Mobile Manipulation in der Telerobotik

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Motivation

Autonomous robots

- Favorable for many tasks (compared to humans)
- Limited cognition → restrictions on environment

→ **Teleoperation**

Human scale environments

- Workspace of human scale required
- Often also locomotion required

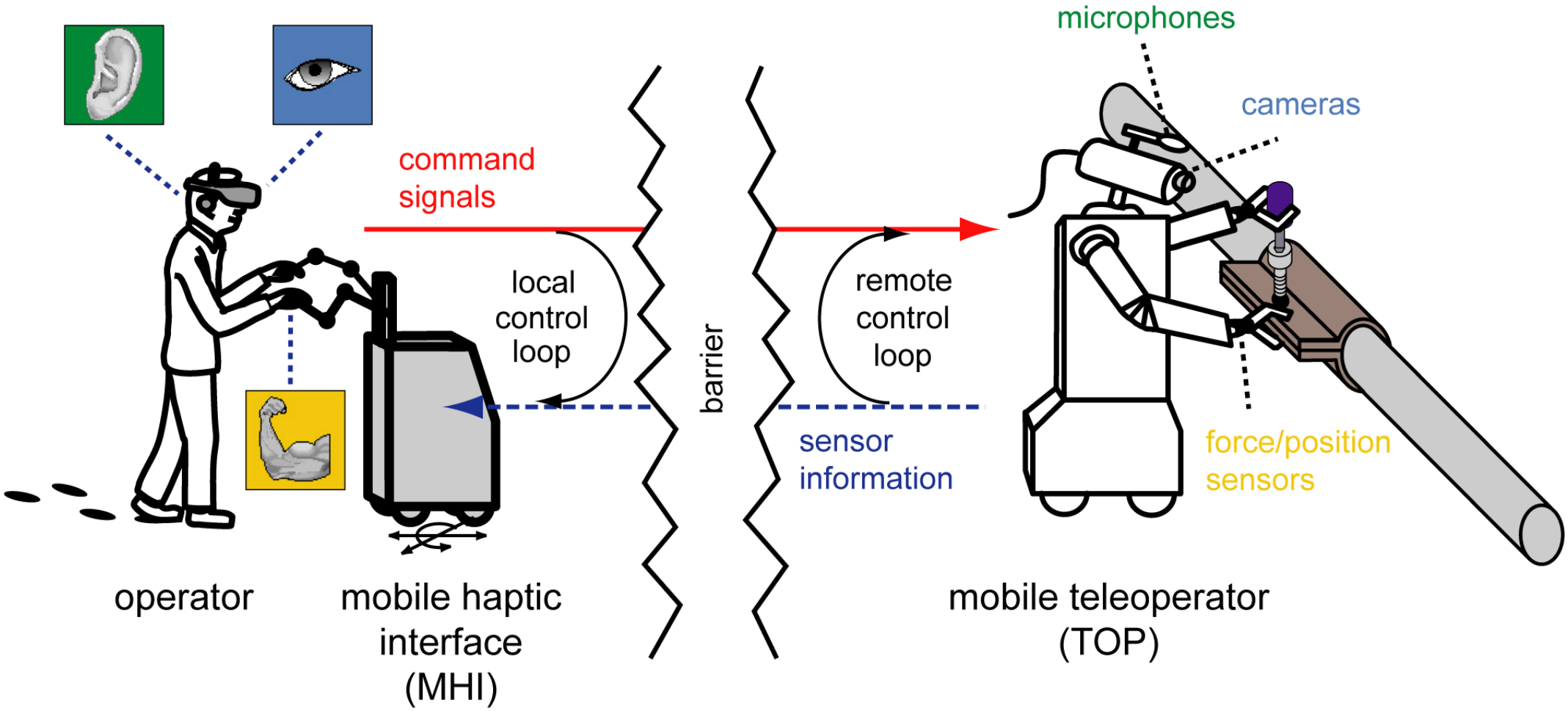
→ **Wide-Area Teleoperation**

Natural sense of locomotion

- Beneficial for navigational skills and feeling of immersion
- Exoskeletons very fatigueing, joystick/foot pedal unintuitive

→ **Coupling of a mobile haptic interface with a mobile teleoperator**

Motivation


microphones
cameras
command signals
local control loop
barrier
remote control loop
sensor information
force/position sensors
operator
mobile haptic interface (MHI)
mobile teleoperator (TOP)

Related Work

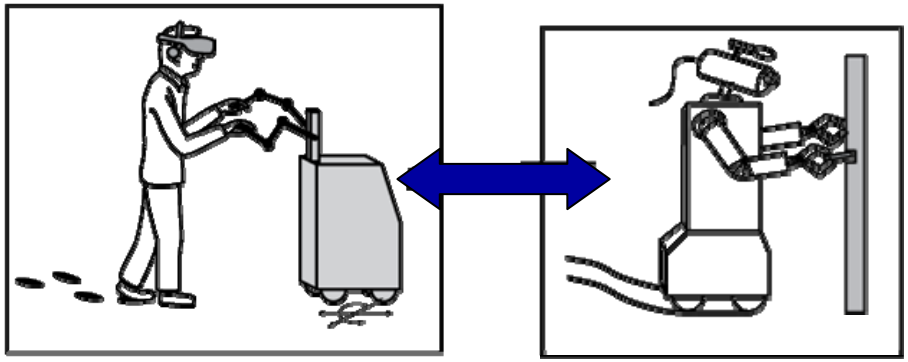
Control of Mobile Haptic Interfaces

- Development [Nitzsche 2003], [Pascale et al, 2006], [Formaglio 2008]

[Nitzsche, 2003]

Wide-area teleoperation

- One arm only, direct mapping only [Nitzsche 2004]
- Bimanual, direct mapping only [Buss 2008]



[Pascale et al, 2006]

