The CAPIO Active Upper Body Exoskeleton

Poster Contribution to the Workshop ‘RoboAssist’, ICRA 2014

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

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

CAPIO

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 environments
- Robotic rehabilitation

**VI-Bot Project (2008-2010)**

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

- Roy Featherstone. 
  *Rigid Body Dynamics Algorithms*.  

- Rosen Diankov. 
  *Automated Construction of Robotic Manipulation Programs*.  

- Martin Felis. 
  *Rigid Body Dynamics Library (RBDL)*.  


