

ASLLA Symposium
Jan. 31, 2019

New Horizon of Telerobotics: **From Stability to Performance**

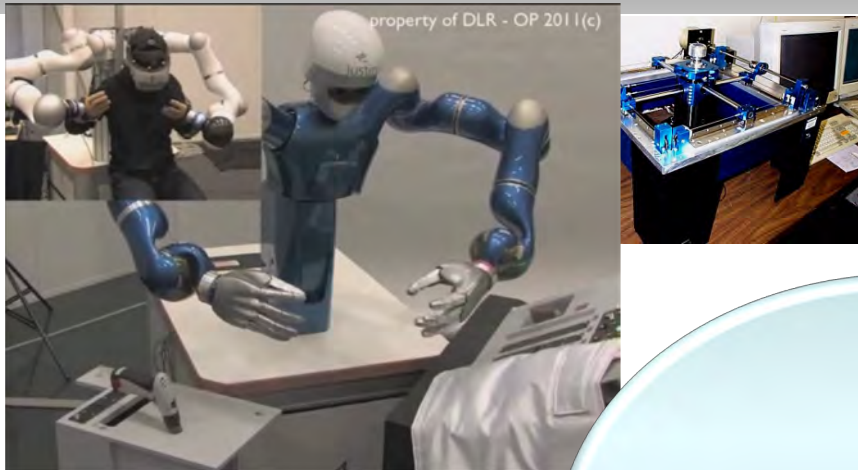
Jee-Hwan Ryu

School of Mechanical Engineering
Korea University of Technology and Education

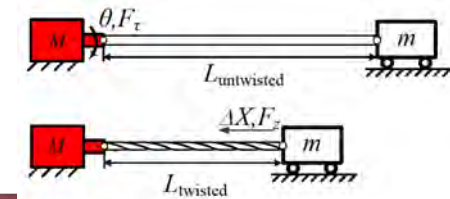


Research Areas in BioRobotics Lab.

Haptics and Telerobotics



Exoskeleton



Human-Robot Haptic Interaction

Autonomous Vehicle



Industrial Applications



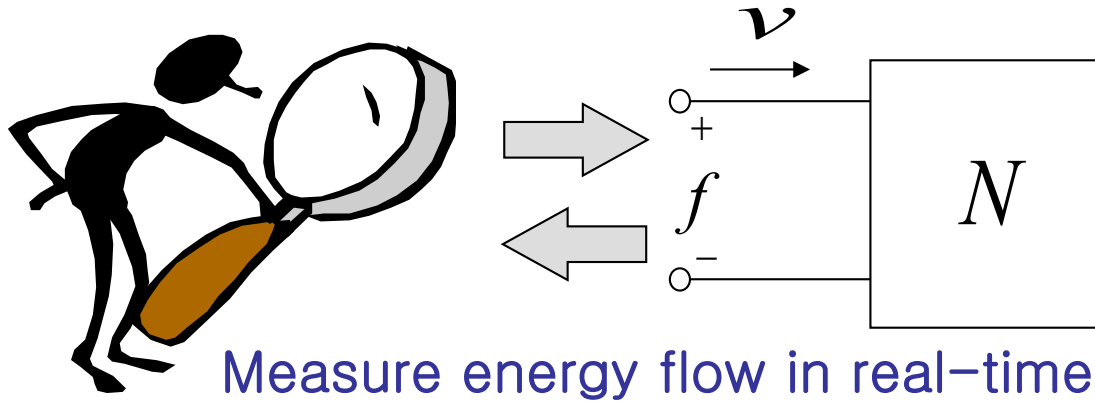
Instability from High Stiffness Coupling



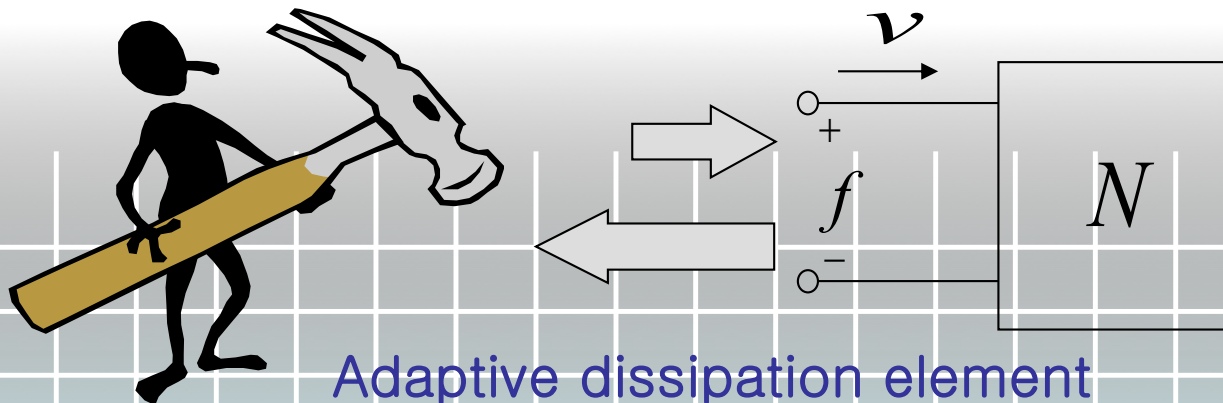
Time Domain Passivity Approach (TDPA)

Passivity Observer (PO)

-IEEE TRA 2002-
-US Patent 2006-

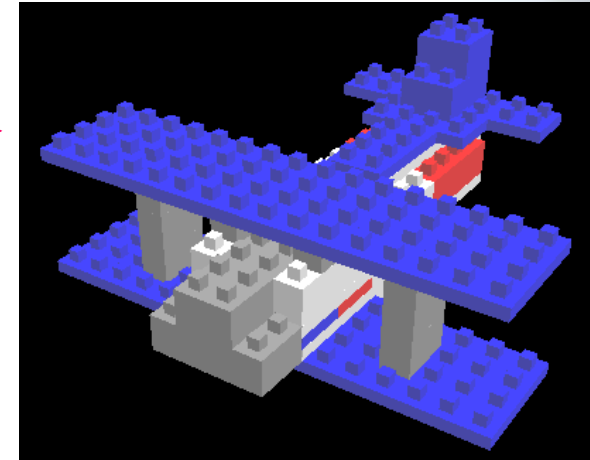


Passivity Controller (PC)



Implemented to Excalibur Haptic Interface at University of Washington

-IEEE TRA 2002-

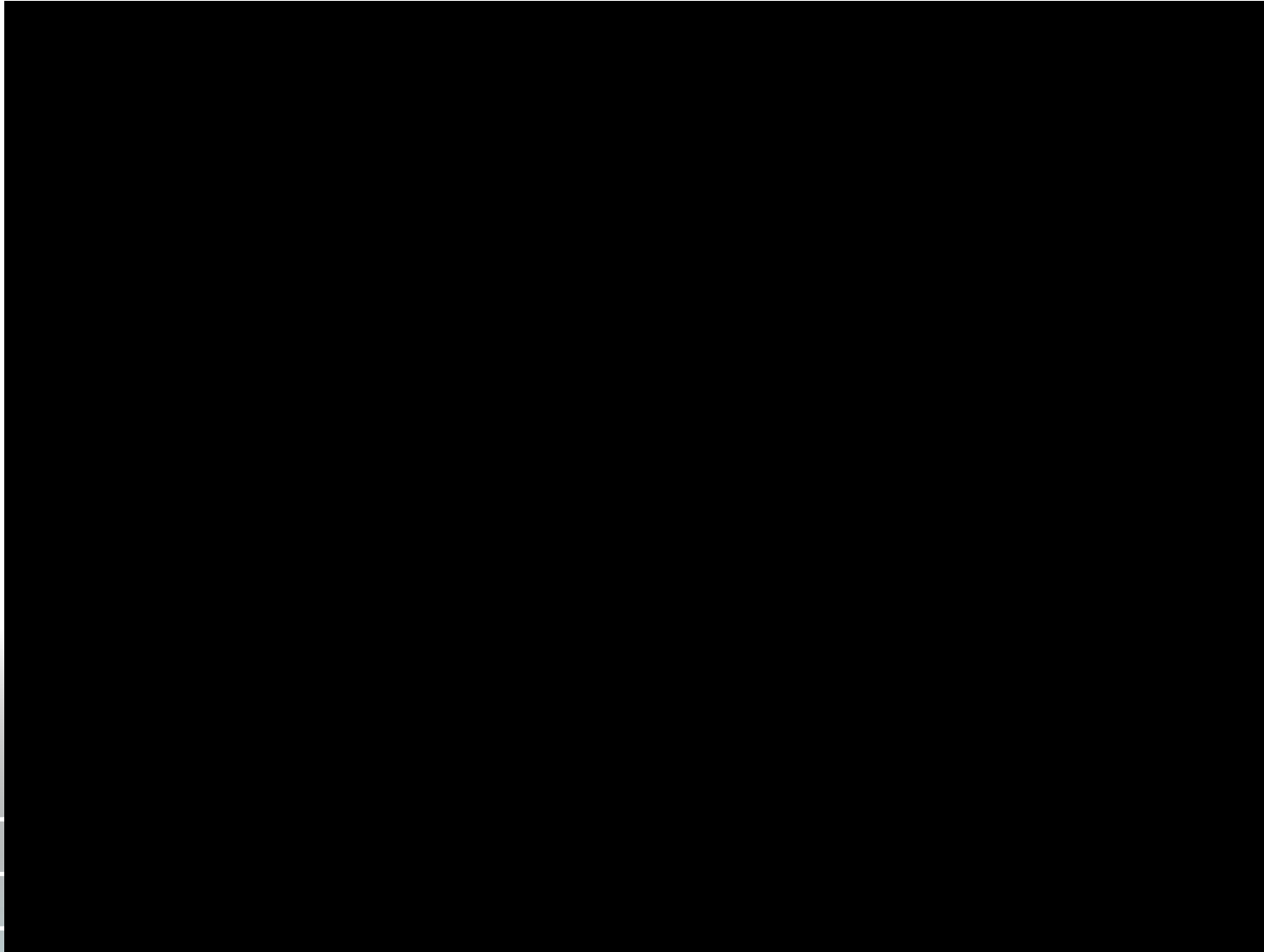


Virtual Lego Airplane

Lego Haptic Device (LHD)

ISSUE: Maximum allowable stiffness

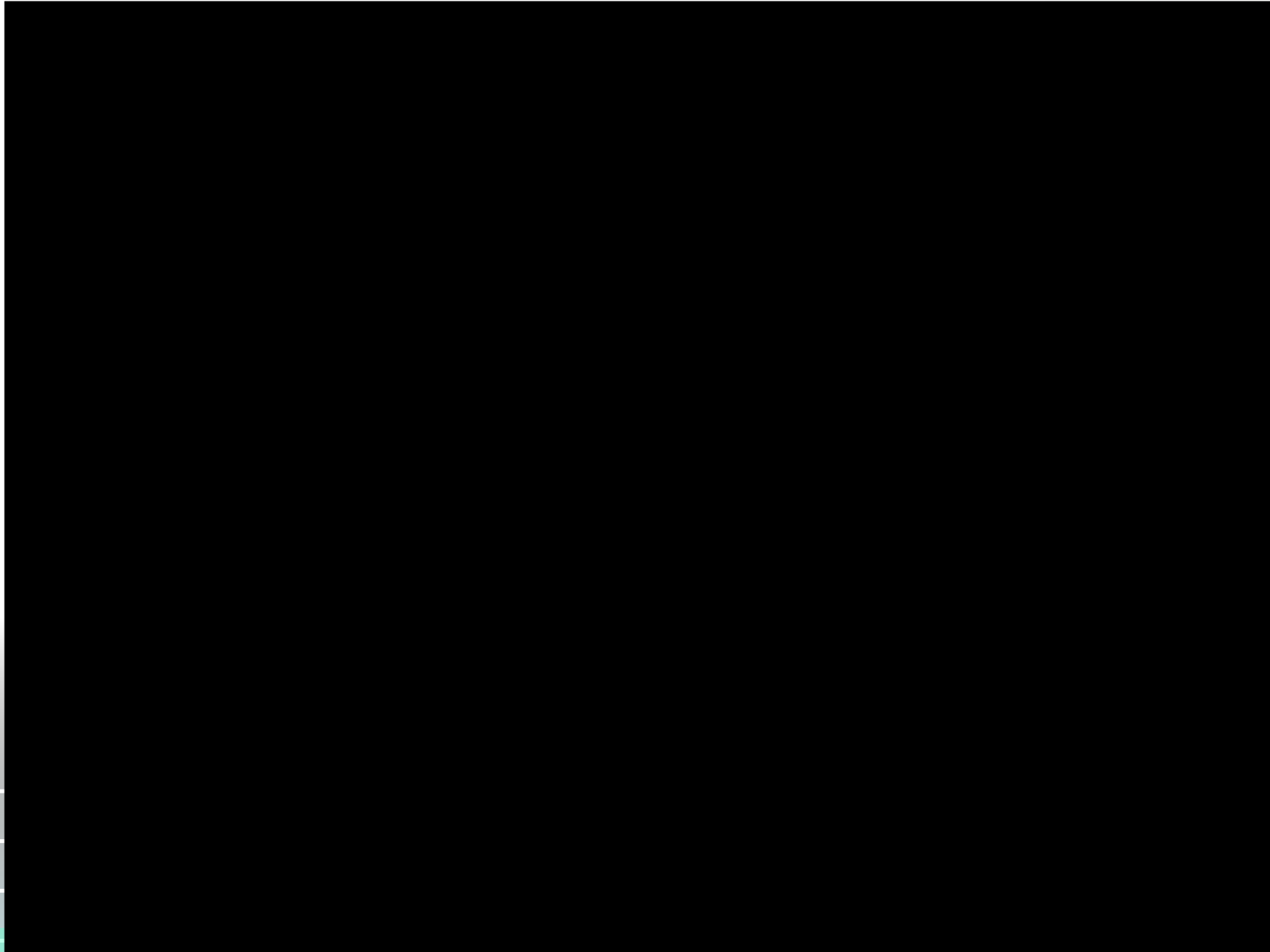
Haptic Interaction with a High Stiffness VE (stiffness = 90kN/m)



