Junior Journal

Suggestion and design of new parts for the Botball competiton robotics set

Mechanical Engineering

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Abstract The robotics competition 'Botball' held by Kiss Institute for Practical Robotics (KIPR) is constantly expanding. In order to improve the set containing all allowed parts for the competition, team BotFusion collected ideas for new parts that would be helpful in the set. Autodesk Inventor was used to visualize the team's ideas regarding new metal parts. This paper presents suggestions and designs for new kit parts, discussions about advantages and disadvantages for construction and analysis of production costs.

Keywords Botball, new parts, mechanical

1. Introduction

Botball is an international educational robotics program which encourages middle and high school students to participate in a team robotics competition. During this competition, participants design, build, program and document their robots. Since the Botball competition is not meant to be attrition warfare but a contest of creativity, knowledge, endurance and dedication, KIPR provides a unified set of mechanical components for all participants. The set itself consists of electrical components like sensors, servos and motors (including parts to connect other parts with them), metal parts, Lego pieces, components by the company IGUS and the KIPR Link (a portable, battery driven computer which runs the software and provides ports for the actuator and sensor hardware). KIPR adjusts the Botball kit yearly to increase the possibilities for participants when designing and building robots.

Due to unsatisfactory part numbers or parts, team BotFusion designed new metal parts and looked up other components which could be useful in future Botball competitions. The results are presented in this paper.

2. Ideas for motor and servo mounting

Servos and motors are the main actuators used in the Botball competition. They are the elements which make effectors move by being manipulated by software that runs on the KIPR Link. Since some effectors put quite some torque or force on the structure, proper mounting of the actor on the structure and proper mounting of the effector to the servo horn is as crucial as the stability of the structure itself. The standard methods to mount big black motors and big black servos are either directly mounting them to the structure using screws or screwing

them to fitted parts. These parts (for example servo brackets or the demo-bot-base-plate) are then mounted to the robot itself. Due to these sometimes insufficient parts to properly mount the actor on the structure, participants are forced to build complex adapter structures which mostly consist of small fragile parts. In the case of the blue micro servos, the set does not even provide brackets to properly mount them. The standard solutions for this problem are either building a cage around the micro servo or simply gluing it to the structure using UGlu. However, since the micro servo would destroy the internal plastic gear box before destroying the mounting structure makes this problem in regards to the micro servo obsolete. Due to that fact, we focused on designing parts to improve structural stability for big black servo and motor mounts.

2.1 Servo and motor mounting plate

During construction, one will often notice that the positions of the holes on the motor which are dedicated to mounting the motor on a structure are kind of problematic. They are not on any kind of grid. KIPR solved that problem by simply providing servo brackets which surround the whole motor. The brackets offer two sets of holes: one for the servo or motor itself and one to mount that servo bracket on a Lego or metal structure (see Figure 1).

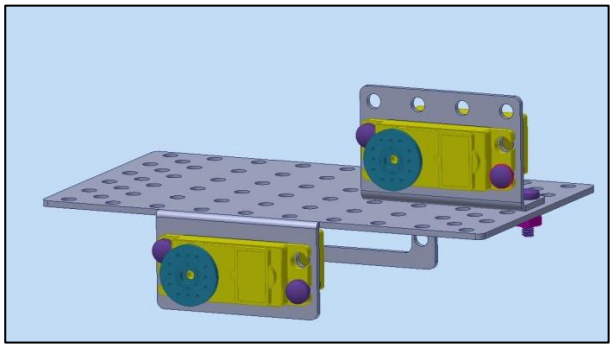

Figure 1. Servo brackets provided by KIPR

Although this method solves the problem of mounting the motor to a structure, it does not provide a good connection to transfer torque. By using a servo bracket like this, one can only mount an effector on one side of the motor's spin axis. That does not matter for light-weight applications like the Demobot. However, once higher torques start to occur, the stress on the connection between the servo horn and the motor itself rises. There are multiple ways of solving this problem. One is simply using two servos which have their turning axes on the same axis and to make both of them work in reverse directions at the same time. This method obviously provides double the torque but at the same time uses two servos or motors. Another method recommended for effectors with multiple degrees of freedom is building a structure which provides holes for mounting on the side of the servo opposite to the axle (see Figure 2).

