MODELING SIMULATION AND ANALYSIS OF ROBOT GRASPING POSE FOR NOVEL OBJECTS

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Abstract

Modern day robotics aims at bringing precision and motor dexterity of humans to machines. Many scientists are working on mimicking the attributes of a human in order to grasp different object. Initially, the robots were preprogrammed to hold different object but this method is not as effective against a novel object because the image of a novel object does not match with the pre-stored program data. Hence end effector will not be able to pick up the object or it may get damaged. In this paper, a new method is discussed on the dimension and the center of mass. The robot automatically calculates the grasping point and finds the suitable pose of the gripper to grasp the desired object. This proposed work of robot simulation is achieved using MATLAB 8.2 and Creo parametric 2.0. The robot model designed using Creo is fed as input into the MATLAB to generate control signals for the robot to grasp novel objects. By this the robot will automatically grasp a new unknown object by comparing the database already created and be able to handle the object dynamically.

Keywords: *D-H Transformation, Grasp points, Novel object, Robot pose, Robot simulation.*

1. Introduction

The research of object grasping and manipulation becomes formidable challenging area [1]. The research on grasp, manipulation analysis and planning has to be applied to the real world situations. Hence increasing the efficiency of grasping and new methods is to be implemented to perform these analysis and planning tasks [2]. Grasping is one of the most fundamental problem in robotics. Robot grasping is a major problem that includes control, planning and tendency to judge the pickup points of various objects. In unstructured environments, familiar types of objects may contain a variety of shapes and sizes. Even with the existence of these variations, humans can learn how to grasp objects by few examples and generalize the learned skills to grasp novel objects [3]. However, a robot in an unstructured environment may encounter problems regarding to objects because of priori experience or knowledge. On such situations a robot requires sophisticated perception, planning and control to grasp an object [4]. Grasping planning can be classified into knowledge based, behavior based and model-based methods [5] [6]. In this paper, we are planning to do knowledge-based grasping. Detailed knowledge is important for manipulating and grasping. The function of a robot gripper is to grasp and manipulate the object by its fingers [7]. The task of restraining objects, sometimes called fixturing and the task of manipulating objects with fingers is called dexterous manipulation [8]. From the image of an object, a location for good grasping is identified and every different

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object can have some similar subparts. [9]. A wide variety of novel object has been tested by grasping knowledge base approach and the result establishes the effectiveness of this approach so as to achieve quick and good grasps of novel objects. Grasping knowledge will enrich and serve as a best experience towards robot gripping [10], if the testing takes place with many different novel objects.

The robot with a camera will determine the center of mass and dimension of an unknown to get grasped. The object's shape and dimensions are scanned and calculated by using the camera. An algorithm is provided to predict the structure of an unknown object. A programmed robot can easily grasp object but difficult to grasp a novel object hence the friction between the gripper and the object also checked in order to avoid the damage to the objects [25-28]. In a case, the robot is performing the pick and place operation for the objects which are preprogrammed and suddenly a different object is placed, then the robot will visualize the object through camera and search for the algorithm in the database and finally executes it. If there is no data found about the object in the database, then the robot will execute the work by the combination of different objects in the database [29-34]. Here the work is carried out using a Twisting Rotation Linear and Rotation (TRLR) robot. Barrett hand is three fingered programmable grippers with ten degrees of freedom, out of which four for longer manipulation and six relatives to the object [11].

A simulator has facilities to model a complete robotic work in visualization capabilities, which is very essential when planning an actual grasping task. The real time vision system and model-based vision system are combining both to bring in a line, the pose of a simulated object with the pose of an actual object in the workspace. A simulator is used to plan, execute and monitor a complete grasping task [12]. Simulation is the imitation of operation of any machine or any system by virtual image. A robotic simulation is an imitated combination of robot motion and its operation. The simulator is software used to simulate the actual robot in a real-world environment exposed to real working conditions [35-39]. The effective design of modeling and simulation is to be tested with different robotic hand for a typical task. A Realistic simulation can be used to learn about grasping if the computer hardware model developed is better [11]. The simulation and design of the robot is carried out using MATLAB and Creo respectively. The designed model from the Creo is converted into XML file and imported into MATLAB. Then using Simulink and simmechanics, all the control algorithms for suitable grasp pose are generated for the simulation.

