

August 17th 2013

IEEE/NSF Workshop on
Cloud Manufacturing and Automation

The Humans in the Cloud: Shared Autonomy over the Internet

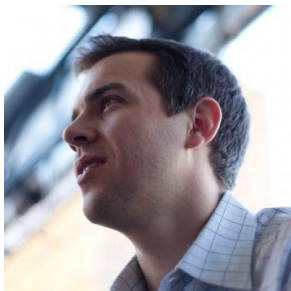
Matei Ciocarlie

Willow Garage Interactive Manipulation Group

Willow Garage Web Robotics Group



The Team



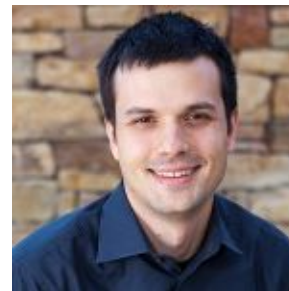
Brandon
Alexander



Jon
Binney



Julian
Cerruti



Matei
Ciocarlie



David
Gossow



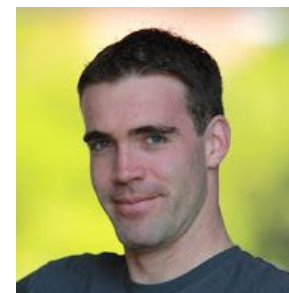
Kaijen
Hsiao



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



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Robotic Manipulation: Looking Ahead

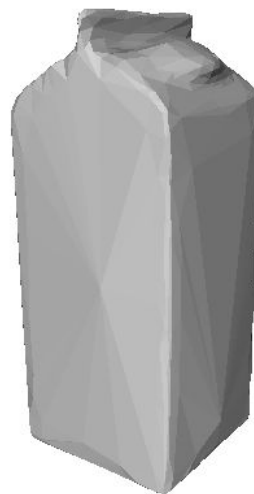
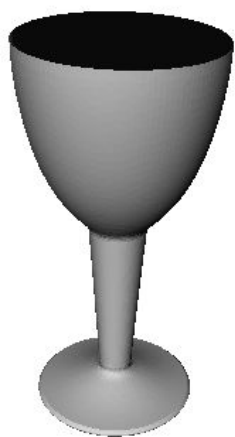
- Key problems: **versatility** and **variability**
- Resources in the cloud
 - **Data**
 - Computation power
 - Advanced cognitive devices – a.k.a. humans!



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ROS **household_objects_database**

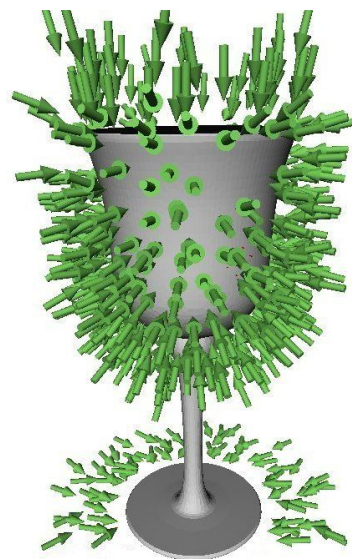
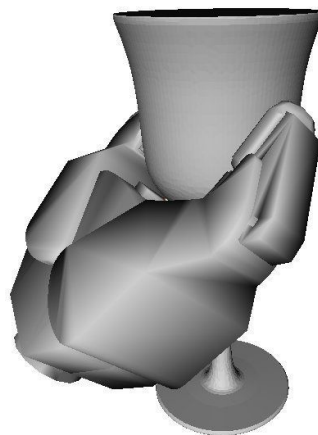
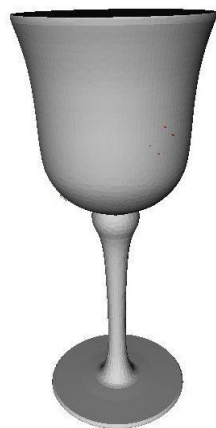
- Real-life objects from major retailers
- Triangular meshes
- Meta-data (maker, model, barcode, etc.)



