MANIPULATION PROTOCOL PROPOSAL

Reference No / Version	RAL-SI-2020-P19-0823-V1.0 (for the latest versions of the protocol, please refer to http:/www.ycbbenchmarks.com/protocols-and-benchmarks)
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Purpose	Assess the performance of a grasp planning algorithm in a physical robot setup, accounting for the limitations of the test platform.
Task Description	Measure reachability and camera calibration of the robot setup; grasp objects in different poses in isolation or in clutter.
Setup Description	List of objects and their descriptions: Subset of the YCB object set (16 objects): Banana, Foam Brick, Gelatin Box, Mustard Bottle, Potted Meat Can, Hammer, Chips Can, Cracker Box, Tomato Soup Can, Tennis Ball, Pear, Scissors, Strawberry, Power Drill, Medium Clamp, Master Chef Can.
	Initial and target poses of the objects: The printable layouts show the object footprints as well as ArUco markers for localization of the board in the robot reference frame. Object poses are defined in the XML files for each layout with respect to one of the markers (bottom rightmost).
	Description of the manipulation environment: Print the layouts in A2 format or compose them using the A4 tiles. The tiles do not display one row and column of markers to avoid misdetections due to partial printing. Place the printouts in front of the robot on a horizontal surface and place the objects on the footprints.
Robot/Hardware/Software/ Subject Description	Targeted robots/hardware/software: Any.
	Initial state of the robot/hardware/subject with respect to the setup: The layout boards location must be chosen to make sure the robot arm can reach the four corners of the layout and most of the board markers and objects can be seen by the vision system (if any). In case no optimal placement exists for both vision and reachability, prioritize the latter. When switching boards, make sure the pose of the layout reference frame with respect to the robot matches that of the previous layout (so that the reachability and calibration scores do not change).
	Prior information provided to the robot: If no vision system is present, place the board so that the reference marker (bottom rightmost) pose in the robot reference frame is known with accuracy. Determine object poses with the XML layout files.
Procedure	For further details, refer to the hands-on tutorial. **Gather reachability data.** Have the end effector reach every target pose defined over the empty layout area, then acquire the reached poses through the direct kinematics and translate them in the layout reference frame. Log the poses in an XML as indicated in the tutorial.

	Gather visual calibration data. Affix a marker to the end effector and log its pose with respect to the end effector reference frame. Have the end effector reach every target pose defined over the empty layout area, then acquire the reached poses through detection of the marker and translate them in the layout reference frame. Place more than one marker if necessary. Log the poses in an XML as indicated in the tutorial. **Determine graspable objects** According to the hardware limitations of the test platform, choose which of the 16 objects can be grasped and lifted by the robot arm and gripper. **Plan for grasps.** Start from layout 0. Place the objects on the layout one at a time or all at the same time (if the grasp planning algorithm allows for cluttered scenarios). Use the algorithm under test to plan for at least 5 grasps for each perceivable and graspable object in the layout. If such pipeline does not feature visual input, plan for all graspable objects. Log the poses in an XML as indicated in the tutorial. **Execute grasps and evaluate stability.** 1. Grasp the object. 2. Lift the object 15 cm above the layout surface (starting position). 3. Hold for 5 seconds. 4. Rotate the end effector 45 degrees around the approach direction to the object, in a 2 second trajectory. 5. Rotate the end effector -45 degrees around the approach direction to the object (back to starting position), in a 2 second trajectory. 6. Rotate the end effector -45 degrees around the approach direction to the object, in a 2 second trajectory. 7. Rotate the end effector 45 degrees around the approach direction to the object (back to starting position), in a 2 second trajectory. 8. Rotate the end effector 30 degrees around the end effector center point, in the vertical plane containing the approach direction to the object, towards the layout surface. 9. If operating in cluttered mode, count how many objects the arm or the grasped object hit during execution of the grasp. 10. Log results. 11. Proceed to the next grasp or object, and back to step 1. If the object slips off during any of the steps, skip to step 10. If all planned grasps for all objects have been executed, switch to the next layout and go back to planning grasps.
Execution Constraints	Any grasping pipeline, with or without visual input, can be used as long as all grasps are planned using the same algorithm. It is acceptable for the manipulator to move the object during the approach or grasping action. Moving protocol objects outside the A2 format layout area is not allowed. Regrasping and grasp stabilization is allowed as long as the object is not put back on the table once it is lifted and only one end effector is used (in case of multi-finger dexterous hands, the hand constitutes the end effector). The object is allowed to slip during the grasp and stability evaluations, as long as this does not cause the object to fall.