Teleoperation Without Time Delay



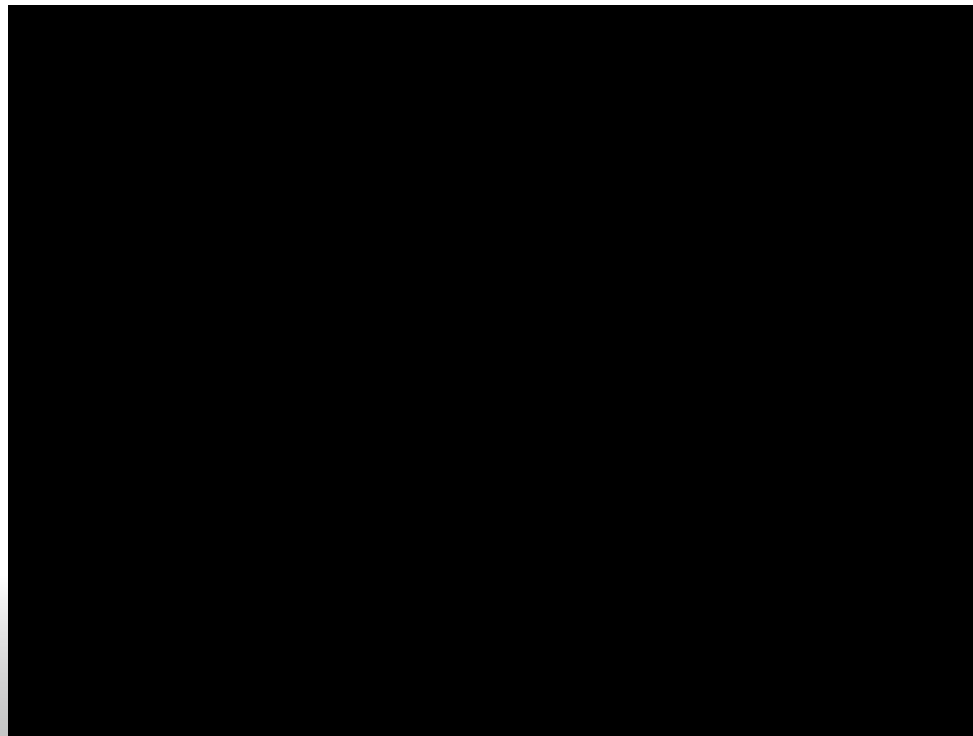
Time-delayed Teleoperation



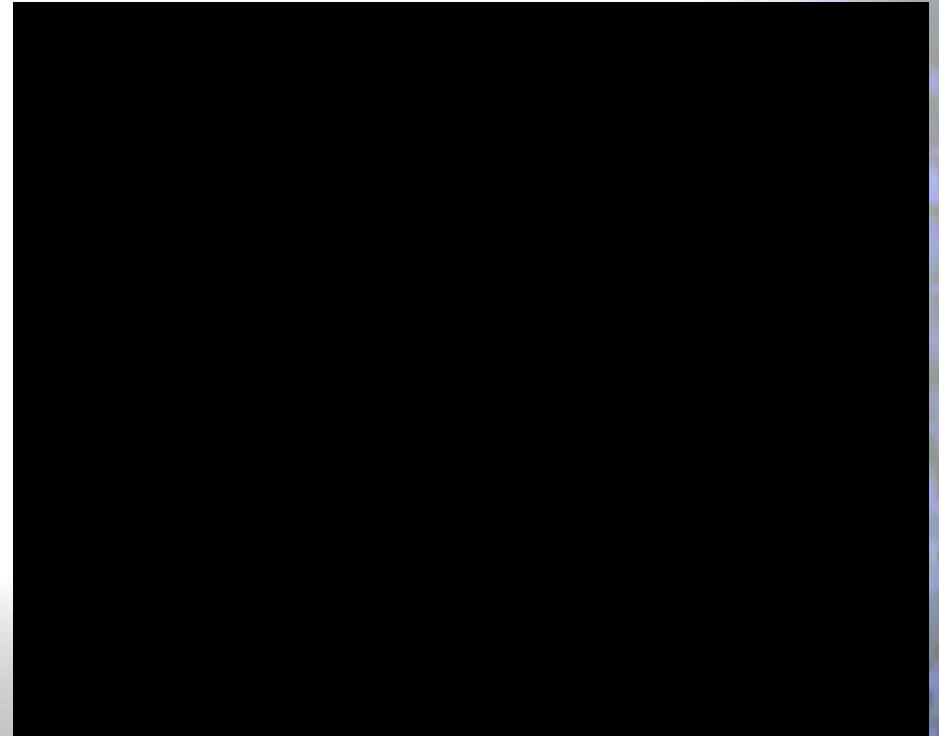
Explicit Force Control

-ICRA2017-

Without TDPA



With TDPA

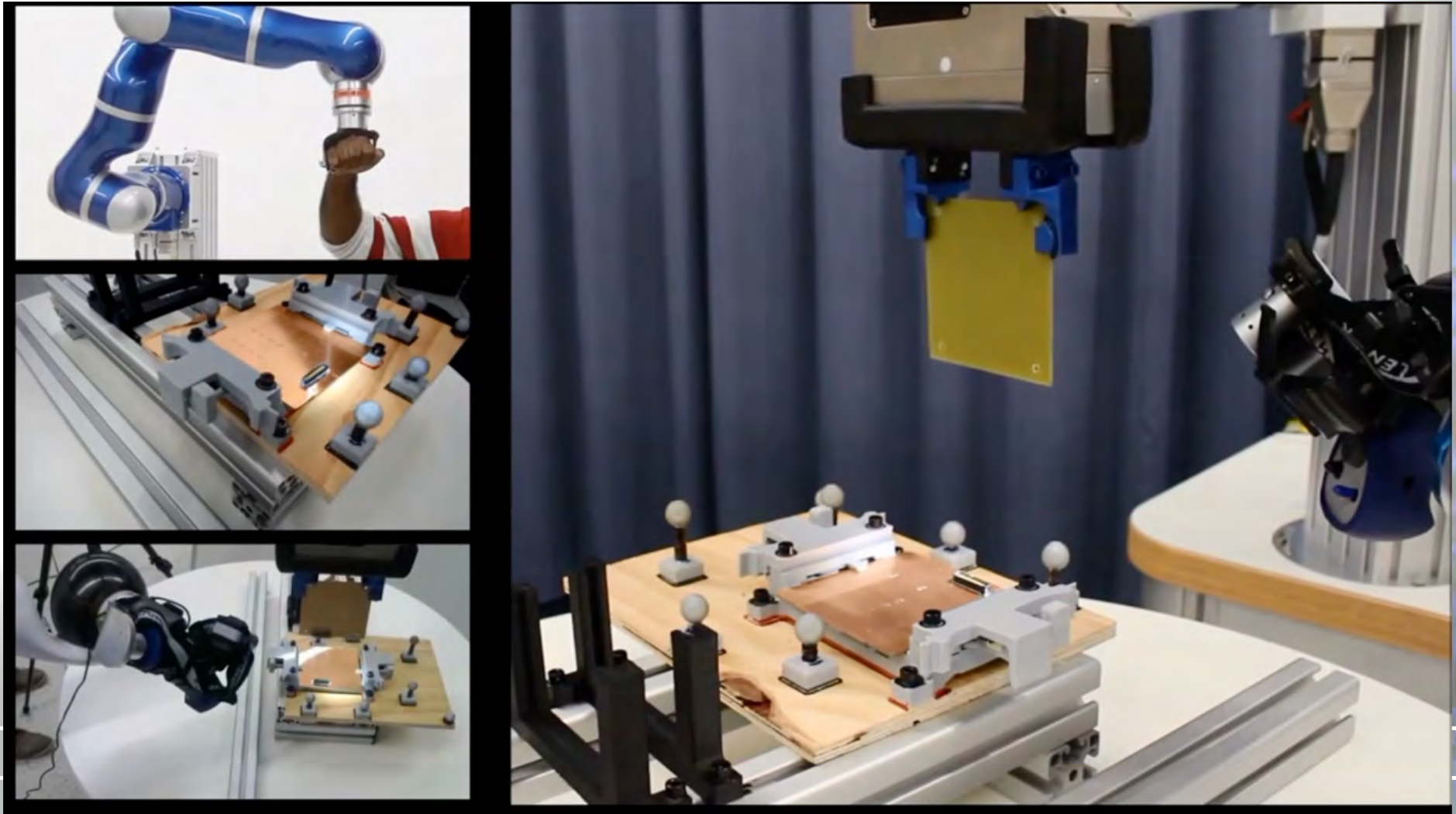


Stanford and DLR, 2017

BRL, KOREATECH

Explicit Force Control for Teleoperation

-Submitted to IEEE IE-



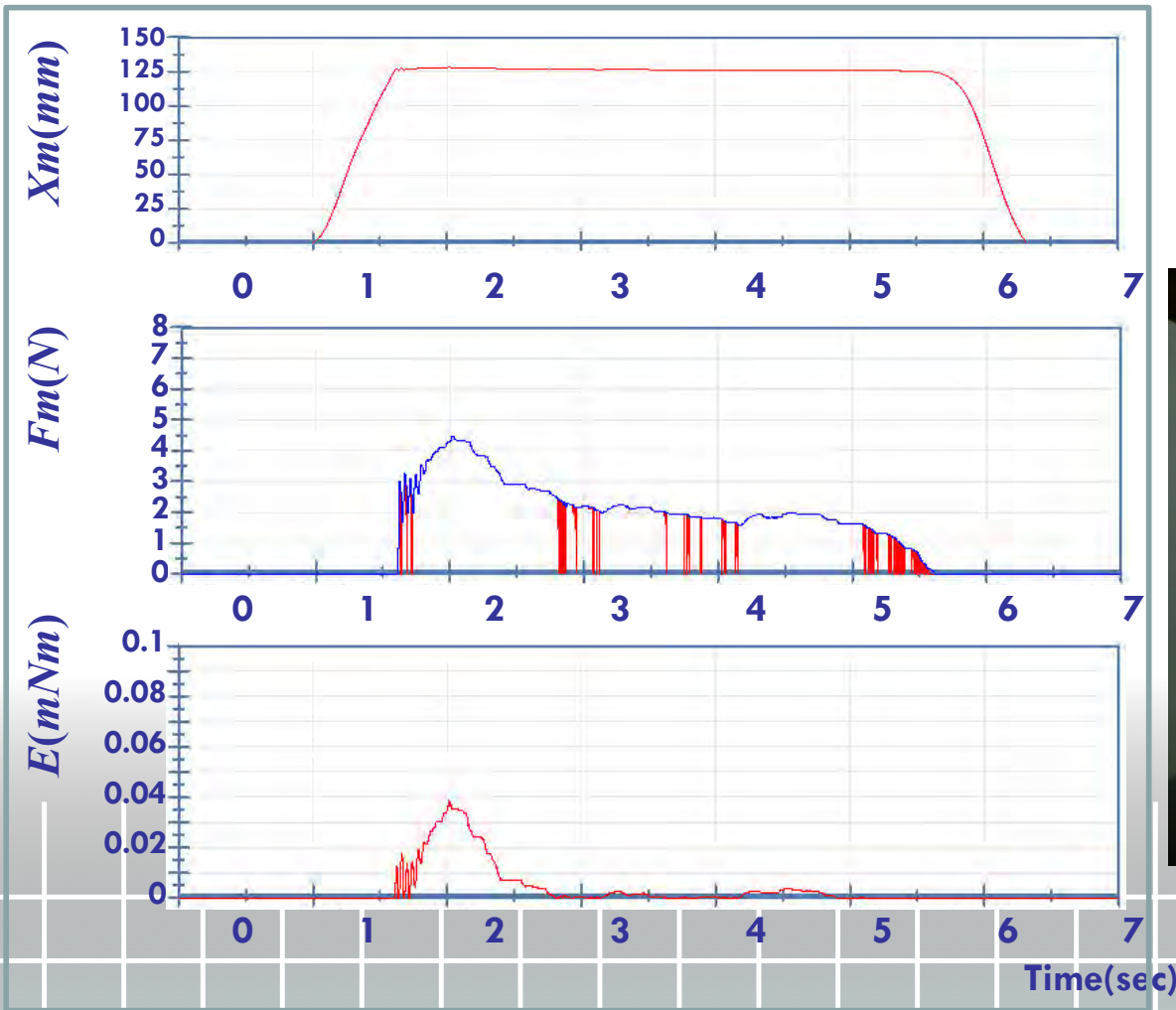
DLR, 2018

BRL, KOREATECH

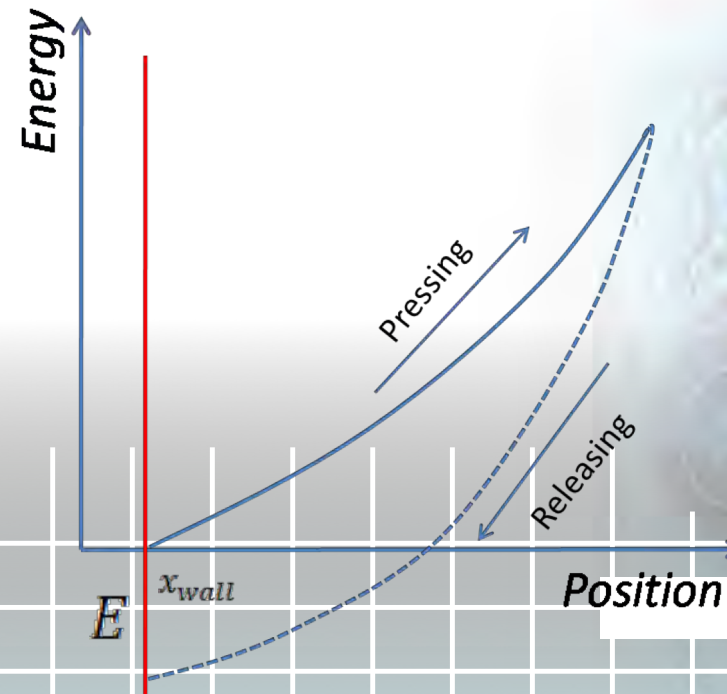
