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# Augmented reality-aided tele-presence system for robot manipulation in industrial manufacturing


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The ACM Symposium on Virtual Reality Software and Technology (VRST)
Beijing, China
2015

# Introduction: Autonomous Robots

Autonomous robots:

"sometimes humans are still needed"

http://spectrum.ieee.org/automaton/robotics/humanoids/darpa-robotics-challenge-robots-falling

# Introduction: Teleoperation

Traditional Haptic Interfaces

Mapping problem

Wearable Haptic interfaces

Constraints

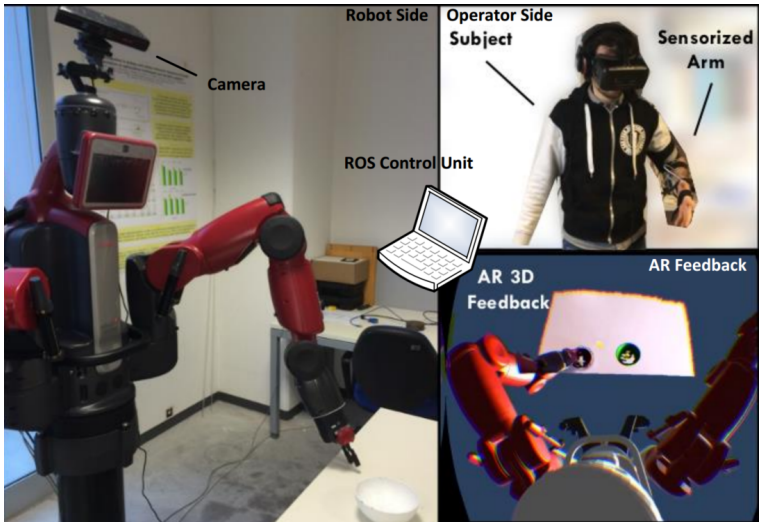
# Introduction: Light Wearable Interfaces

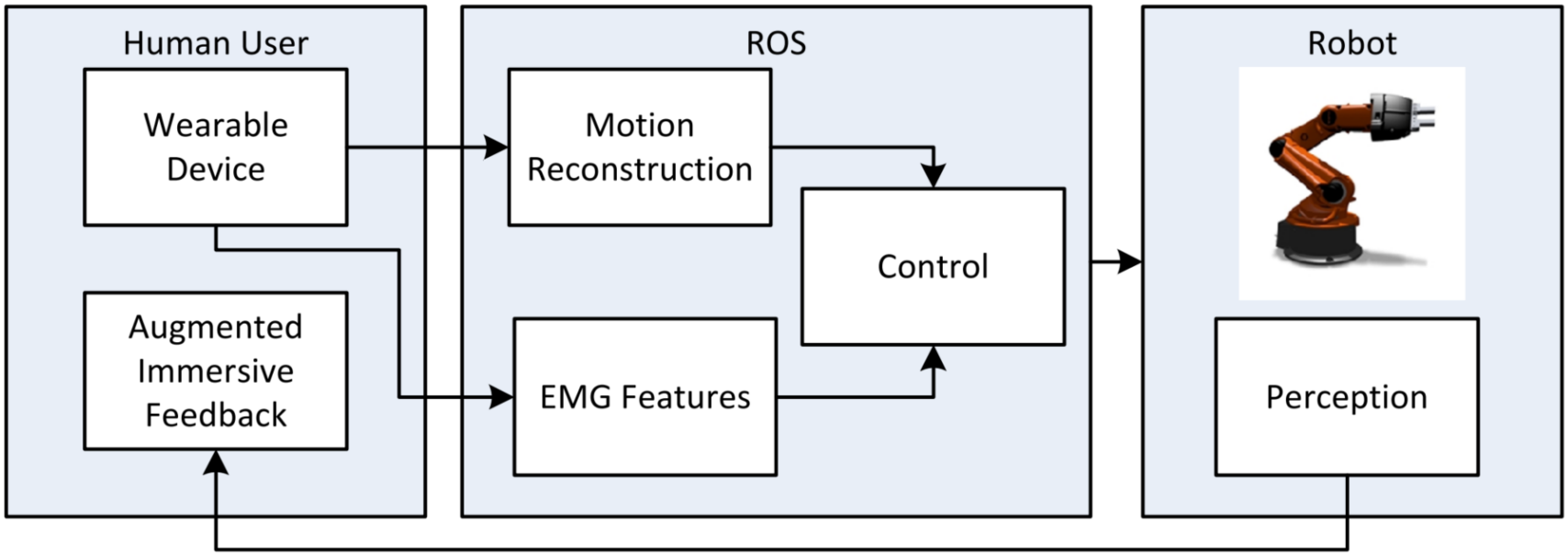
- IMU (Khassanov 2014)

