Aiding Grasp Synthesis using Multiple Viewpoints

RBE 595 Robot Manipulation Project
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1. Objectives

This project is based on using the eye-in-hand system as an aid for grasp synthesis. Instead of using a partial point cloud data obtained from a single viewpoint, we use data from multiple viewpoints to get a more complete data on the target object. With more data available, it reduces the assumptions to be made on the complete geometry of the object. This gives us a higher probability of synthesizing a stable grasp for the object. The Franka Emika robot with a parallel jaw gripper was used for the simulation

This project is based on the following research paper "Viewpoint Optimization for Aiding Grasp Synthesis Algorithms using Reinforcement Learning" authored by B. Calli, W. Caarls, M. Wisse and P. Jonker

2. Implementation Details

Using multiple viewpoints aids us in getting a more complete point cloud data of the target object, enabling us having multiple grasping options. With multiple options, we can choose one based on the requirements. The number of available grasp options satisfying the grasp metric is used as a parameter to define how effective the set of viewpoints are. The implementation process for this study goes as follows:

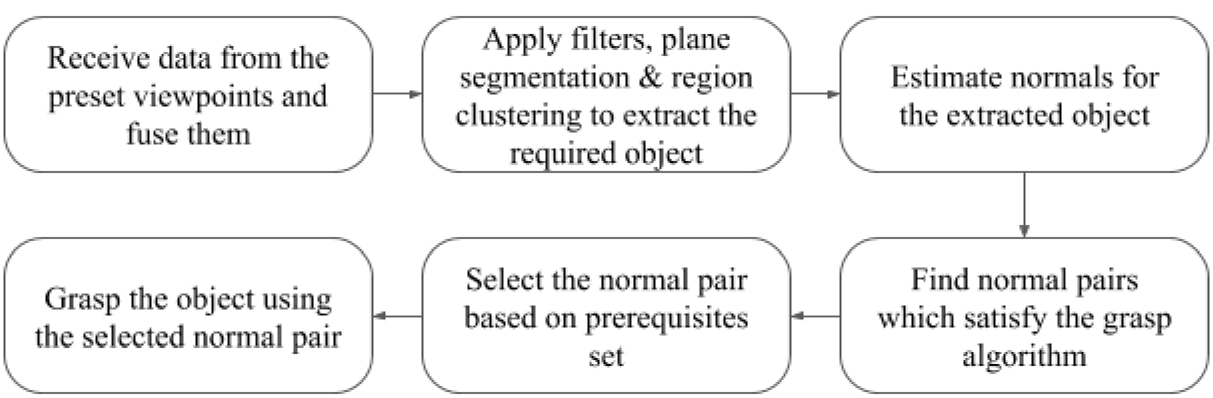


Figure 1. Flowchart showing the implementation process

2.1 Integrating the point cloud data received from multiple viewpoints

The simulation environment was created in gazebo with Kinect as the sensor to generate the point cloud data. Each of the received point cloud data was transformed from the Kinect frame to the world frame so that the point cloud from multiple viewpoints could be merged.

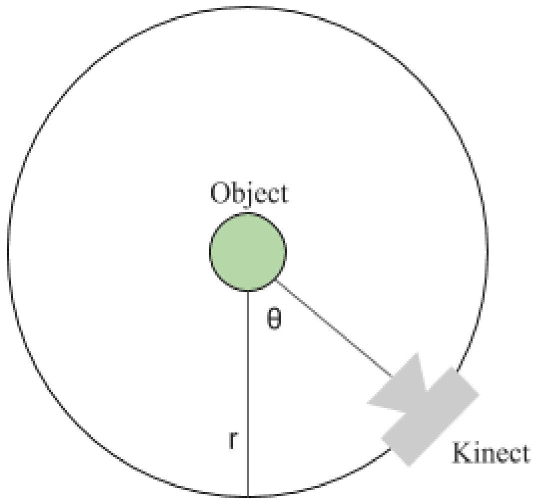


Figure 2. Defined View plane (Top View)

The density of points at the overlapping regions increases for every added viewpoint. To make the point cloud have consistent density, the resultant point cloud was downsampled to a resolution of 0.5 x 0.5 x 0.5 cm. This also enabled faster processing, while still preserving the required details.