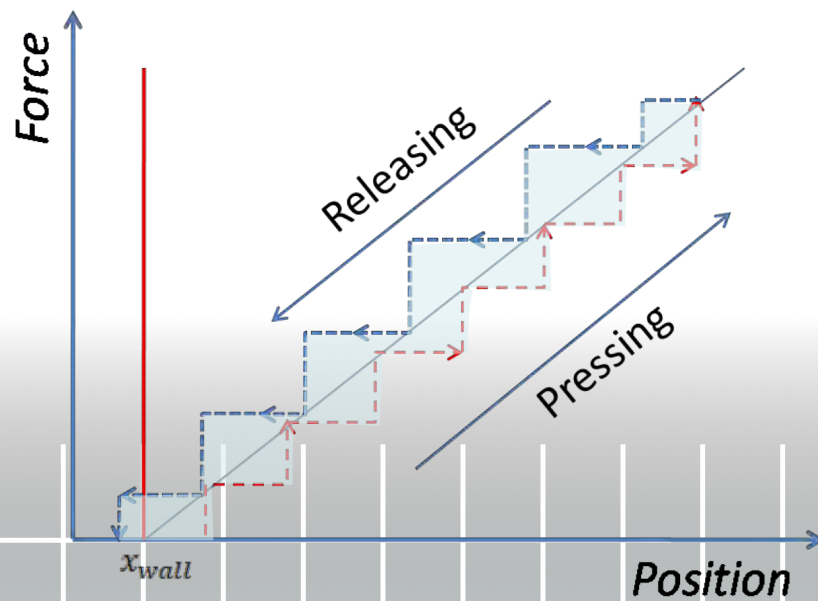
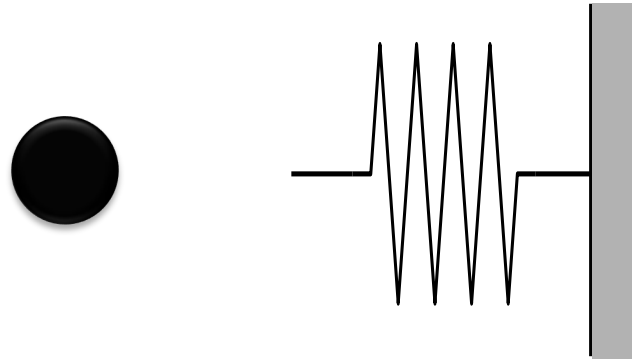
Still Limited for Higher Stiffness

$VE \text{ freq} : 100\text{Hz}$

$k_{ve} : 1.94\text{kN/m}$

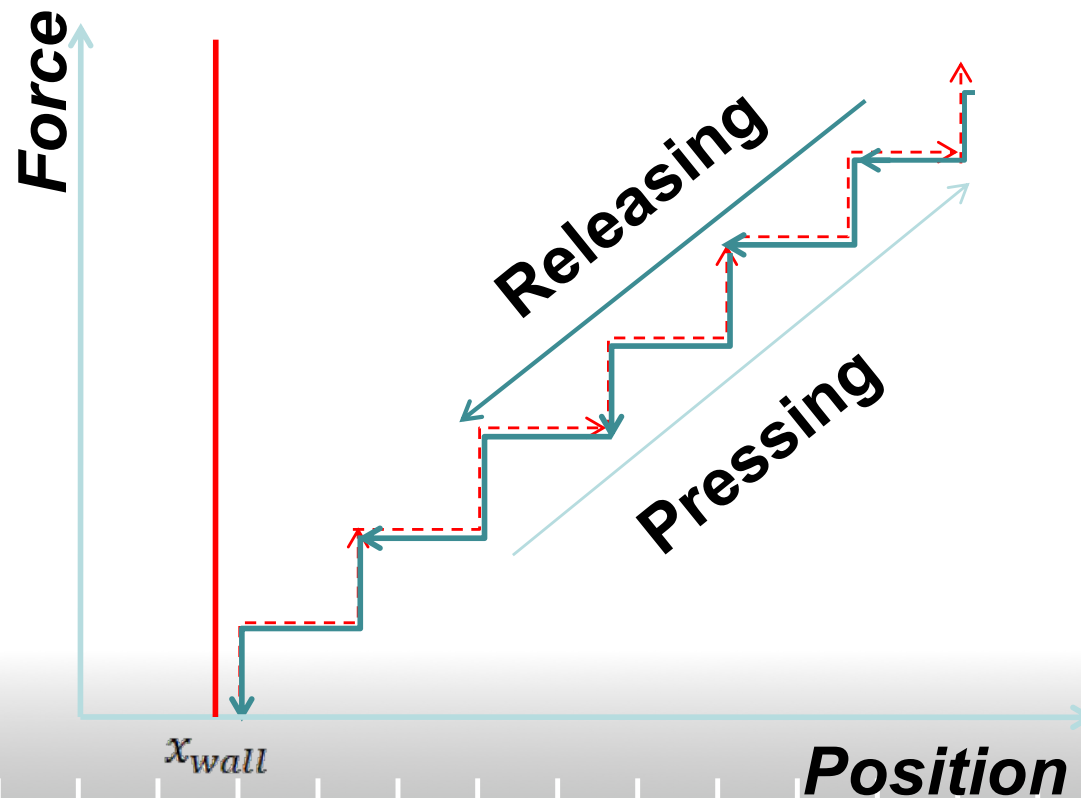


Effects of ZOH and Quantization



Idea of Memory-based Method

- IEEE/ASME MECHATRONICS 2014 -

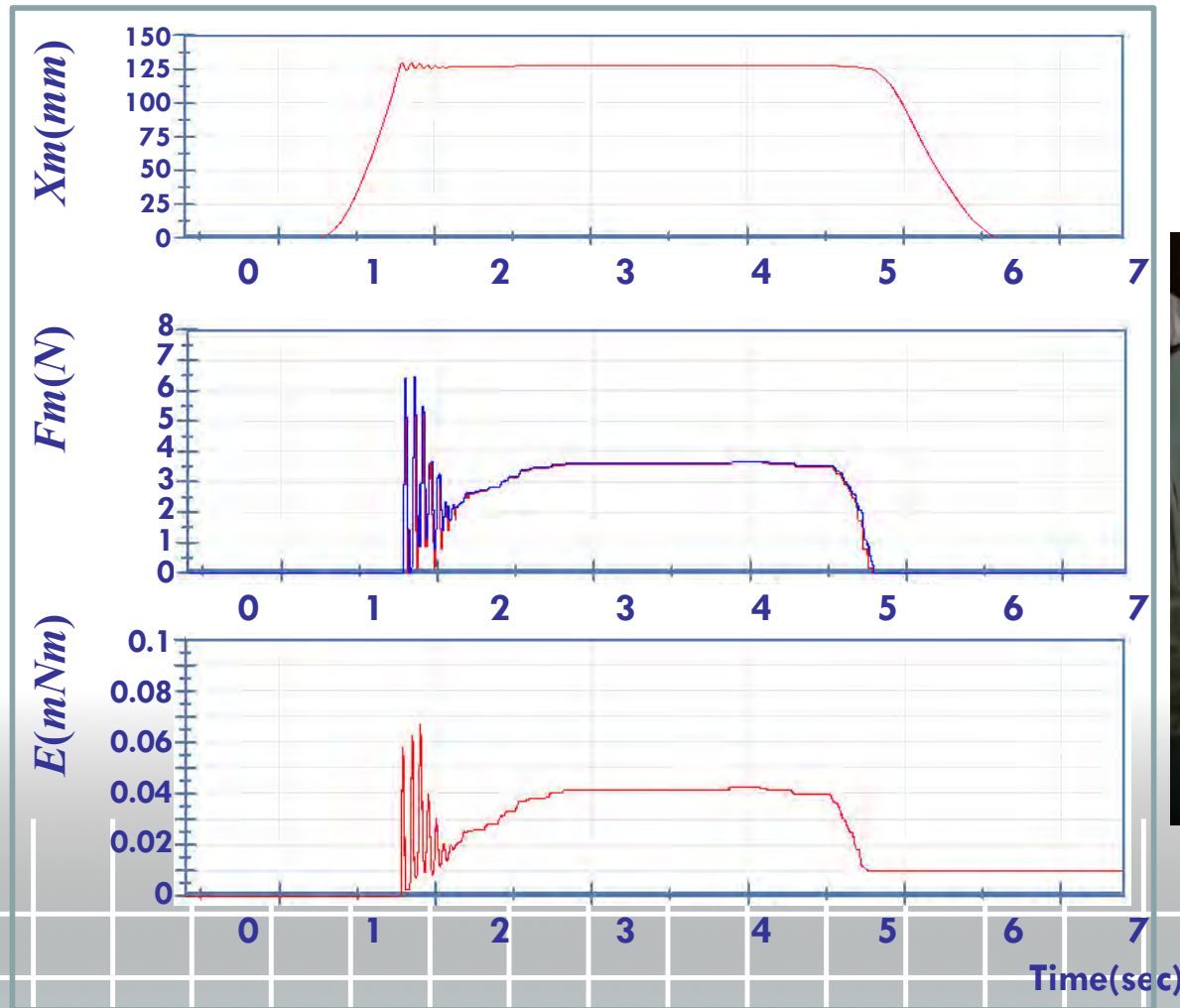


- ✓ Save pressing path to memory
- ✓ Bounding the releasing path with the pressing path