Outline

Coupling schemes

Optimization of base position

Experimental Results

- Manipulation while standing still
- Locomotion
- Video

Conclusion

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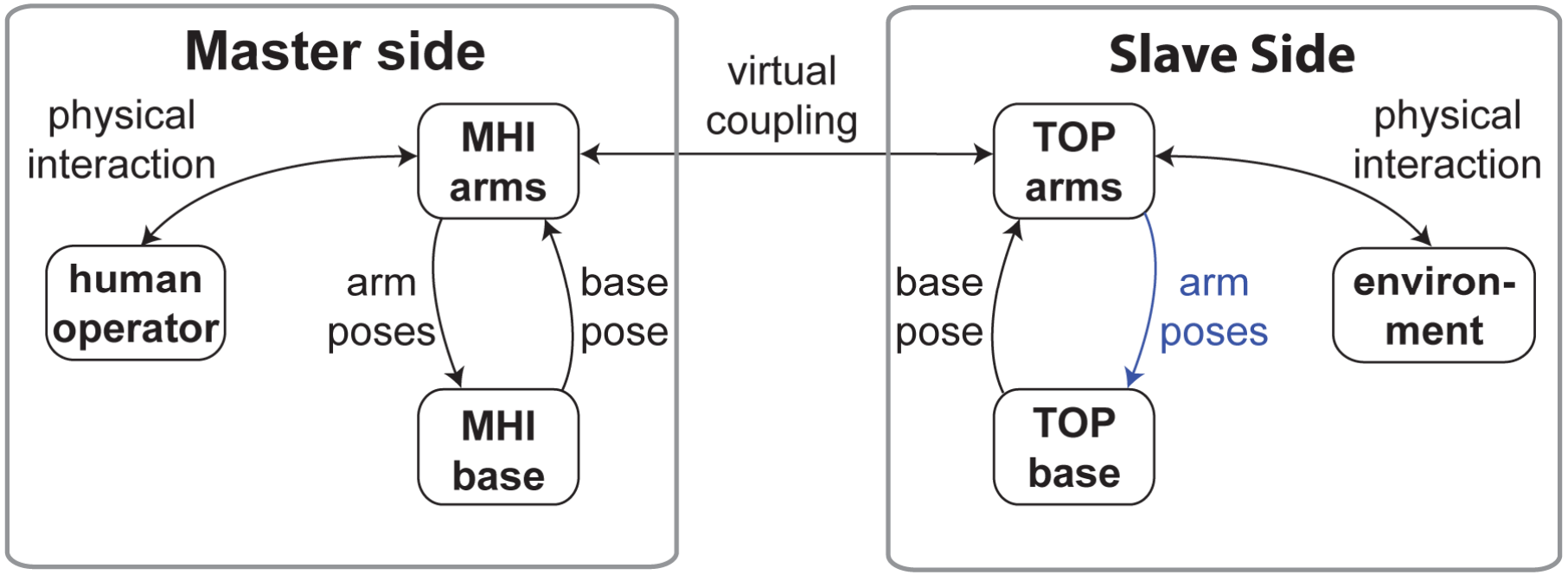
Coupling of End-Effectors Only

Coupling scheme



Disadvantage

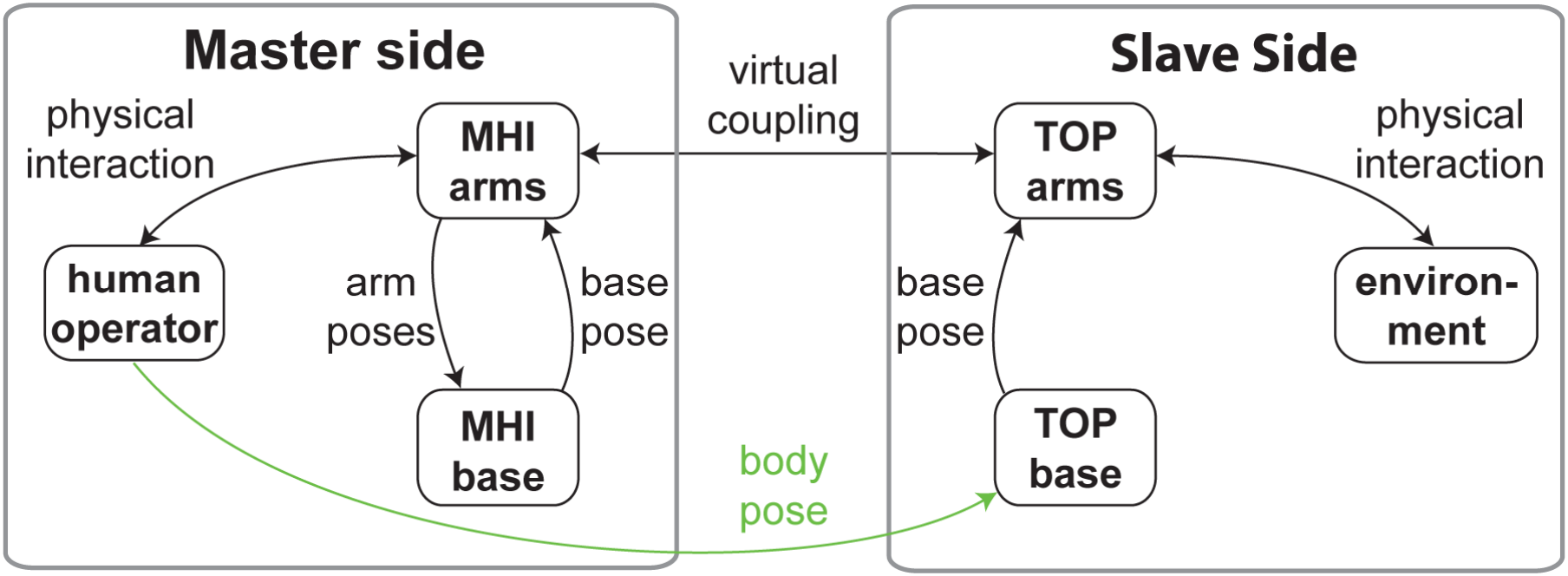
- No direct mapping between operator locomotion and motion of TOP base

