

Improving Reliability and Multitasking with 3D Designing

Vishruth Halebeedu
Los Altos Community Team # 0510
vishruthph@gmail.com

Abstract:

Designing reliable mechanisms that work at least 90% of the time is a challenge as teams are constrained by the limited amount of servos and lego parts. This paper discovers the advantages of custom 3D printing over traditional LEGO parts for robotic parts to successfully and reliably multitask in the 2026 Botball game Stack Attack. Precisely, I want to evaluate the ability of a single 3D printed claw to be able to pick up both the cones and Botguy and deliver them to the upper start box using only two servos. Through multiple prototypes, analyzing dimensions, and multiple fixes and tests, we demonstrate that 3D printing offers far superior reliability and better designs fit to our robot than using legos.

I Introduction:

In the 2026 Botball game Stack Attack, our team identified several high value tasks: retrieving Botguy, transporting the two traffic cones to the upper start box, collecting poms into the packaging bin and putting the drums on the posts. With only 5 servos, our team had to combine tasks efficiently and reliably under one mechanism to maximize our score. One primary target as mentioned earlier was putting the Botguy and cones in the upper start box and parking the robot worth up to 1,200 points, using only two servos. With only two servos, the task required an efficient claw design that can do both tasks accurately.

Our initial approach was to traditionally build a lego contraption. While legos let us build our ideas quickly and make multiple iterations, they introduced multiple problems design changes just wouldn't fix. The fixes grew more complex and mechanically hard to fix if something goes wrong and multiple connection

points fixed by flimsy parts would be almost impossible to fix at competition. These limitations made us finally delve into Tinkercad and learn how to make reliable STLs for our needs. Although learning STLs was pretty challenging, it ultimately gave us freedom to make pieces to exact dimensions and angles in any shape or attachment point designed specifically for our robot.

This experience gave me the central question of this paper: Are custom 3D printed parts more reliable and suited for specialized multitasking than traditional LEGO assemblies.

II. Lego Prototyping :

Our first prototyping for the claw was made from legos. We started with legos as we weren't that fond of 3D printing and it appealed as an accessible method for a successful design. During the designing, we experimented with different claw types using lego gear based grippers and others. This design helped us find useful characteristics necessary for a reliable claw including grip strength and its range of motion. This process helped our team build multiple prototypes and we were able to fix and build them easily. However, when testing for key tasks, it was clearly seen as not reliable. The complexity of components, grip strength especially when gripping both cones and foam surface. We also noticed a major problem was that the claw was not clearly surrounding and gripping the cone on all the sides dropping it very easily. After analyzing data from our prototypes shown in Figure 1 to instead develop custom 3D printed parts. Although lego components seemed as a way to rapidly progress, we soon realized they weren't reliable and weren't meeting our expectations and success required for regionals. These limitations overall empowered us to explore the realm of 3D printing specifically made for the dimensions of cones and other objects in order to reliably multitask

