Soft 3D-print documentation

1 Introduction

The regular legs of the RealAnt robot are well fit for their intended use as can be observed in the paper introducing the robot (Boney, et al., 2020). One possible with the legs comes from the fact that the robot is used for reinforcement learning. This use case makes the RealAnt likely to make more erratic motions and even to slam itself to ground, something that would likely not be the case with an inverse kinematics approach for control. By observing finished RealAnt we could speculate that the motions might cause some durability problems for the robot. One such durability problems was that the shocks caused by the movement caused the screws holding the robot together to come loose. This is a problem since it might require repairing, thus taking away from the time that was meant to be spent to perform research.

A solution to the screws coming loose is using thread locking fluid and can be found on the RealAnt Github (OteRobotics, 2020). The thread locking fluid only solves the issue by fastening the screws, but it does not remove the shocks caused by the robot moving. It is however unclear whether the shocks are a real problem. Our solution was to instead change the design of the robot to incorporate some soft parts to the design as those would likely solve both aspects.

2 Designs

We observed from videos of the robot operating that the soft parts would need to be situated at the bottom part of the leg and at the bottom plate. The soft parts at the bottom plater are required because the robot can also strike the ground with its body first. As the designs focused mostly on the legs we also changed the hard parts of the legs. This included making the hard part fit the soft part as well as making the leg spacer part a bit shorter in order to better fit the actuator.

For our prints we used Ultimaker TPU 95 Red. The settings were 10% infill density, gyroids as the infill shape, and wall thickness of 1 mm. We found that settings produced suitably soft parts, as we also experimented with a higher infill density, but found these to be too rigid for dampening. The 3d-printers used was the Ultimaker S5. Lastly, each person in the group used their own preference of CAD software, which included OpenSCAD and SOLIDWORKS. The slicing software that made the instructions for the 3d printers was Ultimaker Cura. 3d printers that were used were either Ultimaker S3 or S5

2.1 Soft edge leg

The idea behind this design is to create a small and easily printable soft leg part that is held on to the larger and more complex rigid piece with two taps. The taps are slightly larger at the top and the soft part has holes that match the taps. The idea is that the taps can pushed through the smaller diameter portion of the soft parts holes making them fit securely in place. The design can be seen figure 1. The modified leg also features a 0.5 mm smaller leg spacer. The leg spacer modification was done because we found that the normal leg spacer leg combination was difficult to fit into the motors.

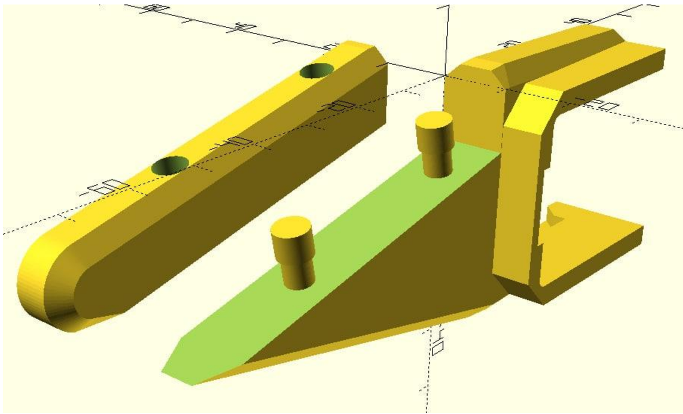

Figure 1: The soft edge leg with both soft and hard pieces visible.

The next iteration for this design was to remove the pegs and to add a hole in the soft part for better softness. The removal of the pegs was done to make the part more uniformly soft. Problems with the initial design was that the hole made the side of the printed part different widths, which required to remove the edge rounding. The edge rounding can be removed as it is likely just a visual addition. This redesign can be seen in *Fig. 2.* This iteration proved to be too soft overall but was rigid on the rounded tip. Furthermore, the now completely straight sides showed issues with layer adhesion on the walls. The adhesion problem can be solved by increasing the printing temperature and the max temperature for TPU 95 of 235 C will be used in further iterations.

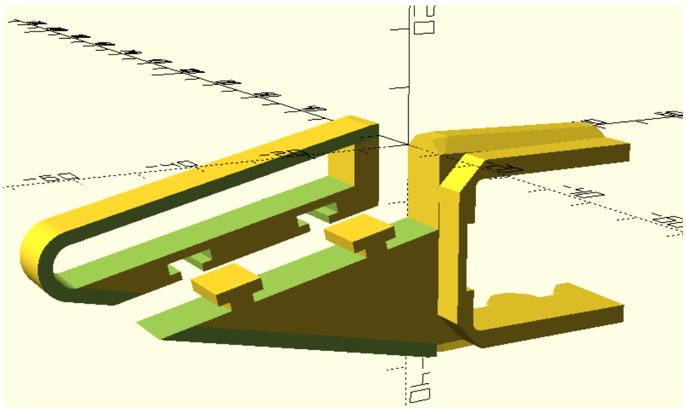

Figure 2: Soft edge leg redesign

The next iteration of the soft leg only keeps the empty circle at the tip of the leg. This done to create a softer tip while preserving the adequately soft long edges of the leg. Leg pictured in *Fig. 3.*

