An evaluation of the grasping range of a “soft” gripper versus a “stiff” gripper

Abstract

A very simple “soft” gripper was designed and a first prototype produced. The gripper consists of two symmetrical passive fingers, which are connected to actuated links coupled to the finger by light springs. The gripper was mounted to a linear slide positioner and presented with objects of various shapes and sizes. The performance of the gripper was measured by the percentage of “successful” grasps for a certain shape and position on the test bed. The results for the prototype soft gripper are compared to those of the same gripper with stiff fingers. It was found that the soft gripper was able to successfully grasp most objects within a much larger range of positions than the standard stiff-linked gripper.

Design

The “soft” gripper has a simple design (figures 1 and 2). A small aluminum link is mounted to the shaft of a servo motor. At the end of this link, a post is mounted, on which a light spring is attached (with a measured spring constant of 38 N/m). On top of this link, a cylindrical aluminum bearing is mounted vertically. This bearing is the axis of the
passive finger, which houses a fiber bearing that fits to the aluminum cylinder. Underneath the passive finger another post is mounted, which connects the other end of the light spring. The gripper is actuated when the small bottom link exerts force on the passive finger through the spring.

Figure 1: A closeup of one finger of the “soft” gripper

Figure 2: A demonstration of the coupling between the active and passive links
The servo motors are from a model airplane kit, and are controlled with a radio transmitter shown in figure 3 below. The travel of the servo motors can be adjusted, but traverse only about 90 degrees at the maximum setting.

![Figure 3: Radio transmitter and receiver unit (left - battery pack, switch, and receiver)](image)

The “stiff” fingers are simply modified “soft” fingers, with a piece of balsa wood to fill in the gap, and electrical tape to prevent motion between the two links (figure 4).

![Figure 4: A closeup of the “stiff” gripper finger, which is a modified “soft” finger](image)
**Experiment**

The experiment that was used to investigate the two grippers was very straightforward. As described above, the gripper was mounted to a linear positioner, which was mounted to a wood base. On the base, a piece of graph paper, with 0.2 inch squares, was taped. The distances were measured from the centerline (marked in red in the figure below). The objects were placed with the edge closest to the gripper positioned on the vertical axis, as shown below. For each placement, done in increments of 0.1 inches, the gripper was moved forward to the full extent of its swing with a smooth, slow motion (although this was not precisely controlled). A successful grasp was defined as one in which the object rested upright on the ground, on the inside of the finger. The object did not have to be completely within the grip of the hand, as the positioning in the direction of motion was arbitrary. Therefore, those cases in which the gripper would completely enclose the object if motion were continued were counted as successful. In the process of grasping, the fingers were not actuated to enclose the objects, as the force produced by doing so was not large enough to move them (mainly do to the light spring constant and small range of motion of the servo motors).

![Figure 5: An overhead view of the experimental set up](image)
Four objects were presented to the gripper (figure 6): two sizes of PVC piping (1.9” OD, .15” wall thickness) and two sizes of square aluminum tubing (2” sides, .125” wall thickness). Of each type, one object was 3.7” tall and the other was 8.8” tall. (The PVC was found cut at these lengths, and the aluminum was cut to match.) The aluminum was presented in two ways: with a flat side facing the gripper, and rotated 45 degrees diagonal to the gripper (figure 7).

![Figure 6: The four different objects presented to the gripper](image)

Note that the gripper was only tested on one side of the centerline (and therefore only one finger). Preliminary experiences showed that the two sides yielded the same results and the gripper was therefore assumed symmetric.
Results

The results of the trials for the three different shapes are shown in figures 8 through 10. As was expected, it was found that the “soft” gripper had a significantly larger receptive field than the stiff gripper for each configuration. The increase ranged from 0.3 inches (small PVC) to 0.7 inches (small aluminum diagonal), which is 17% and 33% respectively.
Figure 8: Success rate ranges for the two sizes of PVC pipe
Figure 9: Success rate ranges for the two sizes of square aluminum tubing
Figure 10: Success rate ranges for the two different sizes of square aluminum tubing, presented diagonally

Note that most of the positions yielded an all-or-nothing result, but in the transition region there was often a position or two that showed successful grasps for some trials, and unsuccessful grasps for others. For these cases, the object being grasped would often pivot when the finger made contact, either into or out of the grasping area. Some of the variability seen in these regions can also be attributed to the variability in the starting position of the passive finger. The friction between the two links would often cause the passive finger to “stick” at a slightly different position each time.
**Discussion**

As was expected, the “soft” gripper, incorporating a passive finger actuated by a light spring, showed a significantly larger successful grasp space. This space was between 17% and 33% larger than the stiff gripper space for the six objects tested. The gripper tested was a very simple design, and many future avenues for design and testing can be taken. The present gripper can be modified to test the effects of stiffer springs and/or different finger configurations (e.g. shapes and materials). Also, different servo motors can be chosen to enable better actuation and actual grasping. Finally, more complex configurations, eventually incorporating some sort of variable stiffness, should be constructed and evaluated.