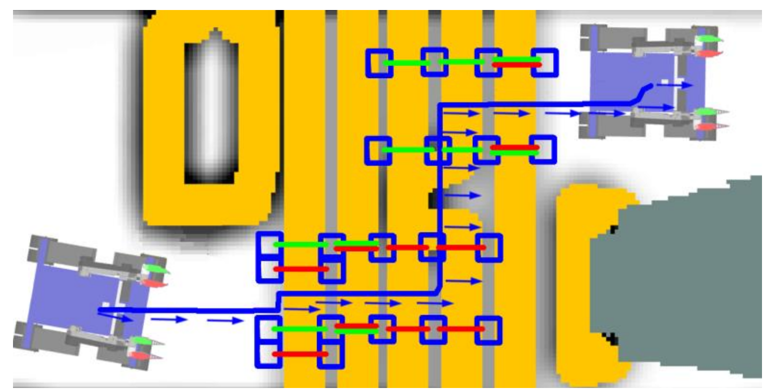


WP5 Navigation

- 3D Mapping and Localization (SLAM)
- Terrain classification

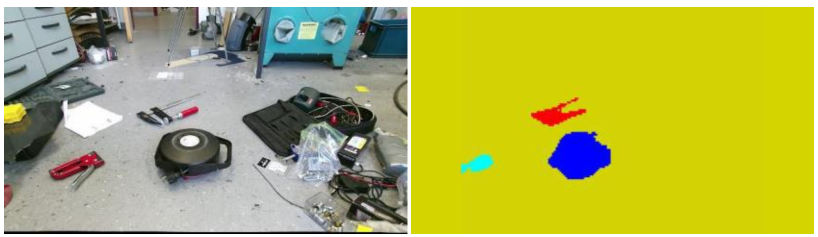
- Hybrid driving-stepping locomotion planning



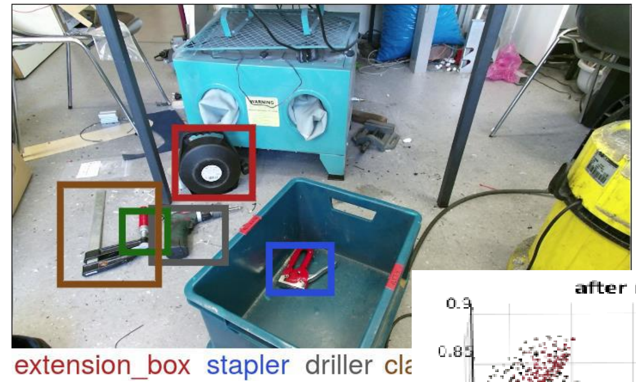


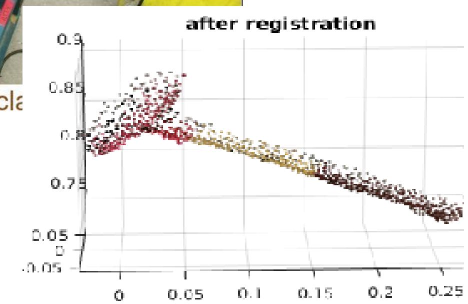
WP6 Manipulation

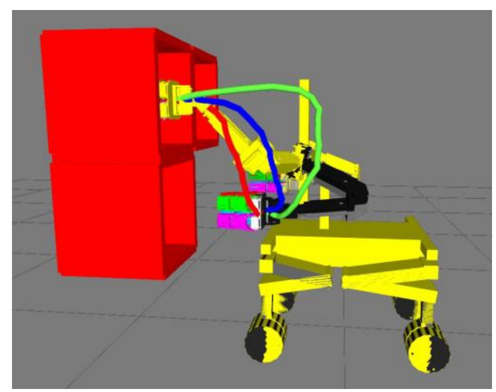
- Object detection
- Semantic segmentation



- Pose estimation
- Trajectory optimization
- Anthropomorphic hand







WP7 Integration

- ROS-based architecture
- Wireless comm. links
- Integrated demonstrations

Expected Result: New Level of Capabilities

- **Perception**: Semantic 3D environment modeling
- **Mobility**: Omnidirectional driving, adaptation to terrain, climbing over obstacles, stair climbing
- **Manipulation**: Two-armed handling of objects, autonomous manipulation skills, tool use
- **Human-robot interaction**: Full-body telepresence, operator assistance functions

=> Breakthrough in the introduction of robots for disaster relief applications

Acknowledgement

- This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 644839 (CENTAURO).