Each viewpoint was defined in a view plane with respect to the target object center as shown in Figure 2. In this study, the Kinect was set at a distance "r" of 1.5m and at a height of 0.5m from the object. The Kinect had a pitch down angle of 30°.

2.2 Extracting the point cloud data of the required object

The target object needs to be extracted from merged point cloud data. Using distance filtering, the background data is removed and then using plane segmentation the major plane (table) is found. Removing this major plane gives us the point cloud of the object in the table. In this study, we have only one object on the table. In case there are multiple objects, using Region Clustering, the point cloud can be clustered into different objects. One of these objects can be selected, which would be used for the Grasp Synthesis Algorithm

2.3 Applying the Grasp Synthesis algorithm

A 3D version of the force-moment balance-based algorithm is used here. Using the parallel jaw gripper we consider only two contact points on the object. The quality of the grasp is defined by the angle between the force application vectors (point cloud normals) and the line connecting the two contact points considered. As the angle gets closer to 0° and 180°, the quality of the grasp increases. Figure 3 shows a representation of this in a 2D case.

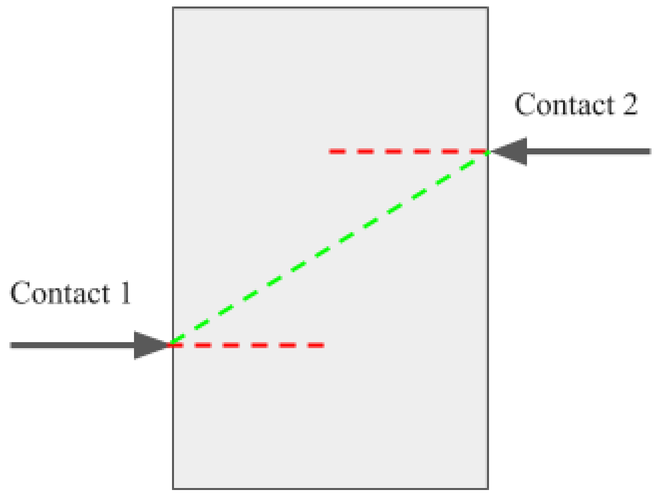


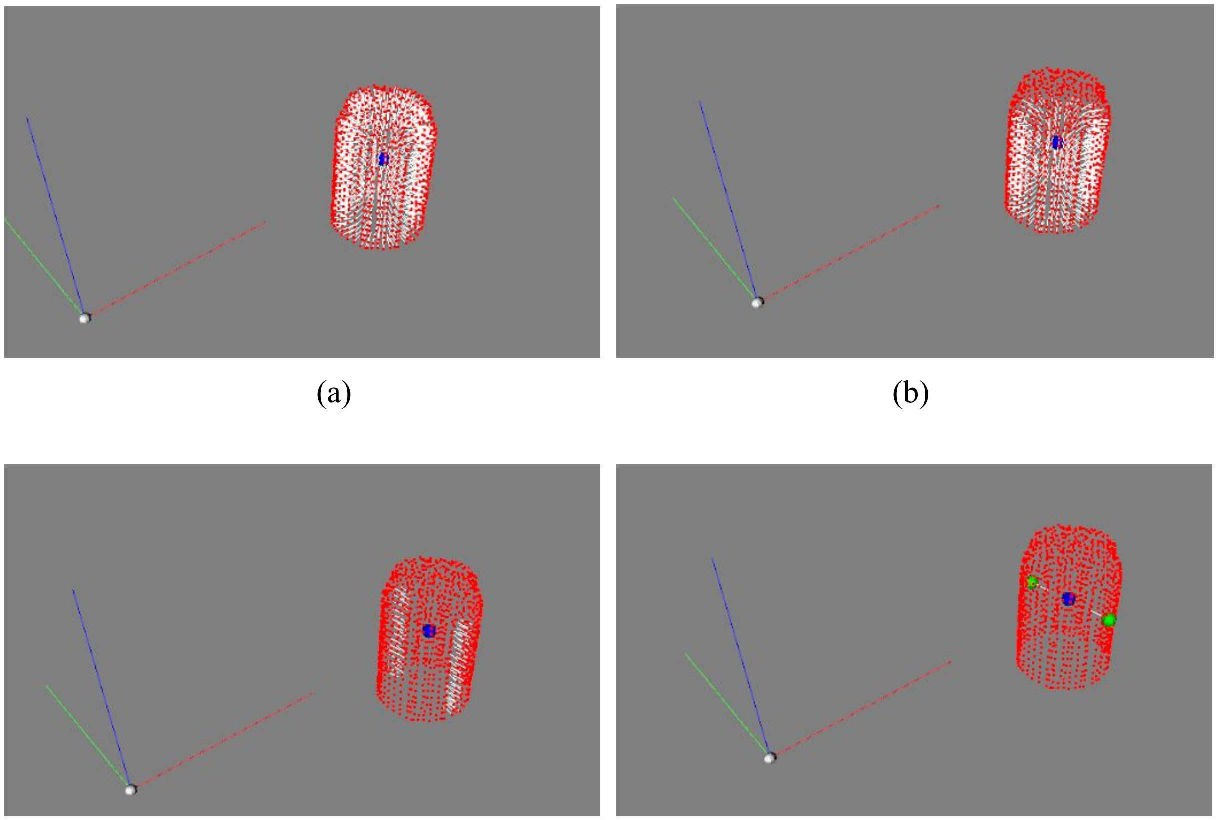
Figure 3. Force-moment balance-based algorithm. The angle between force application direction (Red dashed Line) and the line connecting two grasp contact points (Green dashed line) should within the specified tolerance level

The normal vector for each point is found. For every pair of normal vectors, the Grasp algorithm is applied. All the pairs of normals satisfying the Grasp algorithm within a tolerance of ± 5° are considered as a pair with a stable grasp.