Cones Picked Up with Lego Claw in 10 trials

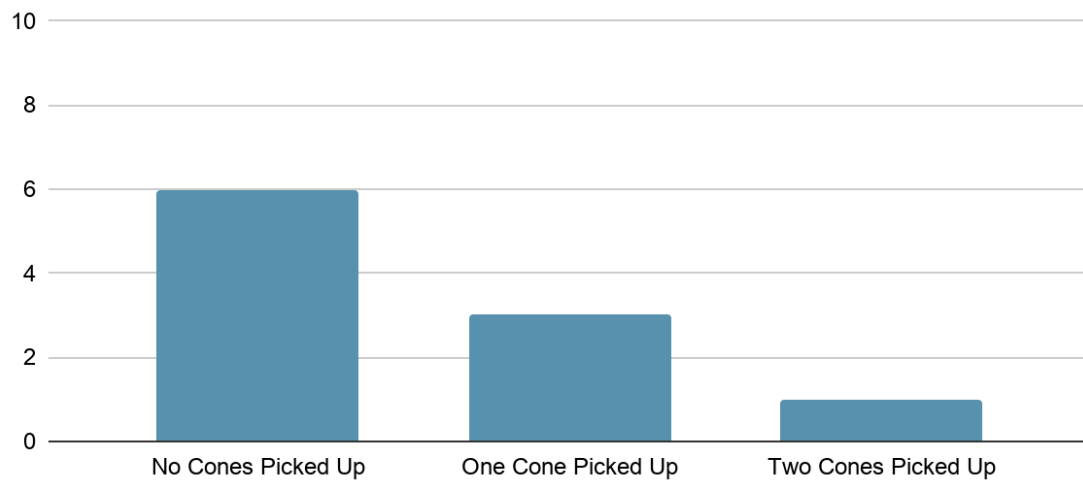


Figure 1: Accuracy of Lego Cone Claw

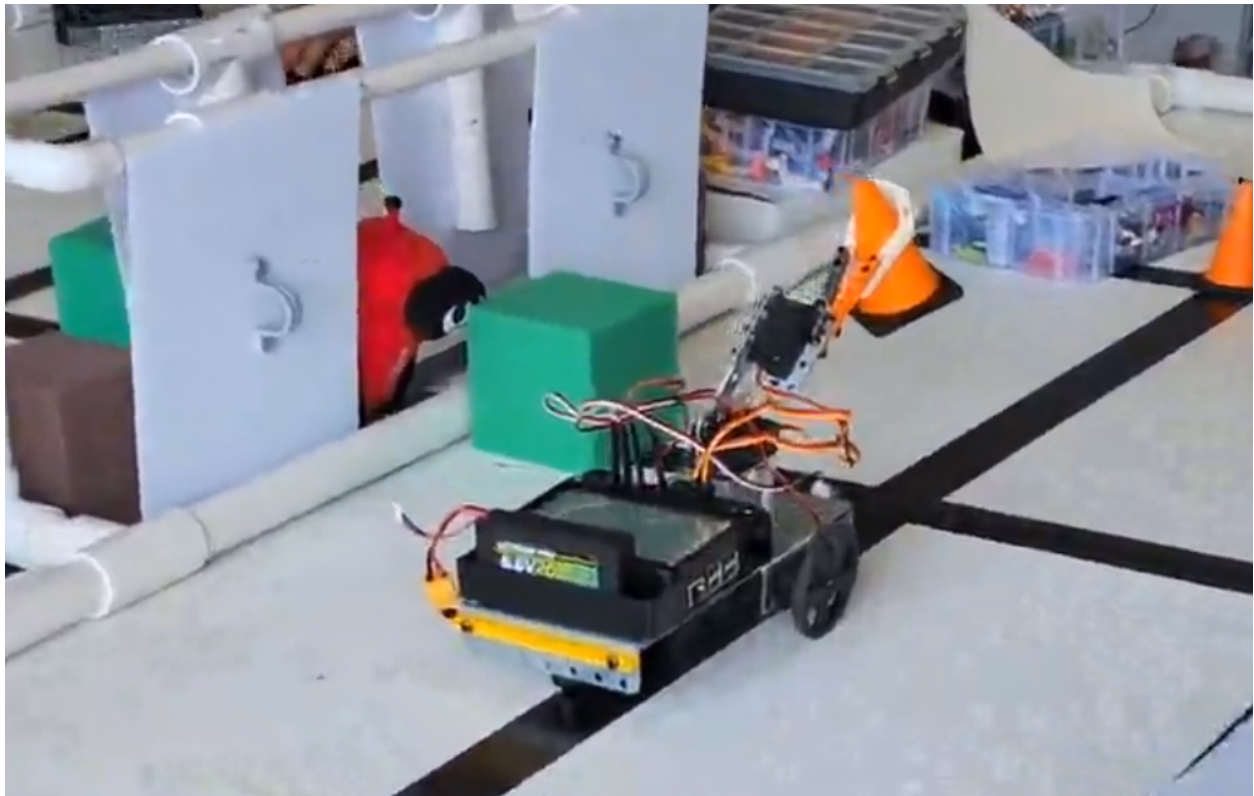


Figure 2: Picture of Early Lego Design

III 3D Prototyping:

After identifying problems with our lego claw, we transitioned to custom 3D printing on Tinkercad to make a more reliable and successful design. The primary goal was to design a single box type claw that can surround the Botguy and the cones on all sides securely grabbing which even a complex lego claw can't perform. Unlike building with LEGO, we noticed 3D printing gives the creator flexibility with design by allowing the creation of certain angles or shapes with multiple different parts while LEGOs have fixed connection points and alignment and size may not always be the same, hurting overall reliability.

One of our major improvements that helped our overall design was determining angle for back wall so it gives extra support. Before, when carrying cones and Botguy putting up would make it fall down as the only support was coming from the bottom and when upside down gravity would pull it down and fall.

However, using physics and trigonometry helped our design to add extra support and make for an overall reliable claw by generating enough friction and normal force to stop it from slipping.

To do this we wanted the force of friction [F_f] to be greater than [$mg \sin \theta$] the gravity component where θ is our back wall angle.

Solving, we found that the angle θ must be less than $\sin^{-1}(\mu N/mg)$.