[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

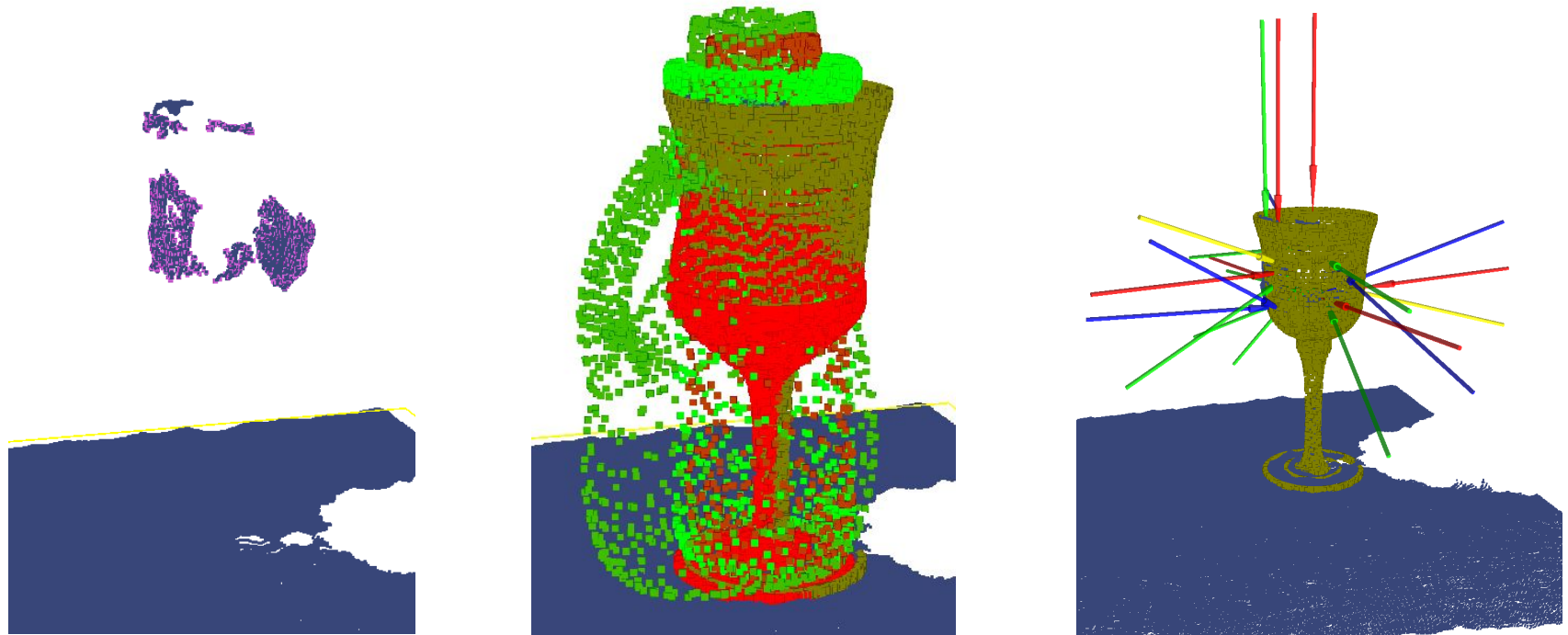
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Possible computation in the cloud

- Grasp planning: move expensive online methods to the cloud



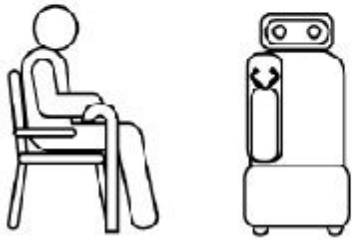
Robotic Manipulation: Looking Ahead

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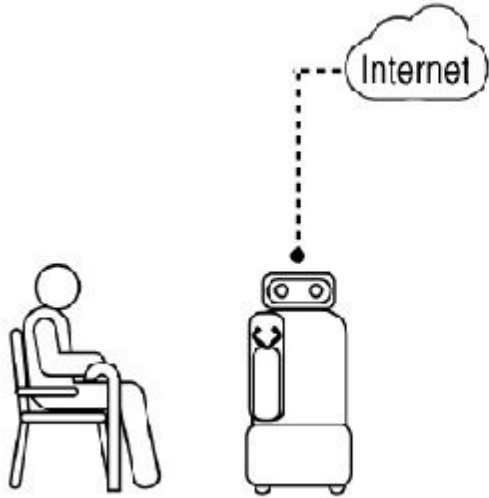


