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IEEE/NSF Workshop on
Cloud Manufacturing and Automation

The Humans in the Cloud: Shared Autonomy over the Internet

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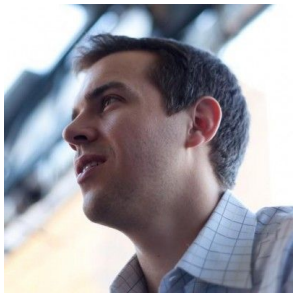
The Team



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Jon Binney

Julian Cerruti

Matei Ciocarlie

David Gossow

Kaijen Hsiao

Julius Kammerl

Tessa Lau

Adam Leeper

Mario Prats

Robotic Manipulation: Looking Ahead

- Key problems: **versatility** and **variability**

- What could we enable?
  - logistics: order packing
  - manufacturing: kitting, bin picking
  - services: delivery

?

Robotic Manipulation: Looking Ahead

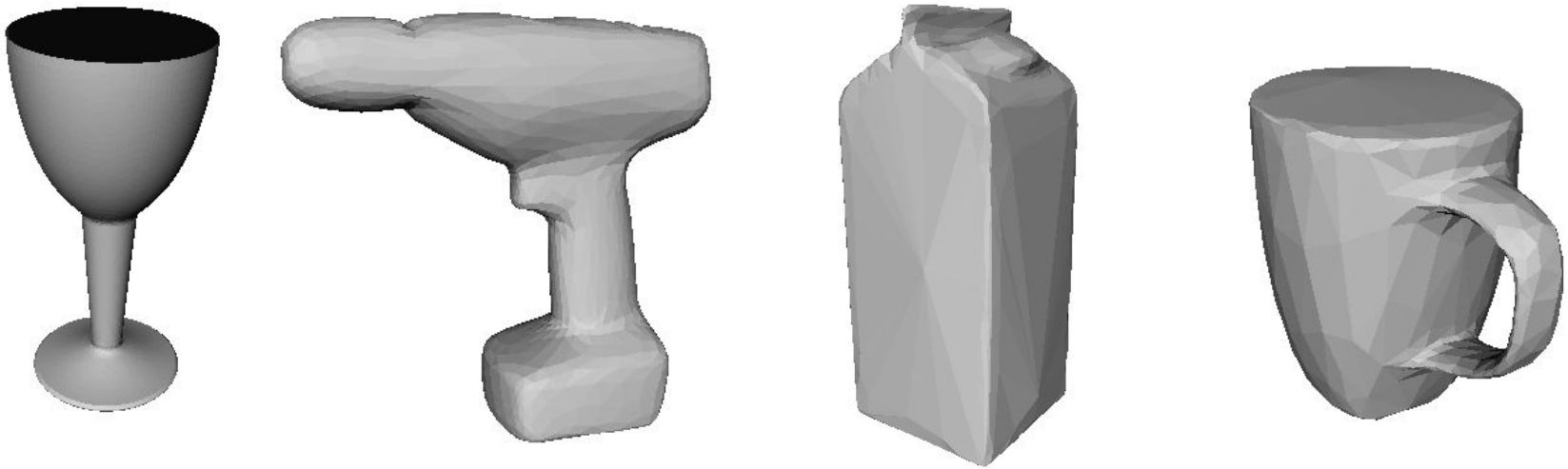
- Key problems: **versatility** and **variability**

- Resources in the cloud
  - **Data**
  - Computation power
  - Advanced cognitive devices – a.k.a. humans!

?

ROS **household_objects_database**

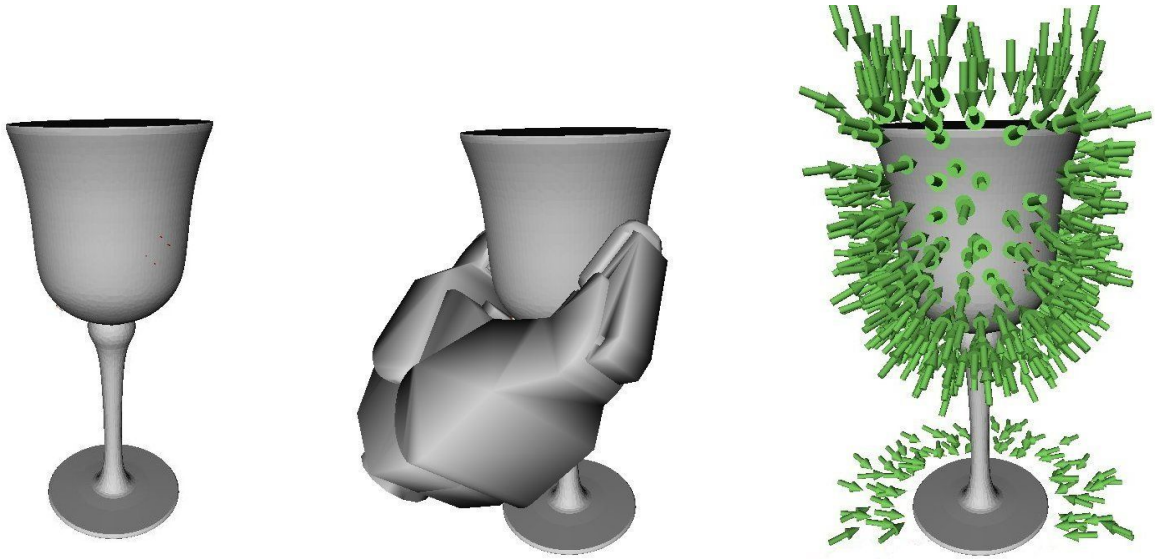
- Real-life objects from major retailers
- Triangular meshes
- Meta-data (maker, model, barcode, etc.)