2.4 Select the final contact point based on the defined prerequisites

To successfully grasp the object we need to choose one of the stable grasps from the ones found in the previous step. For this we define the following three conditions:

a. Distance between the contact points less than 7.5cm. This is because the parallel jaw gripper used has a maximum opening of 8cm.
b. The line connecting the two contact points should be perpendicular (± 10°) to the approach direction of the gripper. The approach direction considered is along the x-axis.
c. Finally, the line connecting the contact points which is closest to the centroid of the object is chosen as the final grasp orientation.



(a) (b)

(c) (d)

Figure 4. The point cloud image of the selected object with all the normal vectors is shown in (a). The pairs of normal vectors after applying the 1st condition is shown in (b). The normal vectors perpendicular to the approach vector i.e. x-axis (red line) are filtered out and shown in (c). The final selected grasp point is shown using a green dot in (d). The blue bot is the centroid of the point cloud

The finally selected grasp contact points are used to move the gripper to the required coordinate to grasp the object. It is assumed that the arm does not collide with other objects in the simulation while moving to grasp the object.

3. Results

The effect of using multiple viewpoints was found by comparing the number of available stable grasps i.e. pairs that satisfy the force-moment balance-based algorithm and distance between the contact points is less than 7.5cm, for each configuration of viewpoints.

The benchmark for this was considered using 16 different viewpoints. The number stable grasps found here was set as 100% and this value was used to evaluate the stable grasps obtained from the combination of other viewpoints. The viewpoints used have been shown in Figure 5.