2. Mechanical Design

Barrett hand consists of disc and links as fingers. Each gripper has to be designed, fabricated for each part shape and part orientation. A robotic arm is exchanged with turret or tool changer. The tool changer took more work space and increase the production time[40-43]. The Barrett hand with complex software routine swaps the tools and parts within half a second. *Figure 1* shows rotating disc of Barrett hand, *Figure 2* shows Barrett finger links and *Figure 3* shows the assemble view of Barrett hand.

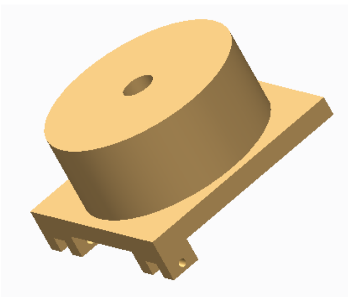

Figure 1. Rotating Disc of Barrett Hand

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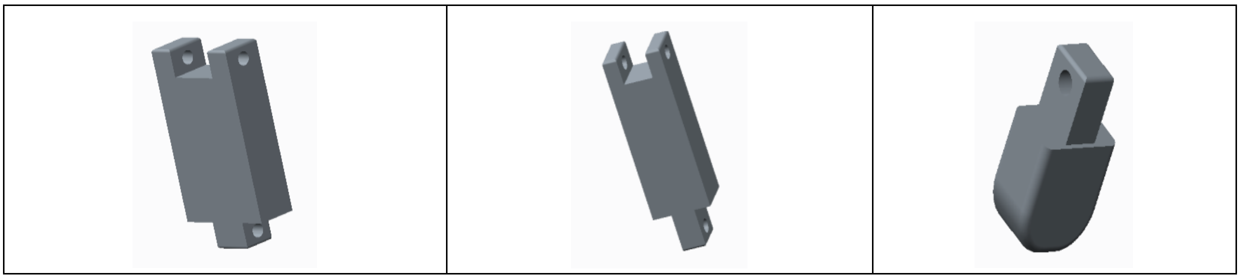

Figure 2. Barrett Finger Links

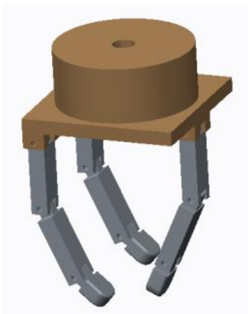

Figure 3. Assemble View of Barrett Hand

3. Modeling Environments

One should know the best grasping points and the angle for the object to be successfully grasped [18]. The algorithm must calculate an optimum grasping pose to feel a good grasp without collision as quick as possible [19]. Sometimes problem may occur due to miscalculation of relative position and posture between hand and the object. To overcome it, adjustment methods are proposed and simulation of the same is done to show the improvement in grasping [23].

Generally, a basic object model consists of cylinders, cones, spheres and boxes with advanced computing strategies create much number of grasp possibilities to result in high quality grasping of an object [17]. The modeling and simulation of the system highly helps in reducing time, cost and improves its efficiency of prototype. Saxena et al., (2008) proposed a learning approach which is used to predict good grasping point for a wide range of objects. In their learning approach, the 2-d location of the grasp in an object image is predicted and the projection of a good grasping point on image plane is identified. Then the images of different position of the object by different camera position are taken. After that the 3-d position of a grasping point is predicted. If both the prediction points are identified perfectly then "triangulate" these images to obtain the 3-d grasping point [9]. The camera is used to determine the pick points of an unknown object and the robot will calculate the angle, coordinate it to execute the work. However modeling is essential for us to interact with the reality which has been achieved by assumptions and testing. The scientists play an important role to design a model and to execute it accurately. The design of the robot is created using Creo software which has been further been exported to MATLAB in the form of XML file to carry the work. The top view of modeling environment is shown in *Figure 4*