Advantage

- No tracking of human operator necessary

Coupling of Body and End-Effectors

Coupling scheme



Disadvantage

- Tracking of human operator required

Advantage

- Direct mapping between operator locomotion and motion of TOP base

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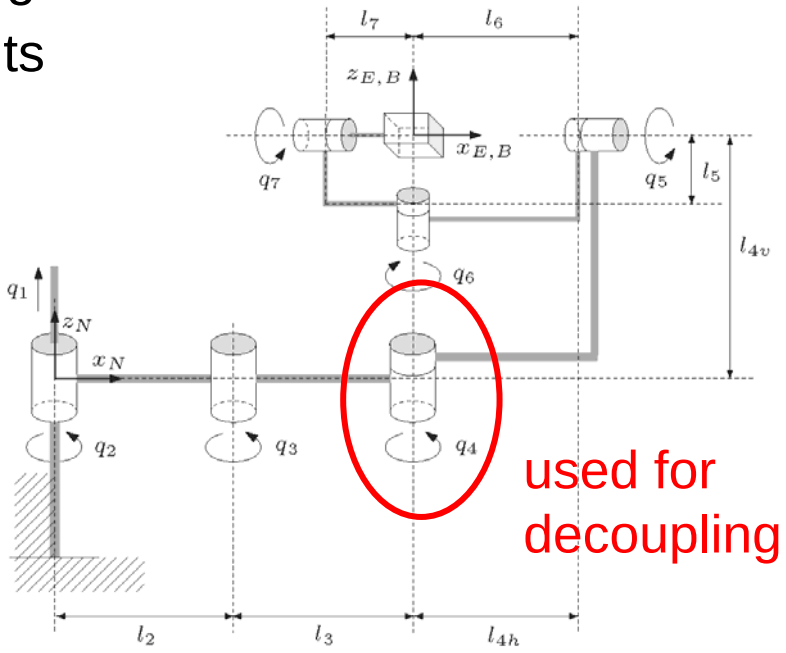
Mobile Haptic Interface

Design objectives:

- Simultaneous locomotion and manipulation in large remote environments
- Manipulations in 6 DOF
- High interaction forces
- Avoid operator fatigue
- Decoupling of translational and rotational movements



Manipulability Measure

Manipulability

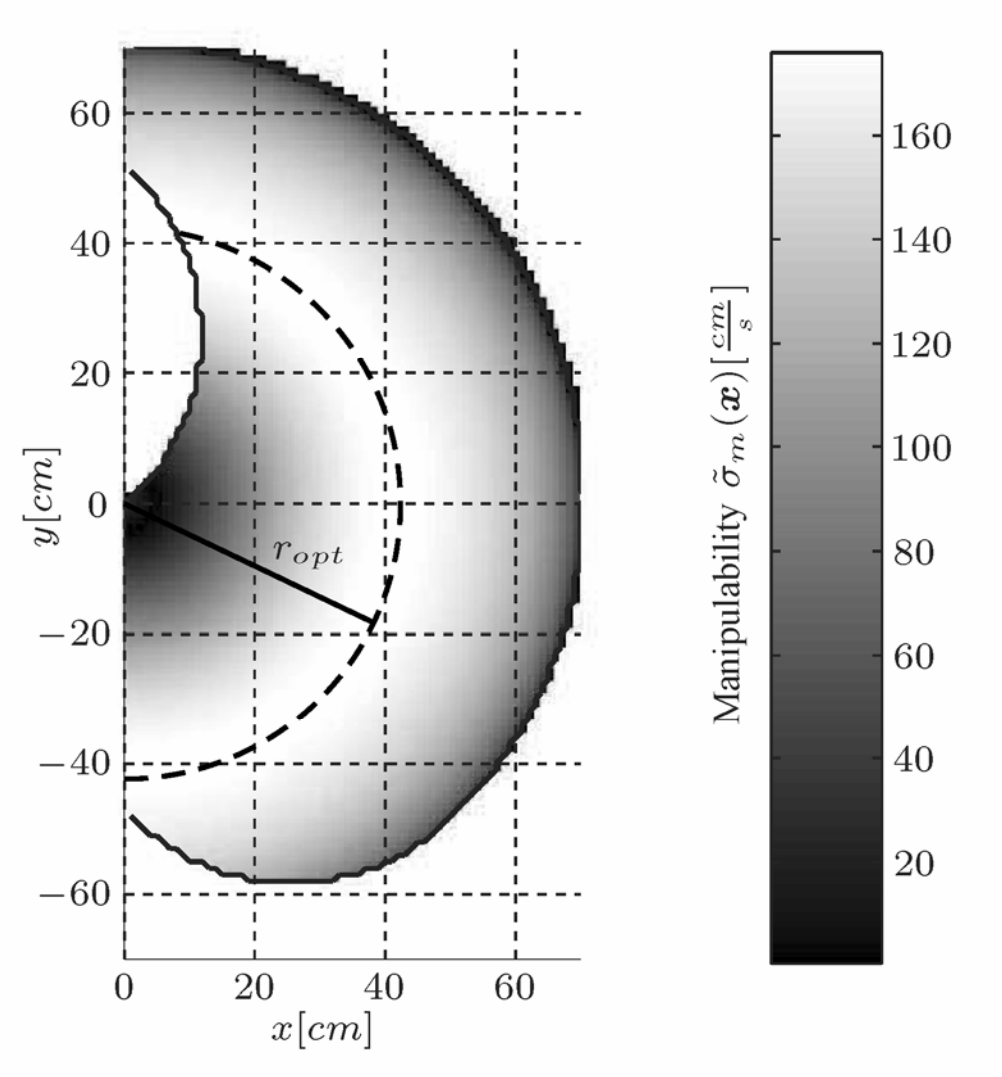
- Velocity manipulability
- Only planar degrees of freedom relevant

Jacobian

$$\boldsymbol{J} = \begin{pmatrix} \frac{\delta x}{\delta q_2} & \frac{\delta x}{\delta q_3} \\ \frac{\delta y}{\delta q_2} & \frac{\delta y}{\delta q_3} \end{pmatrix}$$
$$= \begin{pmatrix} -l_2 \sin(q_2) - l_3 \sin(q_2 + q_3) & -l_3 \sin(q_2 + q_3) \\ l_2 \cos(q_2) + l_3 \cos(q_2 + q_3) & l_3 \cos(q_2 + q_3) \end{pmatrix}$$

Smallest Singular Value

- Maximum speed in arbitrary direction
- Circles of maximum manipulability with radius r_{opt}



