InMoov Arm Refurbishment & Building

Seth Esther

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# Introduction

 In working on programming an Arduino MEGA2560 to control the motion of the hand on the InMoov arm, the motion of the fingers did not seem very fluid and it seemed like there were some troubles with the string that was used to control the fingers. While rotating the control servos the string would actually go slack in certain situations and the fingers themselves would stick in certain positions. Below is what I did to refurbished the arm and some notes to possibly help when building a new InMoov arm. I did not take very many pictures while working on the arm, so I will attempt to find as many as I can from the internet to illustrate what I did or create diagrams.

# Finger Control String Travel Disparity

What I first noticed was during the closing of the fingers, the string used to control the opening of the fingers, falls off the pulleys that are installed on the servos, while the string used to close the fingers would become very taut. Upon further inspection I found that the string that is used to open fingers has to travel farther for full range of motion that the closing string has to travel. This can cause a various problems depending upon which position the fingers and servo are in when the strings are attached and can actually put an enormous amount of stress on the arm itself during normal operation.

To fingers

To alleviate this there needs to be some mechanism that will either keep tension on the control strings at all times a modification to the pulleys that allows for greater range of travel in one direction as opposed to the other. A possible change to the pulley would be offsetting the attachment point of the pulley to the servo. However, this would require a great deal of experimentation and physics calculations to arrive at the point where the pulley should attach. This ultimately would prove fruitless as there is finite amount of space for the pulleys and the servos and offset the pulleys would cause interference with the other fingers pulleys. With this in mind, I chose the former suggestion to create constant tension on the strings.

There are numerous ways in this can be accomplished. I chose to use springs for this task, as they are easy to acquire and implement, and other options would involve engineering a more complicated mechanism that would take more time and component construction than I had.

To attach the springs in the correct manner proved to be a little difficult and require quite a bit of experimentation, but using the following steps achieved a working result that will work for now, but definitely needs improvement.

1. Attach and route the strings as you would normally, but do not connect them to the pulleys just yet. While doing this you should ensure there are no obstructions or hazards to the strings, such as protruding screw tips, string guides not being clean or smoothed, etc.
2. By pulling the strings, place the finger in its fully closed position and finding a stationary object such as a string guide, place a mark on both strings directly next to this object.
3. Again, by pulling the strings move the finger to its fully open position and again, mark the closing control string next to the same stationary object that was used in the previous step.
4. Now mark the string used for closing the fingers make a mark on the string centered between the two marks made in the previous two steps. By lining this middle mark up with the stationary object should place the finger in its neutral position.
5. Using the Pololu control center (or some other comparable servo controller) place the servo in its neutral position.
6. Line up the center mark on the closing control string and attach to the servo. By doing this it will match the servo and the finger to their neutral positions and provide the greatest range of motion for the finger.
7. Using the servo controller move the finger to its fully closed position. When the finger is in its closed position the control string should be taut, but not overly tight. Make a note of the position setting in the servo controller as this should become the closing limit of the that specific finger and care should be take not to exceed this setting.
8. With the servo in the position achieved in the previous step, pull the other control string taut and mark it as close to the fingers as you can, leaving yourself room to tie on the spring.
9. Now using the servo controller move the finger back to its fully open position. This will give you more slack in the open control string to tie on the spring.
10. Tie on the spring at the position you made the mark in step 8.
11. Tie another piece of string to the other side of the spring.
12. Now attach the control string to the pulley only slightly stretching the spring. This should be the position that spring will be at its least compressed.
13. Using the servo controller move the finger through its full range of motion and adjust the upper and lower servo position values to suit the specific finger. While doing this make sure that neither of the strings become slack or overly tight. The spring tension may need to be adjusted and can be accomplished by reattaching the control string to the servo.

This above procedure does have some flaws that will be specific to each arm and each finger and should be dealt with on a case by case basis with a little engineering ingenuity. Some of the situations I came across are:

* Reaching the limits of the servo before the finger is fully closed or fully open
* One or both of the control strings becoming too tight or too slack when the finger is near or at its full range of motion
* Pulleys interfering with either one of the other pulleys or the control strings of the other fingers

# Suggestions for Assembly

 While working on the arm there were several issues that I encountered that could be prevented with a little preparation and work during the construction and assembly phase of the hand and arm. Below are some suggestions to assist with assembly of the arm and help to ensure that the fingers and wrist motion will be smooth and unobstructed.

* After parts are printed match them to the plans you are using for the assembly to verify that they are in fact the correct part for the assembly you are working on
* Temporarily fit the part to the assembly and verify that they are the correct parts and that they do not interfere with any other components of the arm
* Remove all extra material left over from the 3D printing process
* Clean and smooth all the parts taking care to pay special attention to the control string guides and holes. This will help the strings move smoothly and prevent wear during operation of the arm
* While cleaning the mating surfaces of components periodically fit them together and make they are not too loose if they are not moving component
* With parts that are to be glued together, prior to applying the adhesive fit them together to ensure the mating surface has sufficient contact. Also during this process, it is beneficial to make an alignment mark to aid in aligning the parts correctly
* At pivot points, such as the finger joints, make sure the surfaces that will be sliding over each other are smooth and that movement of the part is smooth and offers little to no resistance. A small dab of white lithium grease in these locations will prolong the integrity of these surfaces
* Braided fishing line that has a test strength approximately equal to greater than twice the torque value of the servos they are attached to should be capable of handling any forces that can be applied to them providing the knots used to tie them are adequately secured
* Some of the best knots for tying off the control strings can be found in references to fly tying. Many of these knots are specific to braided fishing line and if tied correctly will survive through an enormous amount of use

Many of these suggestions may or may not work for your current design, but can be applied in general to many aspects of the InMoov project as a whole.