GRASP PLANNING ASSESSMENT PROTOCOL

Reference No / Version	RAL-SI-2020-P19-0837-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 robustness of grasps planned with a particular grasp planner.
Task Description	Systematic execution and evaluation of grasps planned with different grasp planning approaches on given objects
Setup Description	<u>List of objects and their descriptions:</u> The following objects from the YCB object set can be used: *Food items:* chips can, coffee can, cracker box, box of sugar, tomato soup can; mustard container, chocolate pudding box, gelatin box, potted meat can, apple, orange *Kitchen items:* pitcher, bleach cleanser, glass cleaner; plastic wine glass, enamel-coated metal bowl, metal mug *Tools:* power drill, wood block, screw driver, spring clamp *Shape items:* mini soccer ball, softball, baseball, racquetball, cups, foam brick, washers (3 distinct sizes), chain *Task items:* airplane toy Other objects from YCB can be used, using the official name as a reference, taken from the following document: http://50.87.248.224/~ycbbench/wp-content/uploads/2015/09/object-list-Sheet1.pdf
	<u>Initial poses of the objects:</u> Each object is placed at a known initial position and orientation with respect to the robot. The origin of the circular workspace (details in manuscript) is considered as the initial location of the object. The initial position can be for instance taught using teach pendant.
	<u>Description of the manipulation environment:</u> Objects should be placed on a horizontal surface (e.g. a table), on an area with good reachability and dexterity. The table position is fixed with respect to the robot. More details can be found in the manuscript.
Robot/Hardware/Software /Subject Description	<u>Targeted robots/hardware/software:</u> – Arm/manipulator is a free choice. – Gripper choice is up to the user (number of fingers, type of actuation). – The grasp planner to be tested might be specific for a particular

	gripper or also generic for any type of gripper.
	<u>Initial state of the robot/hardware/subject with respect to the setup:</u> The protocol considers only one object in a scene, or a pile of objects built randomly. No obstacles are present in the scene.
	<u>Prior information provided to the robot:</u> – Full model of the object to be grasped is given (CAD model, point cloud). – Gripper is properly identified on the grasp planner; CAD model of the gripper and geometrical properties are available. – Pose of the object with respect to the robot is given.
Procedure	<u>Grasp planning:</u> Given the model of the object and its localization with respect to the robot, plan and choose the best grasp hypothesis. The grasp plan depends on the type of gripper, but can include information on wrist position, fingertip positions, joint angles for each DoF in the gripper, as required by the gripper selected for running the protocol. <u>Grasp execution:</u> Each object is placed at a known initial position and orientation with respect to the robot, inside the circular workspace. The origin of the workspace is considered as the initial location of the object, which is then moved systematically within the defined range (see the manuscript for details). The robot is moved to place the wrist at the appropriate location. The technique to close the hand follows these rules for a fully-controlled hand: start with an initial fully open configuration, then pre-shape the hand based on the planner, and close the fingers with equal speeds while limiting the maximum torque of each actuator until reaching a static state where the object does not move, or a fully closed hand configuration is reached, which occurs in the case of an unsuccessful grasp (object slipping away). The joint angles can be set to reach the fully closed configuration of the hand, which can only be potentially reached if the object slips away. For the case of an underactuated hand, the wrist is placed at the desired (planned) location, and the closing signal is sent to the robot until reaching a state where the object does not move inside the hand, or a fully closed configuration is achieved (when the objects slips away). <u>Grasp repetitions:</u> Each grasp for a given object pose should be executed at least N=3 times. For an object, 6 different poses are considered, giving 6 * *N* cases. If the object mirroring is possible, i.e., for non-symmetric objects, this becomes 12**N*. After placing the object manually as described above, and given the observed scene (e.g. RGB/RGB-D data) or the known object model and pose, we run the grasp planner and execute the best grasp (e.g. the one with maximum

	quality/likelihood). This process is repeated *N* times. Besides, we define an object pose where the object is standing or lying in a stable manner on a flat surface as a stable pose and evaluate the planner's performance based on this discrete number of cases. In case of cluttered scene evaluations, i.e., with more than one object, we randomly throw objects in a bag or a container tray and empty them onto the table, leading to random object placements within the defined circle. We use the best hypothesis for each trial until the scene is cleared. We repeat *N* times the whole clearing up process. <u>Grasp testing:</u> The object is lifted 20 cm above the table at a speed of 10 cm/s. A series of motions are executed as follows to verify grasp stability. A rotational test is performed: rotate the object at post grasp position by +β and -β one after the other (around the z axis of the last link of the robot). β >= 20° (e.g. =90°) is a free parameter that can be selected based on the robot kinematics. The shaking test is conducted afterwards in the sagittal plane (horizontal direction), where the robot shakes the object with a specific amplitude in a sine pattern for 10 seconds. The sine pattern can be generated with an amplitude of 0.25m and peak acceleration of 10 m/s^2. Note that if the user's robot cannot execute the sine pattern with these values (lifting height, speed, time, amplitude, and peak acceleration), then the user should clearly report the values used for their tests. The test is stopped if the object falls out of the hand at a given step. Since the shaking test is performed after the rotational test, we do not perform it if the rotational test fails.
Execution Constraints	