Maximizing Manipulability

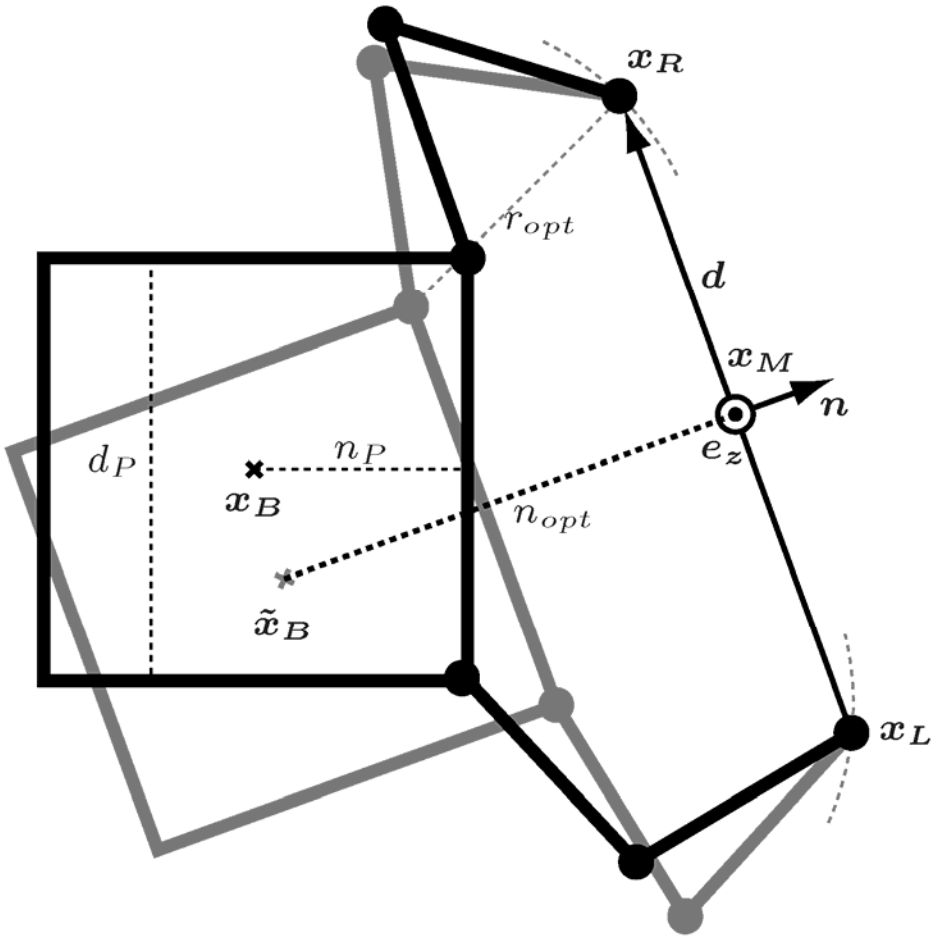
Optimal Position

- Maximum manipulability
- End-effectors on circle with r_{opt}

Geometric Solution

$$\boldsymbol{n} = \frac{\boldsymbol{d}}{\|\boldsymbol{d}\|} \times \boldsymbol{e_z}$$

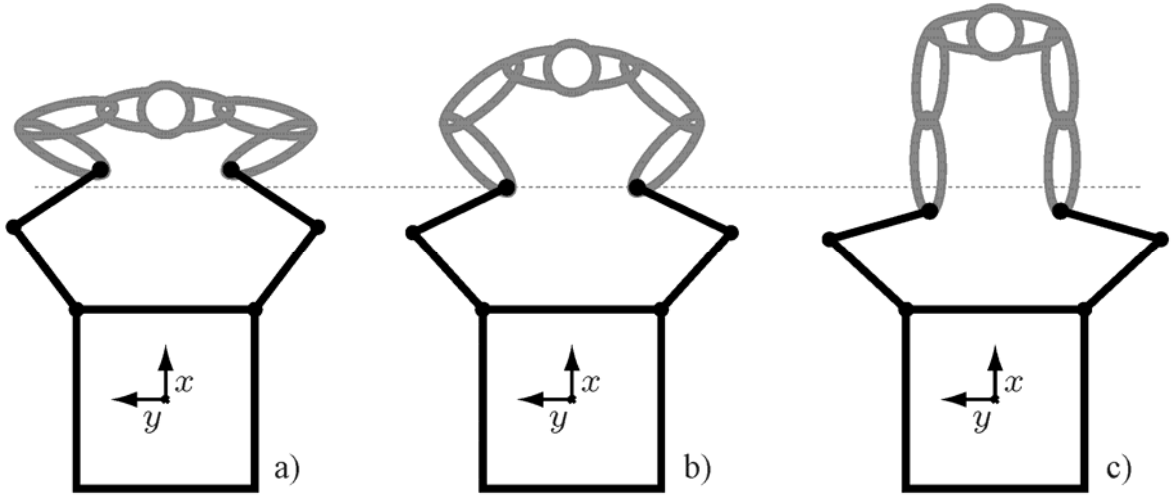
$$n_{opt} = \sqrt{r_{opt}^2 - \left(\frac{\|\boldsymbol{d}\| - d_P}{2}\right)^2} + n_P$$



Including Human Arm Workspace in Optimization Strategy

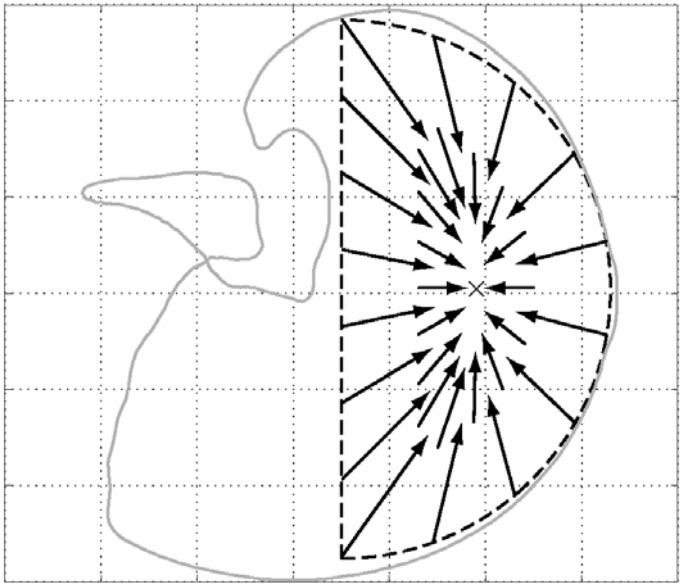
Motivation

- Limited repositioning speed of mobile base
- Suboptimal position in transient phases



