Control of a multi-robot cooperative team guided by a human operator

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Intermediate Presentation Master Thesis

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Cooperative Manipulation Tasks

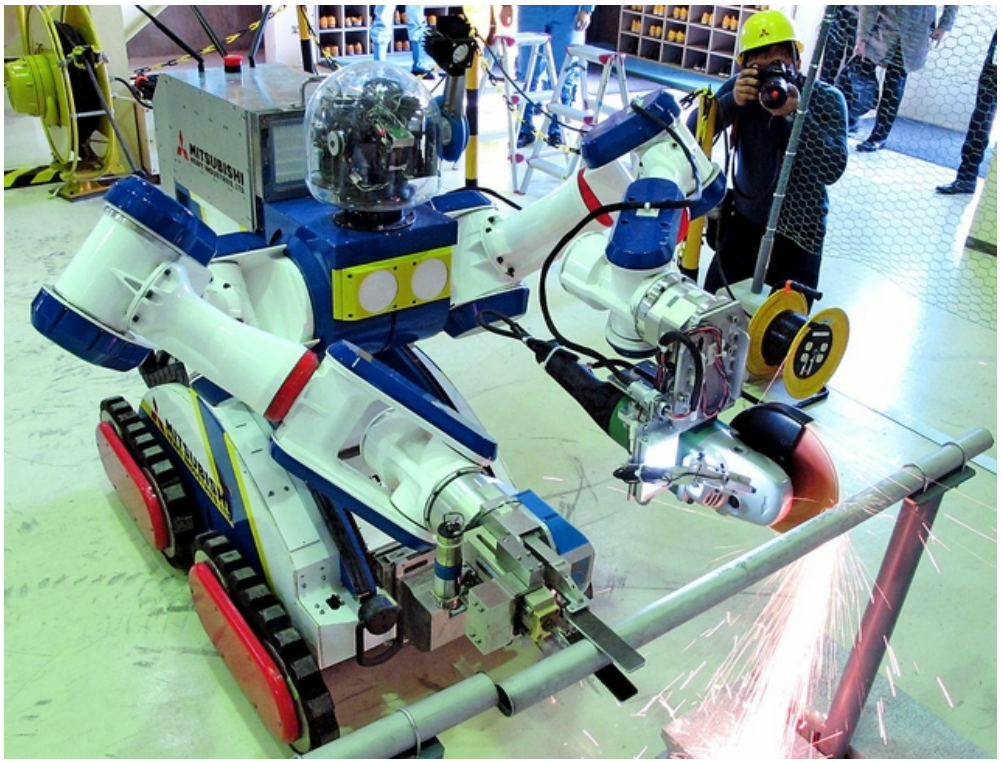

Figure : Demonstration of MHI MEISTeR at Fukushima Daiichi Nuclear Power Station[]

- transportation of large/heavy objects
- assembly of multiple parts
- grasping an object without rigid fixture
- deforming a flexible object
- coordinated use of tools

Problem Formulation

- Precise and stable control especially during free-motion/contact transition
- Perform friction based grasps
- Ability to operate in remote/hazardous areas
- Intuitive high-level control for the human operator

Related Work: Cooperative Manipulation

- Hybrid Position/Force Control [Wen et al. 1992] [Hsu 1993]
  - Control of motion and internal forces
  - Viable for stable contacts
- Impedance Control
  - Object-Environment [Schneider and Cannon 1992]
  - Internal Force-based[Bonitz and Hsia 1996]
  - Combined [Caccvale and Villani 2001; Caccavale et al. 2008]
  - Internal + Object force feed-forward [De Pascali et al. 2015]
- Formation Control [Sieber, Music, and Hirche 2015]

Intrinsically Passive Control (IPC)

- High-level Supervisor and low-level IPC
- IPC + robot: passive
- Power provided by Supervisor
- Environment assumed passive