[Ciocarlie, Pantofaru, Hsiao, Bradski *et al.*, IEEE R&A Mag. 2011]

ROS **household_objects_database**

- Grasp points for the PR2 gripper
- Computed in simulation
- 4 hours / object : approx. 600 grasps



ROS **household_objects_database**

2X speed

[Ciocarlie *et al.*, ISER 2010]

Robotic Manipulation: Looking Ahead

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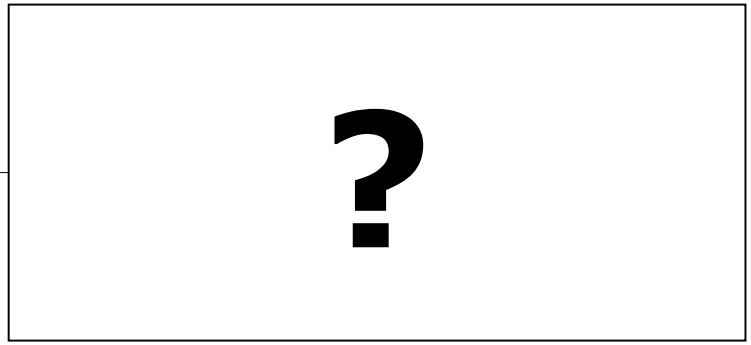
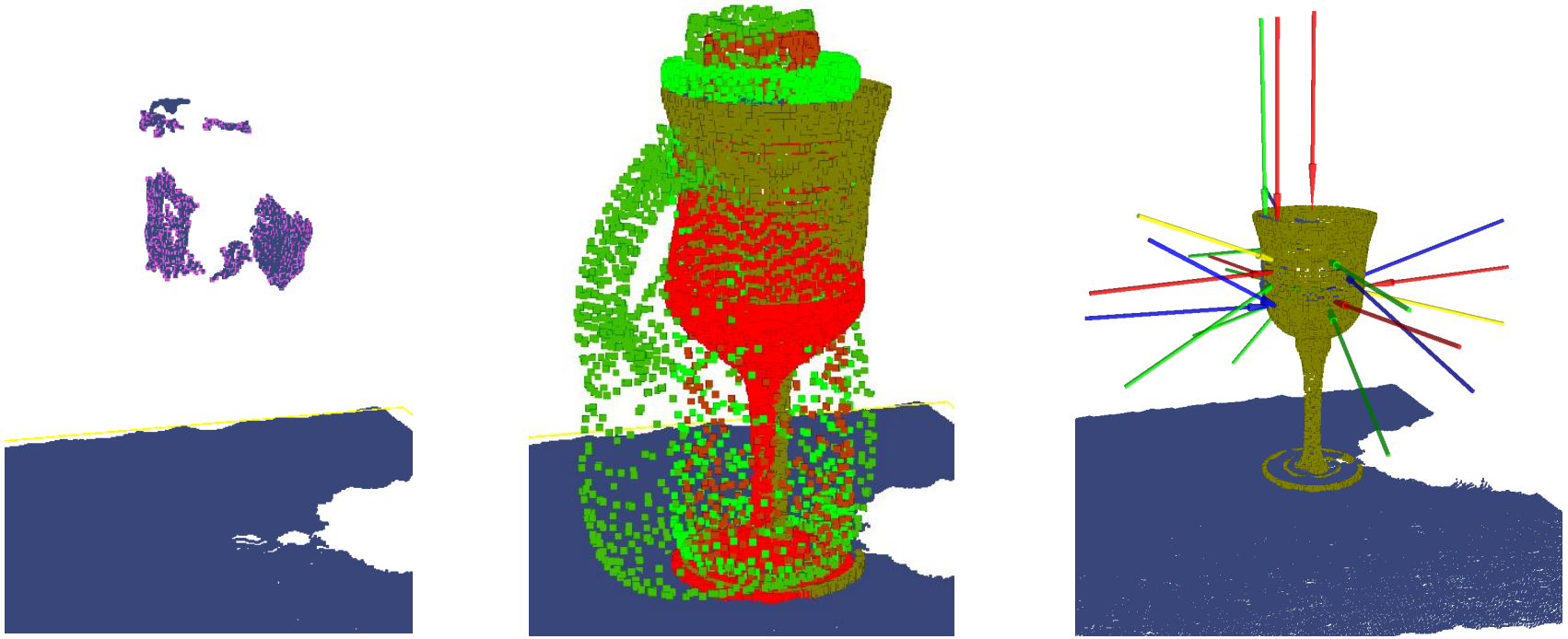
  - **Computation power**
  - Advanced cognitive devices – a.k.a. humans!