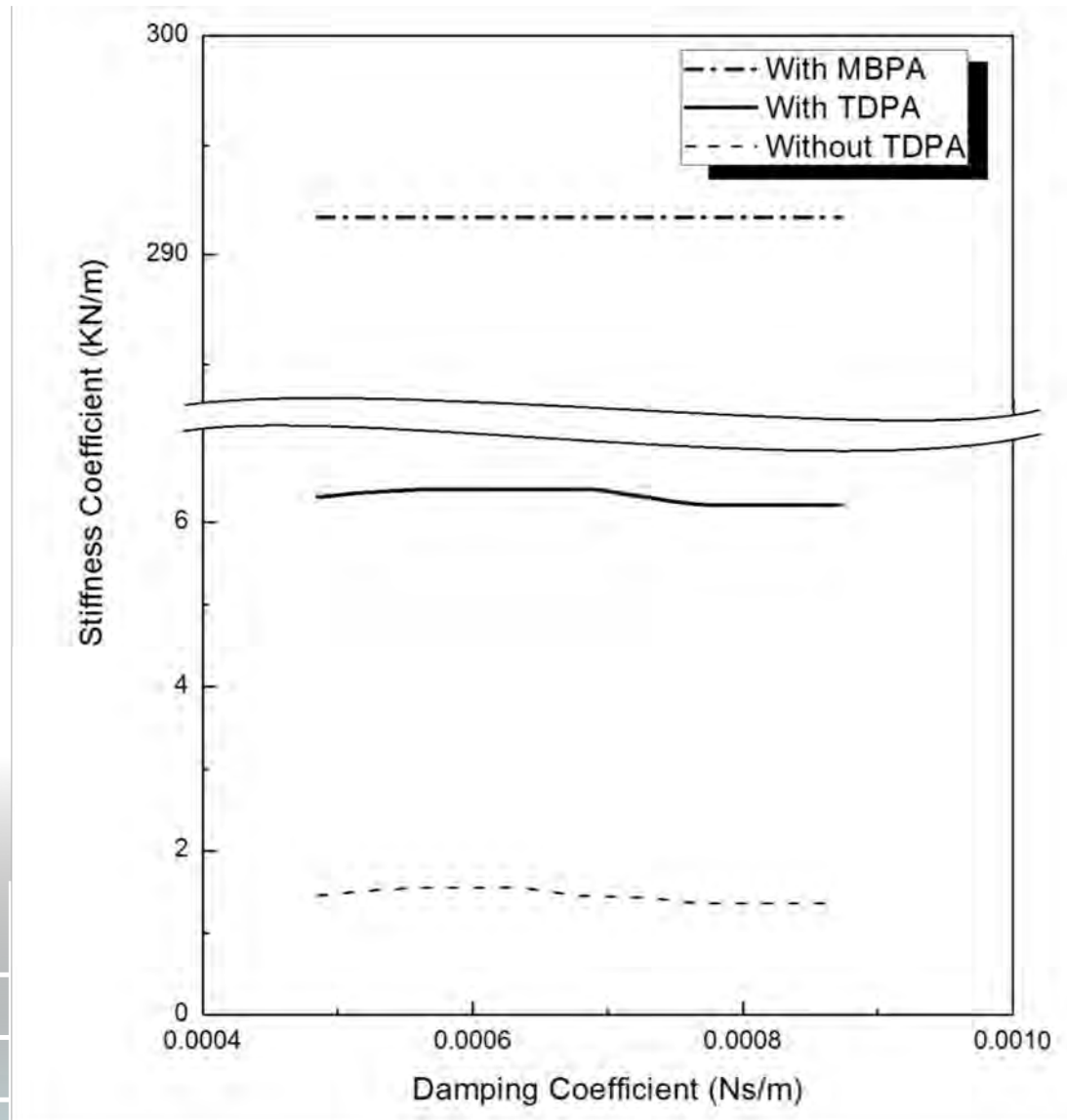
Memory-based Approach

VE freq : 100Hz

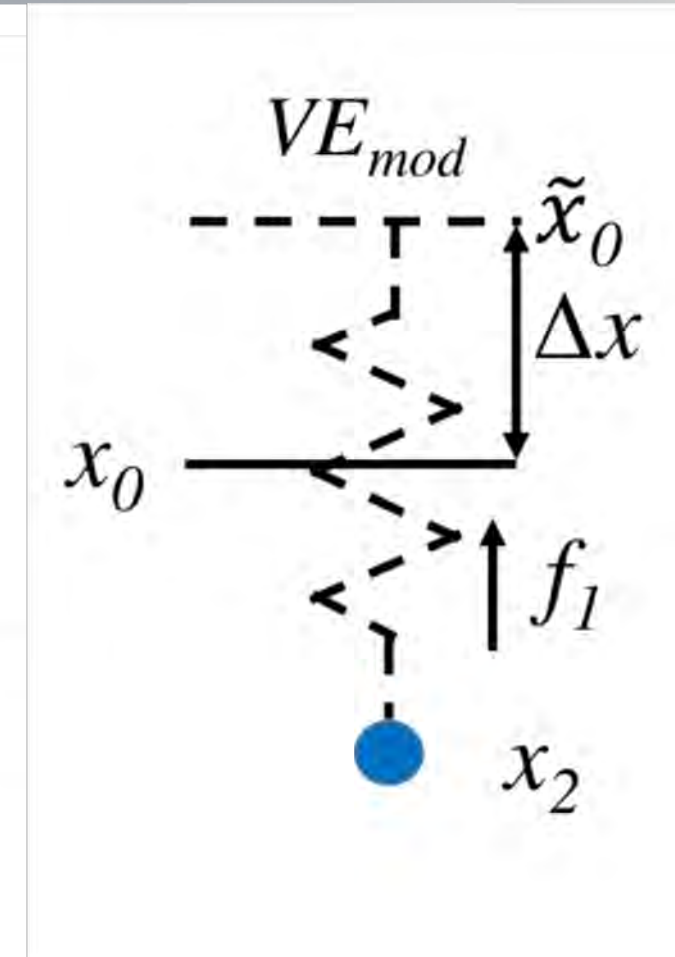
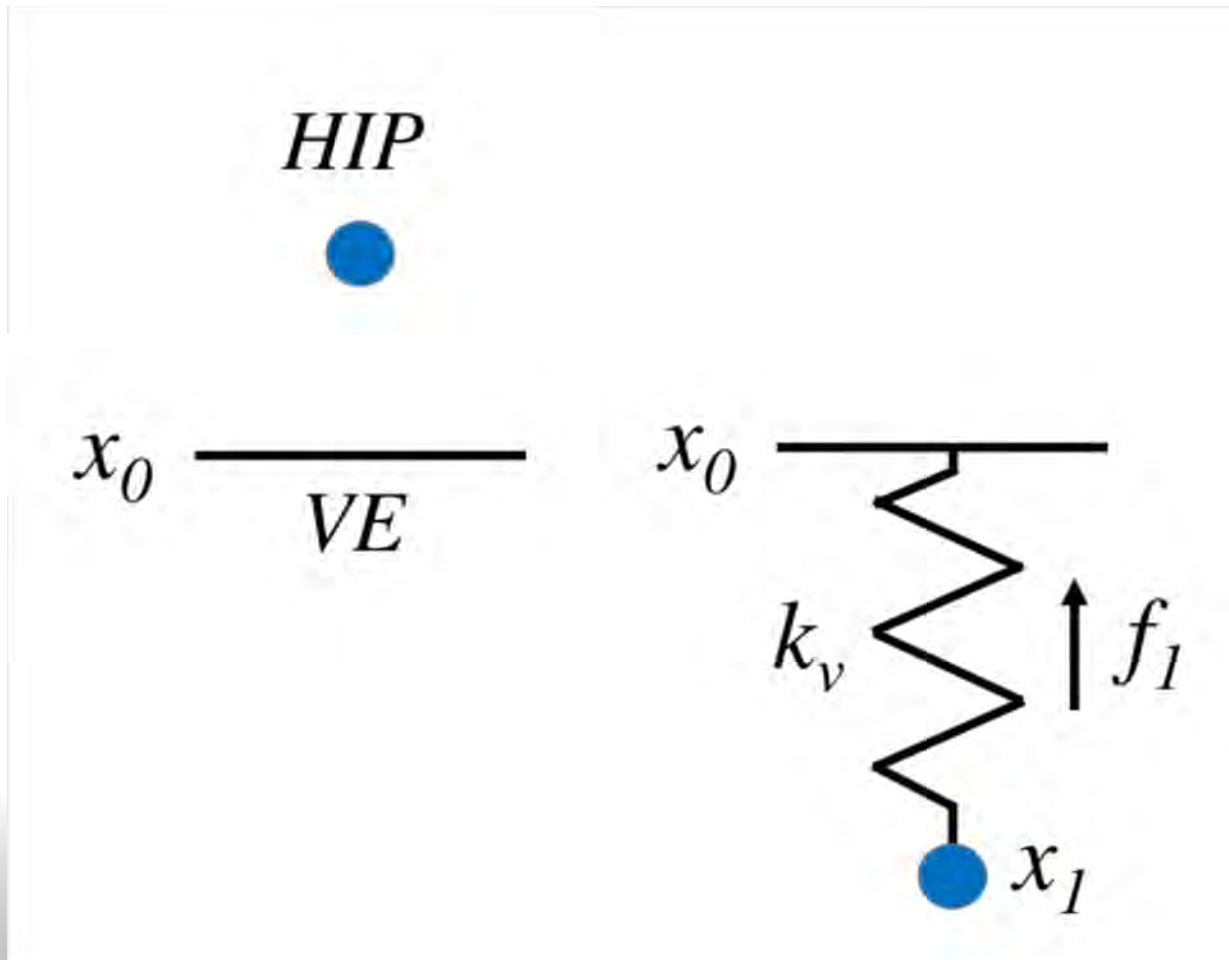
k_{ve} : 1.94kN/m



Comparison Study of MBPA



Successive Force Augment Approach



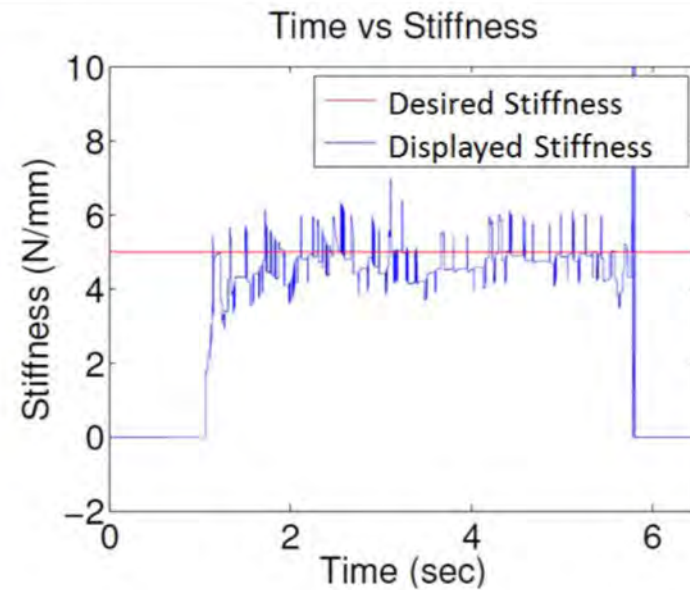
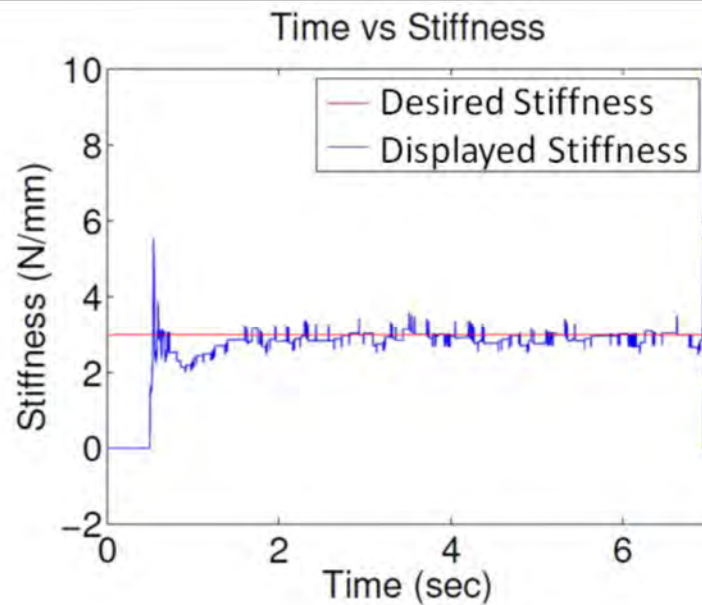
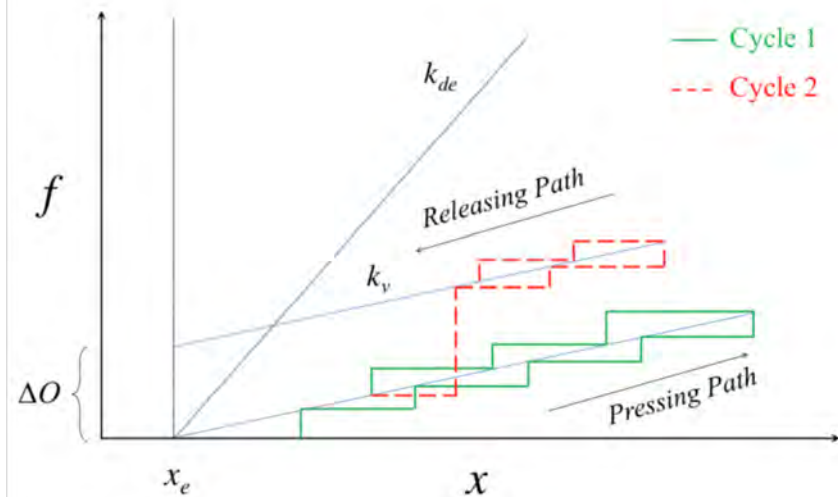
$$K_p = \frac{f_1}{x_1 - x_0}$$

