The CAPIO Active Upper Body Exoskeleton

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Martin Mallwitz, Luis Vaca Benitez, Bertold Bongardt, Niels Will

DFKI Robotics Innovation Center (RIC), Bremen, Germany
– headed by Prof. Dr. Frank Kirchner –

Upper Body Exoskeleton for Teleoperation

DFKI Robotics Innovation Center (RIC)

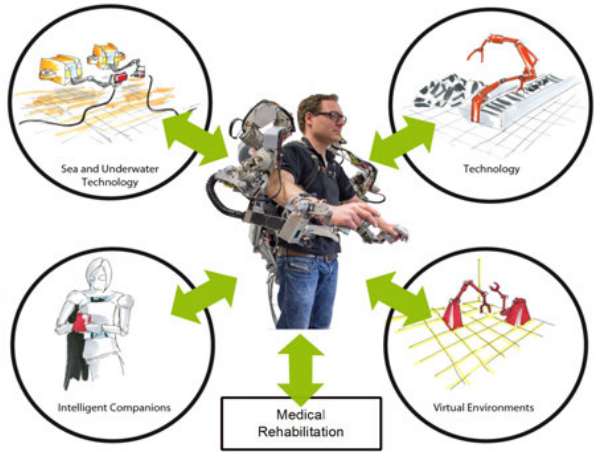
- A young institute (since 2008), part of the DFKI (since 1988)
- Approach: robotics + artificial intelligence
- Projects in space and underwater robotics, search & rescue, electric mobility, brain reading
- Website: `http://robotics.dfki-bremen.de`

Usage of exoskeletons

- Teleoperation of remote controlled target systems
- Manipulation of virtual enviroments
- Robotic rehabilitation

VI-Bot Project (2008-2010)

- An exoskeleton for the right arm
- Actuation system: hydraulics
- Virtual immersion for teleoperation of robotic arms



Potential applications of exoskeletons.

Operator wearing the VI-Bot exoskeleton.

Project Objectives

CAPIO Project (2011-2013)

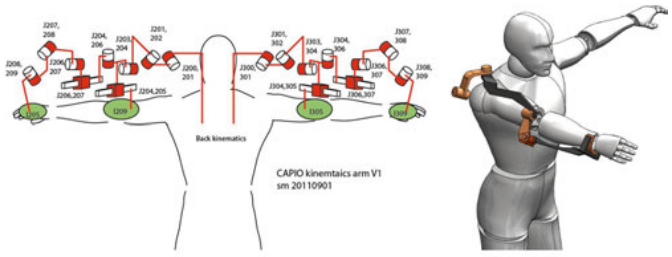
- Active multi contact exoskeleton for the human upper body
- Large cover of human workspace: back, arms, and hands
- Teleoperation of complex robotic target systems
- Rich force feedback experience:
  contact points at hip, shoulders, upper and lower arms
- Perspective application: rehabilitation

Control

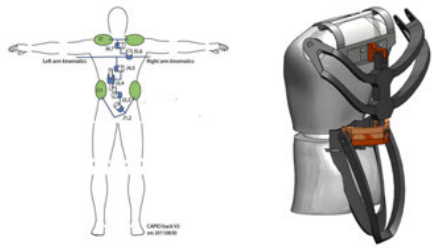
- Safe and comfortable operation
- Strategies for the integration of biological signals (EMG)

Teleoperation

- Following a generic modeling approach, based on kinematics and Cartesian mappings
- Effective teleoperation of robots using mental capabilities of the human



Serial kinematic arm concept.



Serial kinematic back concept.

Passive study for validating kinematic setup.

Results – Hardware

Kinematic structure

- Eight active DOF at each arm, four active DOF at the back
- Four passive DOF and five adjustment DOF
- Novel open joint concept at shoulder and wrist joints

Lightweight materials

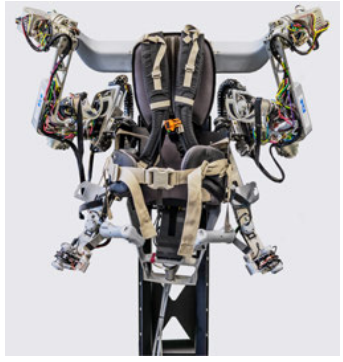
- High tensile aluminium, Carbon-fiber-reinforced-plastics