Possible computation in the cloud

- Grasp planning: move expensive online methods to the cloud



[Brook, Hsiao and Ciocarlie, ICRA 2010]

Robotic Manipulation: Looking Ahead

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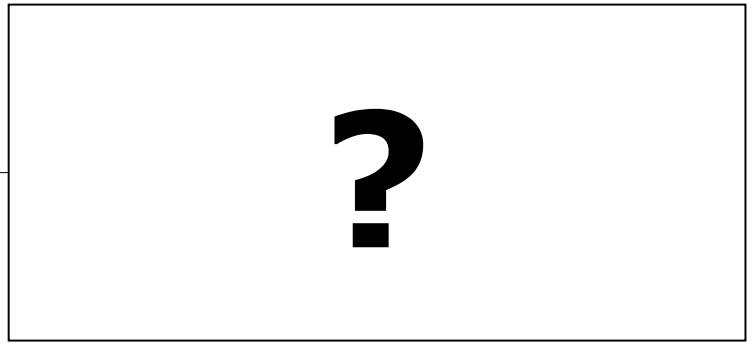
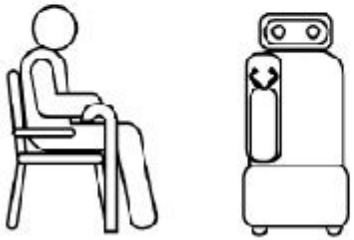
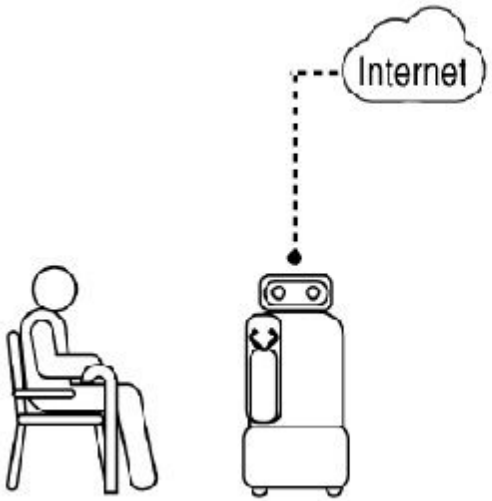


Human-in-the-Loop Manipulation



Human-in-the-Loop Manipulation



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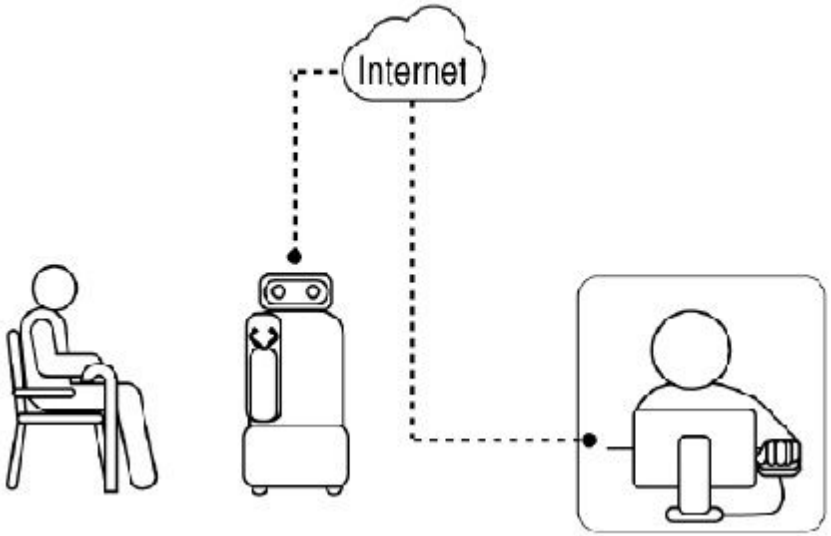