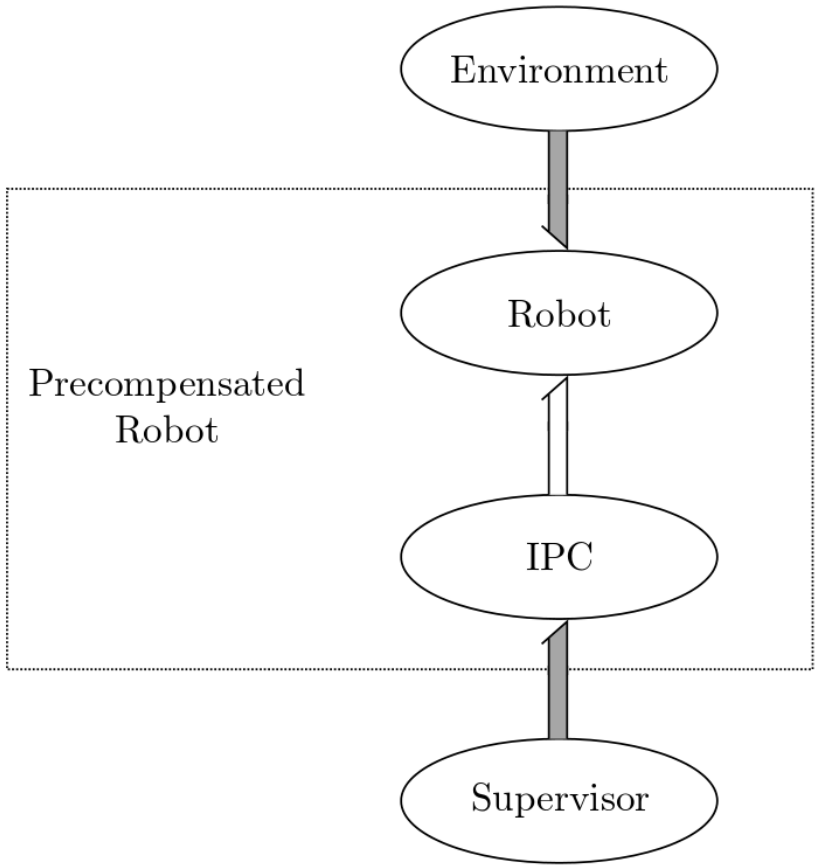

Figure : Overview of the IPC architecture [Stramigioli 2001]

Structure of the IPC

- Spring-mass-damper system
- Simulated virtual object
- Manipulators modelled by inertias
- Potential (inertia) and kinetic (springs) energy
- Energy dissipation in damper: passivity

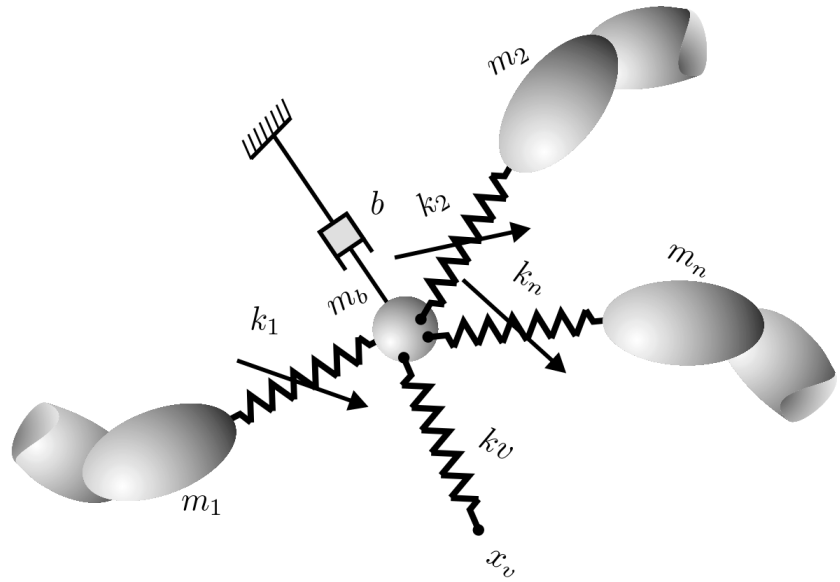

Figure : Mass-spring-damper structure of the IPC [Stramigioli 2001]

Grasping an object

- Variable rest-length springs
- Rest-length: virtual object size
- Power provided by Supervisor