By finding the mass of the claw as 0.075 kg and estimating the coefficient of friction as 0.65 of the claw with the foam cone we found that the angle θ range should be from 22-25 degrees and when integrating into our system our claw became extremely reliable picking up cones as seen in Figure 2 with a 90% accuracy for two cones making picking both comes from a myth using lego to reality with a box shaped 3D claw as seen in Figure 3

3D Printed Claw Accuracy in 10 trials

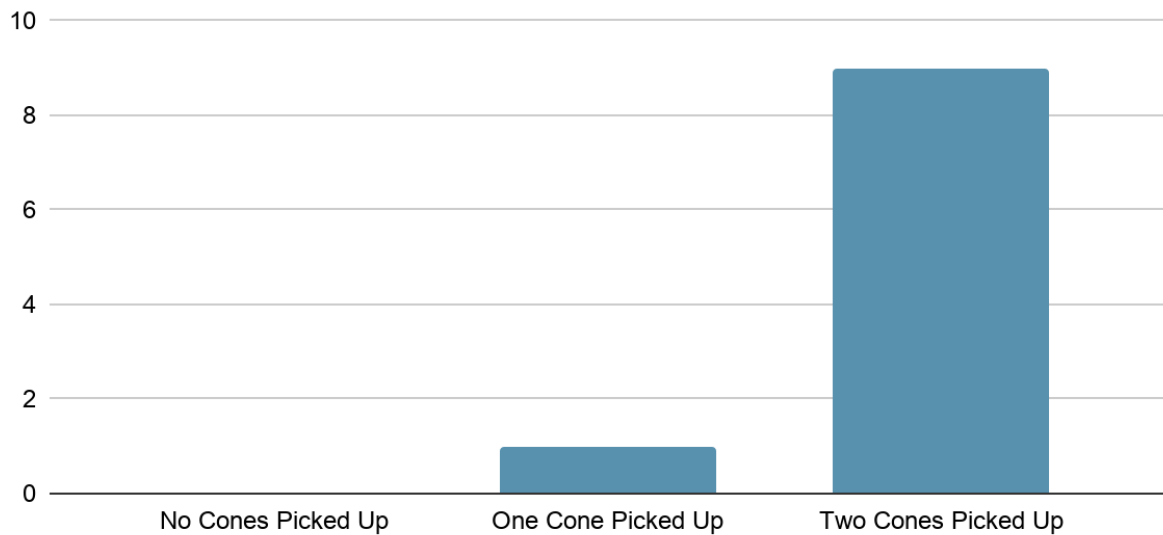


Figure 2: Accuracy of 3D printed Claw

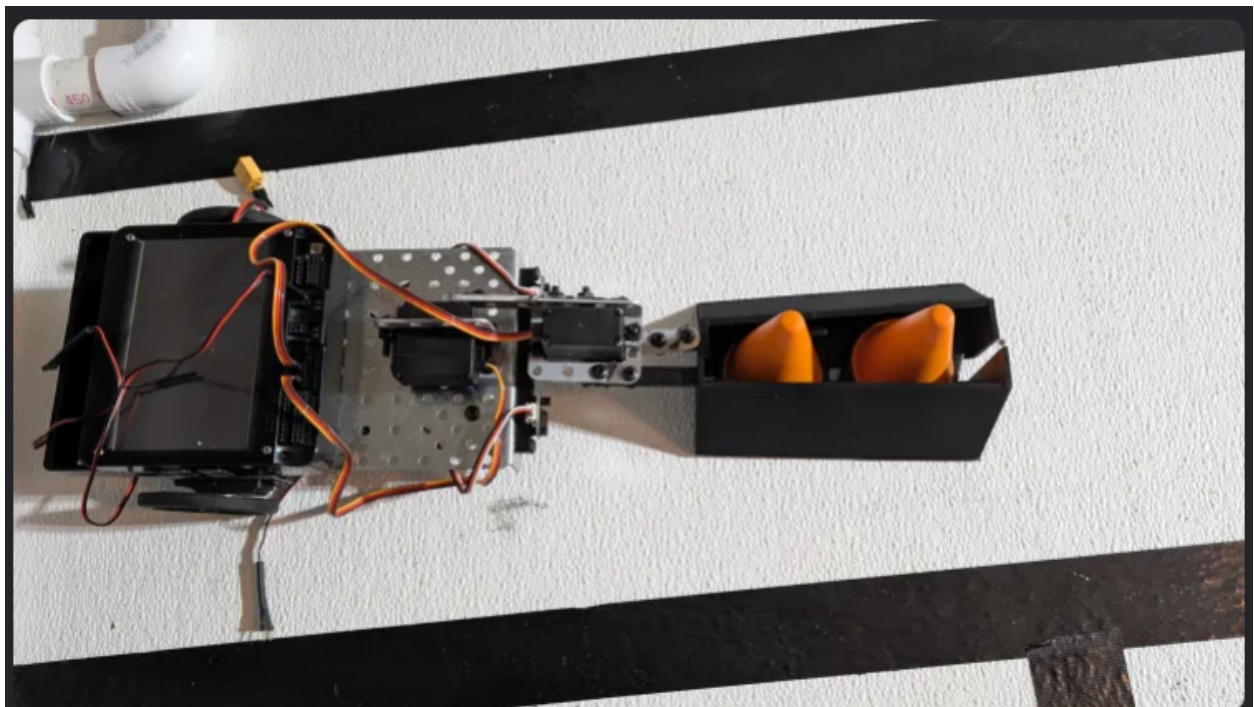


Figure 3: Update 3D printed Claw reliably carrying two cones securely

IV. Multitasking Capabilities Compared

Executing multiple tasks reliably with only two servos for an upward and claw manipulation movement requires a firm reliable design. To maximize score efficiency of both the cones, we used our same original 3D printed box claw and changed a few minor details. Achieving this overall helped improve overall versatility to carry both high scoring game pieces that can reliably carry different shape and sized objects

A. Geometric Strictness of Lego Components vs 3D parts

When a claw is built out of standard lego components to specifically hold a traffic cone, its size is locked for that object. The LEGO claw struggles with having an optimized grip geometry that can safely carry both the cones and Botguy. Both cones and Botguy are shaped very differently with different material and they require different contact points and alignment to safely carry both.

With LEGO mechanisms, claws are fixed by specific structural plans and units. This means that the same configuration of claw must be used for all tasks so the claw is not optimized. Because the LEGO claw can't have different contact surfaces for multiple objects like the Botguy and the cones, it fails in multitasking and overall reliability.

In contrast, 3D printed claws allow for designs and geometry based on the task and have a harder and firm structure for increased support rather than flimsy lego pieces. Instead of having different mechanical claws, the 3D claw can incorporate different regions for tasks. With our box claw, we use the two regions as the back walls for grabbing on to Botguy and the bottom supports for going under the cones and acting as a support floor overall increasing multitasking reliability.

V. Overall Benefits

Across both designing and testing phases, 3D claws have shown their benefits over the shortcomings of LEGO claws. The most significant advantage of 3D printed claws was its reliability to gain 1200 points using only two servos and its unique geometry that enabled stable object contact and secure grabbing.