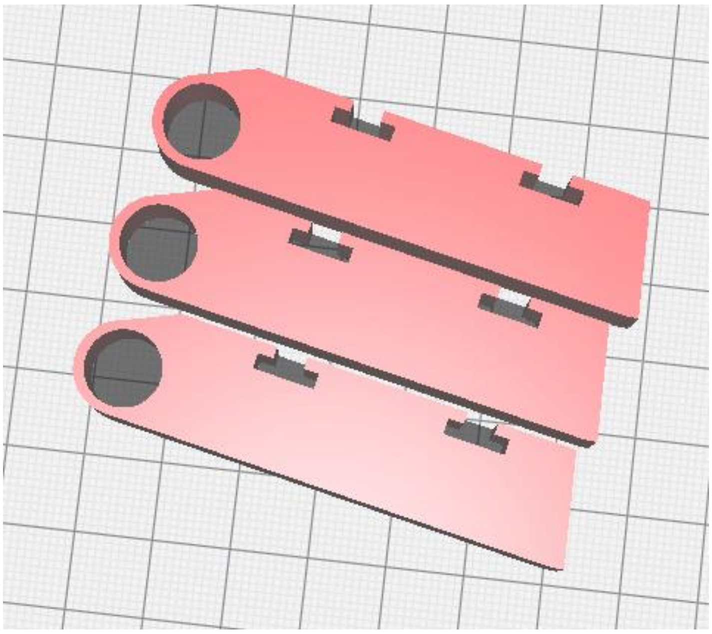

Figure 3: Soft pieces pictured in Cura.

Further iterations also enlarged the t-shapes for easier fastening and added back the chamfers as those likely produce a better leg shape.

2.2 Body soft pieces

We determined that the robot needs a soft piece for the body as the body and the parts connecting the actuators often touch the ground when the robot moves around. The parts can be added to the body plate, which would mean that those pieces must extend past the actuator connectors. The soft parts may also be added to the actuator connectors.

We first tried designs with the soft parts connecting the body plate. One of these can be seen in *Fig. 5,* but we determined that these would be too impractical. The design went as far as adding holes for the body plate where the soft pieces could be connected.

We settled on a design that connects to the actuator connectors. Those parts can be as simple as a soft tube attached to the actuator connector with metal wire. We also designed pieces that can be 3d printed and attached with screws. Both designs are shown in *Fig 4.* After printing the design attached with screws it turned out that the small size of the piece, in combination with the multiple edges close to the holes made the design quite inflexible, so its dampening effect would not be significant. Additionally, this design required us to enlarge the holes in the plastic frame to 2mm by drilling, so this design was also deemed suboptimal as it required modifications to the non-3d-printed components. Thus, we ended up using the simple tube solution instead.

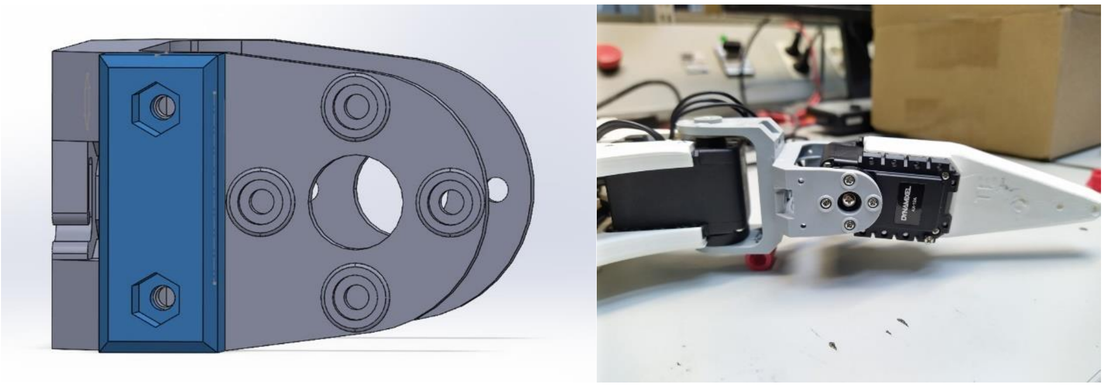

Figure 4: Tube and 3d printed pieces attached to the actuator connector.

2.3 Other designs

Other designs have been made but are yet to be printed. These parts may be difficult to print due to supports that will be needed for the 3d printing to be successful.