<

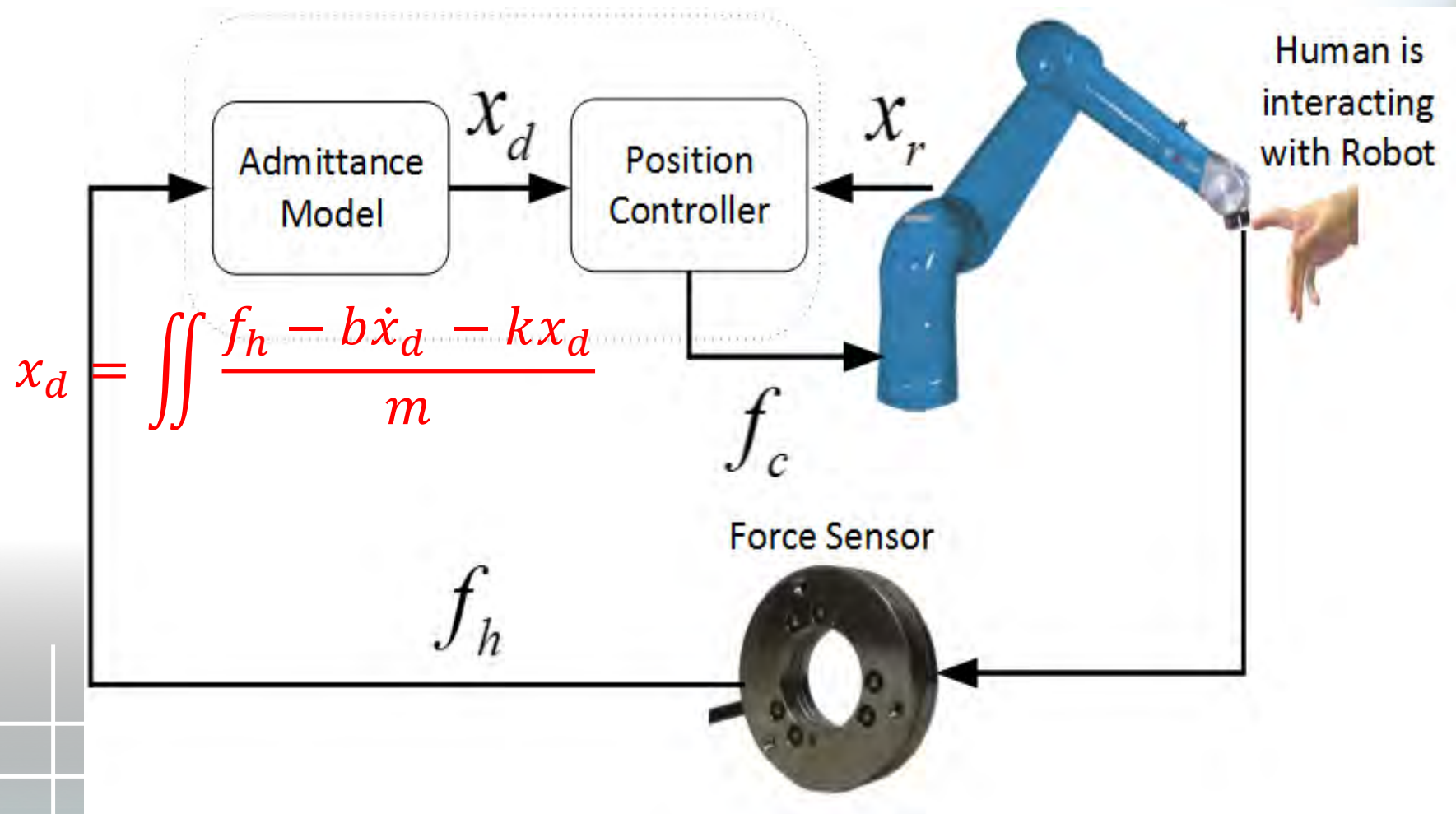
$$K_p = \frac{f_1}{x_2 - x_0}$$

Successive Force Augment Approach

- HS 2016 DEMO -



Admittance-type Haptic Interfaces



Limited Range of Impedance of Admittance-type Haptic Interfaces



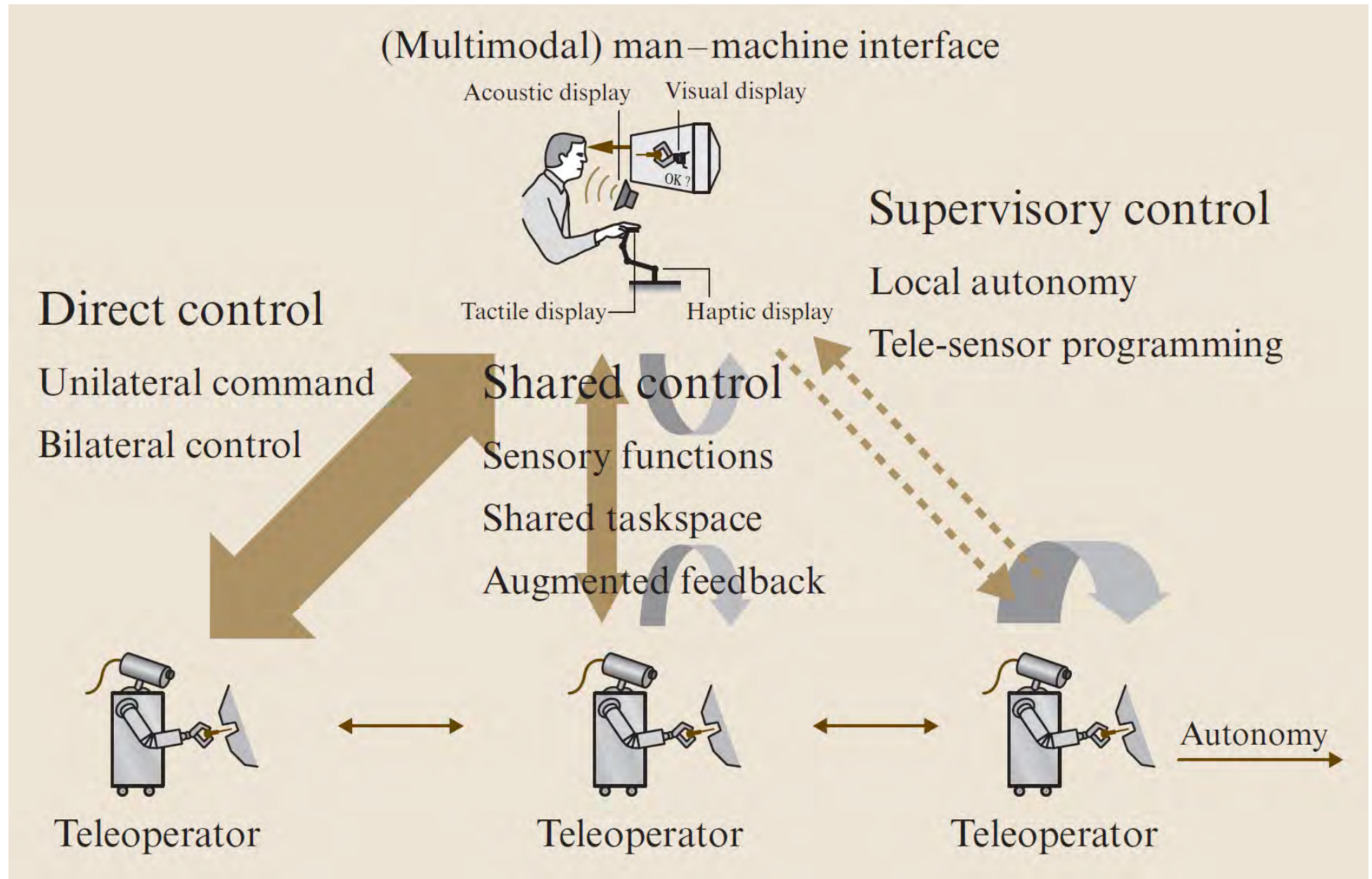
TPDA can Increase the Impedance Ranges

- IROS 2015 -

**With Time Domain
Passivity Approach(TDPA)**

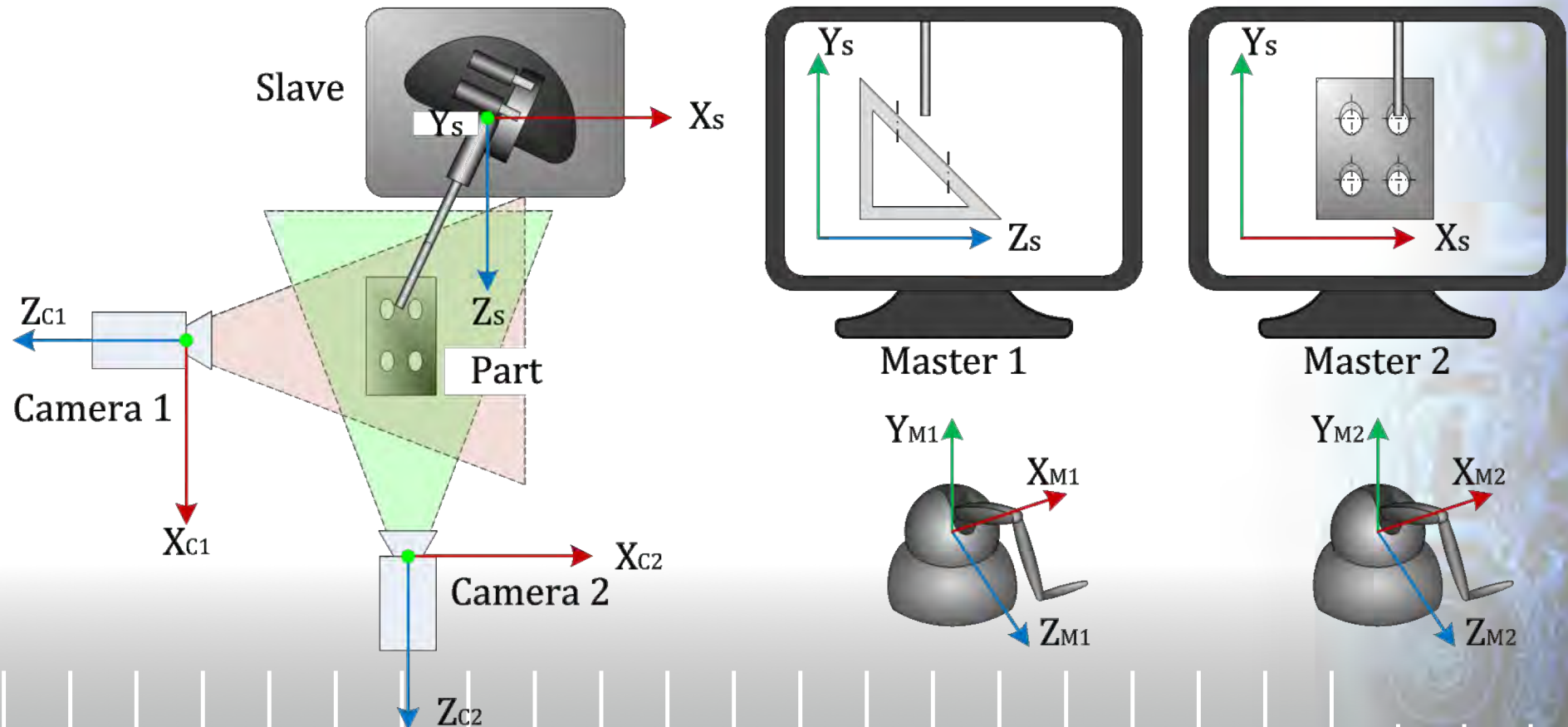


Telerobot Control Architectures



Multi-user Shared Teleoperation

- ICCAS2012 -



- **Field-of-View deficiency based dominance distribution**

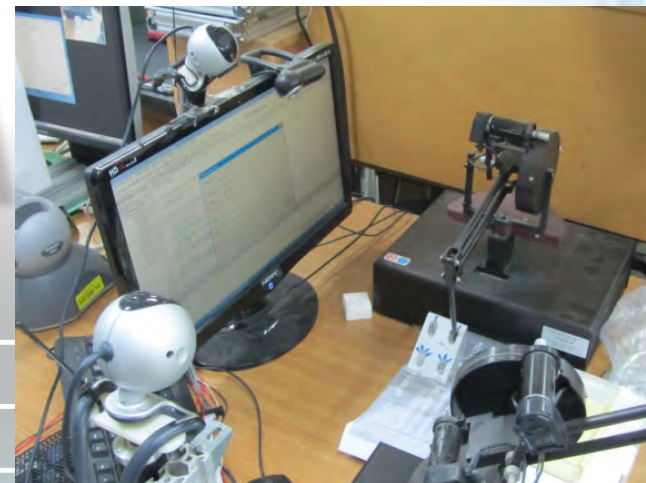
