HUMAN-TO-ROBOT HANDOVER PROTOCOL

<table>
<tr><td>Reference No / Version</td><td>RAL-SI-2020-P19-0835 -V1.0</td></tr>
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<tr><td>Purpose</td><td>Assessing the ability of a robot to perform handovers from a human with unseen objects whose physical properties such as dimensions, shape, rigidity and fillings are unknown</td></tr>
<tr><td>Task Description</td><td>A subject grasps a (filled) object from a table and hands the object over to a robot arm that must infer the object properties on-the-fly. After the handover, the robot arm delivers the object to a pre-defined location on the table</td></tr>
<tr><td>Setup Description</td><td><u>List of objects and their descriptions:</u>
The task is composed of 288 configurations.

We use <u>four</u> types of cups of different shapes, sizes, and materials, and with different degrees of deformability and transparency:
1. high deformability, medium transparency
2. average deformability, low transparency
3. average deformability, high transparency
4. no deformability, high transparency (wine cup from YCB)
These cups are inexpensive and available worldwide. Purchase links:
1. http://bit.ly/2N6n3tm
2. https://amzn.to/2JwRk3l
3. https://amzn.to/2JwRk3l
4. https://amzn.to/33zw4AY

Cups should be filled with different amounts of filling to vary the mass and deformability of the glass.
We use <u>two</u> amounts of fillings. Empty or rice, which is easy to purchase and - unlike liquids - harmless for the hardware. We fill the cups up to (approximatively) 90% of its volume
The subjects are instructed to grasp the cup in <u>three</u> different ways

<table>
<tr><td></td><td>Grasp 1</td><td>Grasp 2</td><td>Grasp 3</td></tr>
<tr><td>Cup1</td><td>  </td><td>  </td><td>  </td></tr>
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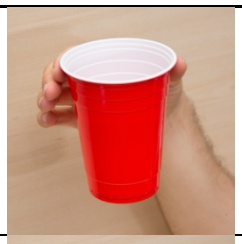
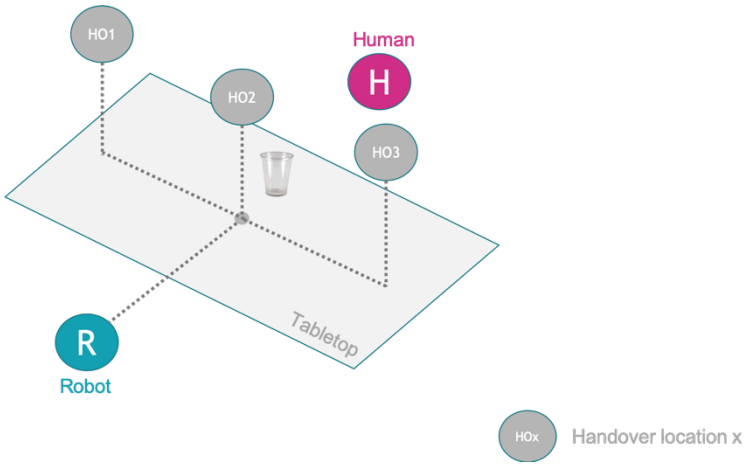
</td></tr>
</table>

Cup2			
Cup3			
Cup4			

The subjects are instructed to perform the handover at <u>three</u> predefined handover areas.



<u>Four</u> subjects are required to complete the handovers

<u>Initial and target poses of the objects:</u>
For each execution of the task, the glass is initially placed at the center of the table. Participants will grasp and carry the glass to different approximate handover areas above the table, 40cm above the table, within a sphere of 10cm diameter. After the handover, the robot places the glass back at the initial location at the center of the table. Participants are free to choose the best way to measure the final error (e.g. using printable stencils as for YCB)

<u>Description of the manipulation environment:</u>
Conduct the experiment on a table (e.g. a cheap IKEA table), which can be covered with a white tablecloth (e.g. white tablecloth used in YCB)

Purchase link: https://amzn.to/2X5qnaN

Robot/Hardware/Software/Subject Description	**Targeted robots/hardware/software:** Any robotic arm with at least 6 degrees of freedom (e.g. KUKA, UR5) equipped with a gripper (e.g. a 2-finger gripper or a complete robotic hand) Up to two cameras. In addition, a third camera to record the overall scene shall be used for evaluation purposes only
	Initial state of the robot/hardware/subject with respect to the setup: Any initial robot pose can be chosen with respect to the environment setup; however, we expect the subject to stand on the opposite side of the table with respect to the robot. Subjects are previously instructed with all the handover configurations that they must perform (e.g. cup type, filling amount, grasping type, and handover areas)
	Prior information provided to the robot: Only the high-level semantic category of the object is provided. Databases of the specific objects or their 3D models are not provided prior to the task, as well as any other partial knowledge (e.g. object dimensions, shape or weight). Information of each object should be estimated on-the-fly via perception (e.g. vision or robotic sensors)
Procedure	For each configuration: 1. Prepare the glass with its filling 2. Place the glass at the center of the table 3. The subject grasps the glass from the pre-defined location 4. The subject carries the glass with the intention of handing it over to the robot at a pre-defined approximate handover area above the table 5. The robot should track and predict the pose of the object to move the arm towards the handover area 6. The subject hands the glass over to the robot 7. The robot closes the end effector and grasps the object 8. The robot delivers the glass to the initial location.
Execution Constraints	Each subject is instructed to use only one hand and always the same. No prior knowledge of the objects is available apart of its high-level category (i.e. cup). The location to deliver the cup must be inferred using perception from the initial location and not hard-coded. Learning across executions of configurations is not allowed.