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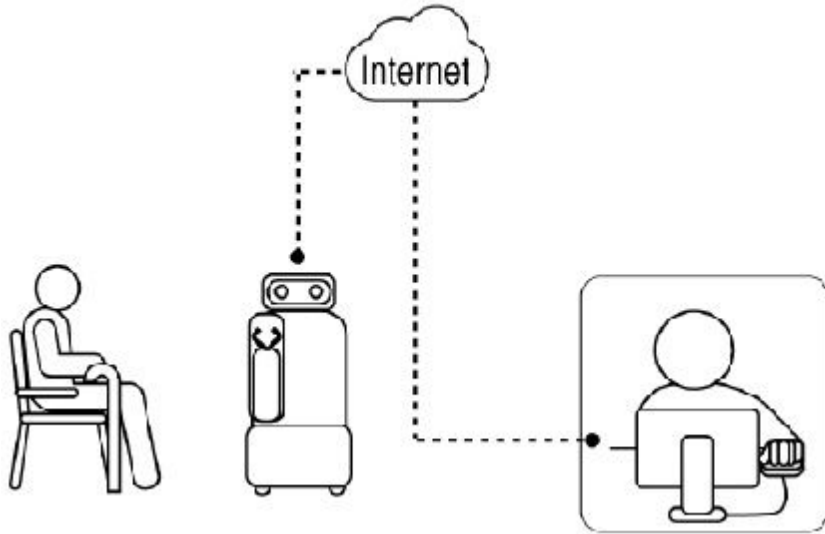
Human-in-the-Loop Manipulation