Extension

- Consider human arm workspace



Advantages

- Faster arm motions possible
- Less repositioning efforts

Disadvantage

- Tracking of operator position required

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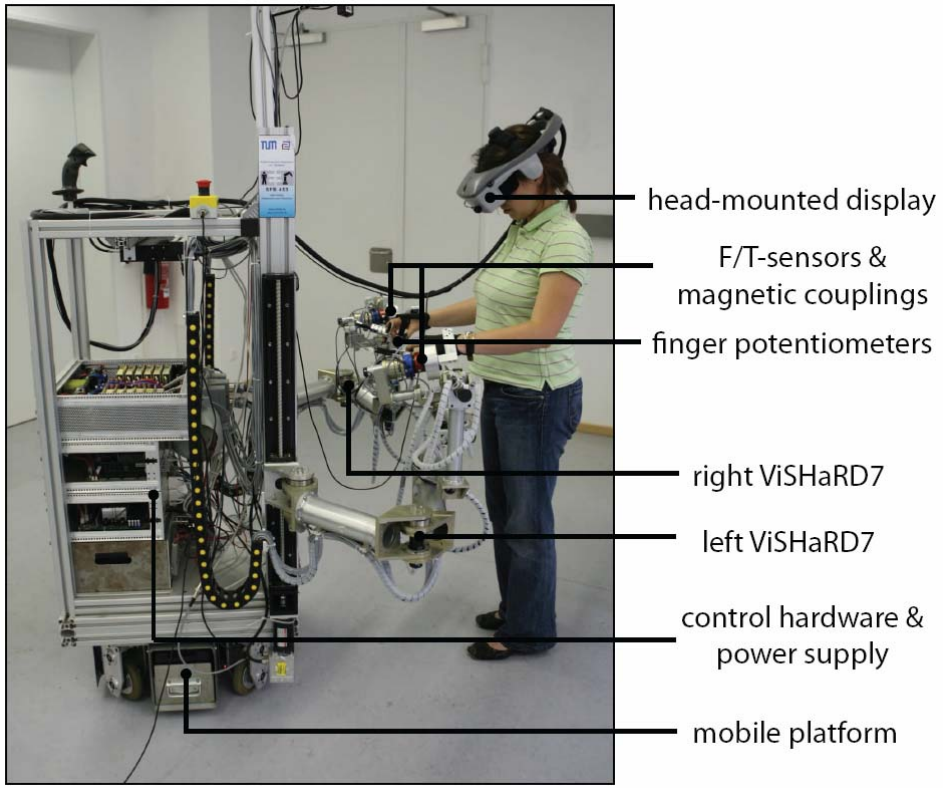
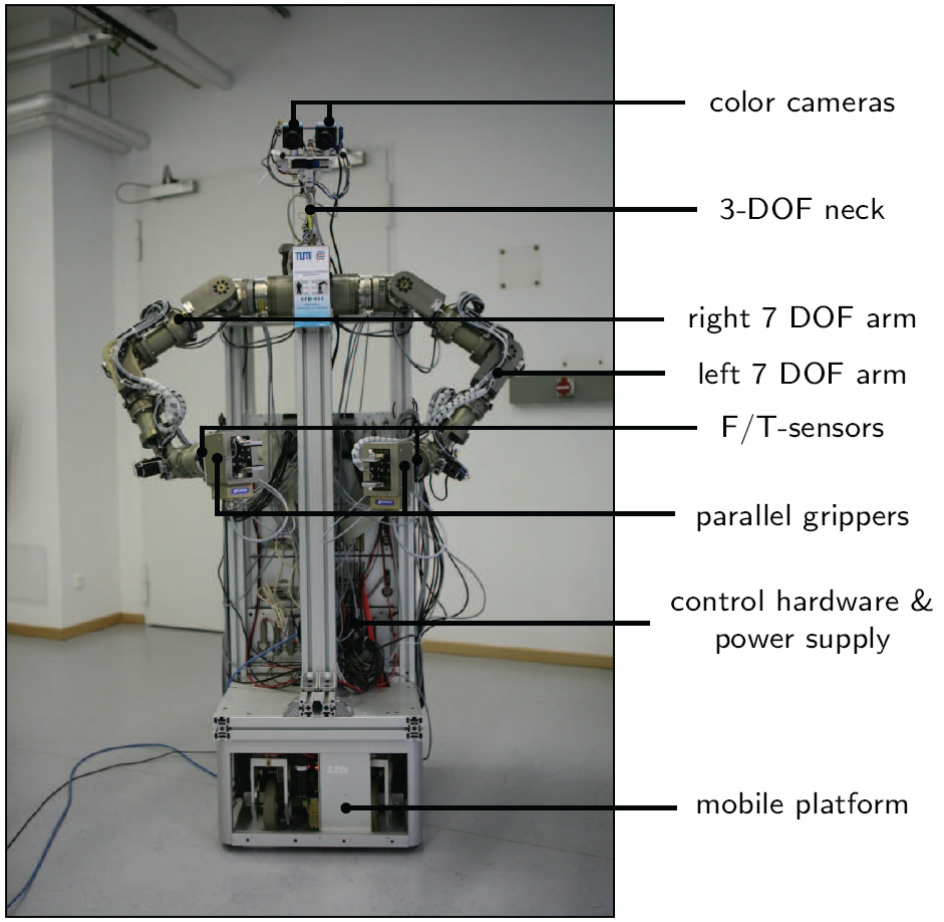
Experimental Setup

Mobile Haptic Interface (MHI)