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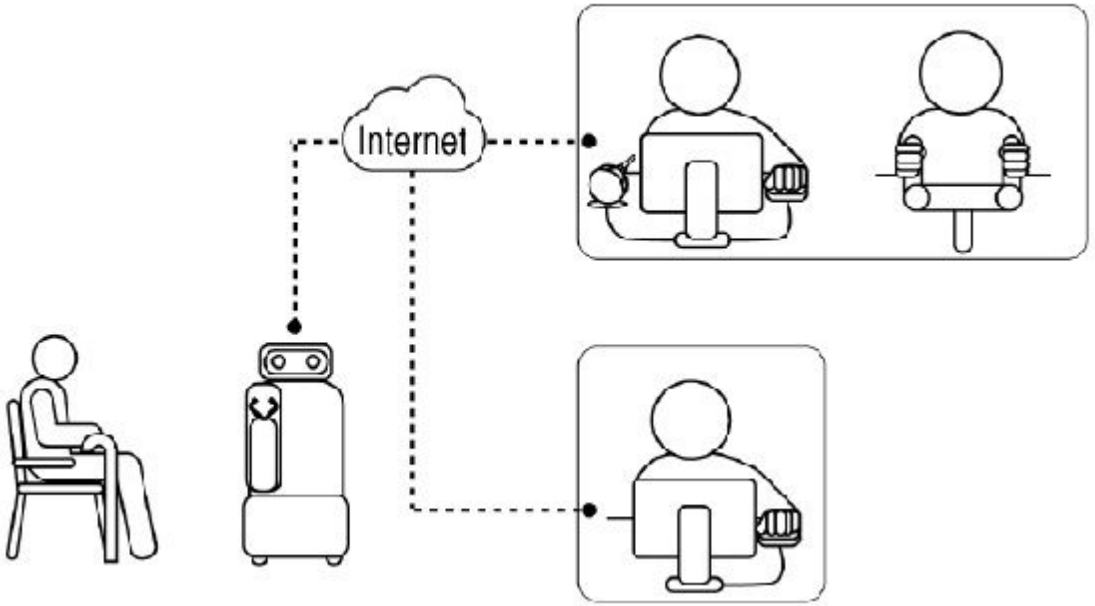