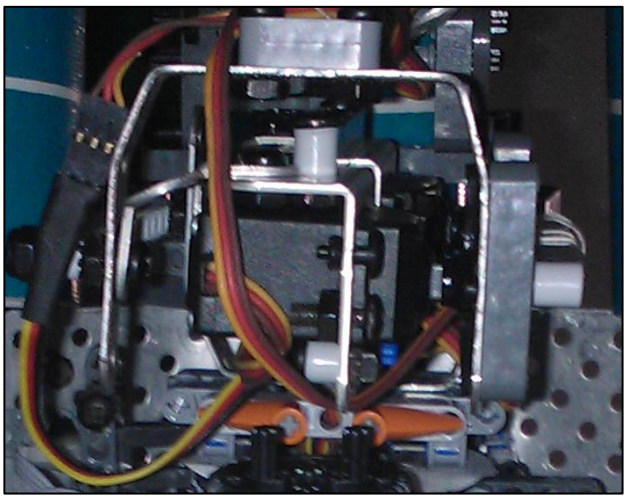

Figure 2. Joint of Jane's 4 degrees of freedom arm

The robot "Jane", which was built by team "htl donaustadt" for the GCER Botball competition 2013, used the servo bracket as a base plate on which a bent cross shaped metal piece is mounted to establish a second turn axis on which the U-shaped bent metal can turn. This provides some axial stability and makes it possible to turn an effector by 180 degrees around the servo. However, this construction does not endure repetitive usage, since the vertical forces occurring from inertia forces when accelerating or slowing the effector loosen the screw which is used to connect the servo bracket base plate and the bent cross shaped metal plate. Hence the link will loosen after 10 to 20 fast turns depending on the weight of the effector if the screw is not tightened again. Another problem is that this construction is not exactly right-angled causing the effector to turn in axial direction as well as radial direction.

All of these are reasons why team BotFusion thought about alternative ways of mounting a motor to a structure. One of the main factors for the new part was bringing the servo horn onto a grid usable by the Lego pieces in the Botball set. This also implies that the servo horn would be on the same grid as the metal pieces since those have a hole spacing of double the Lego hole spacing. Consequently it becomes more comfortable to build structures which require a stronger link between the moving part and the static part of an effector.

Concluding a plain plate with a recess for the motor is most reasonable because it is simple and effective (see Figure 3).

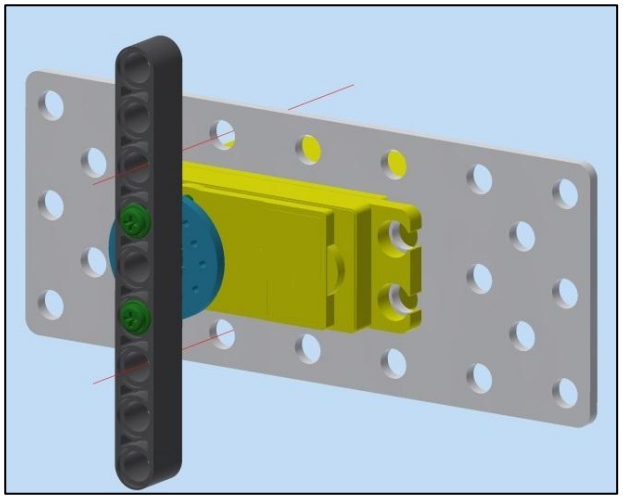

Figure 3. New designed servo bracket

As one can see, the new designed plate is a smaller version of a plate which is already in the Botball set. The only difference is the recess for the motor and the holes provided for motor mounting.

Comparing this servo plate with the old bent servo brackets, there are multiple pros and cons:

First of all, as mentioned multiple times already, this plate aligns the servo turn axis and thus the servo horn on a grid which can be used by Lego, not only in one but in both radial directions. This is not only helpful for building effectors with multiple degrees of freedom, but also makes mounting gearboxes and the like in drivetrains easier. Furthermore, looking at the economic aspect, this plate might require more base material than the old bracket, but it is not bent, reducing manufacturing costs immensely.

Although there are these two positive main factors, one needs to point out that this servo plate has some problems which should be considered: First of all, unlike the old servo bracket it is not bent, meaning users would need to build an L-shaped structure to hold the plate in case one needs a horizontal turn axis on top of a plane plate. For example mounting the servo for the lever arm effector on the Demobot would not be possible using this plate only. An easy workaround for this problem is using simple Lego parts or structures as mounting aid. Furthermore, the size could decrease the servo plates usefulness. Due to the great width and height of the plate, it is possible that it cannot be used to mount driving wheels directly, since the height of the plate might be greater than the diameter of the Lego wheels provided in the Botball set. The dimensions of the plate are shown in Figure 4.

Regarding manufacturing, the same process used to produce the current servo bracket and the Demobot base plate should be applicable, since it has similar attributes to those existing parts with the exception of not being bent.