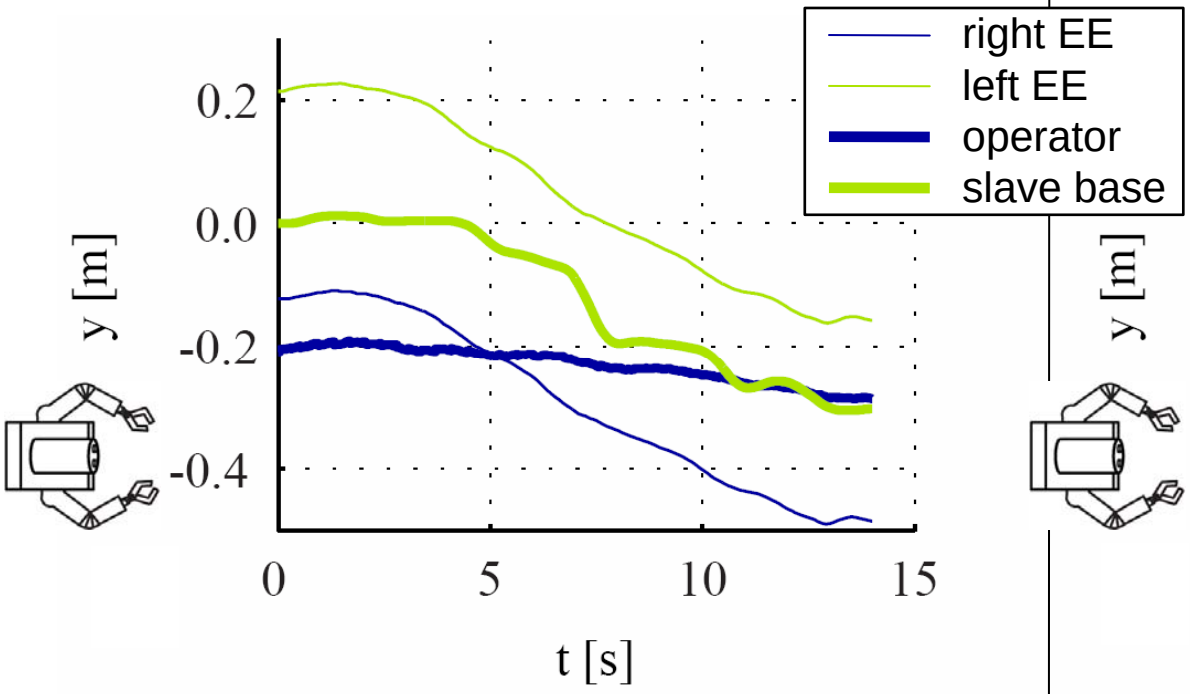


Mobile Teleoperator (TOP)