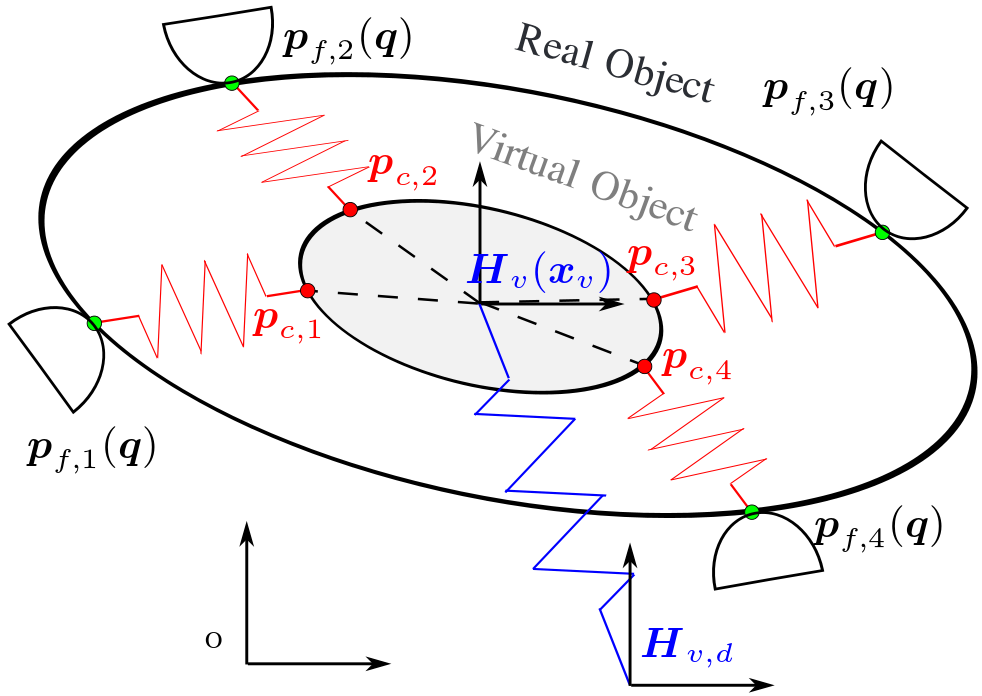

Figure : Virtual and real object [Wimboeck, Ott, and Hirzinger 2008]

The Supervisor

- Two power ports per IPC-robot-system
- Human operator takes role of Supervisor
- Connected via delayed communication line

Tele-operation

- Preserving passivity
- Scattering or Wave variables

Grasping force optimization for friction contacts

- required contact normal force is dependent on tangential forces
- high tangential forces arise during acceleration
- other requirements: safety margin, maximum grasping force $\Rightarrow$ cost function
- linear matrix inequality (LMI) problem

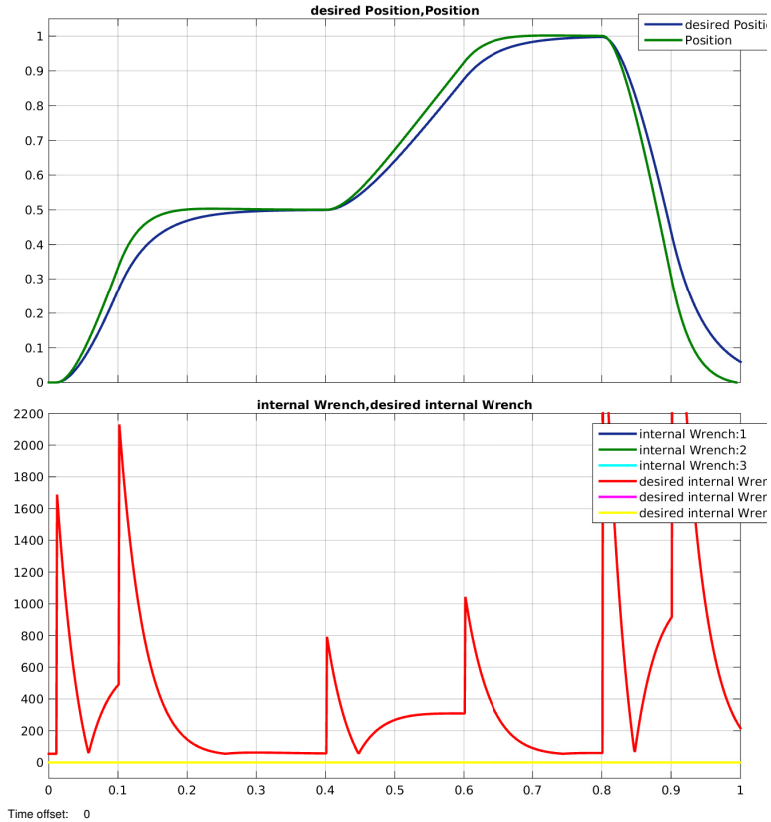

Figure : Position, Internal wrench

Comparison of Grasp Controllers 1

Impedance-based reference trajectory generation [Caccvale and Villani 2001]