All in all, team Botfusion recommends a mixture of the old servo bracket and the new designed servo plate in case KIPR considers including this part into the official Botball set. A quantity of two or more could be considered reasonable.

If one considers further development of this part, one should think about removing the top row of holes and turning the O-shaped plate into a U-shaped one. Although that provides less stability, it might ease mounting and increase usage possibilities.

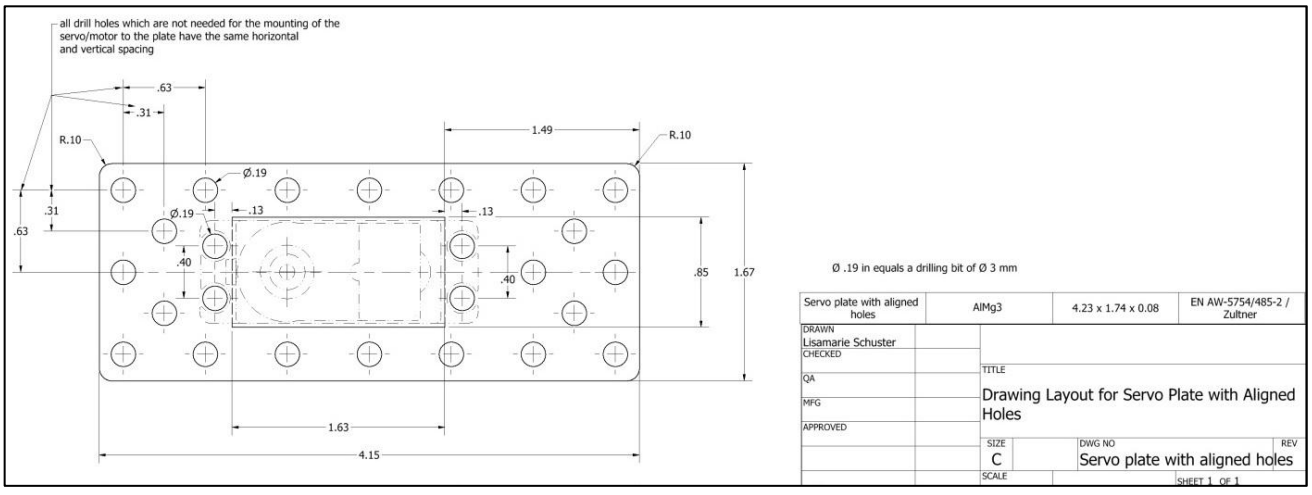

Figure 4. Dimensions of the new designed servo plate

2.2 Lego compatible servo horn

After mounting the servo or motor onto the structure, one needs to mount the effector to the turning axle of the motor. KIPR provides small plastic servo horns or the new metal servo horns for that purpose. Although they are usable, mounting Lego lever arms onto the plastic servo horn is a hassle. Regarding the new metal servo horns, the idea behind them is great, but the execution is somewhat lacking. The long lever arm may be usable, but the holes for the round servo horn are badly manufactured making screwing into them quite a challenge.

In the end, all current servo horns require the user to screw the servo horn onto the motor turn axle to screw the effector to the servo horn. Those screws sometimes block or grind on the structure when the motor turns. To prevent that, team BotFusion thought of including a servo horn into the Botball set, which allows direct mounting of Lego axles and/or pins. The dimensions of this servo horn can be seen in Figure 5.

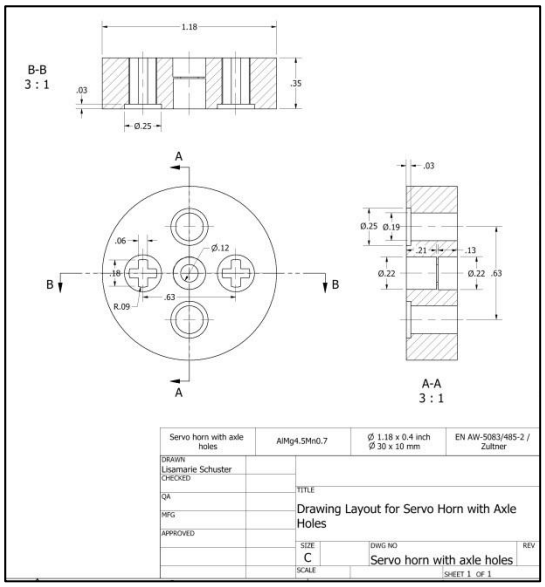

Figure 5. New designed Lego compatible servo horn

As you can see, the servo horn has similar dimensions to a Lego piece apart from having a hole in the center to mount it on the servo axle.