Manipulation While Standing Still

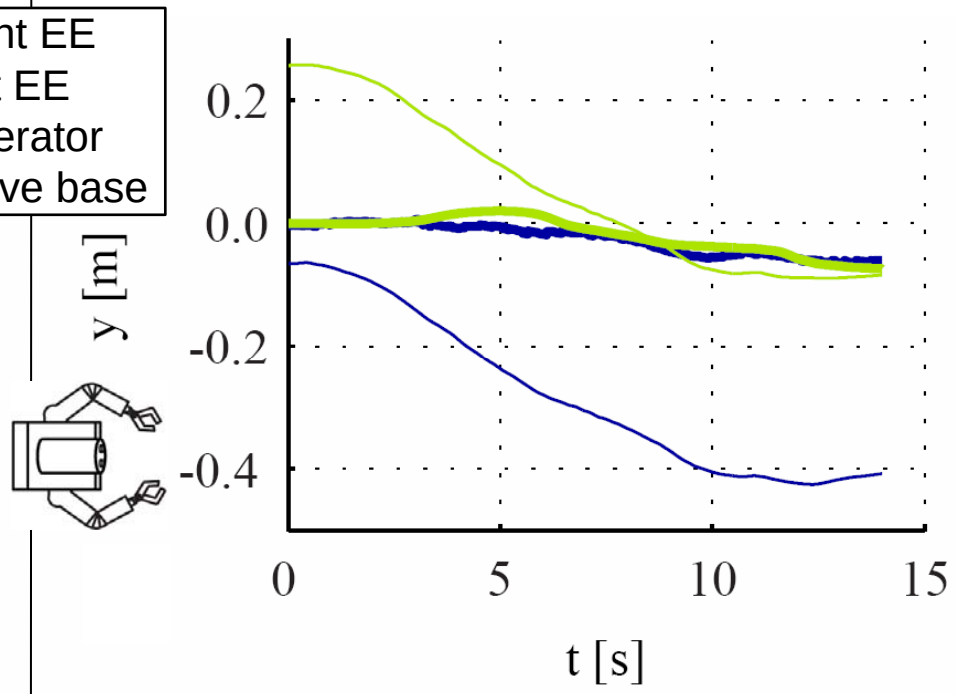
Coupling of End-Effectors Only



- No tracking between operator body and teleoperator base

+ End-effectors maintain same distance from body

Coupling of Body and End-Effectors

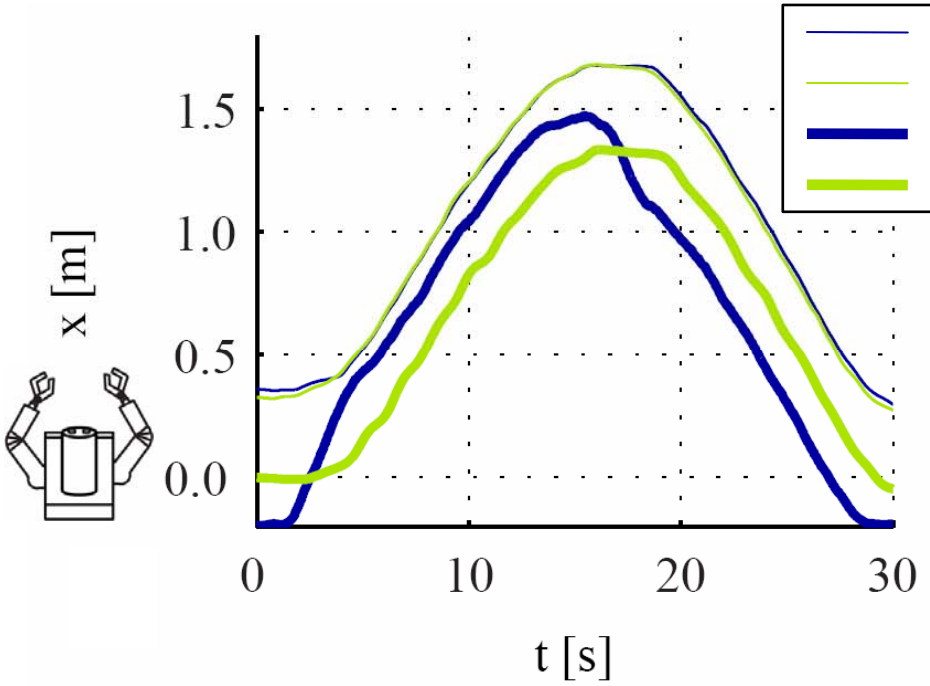


+ Tracking between operator body and teleoperator base

- End-effectors reach workspace boundaries

Locomotion

Coupling of End-Effectors Only



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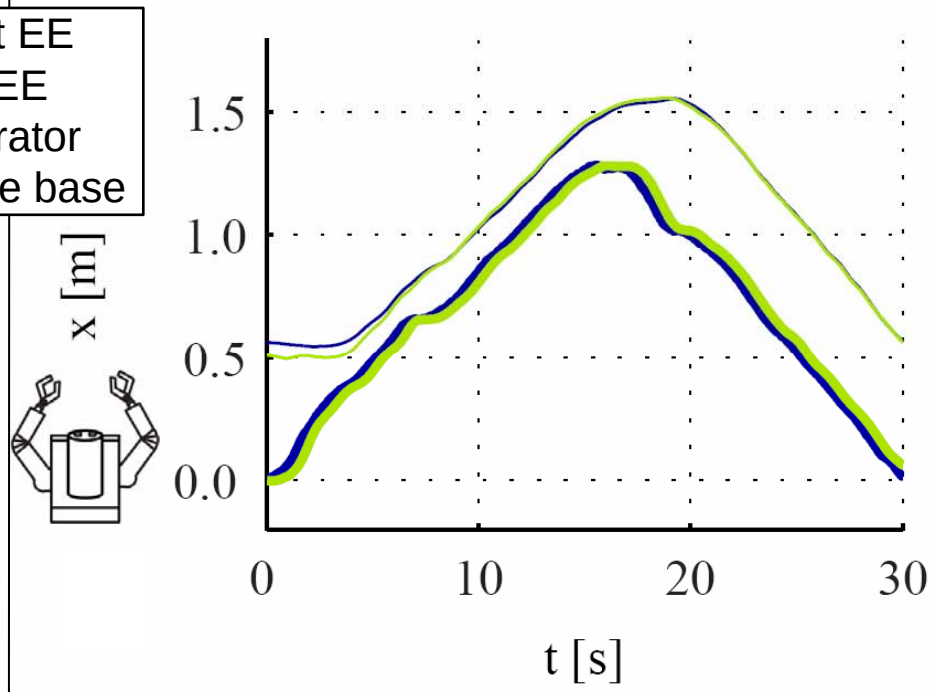
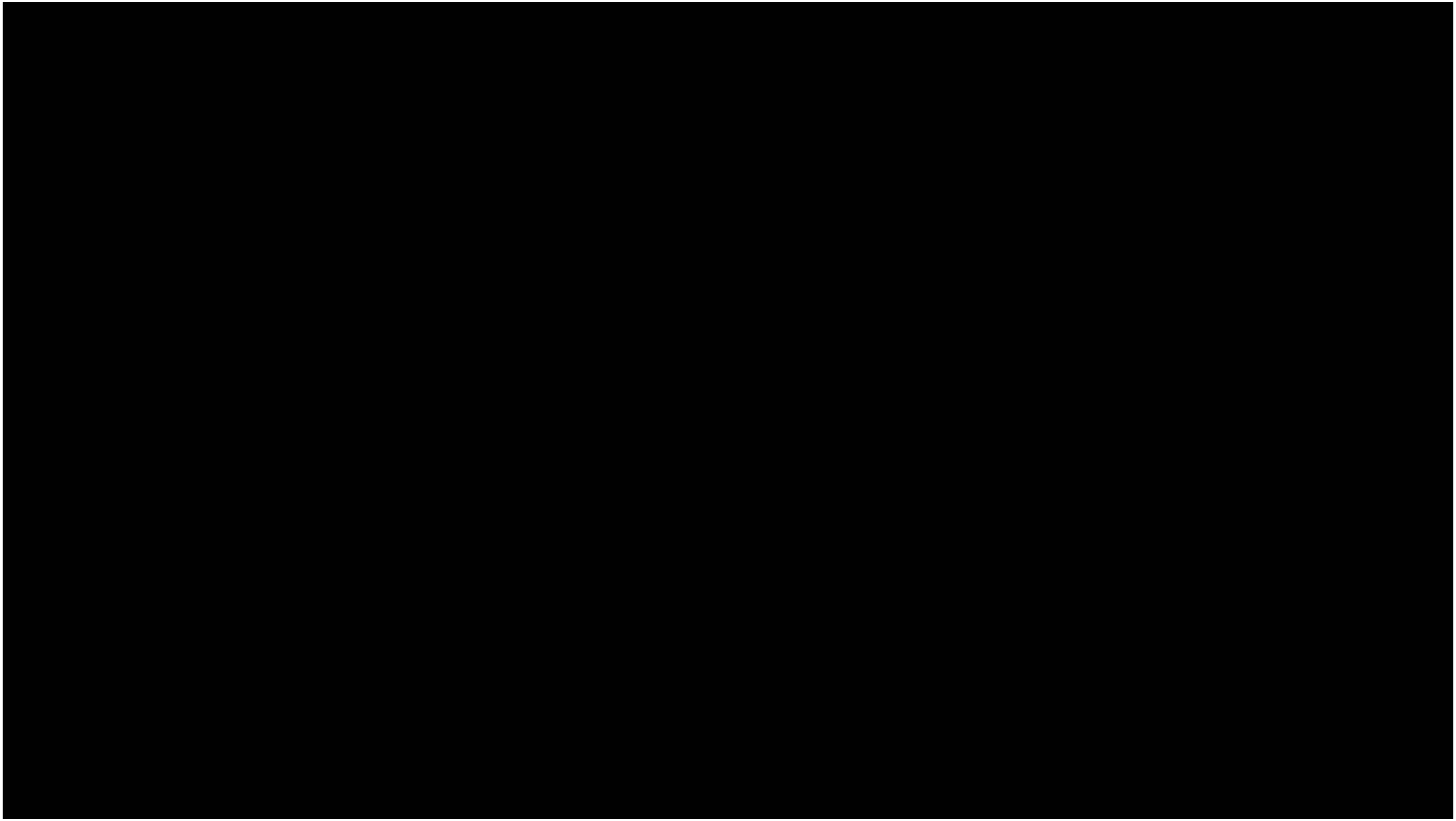
Coupling of Body and End-Effectors