Actuators

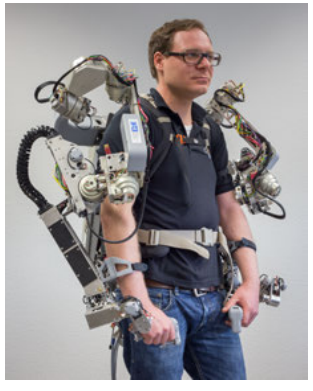
- All actuators equipped with serial-elastic elements
- Example shoulders and elbows: brushless DC motor, gear system, spring element, position sensors combined: highly integrated design, high power–weight ratio

Sensors and electronics

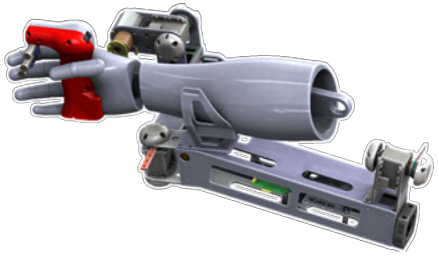
- Using deflection of elasticities as sensor for control tasks
- Precise magnetic sensors based on nonius principle
- Inhouse developed FPGA based power electronic



The CAPIO active upper body exoskeleton.



Operator wearing the CAPIO exoskeleton.



Lower arm structure, open joint concept.

Results – Software and Applications

Workflow

- Using the inhouse software `CAD2SIM`
- Kinematic-dynamic modeling based on originary CAD data
- Output – kinematics and visualization: `OpenRAVE`
- Output – dynamics: 'rigid body dynamics library' (`RBDL`)

Control

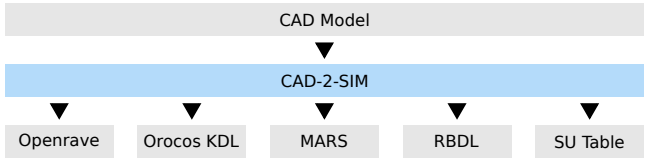
- Low-level – distributed torque control of actuated joints
- Mid-level – combination of approaches in joint space and in Cartesian space (multi body dynamics)
- High-level – selection of the modes for operation

Teleoperation

- Inhouse operation of several platforms:
  AILA humanoid, Mitsubishi PA-10, and Schilling ORION 7P
- Teleoperation of a robot in $>$ 3000 km distance
  (Bremen, DE – Magnitogorsk, RU)

Rehabilitation

- Elbow orthosis integrating EMG signals into control



Workflow scheme for the conversion tool `CAD2SIM`.

An integrated actuator at the shoulder.

Teleoperation of the RIC humanoid robot AILA.

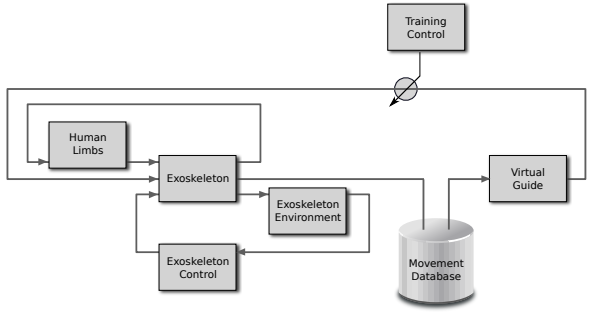
Future Work

System

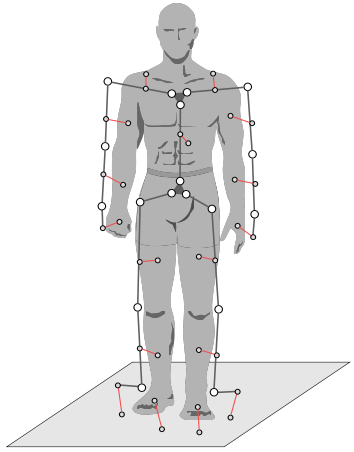
- Reduction of system weight
- Systematic evaluation of system
- Improvements in actuators, structure and software
- An exoskeleton for the whole human body

Applications

- Systematic evaluation of approaches for teleoperation
- Control of further robotic systems: e.g., rovers equipped with arm manipulators
- Applications to real world industrial applications
- Applications to real world rehabilitation



A scheme for an application in rehabilitation.



A sketch of a full-body multi-contact exoskeleton.

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