Dominance Distribution Experiment

Task description



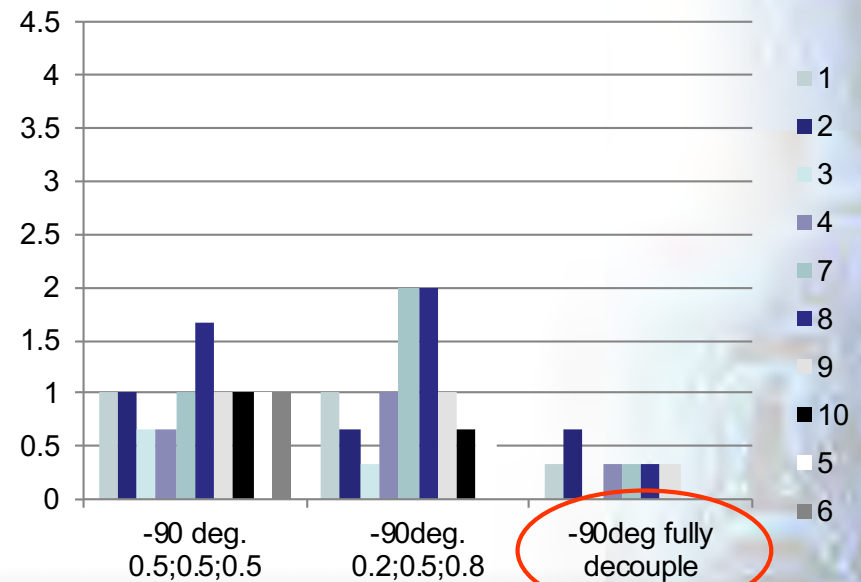
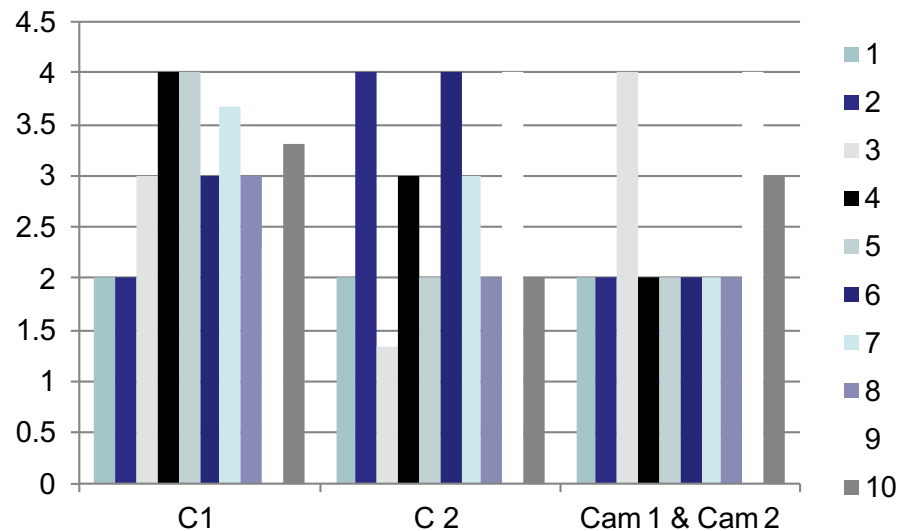
Evaluation criteria:

Completion time
Number of collision



Single Operator vs. Dual Operators

Number of Collision

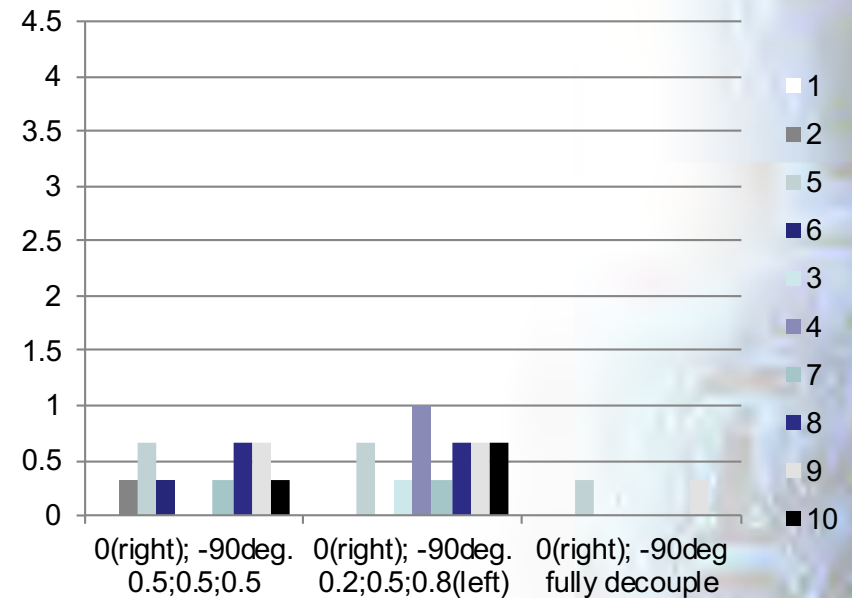
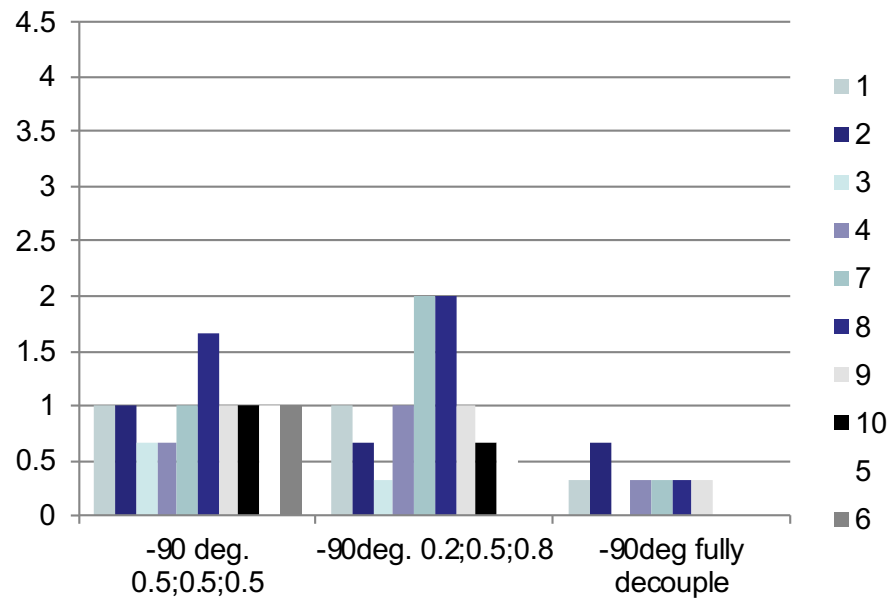


Single operator

Dual operators

With vs. Without Kinesthetic Coupling

Number of Collision

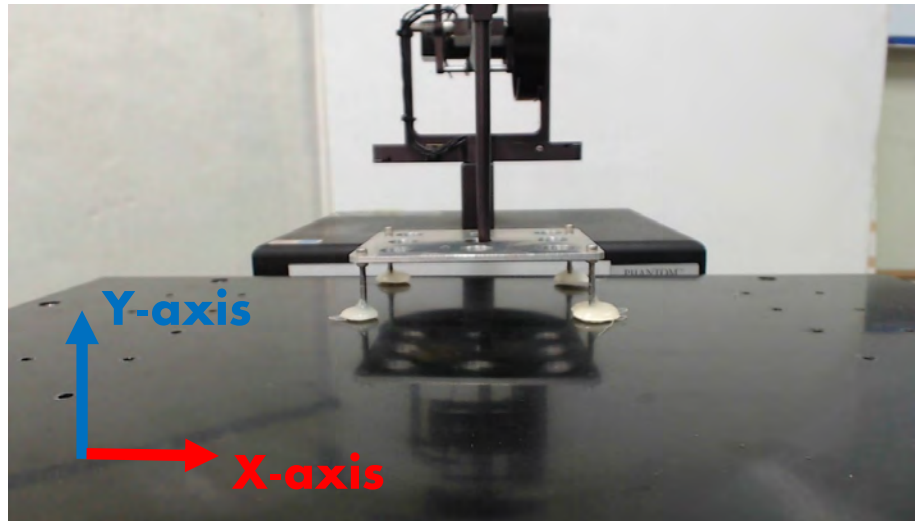


Without coupling

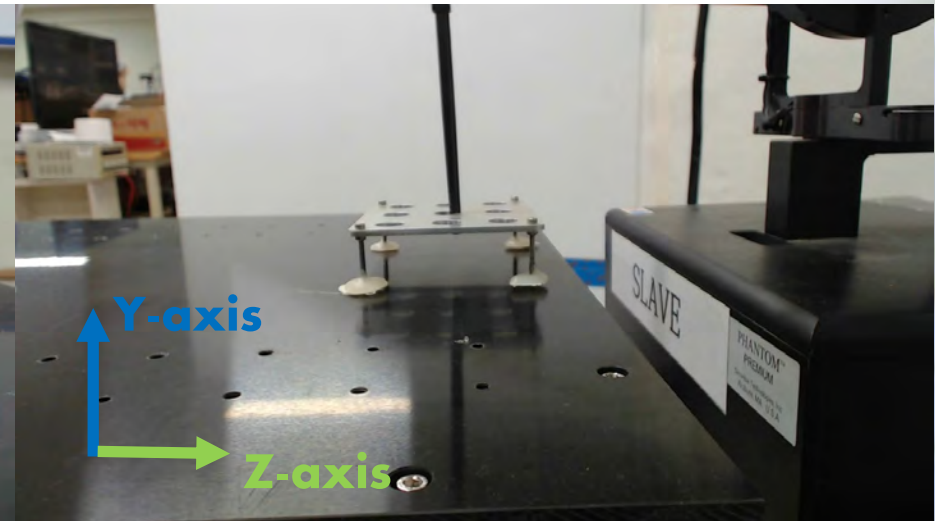
With coupling

Dynamic Authority Distribution (DAD)