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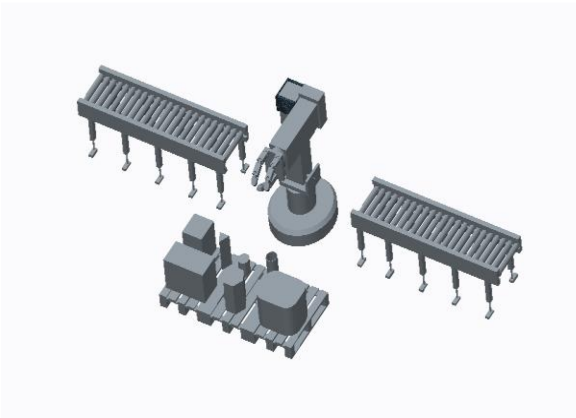

Figure 4. Top Views of Modeling Environment

Figure 5 shows the modeling of Barrett hand with objects in Creo parametric 2.0.

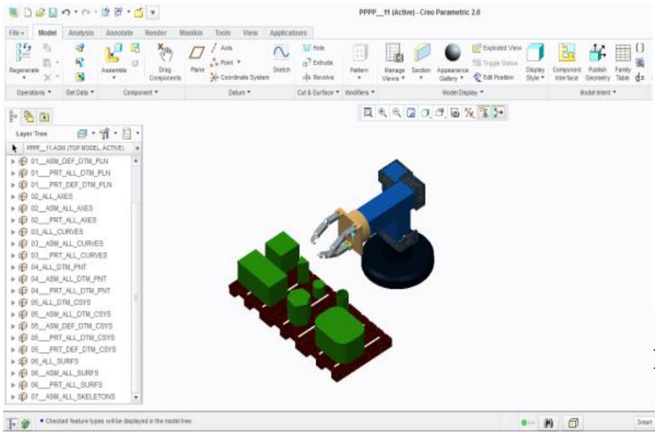

Figure 5. Modeling in Creo parametric 2.0

3.1 Flow Chart

A supervised training is used by robotic hand to learn good grasp. This method allows trying a large number of grasps of an object and report into training set. From the training set, generate basis functions of both, the new set of grasping parameters to be predicted and to find an optimal set of grasping parameters for an object [24]. The work flow chart is shown in *Figure 6.*

