A 3D-printed robot gripper for object-throwing

William Hart

Mentored by Dr. Chad Kessens, Ms. Kristi Davis, and Mr. Mason Russell

Introduction

Industries utilize robotic manipulators and autonomous devices to assist workers. 3D printing is becoming increasingly popular in the ever-growing world of robotics "for low-cost manufacturing [and] the ability to manufacture various 3D object designs from CAD models in a relatively short time with minimum cost and efforts" (Telegenov et al., 2015). While 3D printed plastic components were the keystone of this project, additional hardware and software were needed to maximize functionality.

The goal was to design a gripper with the ability to pick up and release a projectile, while in a throwing motion, towards a small target. This gripper must first successfully grasp the object from a table, then continue to hold the object during a dynamic arm movement, and then finally release the object at the proper time while in this motion toward a target. A design for an accurate, autonomous, 3D printed, two-fingered robotic grasper was tested.

Materials and Methods

Multiple designs were researched to collect the best ideas from the most attainable, time-efficient, and low-cost projects. The final design was based closely on the work of Telegenov, mimicking the actuation, gear train, and palm shape. Autodesk Fusion 360 was utilized to make the first iteration of the gripper, which had three fingers and one degree of freedom (DOF) per finger. The fingers were much longer than the object. At approximately double the diameter of the object, the idea was that these dimensions would allow the object to "roll" off the top fingers while in the throwing motion, increasing distance. However, the measured effect was insignificant, so the length of the fingers was decreased to the diameter of the object so that the gripper could more easily pick up the object from a flat surface (Figure 1).

Figure 1 (left): Fusion 360 model rendering of the gripper without the manipulator.

Figure 2 (right): The gripper is actuated with a gear train.

Materials and Methods (continued)

A MarkForged ORGX7 3D printer was utilized to construct the palm, mounting base, and fingers. The plastic was assembled with 4-40 machine nuts and screws, M6 bolts, as well as 4 mm pins and 2.5-inch hex standoffs. After the gripper was constructed, the Arduino was wired. Arduino IDE software was used to control the gears for the gripping (Figure 2). Once wired, the Arduino was screwed to the gripper base, and the gripper was connected to the Universal Robotics UR-16e arm. The arm was controlled using the ROS MoveIt program to generate its throwing motion.

Figure 3 (left): The gripper prior to being attached to a manipulator arm or Arduino.

To improve functionality, the design had many modifications, ranging from the size of the holes in the gripper, because of variance in tolerance for different plastic types, to the idea of using a solenoid for quick release, to the use of different gear types and sizes. The radius of the target was 30 centimeters (equal to five object lengths), constructed from tape. A physics analysis based on maximum joint motor speeds predicted the horizontal range of this projectile to be 1.2 meters, which acts as the predicted mean with an absolute error of 30 centimeters in the statistical tests (Figure 4).

Results

Since robotic manipulators are generally not designed for dynamic object throwing, there is a lack of published rigorous statistical testing on this topic. A one sample *t*-test was performed to compare the mean horizontal distance from the target to the object thrown by the robot against the calculated mean. The mean error from the target was 19.5 centimeters with a standard deviation of 10.8 centimeters. This data was significantly different than the mean of greater than 30 centimeters. Therefore, the null hypothesis was rejected; $t(29) = -5.30$, $p < .0001$.

Results (continued)

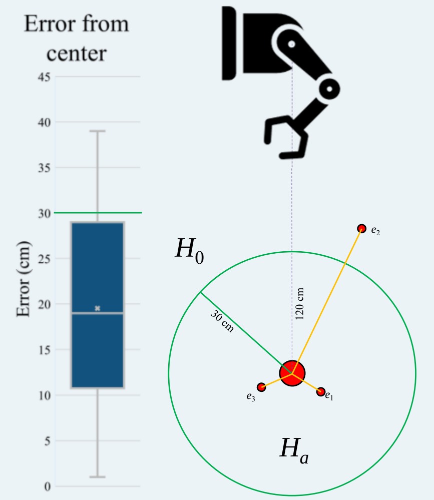

Figure 4 (left): Absolute value error data from the target of 30 trials ($n = 30$) of the robot's throw depicted in a simple boxplot, next to a diagram of the target . The green line on boxplot represents the circumference of the 30-centimeter radius target. The larger red circle is the small target (radius of 2 centimeters). The yellow lines represent errors from target. The purple dotted line is distance to target from center of manipulator. Error(e) = 0 at center of larger red circle. Not to scale.

Conclusions

The purpose of this study was to create a gripper for grasping and throwing an object. On average, the robot successfully grasped and threw the object to within a 30-centimeter radius of a small target (2-centimeter radius) located 1.2 meters away from the base of the robot. Thirty trials ($n = 30$) resulted in a 95% success rate.

Applications of the mechanism may include a variety of gripper designs, with possibilities ranging from a gripper sorter for global companies like Amazon, to fruit picking, or other low volume manufacturing. Additional advancement would allow use on a robotic manipulator with greater rotational velocity capabilities to throw both further and more accurately.

References

Ma, R. R., Odhner, L. U., & Dollar, A. M. (2013). A modular, open-source 3D printed underactuated hand. *IEEE International Conference on Robotics and Automation*. 2737–2743. https://doi.org/10.1109/ICRA.2013.6630954

Telegenov, K., Telegenov, Y., & Shintemirov, A. (2015). A low cost open-source 3-D-printed three-finger gripper platform for research and educational purposes. *IEEE access*, *3*, 638–647. https://doi.org/10.1109/ACCESS.2015.2433937