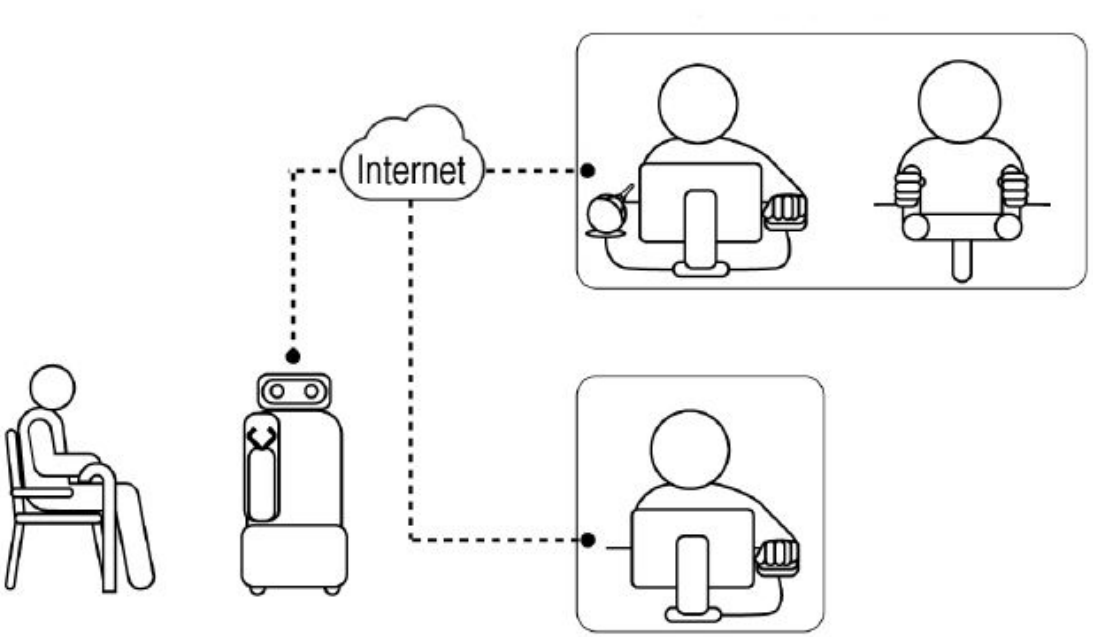
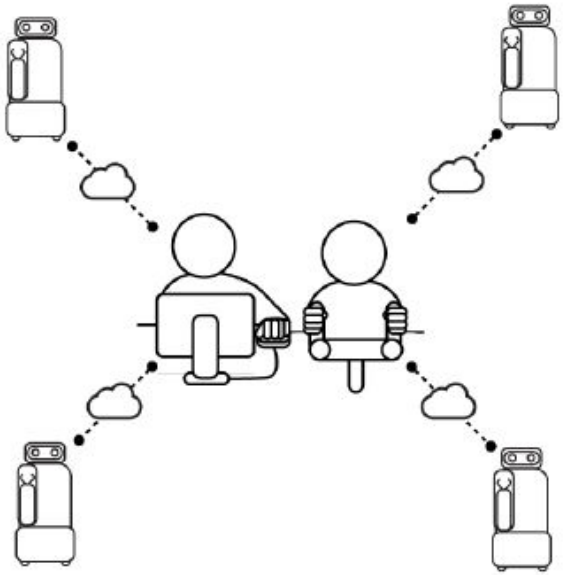
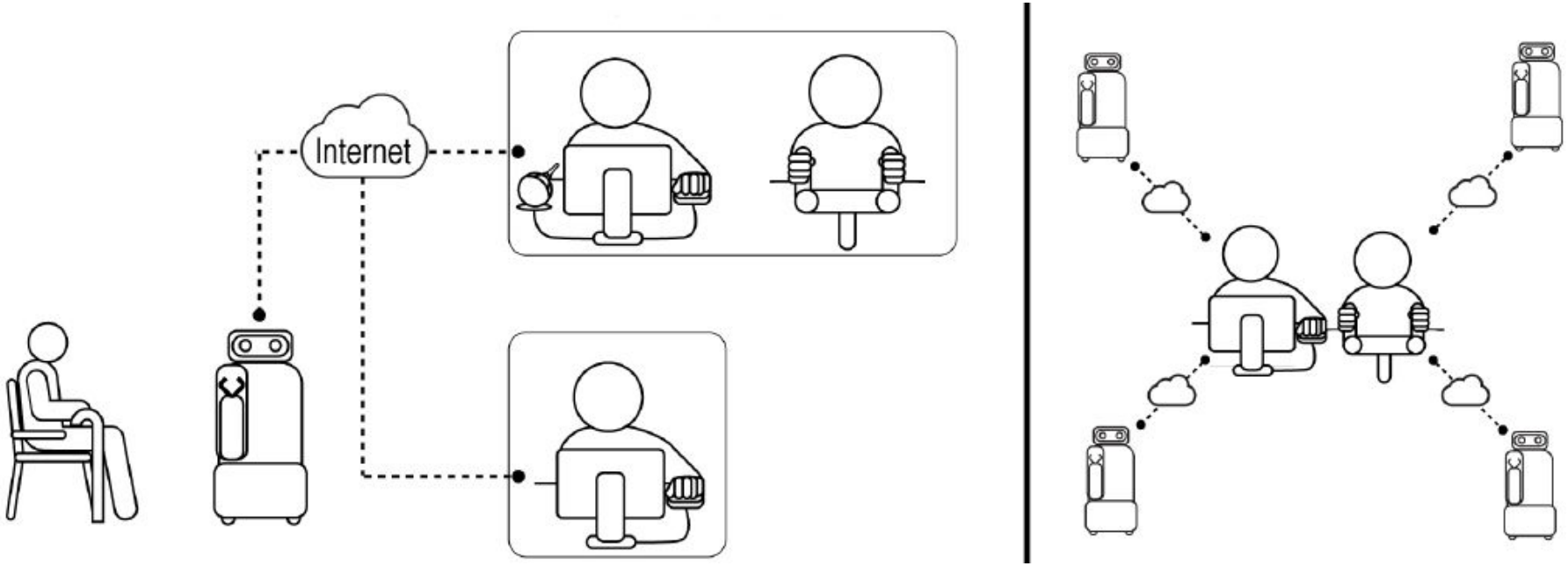