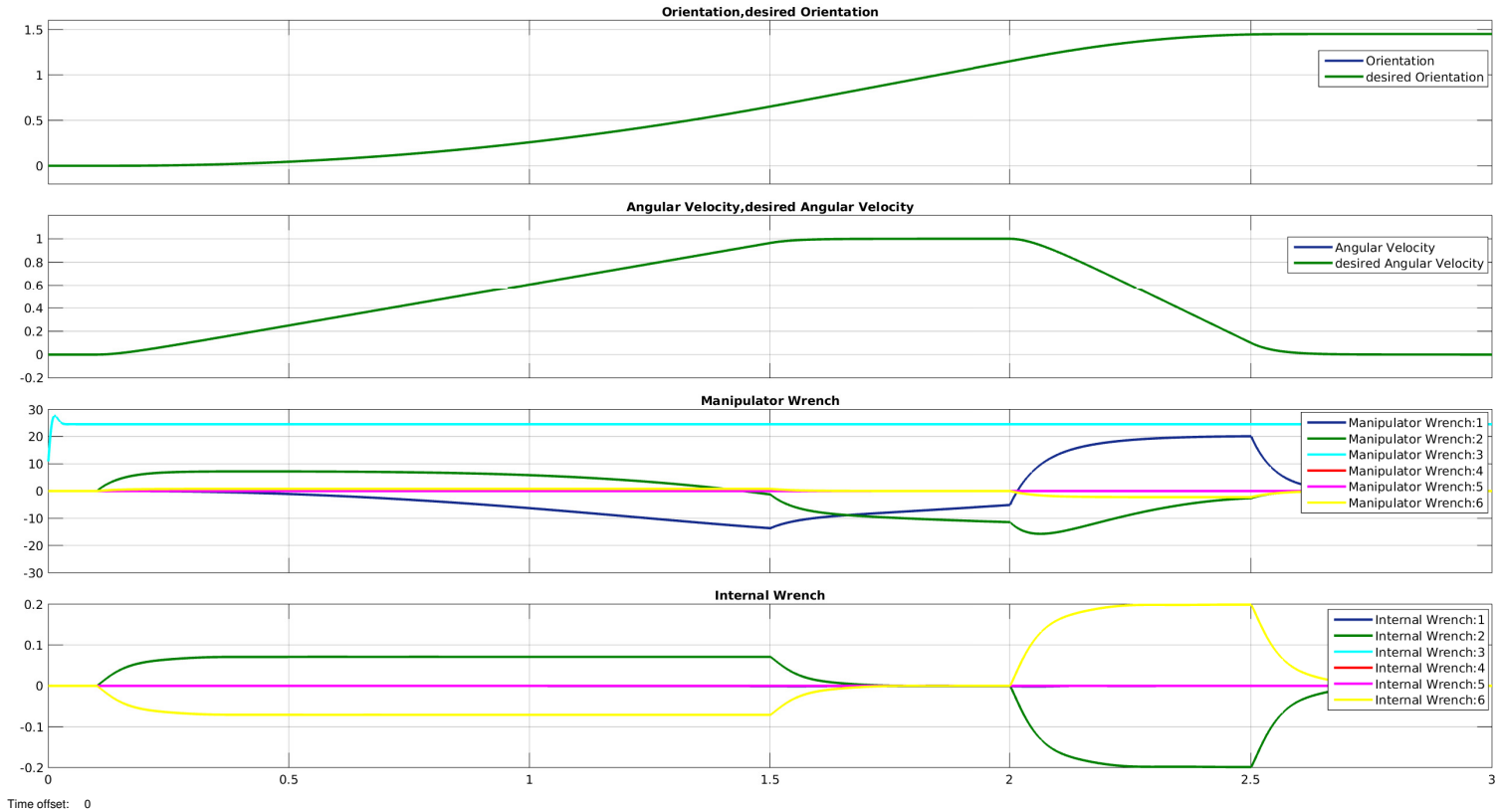

Figure : Position, Velocity, Manipulator wrench, Internal wrench

Comparison of Grasp Controllers 2

Internal impedance control with object force-feedforward [De Pascali et al. 2015]