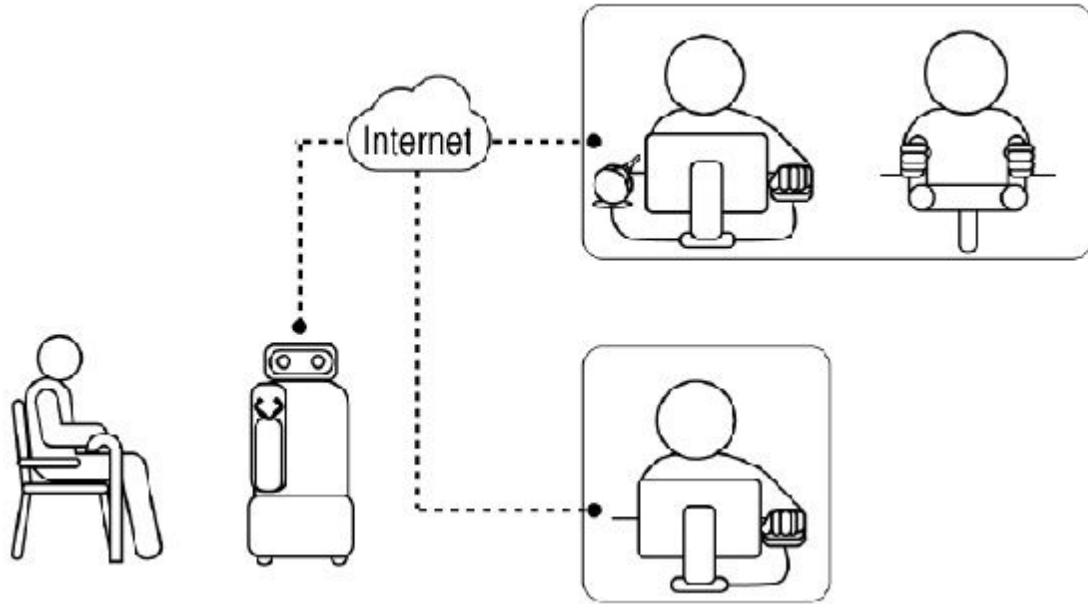
Human-in-the-Loop Manipulation



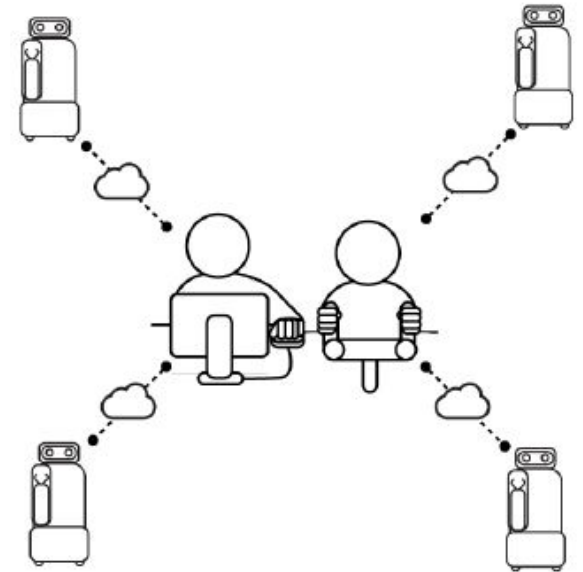
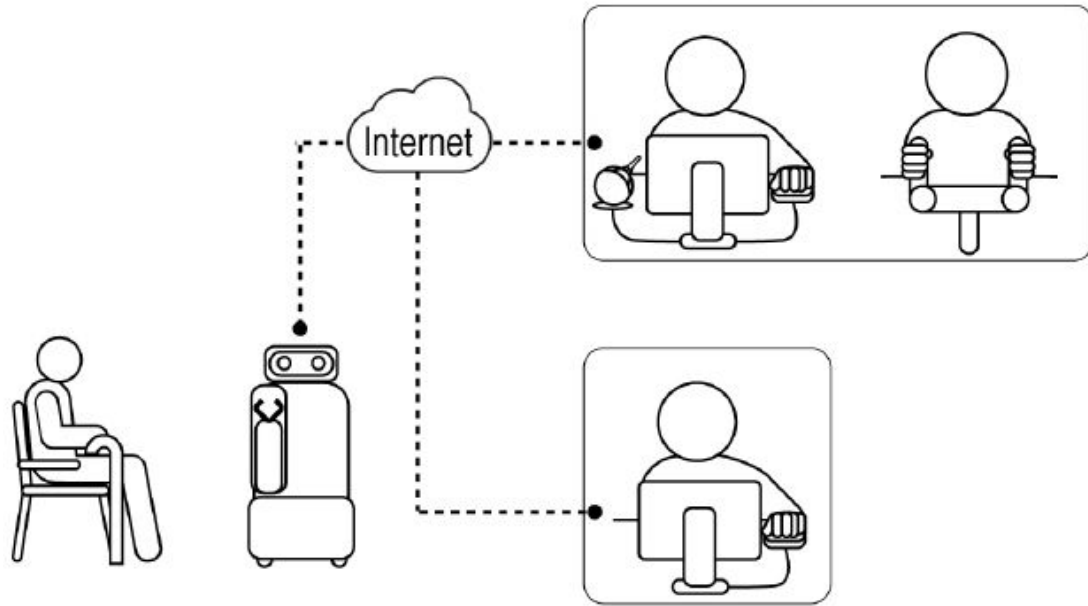
Human-in-the-Loop Manipulation