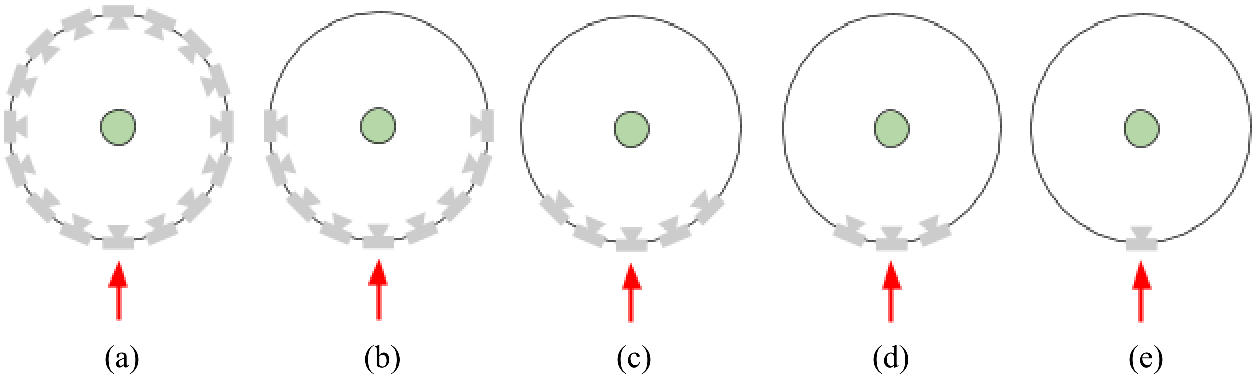


Figure 5. (a) Benchmark configuration : 16 viewpoints. (b) Configuration 1 : 9 viewpoints (-90° to +90°). (c) Configuration 2 : *5 viewpoints (-45°* to +45°). (d) Configuration 3 : *3 viewpoints (-22.5°* to +22.5°). (e) Configuration 4 : *1 viewpoint (0°). The step size for each of these viewpoints was chosen to be 22.5°. The red arrow shows the approach direction of gripper*

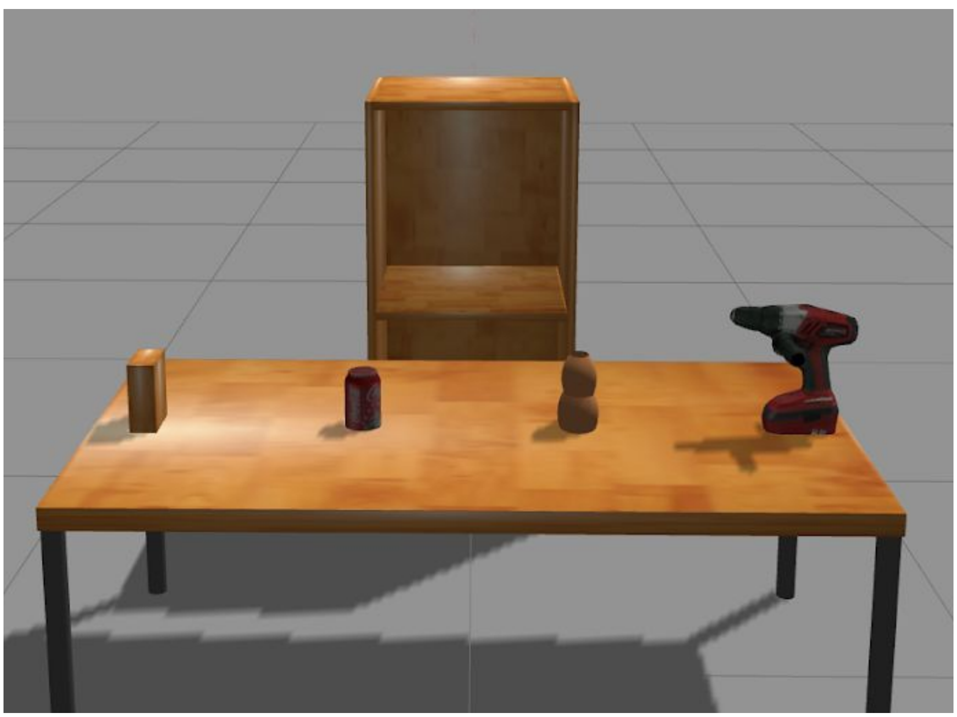


Figure 6. The object models used in the simulation: A rectangular prism, a can, a vase, a driller

