The Humans in the Cloud: 
Shared Autonomy over the Internet

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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

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

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

Strategy 3: Grasp Execution

[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]

[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
Thank you!