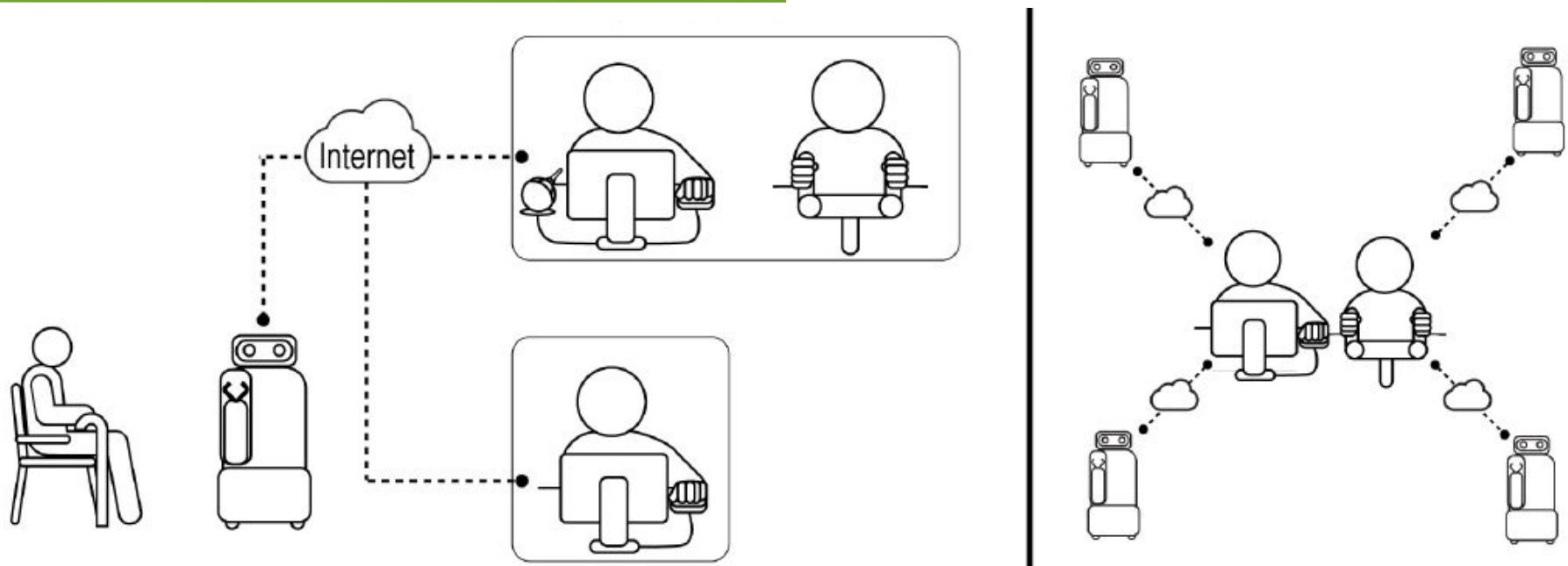
Human-in-the-Loop Manipulation



Human-in-the-Loop Manipulation



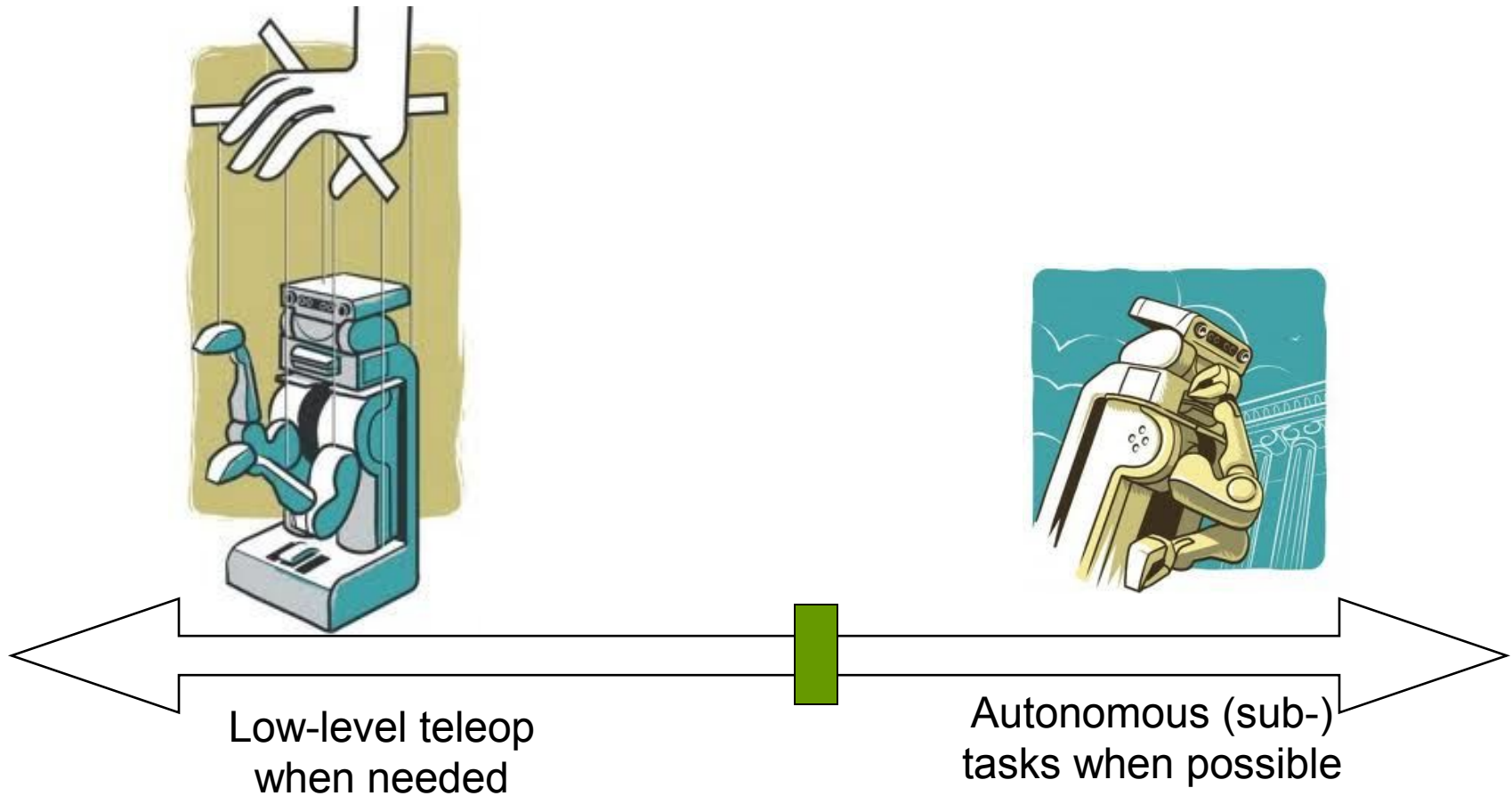
Human-in-the-Loop Manipulation



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