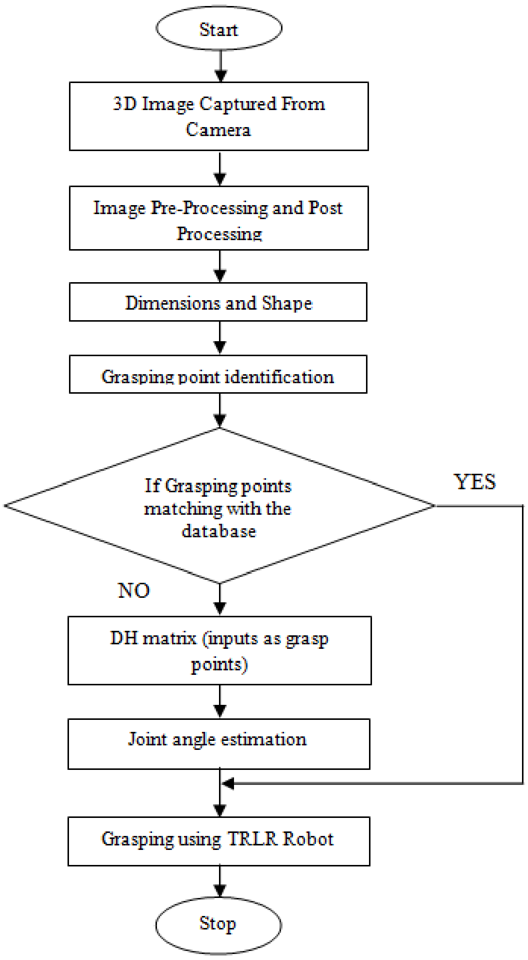

Figure 6. Work Flow Chart

The image captured by the camera will be 3D based. Once the image is captured, it will be preprocessed and post processed for identifying its specifications like dimensions and shape. After the identification of the shape and dimension, the grasping point will be found. The grasping point is compared with the database (already prepared one) values. If the database value matches with the grasp point, the grasp is done using TRLR robot. If it doesn't match, the D-H matrix values calculated will be considered as grasp points and the joint will be estimated. After the estimation, grasping is done by the TRLR robot.

3.2. Grasp Point Identification

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An object detection method requires in-depth offline training step for every object in order to recognize it in new images. The training process depends on every method, but getting as much information as possible is essential to create a robust object model [21]. The application of deep learning is required to detect similar problems associated with grasping and to learn the context features [15].

Three main properties of grasping were considered. First, the grasp should be able to achieve good contact with object. Second, the grasp should be stable. Third, the grasp must be able to apply forces on the object effectively [16]. *Figure 7* shows the block diagram of grasp point identification. The grasp point identification is been carried out in following steps:

i. **Data preprocessing**: - The data preprocessing is nothing but to determine the data points of the object.
ii. **Camera: -** The camera is used to scan the object and it will determine the centre of gravity and centre of mass of the object
iii. **Grasp point identification: -** Based on the centre of gravity and centre of mass the pick points are calculated in grasp point identification.
iv. **Processing: -** By calculating this pick points the work can be executed.

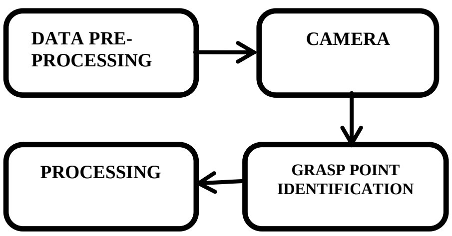

Figure 7. Block diagram of grasp point identification

Generally, the robot grasping varies with respect to the perception of human and the robot. Without training the grasping may be inaccurate with the robot. To overcome these grasping problems the software and camera arrangement were introduced. The grippers are well designed such that it should not damage the object. To have a stable grasp, the algorithm should be accurate to determine the pick points of the novel objects. And the camera should have the capability to judge the shape and dimensions of the object to execute the operation accurately. By executing all these things, it can perform the work perfectly without any errors or collision in the system.

The grasp point detection finds the surface of all models with a definite threshold and generates 2D information then gets the rim points and edges of the object from the details. Then calculate the centre of mass for every object [20]. To generate observation space for grasping the object, probabilistic models can be used. A probabilistic model helps to learn about the task constraints in robot grasping [13]. The segmentation of an unknown object will be achieved with a 3-d mesh generation. The robotic grasping depends upon the shape and dimension of the object. And the grasp pose for the TRLR robot will be determined using the inverse kinematics. This helps the robot to detect the angle position to grasp the object. As per the conventional stability, to get a stable grasp the pick points should be near to the centre of mass of the object. We intersect the point with horizontal planes through the centre of object. With these *n* cutting plane points *pi*, we calculate the convex hull V. The expressions are shown in Equation (1). The distance between two hull points to the centre of the object is c and we calculate the altitude d. where v is the direction vector to the two neighboring hull point and w is the direction vector to c. Finally, the algorithm finds the shortest normal distance “d” of the convex hull line.

$$d = \frac{\|\vec{v} * \vec{w}\|}{\|\vec{v}\|}$$

(1)

The second grasping point is been determined by the reflection of the first grasping point using the centre of the object. We can check the grasp of the object on the detected grasp points with a 3D model. *Figure 8* shows the grasp points of various objects.