Different object models as shown in Figure 6 were used in the simulation and the results for the number of stable grasps for each viewpoint configuration were determined. The results for this have been shown in Figure 7.

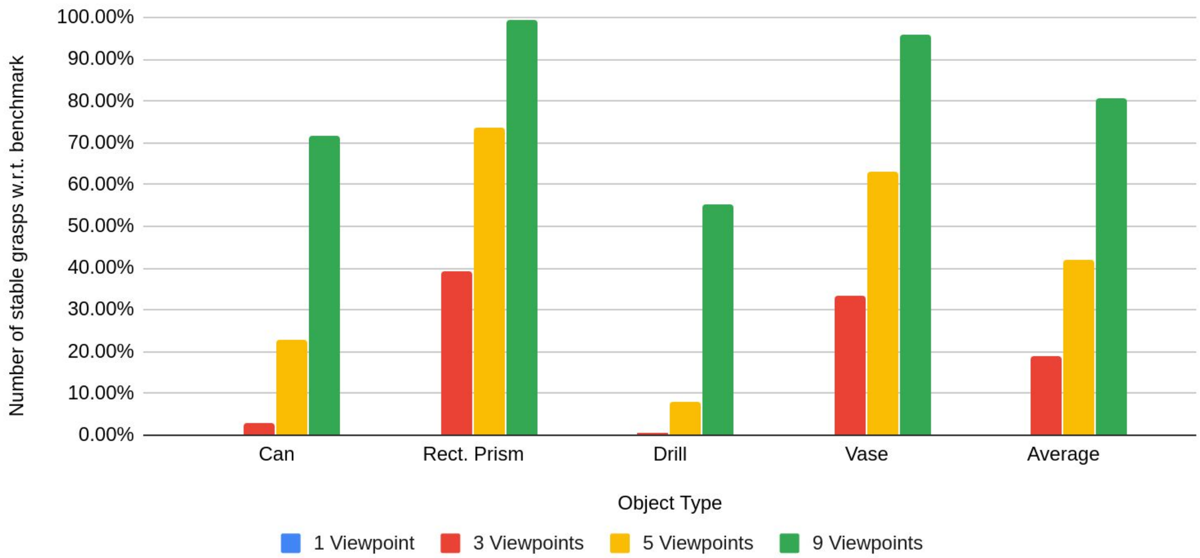


Figure 7. Number of stable grasps achievable with respect to the benchmark configuration for each of the different objects

The benchmark values for each of the object using the benchmark configuration was as follows.

	Can	**Rect. Prism**	**Drill**	**Vase**
Number of stable grasps	503	821	485	204

4. Discussion and Conclusion

The simulation results show that using just 1 viewpoint does not lead to the synthesis of a stable grasp. This can also be said by the fact that by using only one viewpoint we cannot get a complete 180° view of the object which is the required minimum for the force-moment balance-based algorithm to work.

Increasing viewpoints increases the number of possible stable grasps available. Higher the available number of stable grasps, the higher the probability of finding a grasp meeting the requirements. An increase in the number of stable grasps varies based on the geometric nature of the object. For irregular objects like a drill, a higher number of viewpoints are needed as compared to regular objects like prism and cylinder as seen in the results.

In all of these simulations, we were able to obtain a stable grasp for all objects in all viewpoint configurations except for the single viewpoint one. This shows that taking advantage of the eye-in-hand system by using multiple viewpoints gives us better results.