Human-in-the-Loop Manipulation

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



Tiered Human-in-the-Loop Grasping

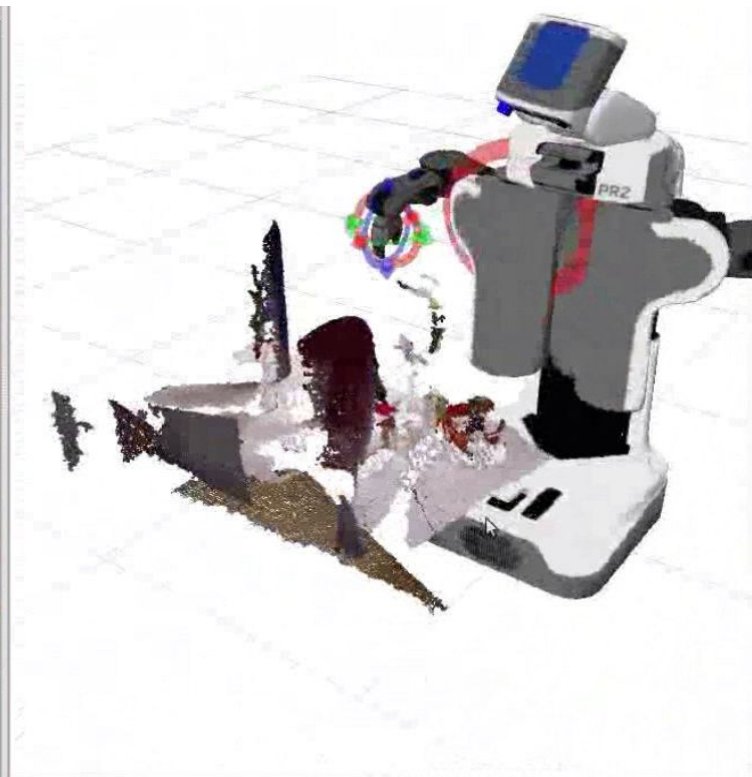
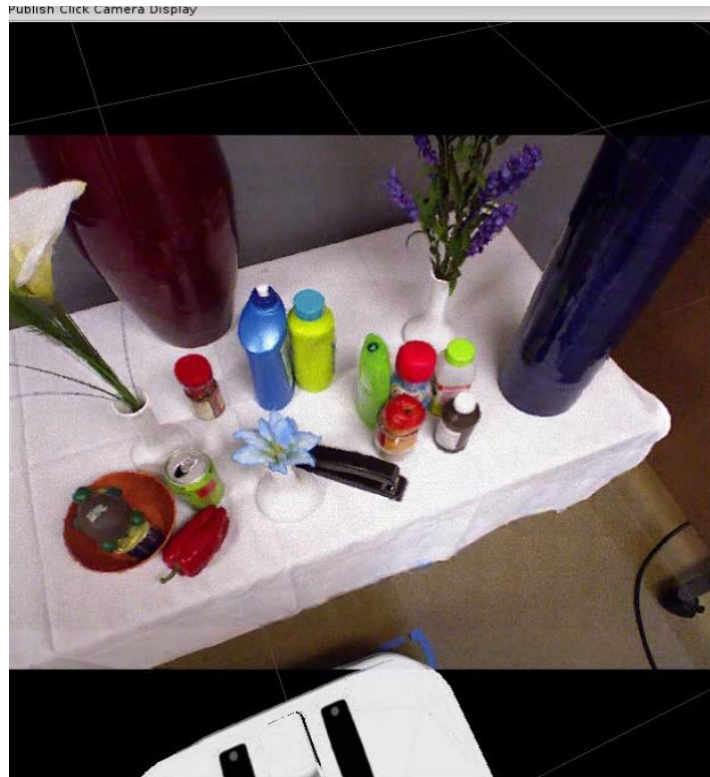