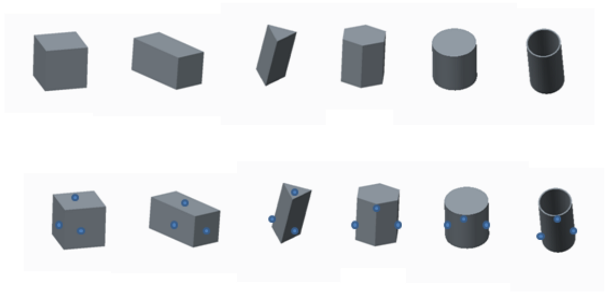

Figure 8. Grasp Points

3.3. Grasp Pose

RajeshkannaAla et al., (2015) proposed an algorithm providing a way to grasp any object using boundary, envelope, and functional grasps. This algorithm is based on identifying graspable segments, analyzing geometrically and incorporating the memory of grasping experience [14]. A grasping algorithm also decides at which angle it has to grasp the object. The robot works in the inverse kinematics method. After detecting the object, the robot will look for the pick points through which the coordinates are determined. With the help of these coordinates the robot will decide in which angle the object is to be picked and placed. The tabulations for D-H parameters are shown in *Table 1* and *Figure 9* shows grasp pose view.

Table 1. D-H Representation

A	#	θ	d	a	α
A_1	1	θ_1	0	0	90
A_2	2	θ_2	0	a_2	0
A_3	3	θ_3	0	a_3	0
A_4	4	θ_4	0	a_4	-90
A_5	5	θ_5	0	0	90
A_6	6	θ_6	0	0	0

The final transformation matrix is given by Eq. (2)

$$\begin{pmatrix} C_1(C_{224}C_2C_0 - S_{224}S_0) - S_1S_2C_0 & C_1(-C_{224}C_2C_0 - S_{224}S_0) + S_1S_2C_0 & C_1(C_{224}S_1) & C_1(C_{224}a_1 + C_{22}a_0 + C_2a_0) + S_1C_2 \\ S_1(C_{224}C_2C_0 - S_{224}S_0) + S_0S_2C_1 & S_1(-C_{224}C_2C_0 - S_{224}S_0) - S_0S_2C_1 & S_1(C_{224}S_1) & S_1(C_{224}a_1 + C_{22}a_0 + C_2a_1) - C_2C_1 \\ S_{224}C_2C_0 + C_{224}S_0 & -S_{224}C_2C_0 + C_{224}S_0 & S_{224}S_2 & S_{224}a_1 + S_{12}a_3 + S_2a_2 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

(2)

Alternatively, Equation (2) expressed with trigonometric function Equation (3) and Equation (4)

$$S\theta_1 C\theta_2 + C\theta_1\ S\theta_2 = S\ (\theta_1 + \theta_2) = S_{12}$$
(3)

$$C\theta_1 C\theta_2 - S\theta_1\ S\theta_2 = C\ (\theta_1 + \theta_2) = C_{12}$$
(4)

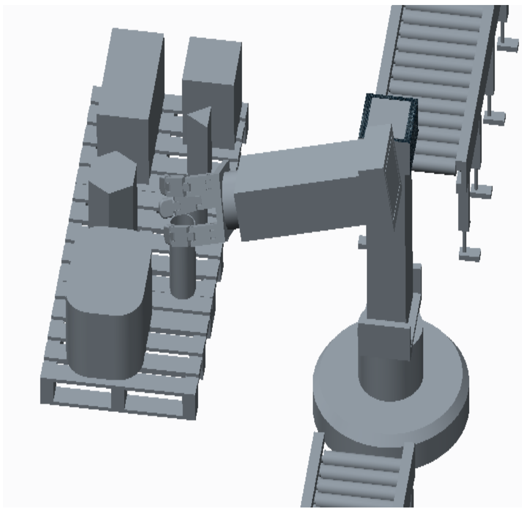

Figure 9. Grasp Pose View

3.4. Experimental Setup for Grasping of Novel Object

When modeling an object as a set of shape primitives, such as cones, spheres, cylinders and boxes, we can utilize a set of rules to generate a set of grasps starting positions and pre-grasp shapes that can be tested on the object model [22]. *Figure 10* shows the grasping setup of known object. This setup consists of base, frame, pillar,

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gripper and two cameras. The snap of the inline objects has taken using the cameras and then compared with the database which consists of grasping algorithm for standard models like cylinder, cone, sphere and box. If the particular shape matches with the database then it commands the TRLR robot to do the operation.