- EMG (Vogel 2011)

- Is it possible to substitute the haptic feedback?
  - Visual virtual fixtures are a viable solution (Bettini, 2004)
  - Body-based teleoperation and a high level of embodiment improve user's dexterity in performing manipulation tasks (Almeida, 2014)

# System Overview

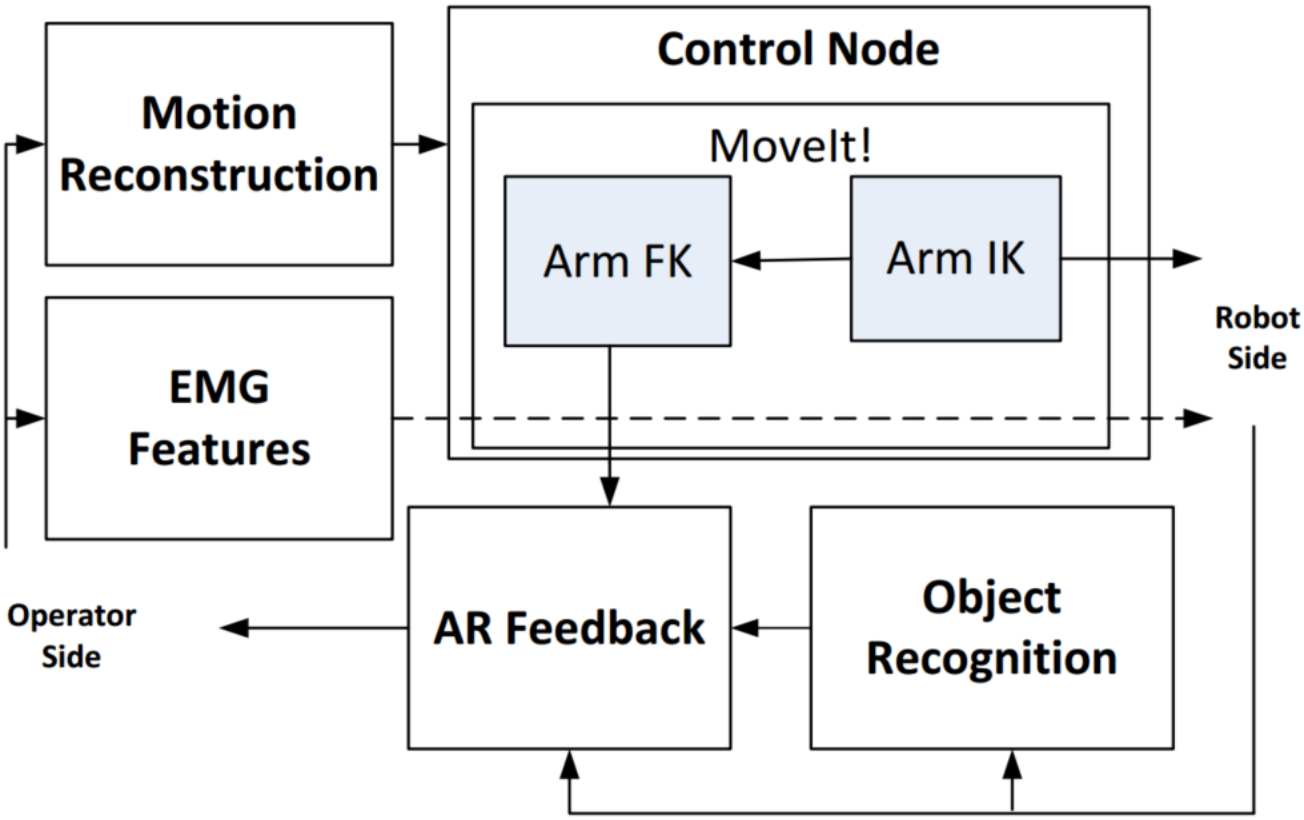


# Operator Side

- 3 IMUs (100Hz) and a surface 8-channel EMG sensor (4kHz – 300Hz).