+ Tracking between operator body and teleoperator base

- End-effectors reach workspace boundaries

Video



Video


ROBOT CUP
HRP-2 Teleoperation and Cooperation with On-Site Human
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Conclusion

Wide-area teleoperation

- Exoskeletons very fatigueing, joystick/foot pedal unintuitive

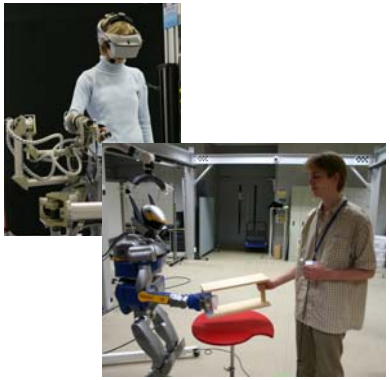
→ Mobile haptic interface coupled with mobile teleoperator

Two coupling schemes for wide-area teleoperation:

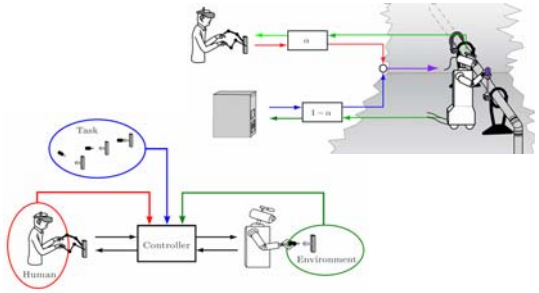
- Coupling of end-effectors only
  - Optimization of base positions by using local optimization strategies
  - No tracking of operator required
  - Enhances ease of use
- Coupling of body and end-effectors
  - Direct mapping of operator locomotion to base position
  - Tracking of operator required
  - Visual cues more closely resemble proprioception

Haptic Interaction

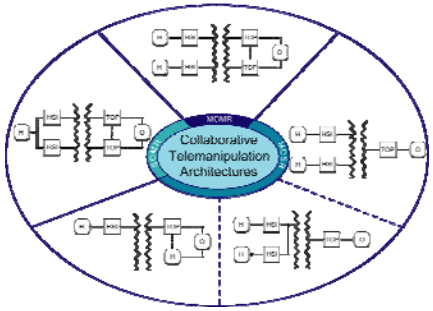
High-Fidelity Telepresence and Teleaction



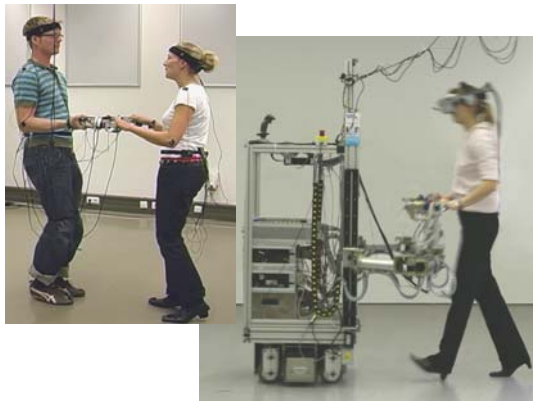
Advanced teleoperation controllers



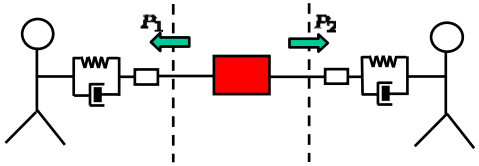
Single and multi-user scenarios



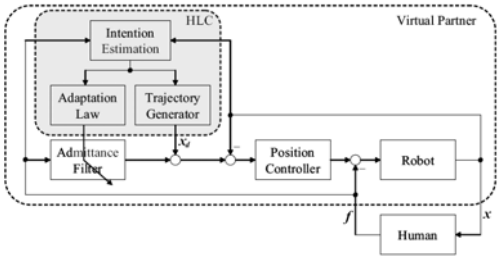
Haptic Human-Robot Interaction



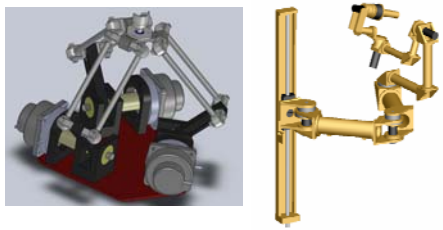
Analysis of human-human interaction



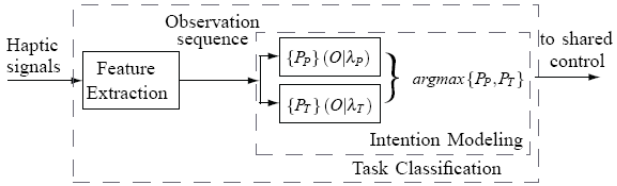
Synthesis of interactive robotic systems



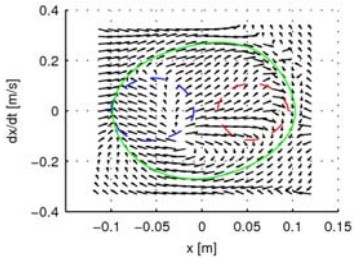
Design and control of haptic interfaces



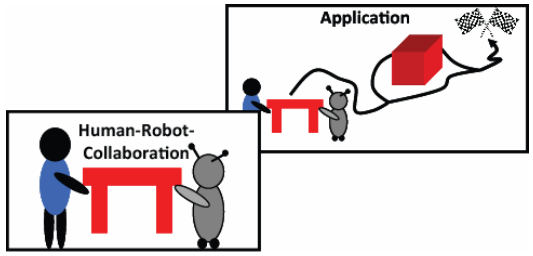
Intention recognition



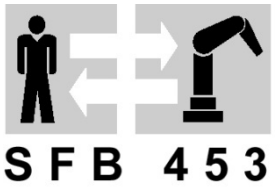
Adaptation



Joint decision making



Acknowledgements



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