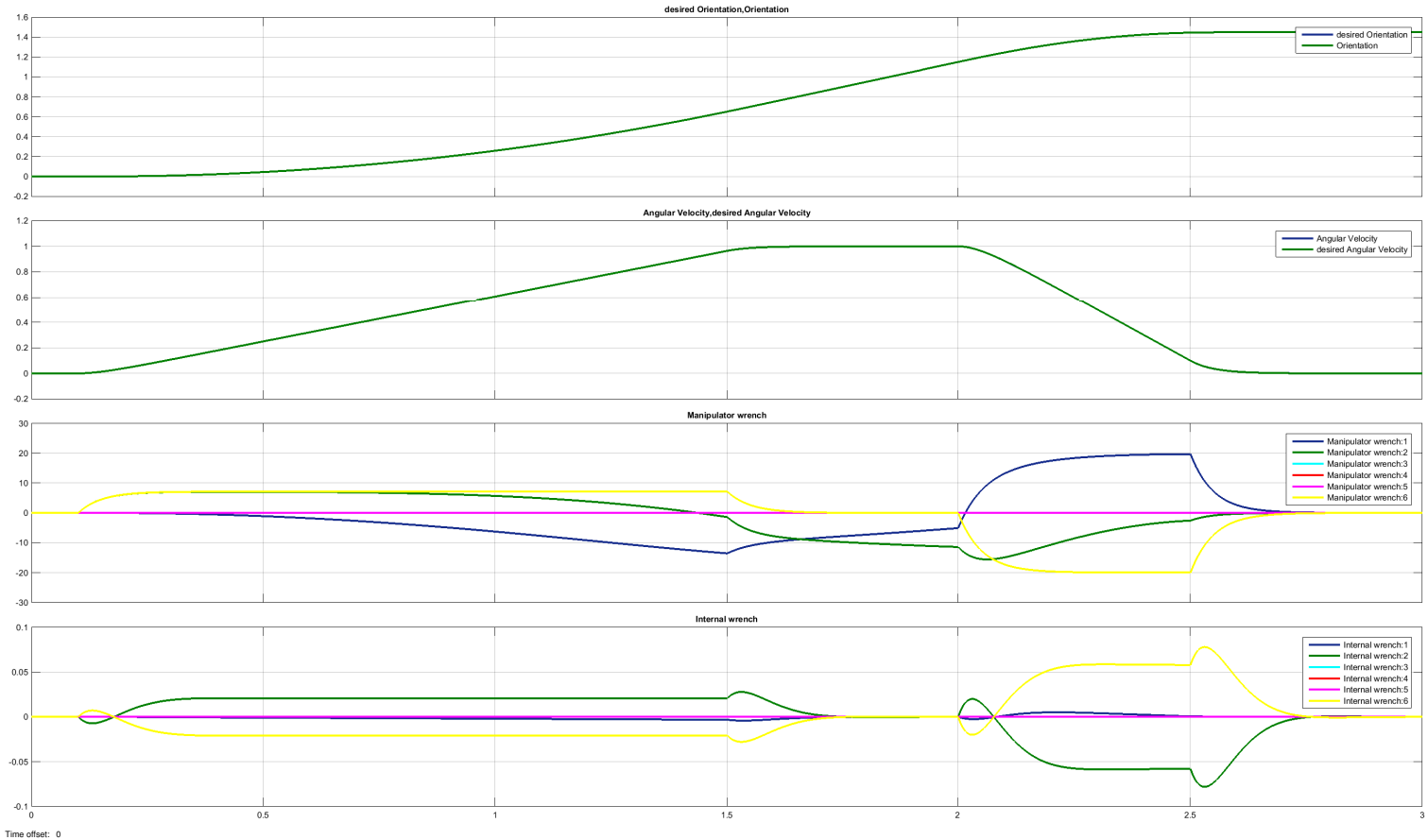

Figure : Position, Velocity, Manipulator wrench, Internal wrench

Conclusion

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