- The signals synchronization is guaranteed by the wearable device. (Avizzano, 2014)
- HMD for the 3D AR feedback (Oculus Rift DK2).
- Bluetooth 4.0 Communication with the host PC

# ROS Control Unit

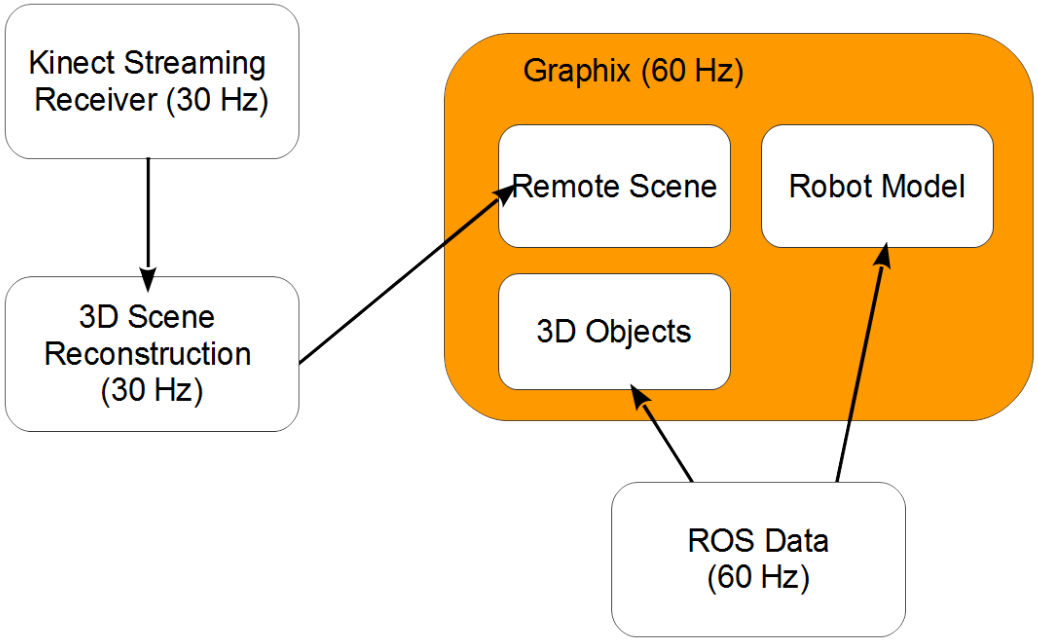


# AR Feedback

- **First module**: superimposes the animated robot model to the scene, complementing the camera view of the real robot.
- **Second module**: provides virtual fixtures
  - Virtual representation of the objects
  - Color information