Human-in-the-Loop Manipulation





Human-in-the-Loop Manipulation

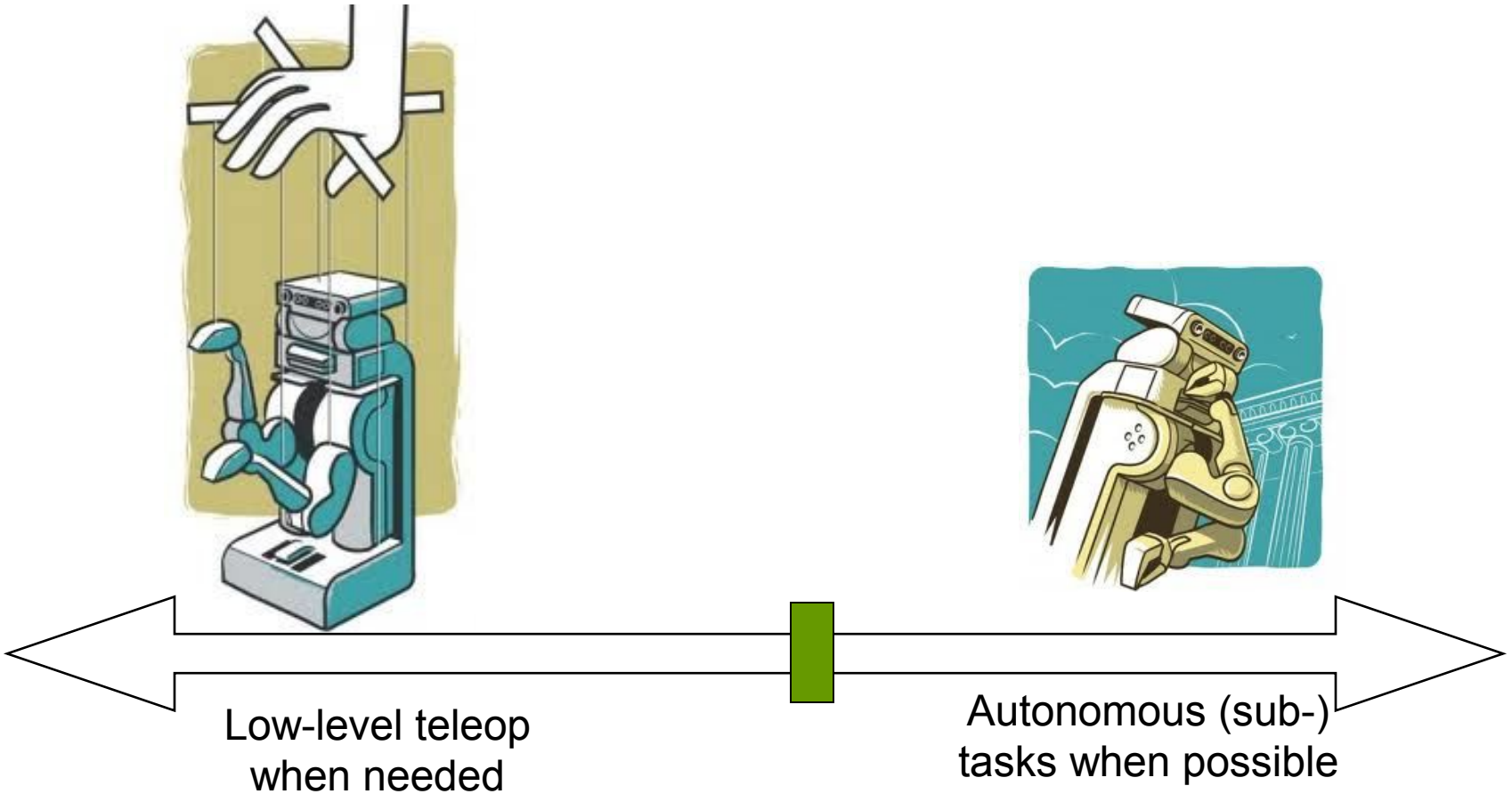


- Simplify control of a high-dimensional system for complex tasks
- Reduce communication bandwidth
- Enable robot programming and operation by non-experts

[NSF SBIR 1256643 Phase I and II]