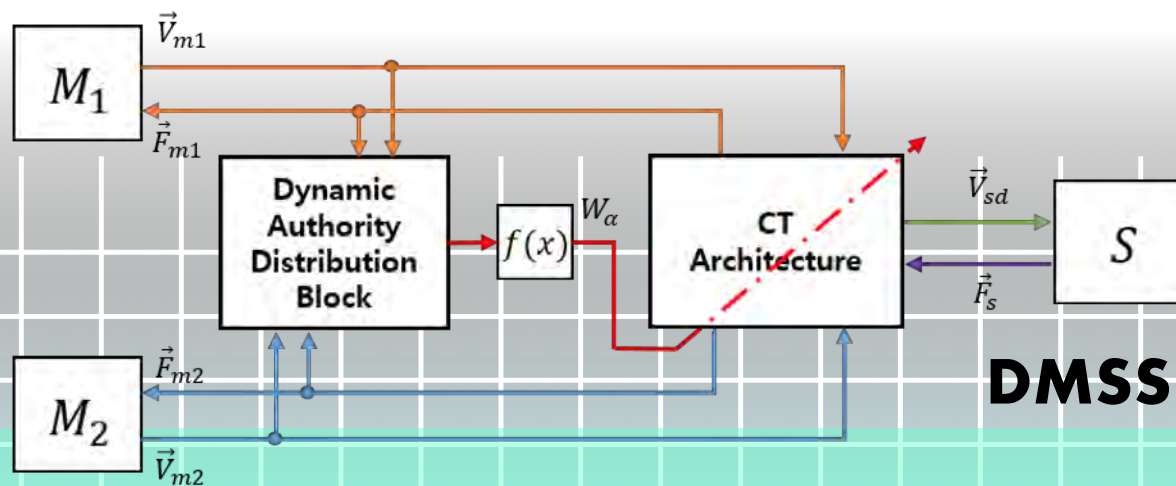
- IROS2015 -



Master 1 camera



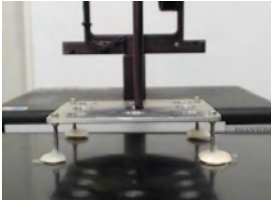
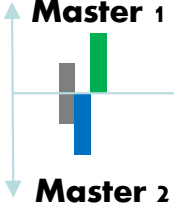
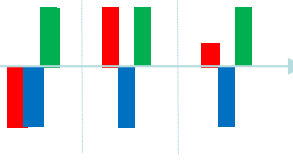
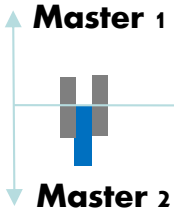
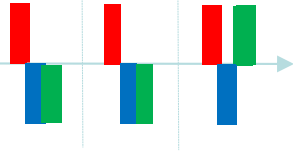
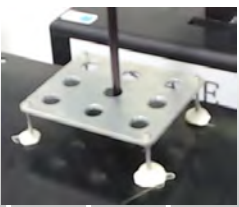
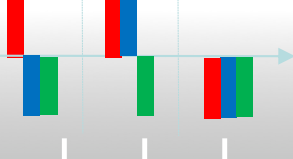
Master 2 camera



DMSS Architecture

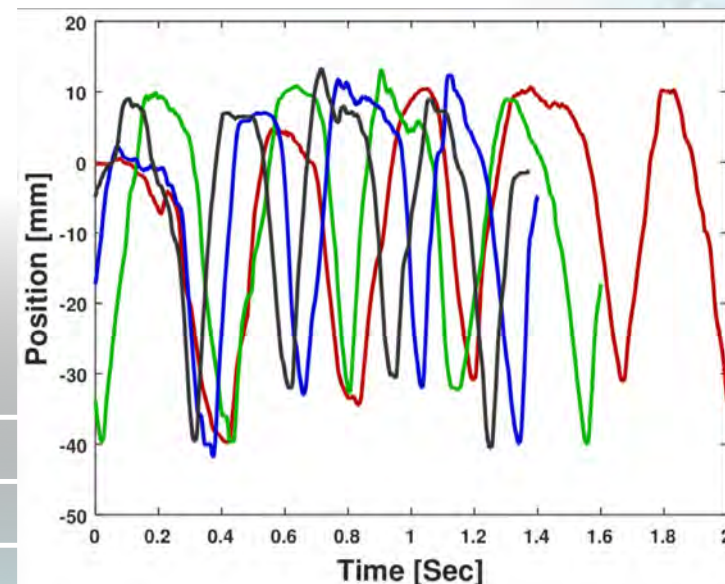
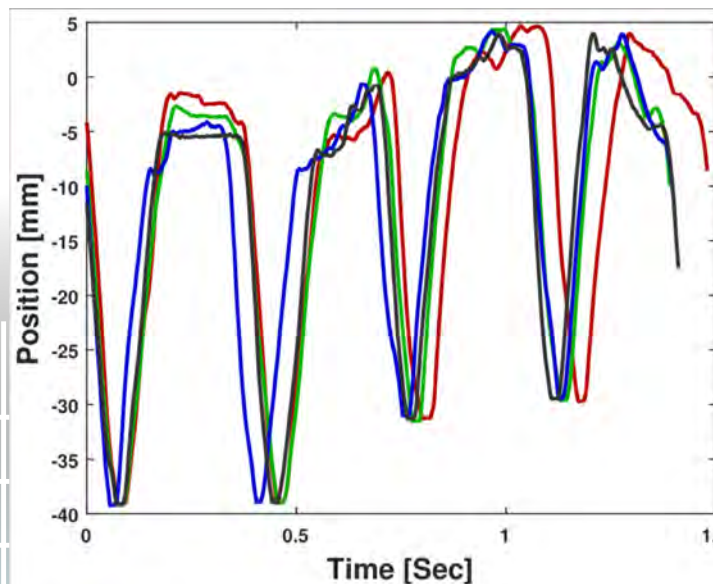
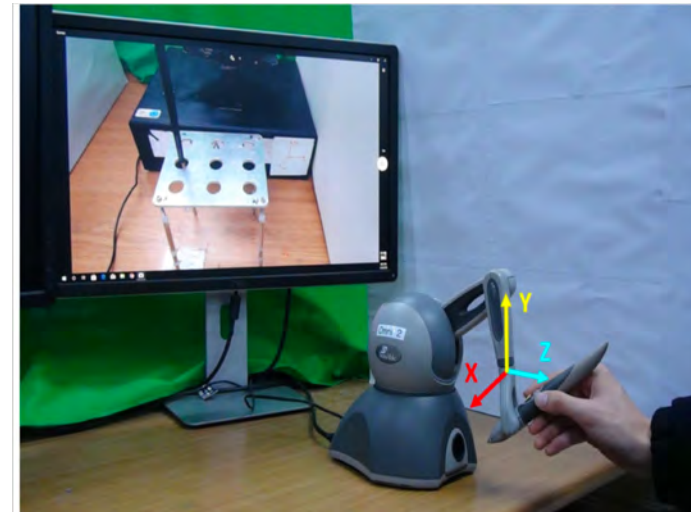
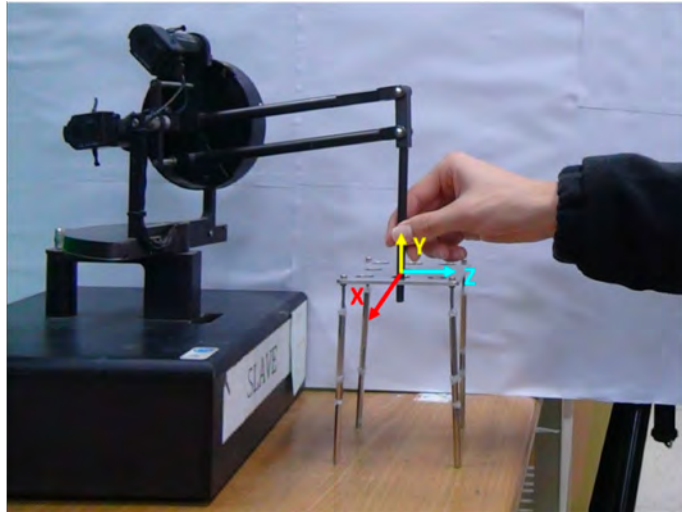
BRL, KOREATECH

Experiment with Different Camera Angle

Master 1 Camera	Master 2 Camera	Common axes	Expected Convergence	Outcome Convergence	Average Time of Convergence	Average Number of Conflicts
 X & Z	 X & Y	X-axis	Master 1  Master 2		seconds 	number 
 X & Z	 X, Y & Z	X-axis Z-axis	Master 1  Master 2			
 X, Y & Z	 X, Y & Z	X-axis Y-axis Z-axis	Master 1  Master 2			

Replace a Operator with Artificial Agent by Learning from Teleoperation

- WHC2017, AH2018 -



Replace a Operator with Artificial Agent by Learning from Teleoperation

- WHC2017, AH2018 -

Step I. Recording Demonstrations through Teleoperation

Interactive Virtual Fixture

- EH2018 -

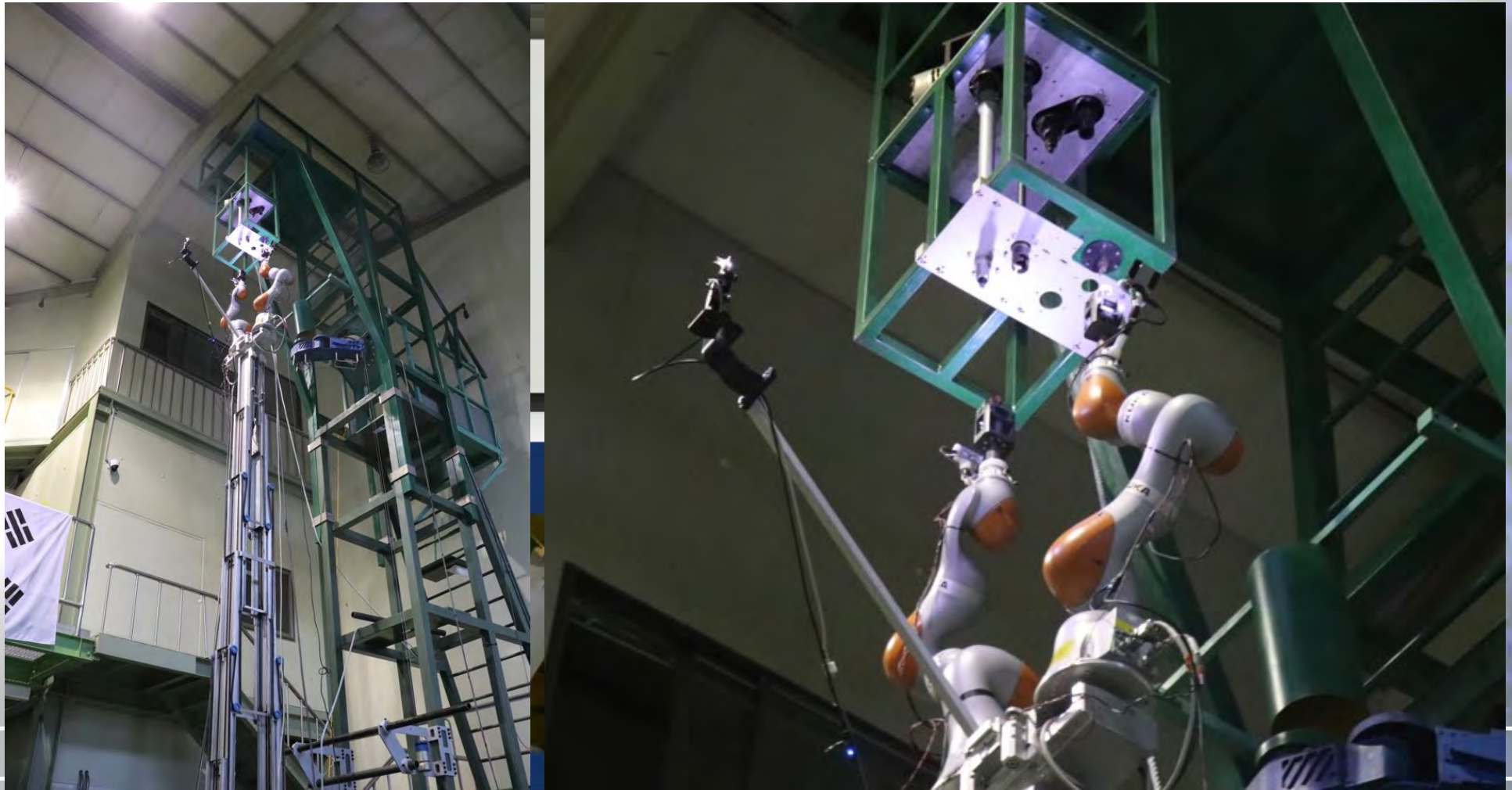
Target Environment



Robot and Tool

How can we generate a virtual fixture for a peg in hole task?