# Compact Components (CoCo)

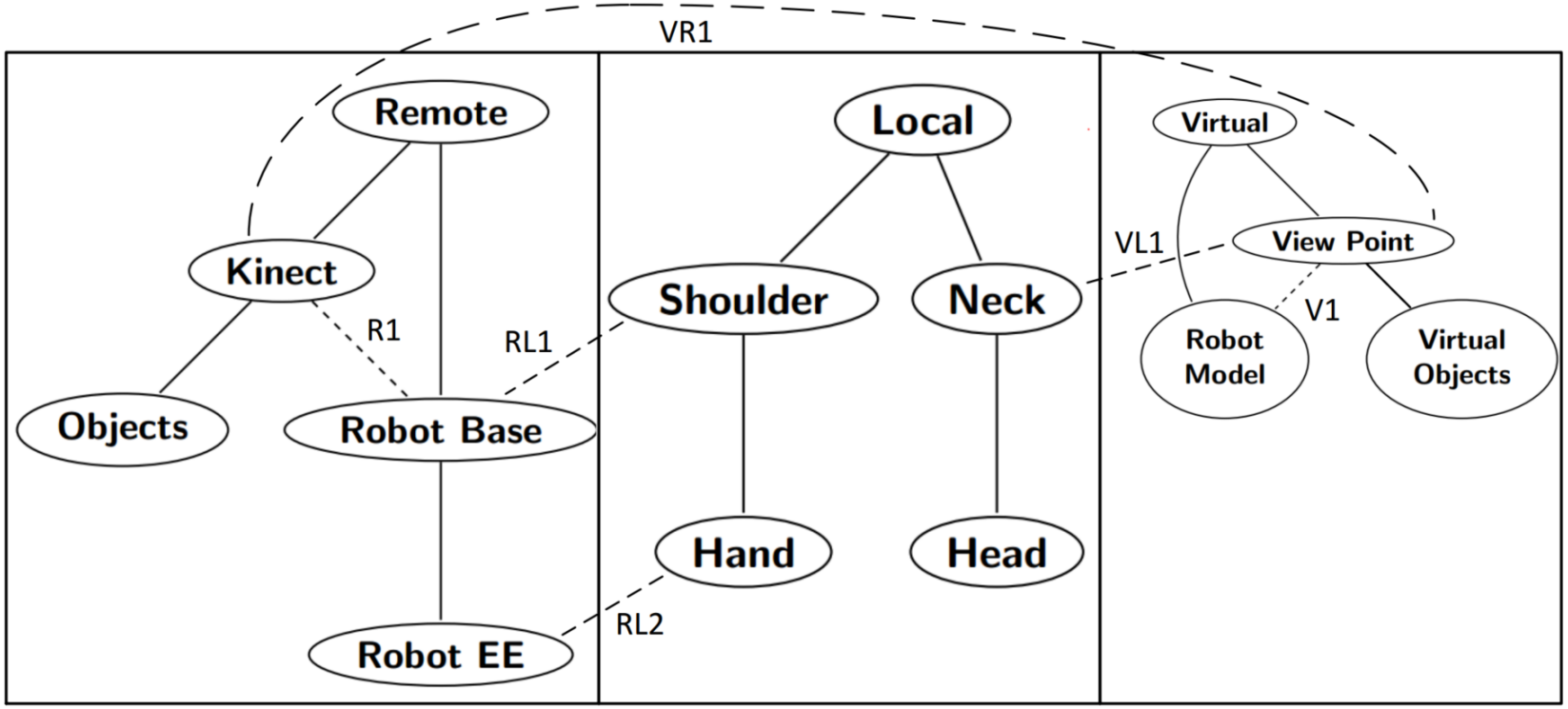
- ROS-integrated framework for high-performance Mixed Reality
  - Core Library + specialized mod




**See Also:**
Filippeschi A., Brizzi F., Ruffaldi E., Jacinto J.M. & Avizzano C.A. (2015). Encountered-type haptic interface for virtual interaction with real objects based on implicit surface haptic rendering for remote palpation. In IEEE IROS Proceedings