Human-in-the-Loop Manipulation

- Combine **robot capabilities** and **human cognition**



Tiered Human-in-the-Loop Grasping

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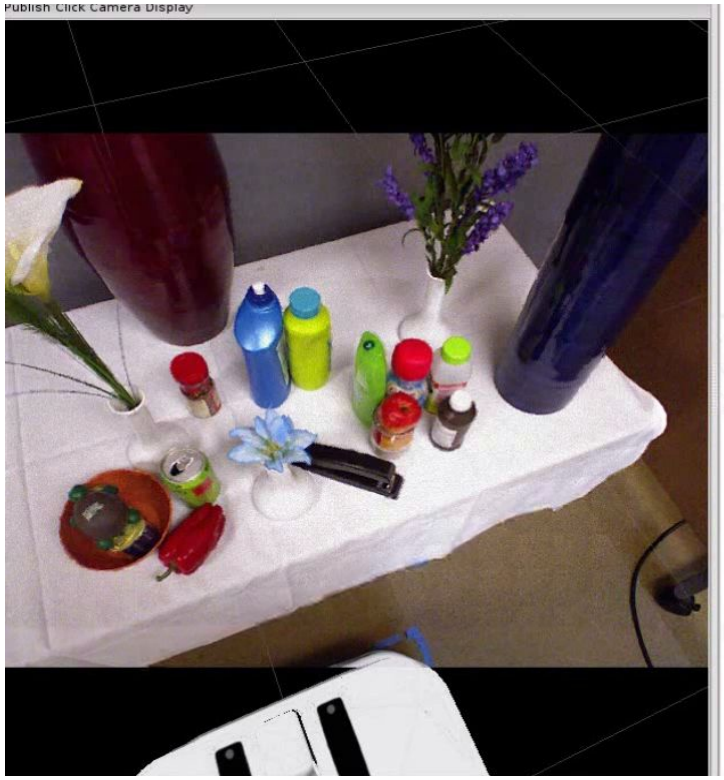
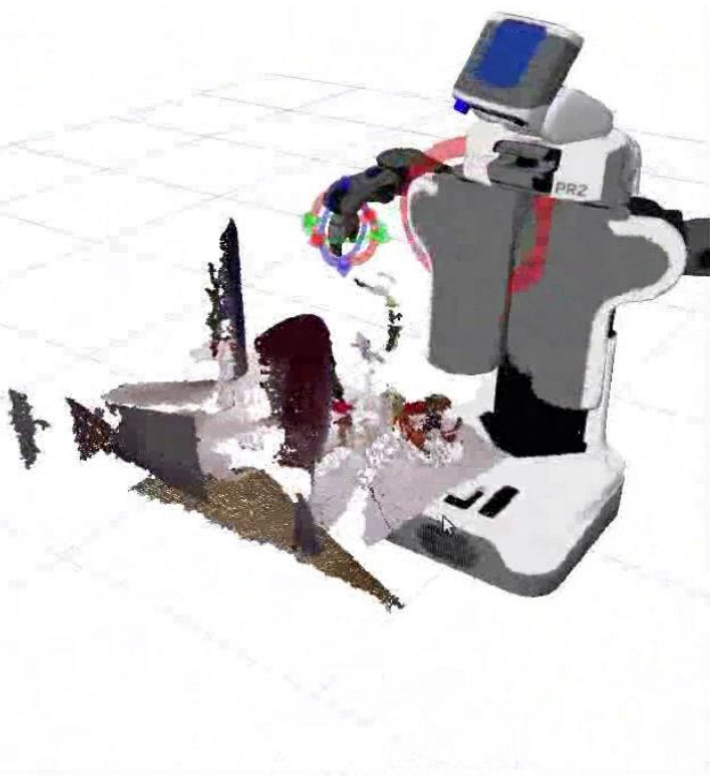
[Leeper, Hsiao, Ciocarlie, Takayama and Gossow, HRI 2011]