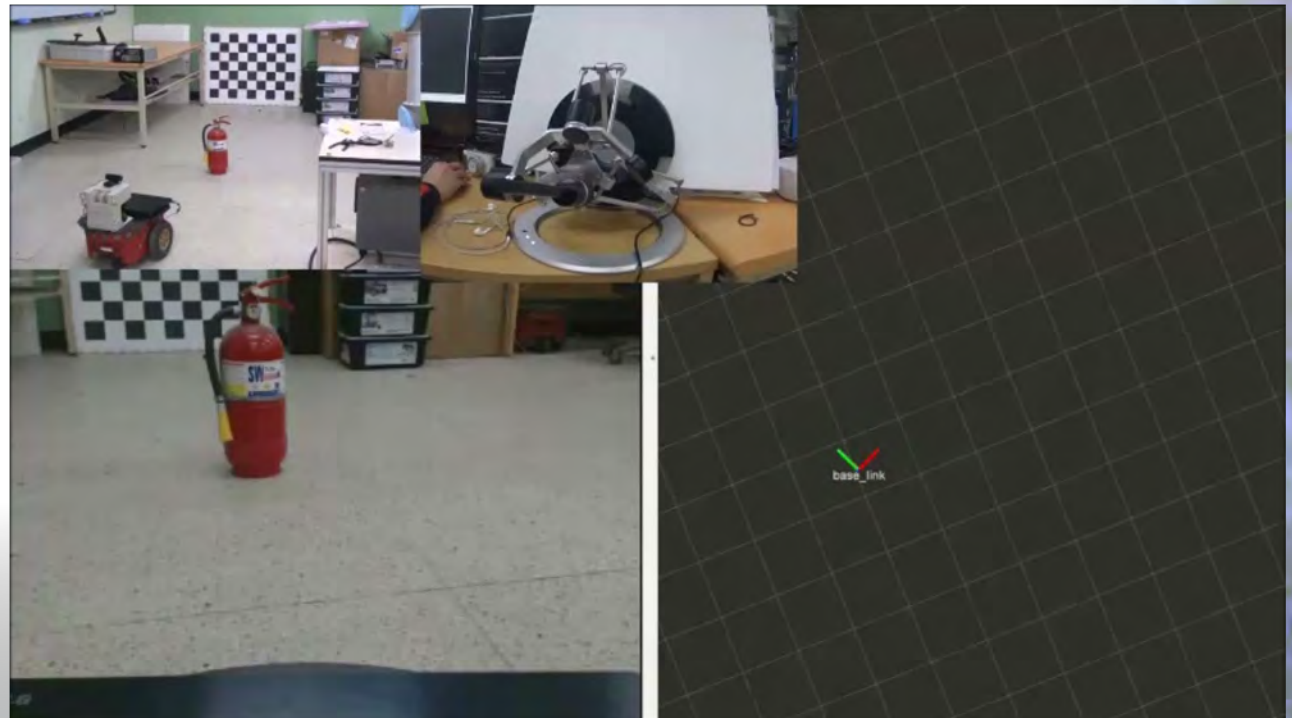
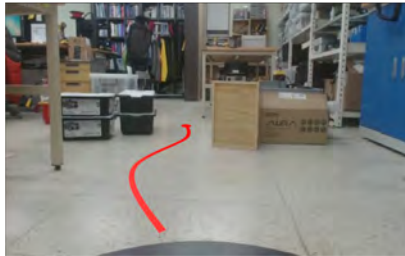
Nuclear Plant Maintenance



Left-Click: Move X/Y. Right-Click: Zoom. Shift: More options.

26 fps

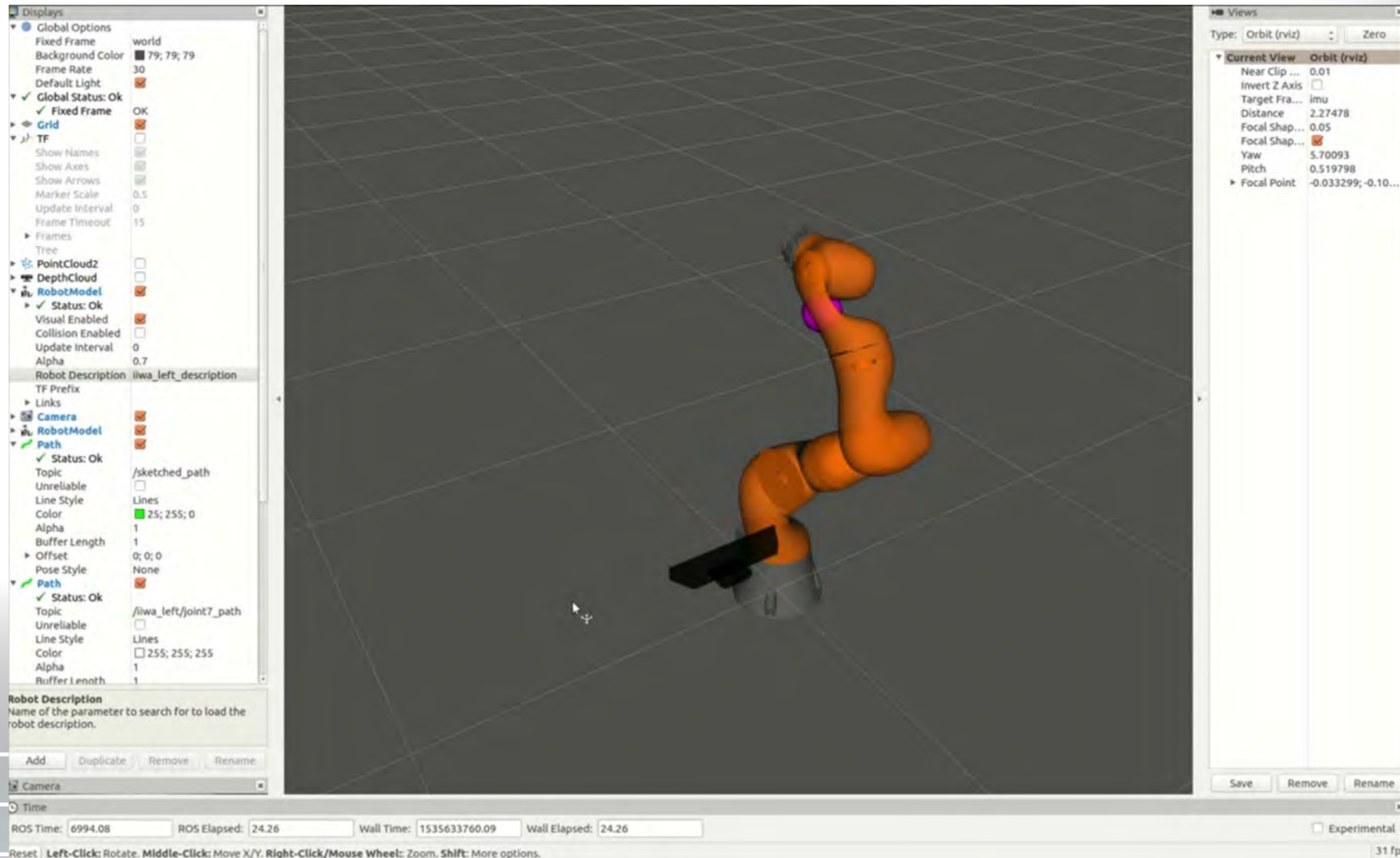
Sketch-based Trajectory Planning



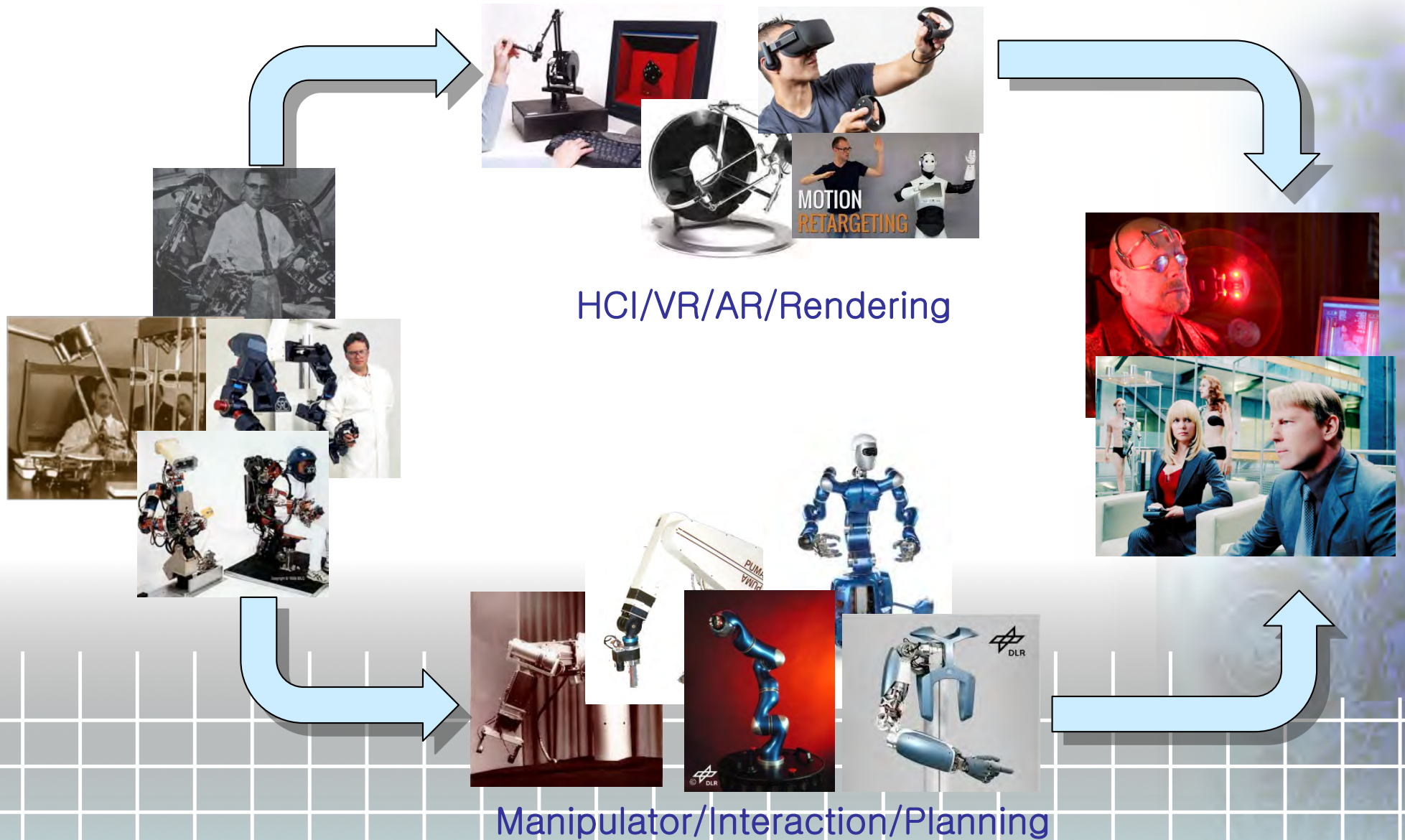
"Development of the Human Interactive Autonomy for the Shared Teleoperation of Mobile Robots,"
IROS2016

Extension to Multi-DOF with Elastic Planner

- UR2018 -



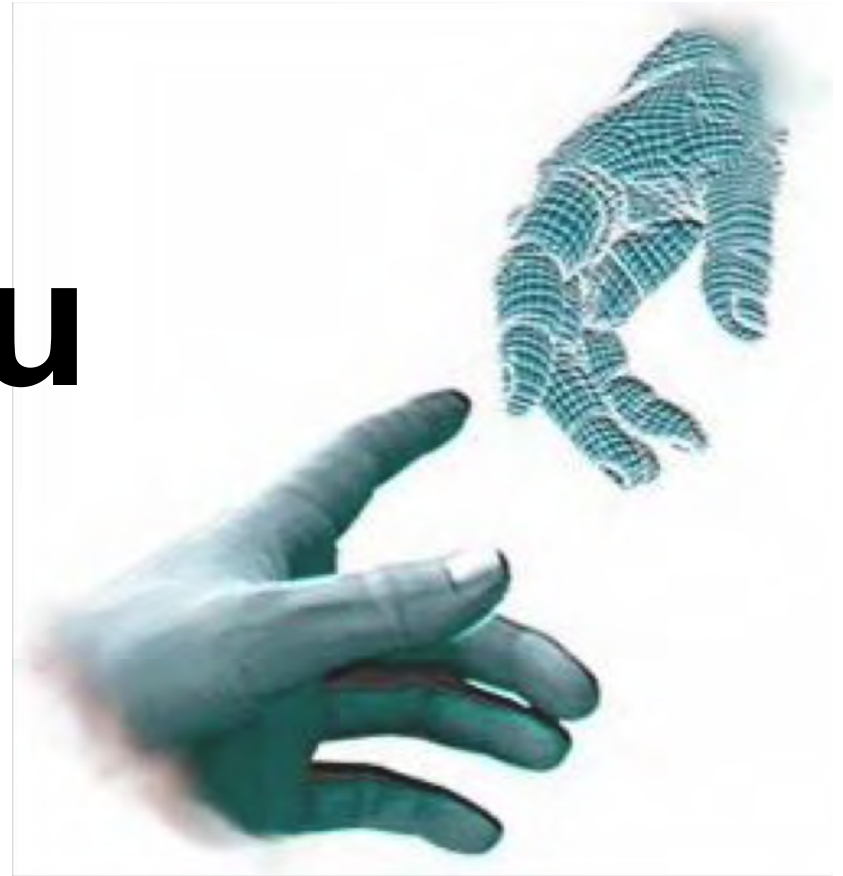
New Horizon of Telerobotics



BRL, KOREATECH

Thank you

Q & A



<http://robot.kut.ac.kr>