# Reference Frames Calibration

- 3 frames groups
- Calibration procedures



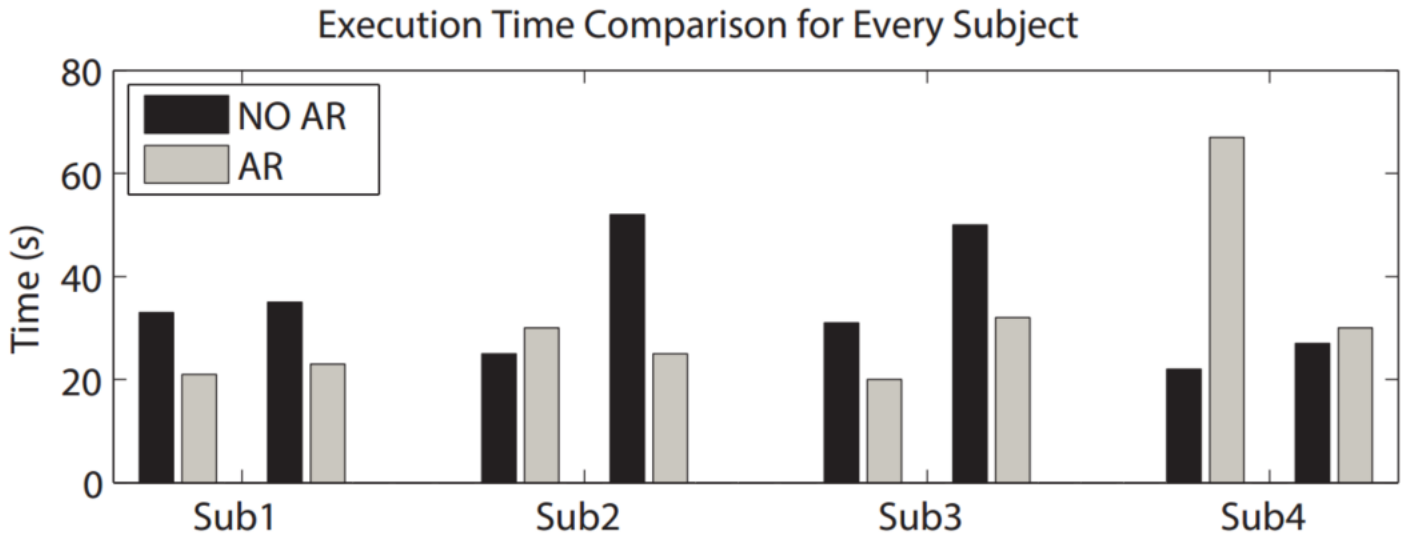
# Methods

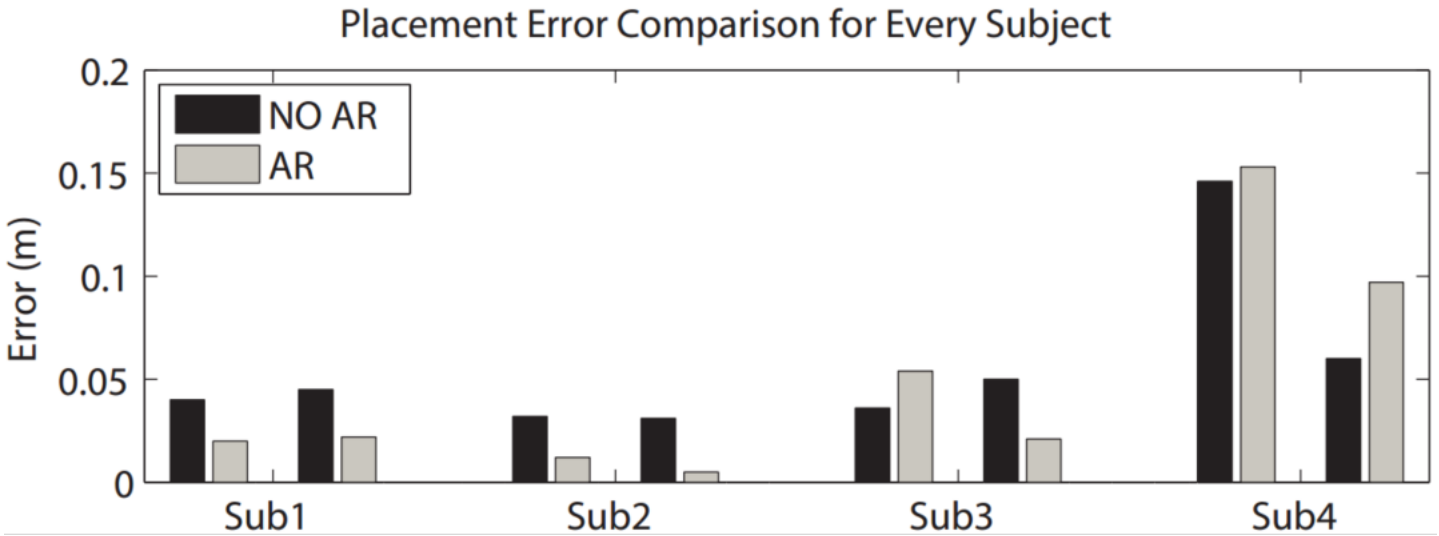
- **Task**: teleoperating a remote robot to pick a known object from a starting position and placing it in two different target poses $T_1$ and $T_2$.
- **Four subjects** with no previous training, protocol:
  1. The wearable device and the HMD were mounted on the operator's body (10-15 mins)
  2. Familiarization with the system (5 mins)
  3. The subject was asked to perform the task twice for every target pose, w/o AR (only the meshified scene) and w AR (target pose, objects and animated robot model)
  4. Subjects 1 and 3 first performed w/o AR and then w AR feedback, while subjects 2 e 4 first performed w/o AR and then w AR.

# Experimental Protocol

1. The wearable device and the HMD were mounted on the operator's body (10-15 mins)
2. Familiarization with the system (5 mins)
3. The subject was asked to perform the task twice for every target pose, with no augmented information (only the meshified scene) and with the AR feedback (target pose, objects and animated robot model)
4. Subjects 1 and 3 first performed w/o AR and then w the full AR feedback, while subjects 2 e 4 first performed w/o the full AR feedback and then w AR.

# Results



# Discussions

- According to the results there is a slight improvement in positioning error and execution time with AR (further tests are needed)
- Anecdotally it has been reported by the subjects that the most useful information provided by the AR feedback is the color mapping of the distance to the target object mesh.