Tiered Human-in-the-Loop Grasping



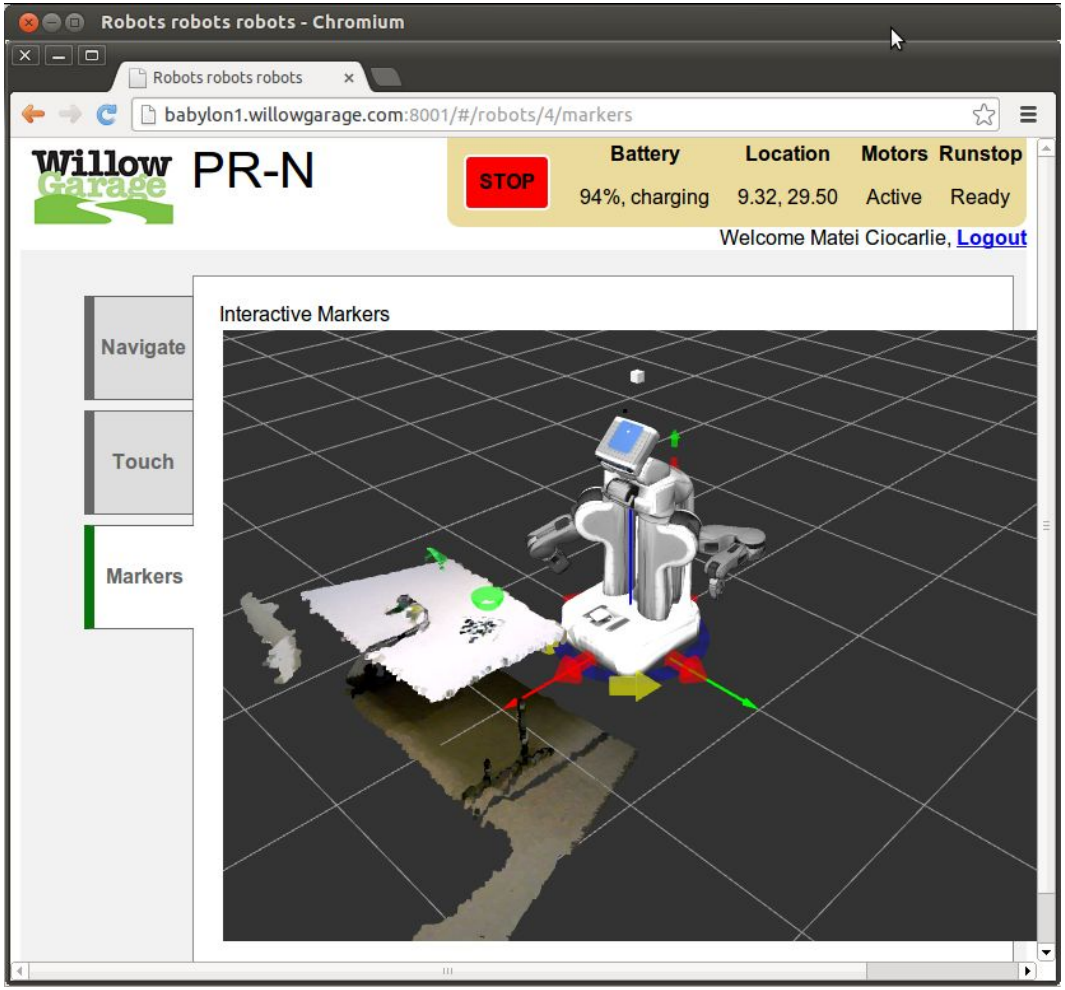


[Leeper, Hsiao, Ciocarlie, Takayama and Gossow, HRI 2011]

Constraint-Aware Teleoperation Controller

[Leeper, Hsiao, Ciocarlie, Sucan and Salisbury, Humanoids 2013]

Over the Web... and into the browser



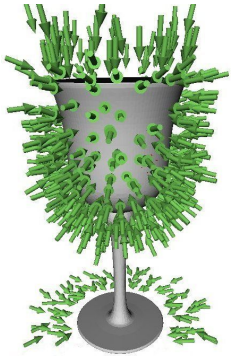
Point Cloud Streaming

[Courtesy of Julius Kammerl]

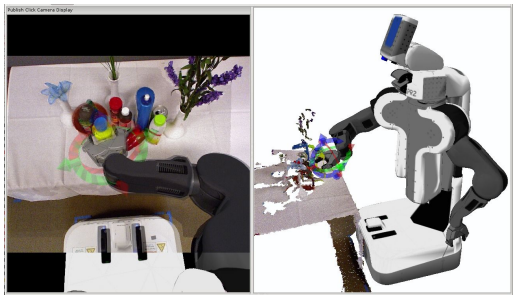
Interactive Markers in the Browser

[Courtesy of David Gossow]

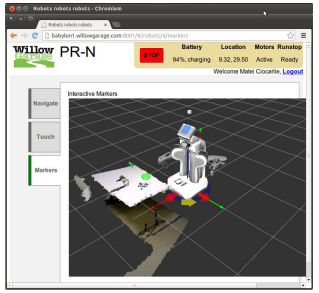
Cloud Robotics at Willow Garage



- Increase **versatility** and handle **variability**
- **Resources**
  - data - objects, grasps [1]
  - computation - grasp planning [2]
  - tele-operation - tiered HitL [3,4]



- **Browser-based tools**
  - Interactive Markers - ROS package [5]
  - point cloud streaming - ROS package [6]



[1] Ciocarlie, Pantofaru, Hsiao, Bradski *et al.*, IEEE R&A Mag. 2011
[2] Brook, Hsiao and Ciocarlie, ICRA 2010
[3] Leeper, Hsiao, Ciocarlie, Takayama and Gossow, HRI 2011
[4] Leeper, Hsiao, Ciocarlie, Sucan and Salisbury, Humanoids 2013
[5] http://www.ros.org/wiki/interactive_markers
[6] http://www.ros.org/wiki/depthcloud_encoder

Thank you!