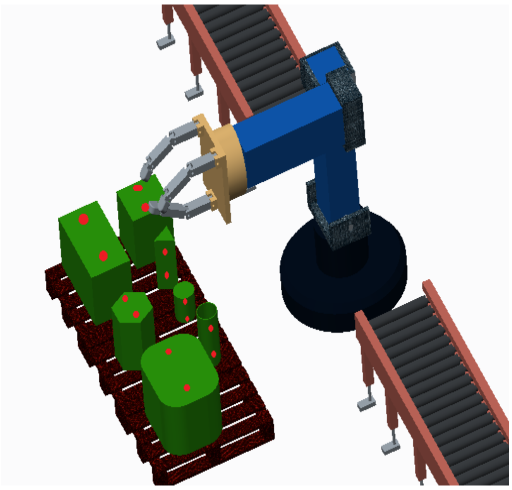

Figure 10. Grasping setup of known object

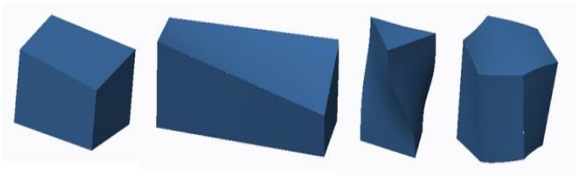

Figure 11. Novel objects

Figure 11 shows some novel objects to be grasped. If the unknown or novel object presented does not match with the database, then with the MATLAB tool box, the robot finds out the bounding box and centre of mass value for the novel object. The bounding box value of the novel object close to the standard model value helps to choose an algorithm for that particular shape. Then the D-H matrix of that shape is found to form the kinematic equation of the manipulator. From the equation the joint angle is then estimated and the TRLR robot is given command to pick the novel object.

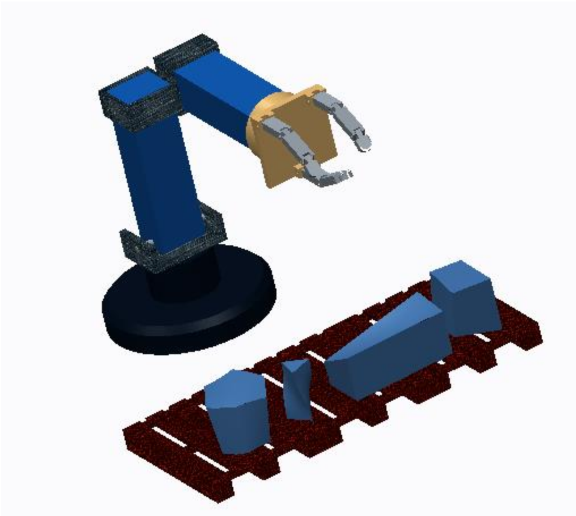

Figure 12. Setup of robot with novel objects

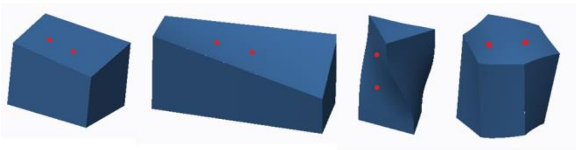

Figure 13. Grasping point of novel objects

In *Figure 12* shows the setup of robot with novel objects. Grasping points for the novel objects is shown in *Figure 13*. *Figure 14* predicts the grasping setup of novel objects with grasping points.