- Certain positions assumed autonomously by the remote robot can impair the execution of the task.

# Further Developments

- Further exploration of the virtual fixtures approach
- Addition of a vibrotactile haptic feedback
- Possibility to use the system for programming task by demonstration.

# References

[1] Khassanov, Y., et al. 2014. Inertial motion capture based reference trajectory generation for a mobile manipulator. In IEEE/ACM HRI, 202–203.

[2] Vogel, J., et al. 2011. EMG-based teleoperation and manipulation with the DLR LWR-III. In IEEE IROS, 672–678

[3] Bettini, A., et al. "Vision-assisted control for manipulation using virtual fixtures." *Robotics, IEEE Transactions on* 20.6 (2004): 953-966.

[4] L. Almeida, B. Patrao, et al. Be the robot: Human embodiment in tele-operation driving tasks. In IEEE RO-MAN, pages 477–482, 2014.

[5] Avizzano, C. A., et al. 2014. A novel wearable biometric capture system. In IEEE MED.

# Frontiers

- Research Topic

***«Augmented Reality for Robotics»***

http://journal.frontiersin.org/researchtopic/3921/augmented-reality-for-robotics

# thank you!

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PERCRO Perceptual Robotics Laboratory

# CoCo

- Tasks running in parallel to lower the service time (16 ms)
- Every task can be periodic (e.g. scene update) or triggered
- It is the same idea used in the OROCOS framework but applied to rendering
- Different modular components can be used (also haptic rendering guaranteed up to 1KHz)