Tiered Human-in-the-Loop Grasping



[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, Sucas and Salisbury, Humanoids 2013]

Over the Web... and into the browser



A screenshot of a web browser window titled "Robots robots robots - Chromium". The address bar shows the URL "babylon1.willowgarage.com:8001/#/robots/4/markers". The page content includes the Willow Garage logo and "PR-N" text. A status bar at the top right displays "STOP" in a red button, "Battery 94%, charging", "Location 9.32, 29.50", "Motors Active", and "Runstop Ready". Below this, it says "Welcome Matei Ciocarlie, Logout". A sidebar on the left has buttons for "Navigate", "Touch", and "Markers". The main area is titled "Interactive Markers" and shows a 3D rendering of a robot on a grid floor with various colored markers and arrows.

Point Cloud Streaming



[Courtesy of [Julius Kammerl](#)]



Interactive Markers in the Browser

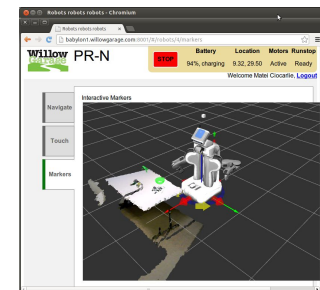
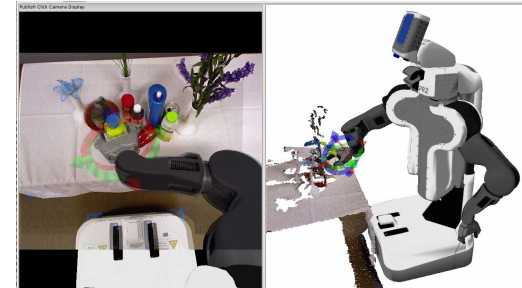
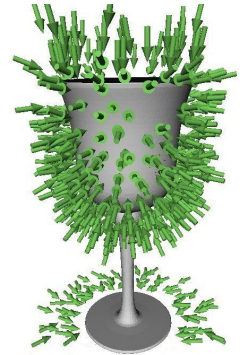


[Courtesy of [David Gossow](#)]



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, Sucas and Salisbury, Humanoids 2013

[5] http://www.ros.org/wiki/interactive_markers

[6] http://www.ros.org/wiki/depthcloud_encoder

Thank you!