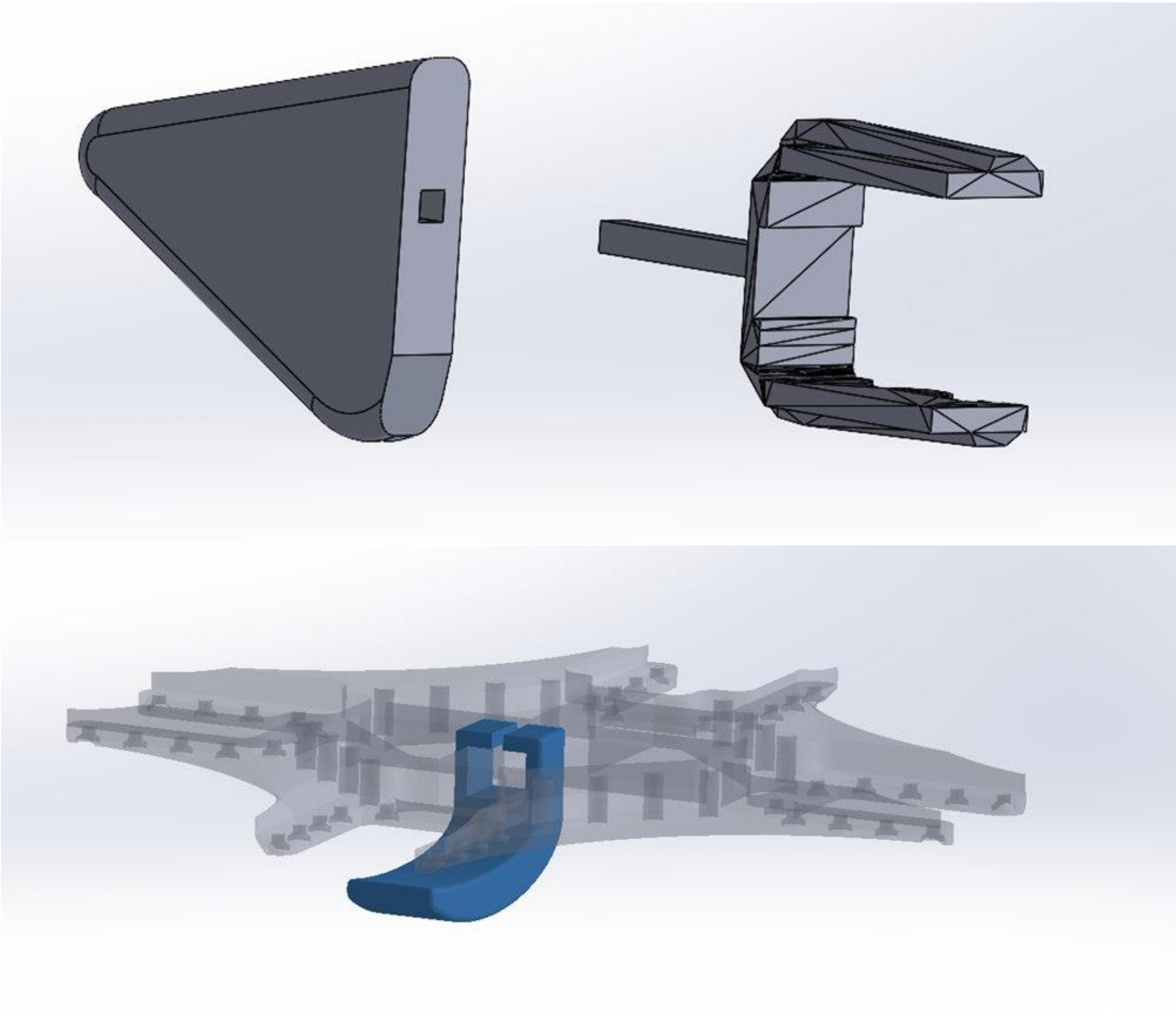

Figure 5: Unused leg designs

Results

For the soft edge leg pieces, we figure that the settings used produce sufficiently soft parts for our impact dampening use case. By examining the part, we could also observe that the rounded front end and particularly the holes are less flexible and may reduce the dampening gained from the soft piece. This reduced dampening is likely not an issue for this use case, but it is something that can be considered in later designs. Secondly, we noted that when printing several soft pieces together the printing speed should be reduced from the default setting to reduce printing defects.

The first iteration proved to be the best as the provides good ruggedness and an easy printing process. The first iteration does have the drawback of not being uniformly soft along the long edge due to the fastening mechanism. However, that will likely not be an issue as the long edge will rarely contact the ground. Instead, it is the rounded tip of the soft part that will contact the ground. When examining the rounded tip, we found that the shape increases the rigidity which is not ideal as this will reduce the dampening effect. Although the dampening effect may be reduced, we still believe that it is enough for our purposes.

The final iteration of the soft leg piece has a softer rounded tip because of hole that has been added. It also has a redesigned fastening mechanism which makes the long edge more uniformly soft. Both changes result in the part being more difficult to print and to fasten to the hard piece because this new part needs supports to be added for the print to be successful. The supports increase the number of printing defect and parts that need to be removed from print. This contributes to the largest drawback of the part, concerns regarding the durability. From visual inspections we can speculate that the final iteration of the soft leg part will likely break more easily around the rounded tip due to printing defects and the hole that was added.

In conclusion the first iteration of the soft leg piece is likely the best overall, but the final iteration has better results in rigidity.