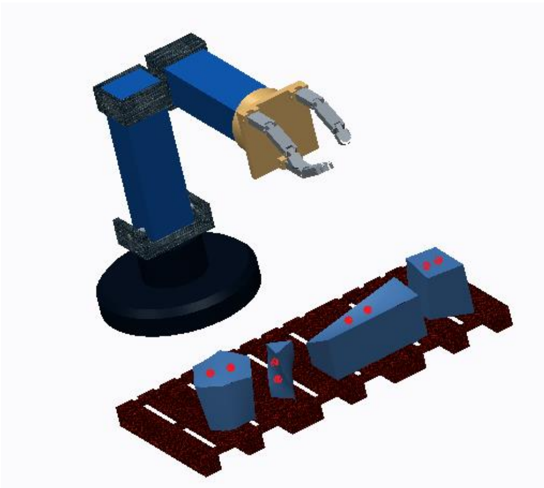

Figure 14. Grasping setup of novel objects with grasping point

The grasping setup of novel objects with similar grasp point is modeled in Creo parametric 2.0 and is converted to XML file. It is imported into MATLAB for simulation. *Figure 15* shows the simulation result of robot grasping setup for grasping novel objects.

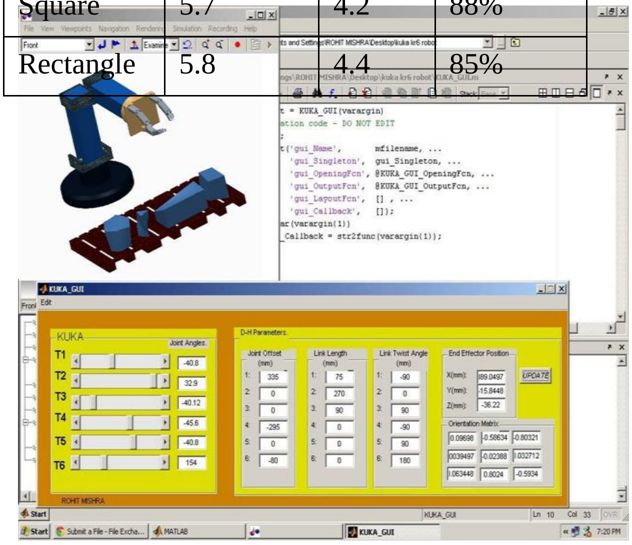

Figure 15. Simulation of robot grasping in MATLAB

4. Result and Discussion

The simulation experiment has been carried out for similar geometric shapes like conical, cylindrical, square and rectangle. The average time taken for grasp point detection is about 5.5 sec and for grasp pose is 4 sec. The success rate of grasping similar cylindrical and conical shape is 100%. For square and rectangular shape is 88% and 85% respectively. The tabulations for grasp point detection and accuracy are shown in *Table 2*.

Table 2. Grasp Point Detection and Accuracy

Similar Shapes	Grasp Point Detection (Sec)	Grasp Pose (Sec)	Accuracy
Cylindrical	5.5	4	100%
Conical	5.5	4	100%
Square	5.7	4.2	88%
Rectangle	5.8	4.4	85%

The algorithm requires less simulation time for preprogrammed similar geometrical shapes. In case of irregular shape, grasping accuracy is very less and simulation time is more.

5. Conclusion

Based on the camera image and the image processing techniques the dimensions and shape of the object is calculated. From the dimensions and shape results, suitable grasp points are generated successfully. Now the grasp points (assumed as coordinates in 3D space) are given as inputs to the TRLR robot. Based on the D-H matrix results for inverse kinematics are calculated which gives the joint angles for the TRLR robot. All these practices are performed using MATLAB simulation. A simple neural based learning algorithm has been implemented and tested to grasp novel objects, which fails in several practical applications. But this system is suitable only for rigid bodies. This algorithm/method does not fit for deformable objects i.e. objects which change its shape, dimensions and mass with respect to time. Another important drawback is that mass is considered as a constant in this system.

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