Additionally, 3D printing helps in overall testing and fixing of errors. When designing in 3D one can see what your 3D component will look like and how it will work. Using this you are able to imagine and put into reality measurements and test it out multiple times without worrying to build something new again. One major drawback of legos is its copying. If one wants to make multiple copies of a part in case it breaks while testing, with LEGO you would have to build it all over again, decreasing reliability if you make the part with an error. In 3D, however, if there are problems you can easily fix it and create multiple copies of your design in case it breaks at a tournament still maintaining a team's performance even though their claw breaks down. With this, teams can save time of their design process and focus on other activities.

VI. Conclusion and Future Work

This paper demonstrates that custom 3D printed mechanisms provide a more reliable and mechanically feasible component than LEGO based parts in Botball. In the 2026 game Stack Attack our initial LEGO claw showed the shortcomings of fixed geometric structures which have inconsistent force distribution and overall reduced reliability. By shifting to a 3D based design approach, we were able to directly engineer our own parts and claws to create our own structure and geometry to reliably multitask and receive both the botguy and the two traffic cones. Using physics and trigonometric analysis, we were able to optimize our claws back angles to maintain a stable grip on multiple different game objects. Some future projects would be to test other materials of 3D printing like PLA, PETG, etc to see if they have an impact on claw reliability. Overall, the results of this project show

that 3D printing significantly enhances both reliability and multitasking in Botball robots and the real world when compared to LEGO based designs.

References

1. Yumbla, Francisco, et al. "An Open-Source 3D Printed Three-Fingered Robotic Gripper for Adaptable and Effective Grasping." *MDPI*, MDPI, 4 Jan. 2025, www.mdpi.com/2313-7673/10/1/26.
2. PS,, Xin Y;Zhou X;Bark H;Lee. "The Role of 3D Printing Technologies in Soft Grippers." *Advanced Materials (Deerfield Beach, Fla.)*, U.S. National Library of Medicine, pubmed.ncbi.nlm.nih.gov/37971199/. Accessed 13 June 2026.
3. *A Low-Cost 3D Printed Electromagnetic Gripper for Robotic Arms - Sciencedirect*, www.sciencedirect.com/science/article/pii/S0957415825000832. Accessed 13 June 2026.
4. Tawk, Charbel, et al. "A 3D Printed Modular Soft Gripper Integrated with Metamaterials for Conformal Grasping." *Frontiers*, Frontiers, 13 June 2026, www.frontiersin.org/journals/robotics-and-ai/articles/10.3389/frobt.2021.799230/full.