This part would increase flexibility for robot constructors, since one can simply disconnect the Lego pin link when using a lever arm or whatsoever on the servo horn, thus removing the necessity to unscrew the screws connecting the servo horn and the lever arm.

The problems with this part mostly lie in the production: The manufacturing process might take long since one would need to mill, print or cast it, depending on the used material. The thickness of the part could also increase expenditure spent on producing such a component. Another problem is that the wall between the holes meant for Lego pins and axles and the hole for the servo axle might become extremely thin, making the component rather fragile. In case of considering adding this kind of part to the Botball set, that problem should be further analyzed.

Regarding necessity of such a part, it does not provide any structural improvement. It is just meant to be of help to the user while mounting something on a servo axle that might be removed multiple times during construction and reconstruction processes. Thus this part is not essential to the Botball set, but rather a probably useful addition to it.

3. Suggestion of additional parts for the Botball set

During robot assembly, one might think "why can't there be a part like that" while using the Botball set. This section will analyze some parts which might be useful additions to the Botball set, mostly consisting of Lego parts.

3.1 Increasing the number of differentials

The Lego kit of the Botball set contains one particular rarely used gear: the differential (Lego part number 6573, see Figure 6).

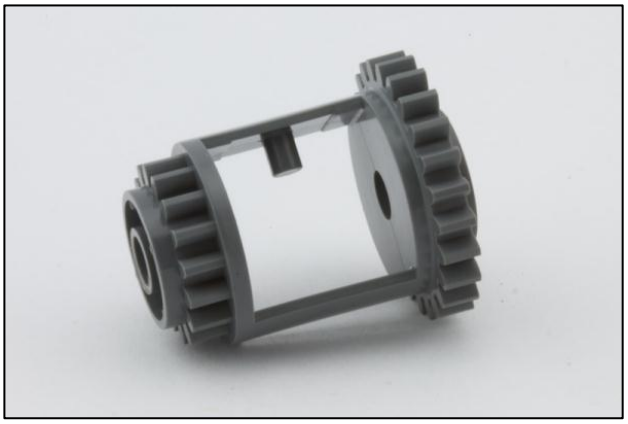

Figure 6. Lego differential [1]

This part has the function to act like a turning gearbox, making it possible to add or subtract the rotation speed of two Lego axles on one Lego axle. This allows transmitting the power of two different motors onto one wheel. The problem while using it is that the set only contains one differential. There are not many reasons to use a differential on a single wheel. It becomes more useful once one starts to use differentials on both wheel axles. That makes it possible to use two motors in a manner, where one motor drives the wheels in reverse directions

and the other motor drives them in the same directions. Doing that, one can use one motor to steer and one motor to drive forward and backward.

The reason why one would want to be able to do that is to make Lego drivetrains more competitive. In the past, drivetrains in Botball which have been built from scratch used to be built by either directly connecting the wheels to the motors like on the Demobot or by using simple gearing to gain speed by creating a transmission ratio. These drivetrains usually cannot reach the performance level of the iRobot Create allowed in the competition. Although the speed could be reached with an extremely high gear ratio, the robot would be uncontrollable at that point. By introducing a second differential into the Botball set, one could, for example, use the experimental 3-motor-drivetrain (see Figure 7) built by team "htl-donaustadt" after the competition in 2012.

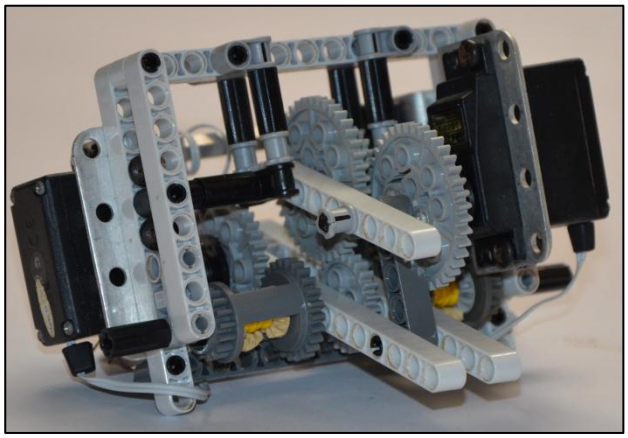

Figure 7. Experimental 3-motor-drivetrain

This drivetrain uses one differential on each wheel axle. Two of the three motors are used to steer the wheels separately with a transmission ratio of 6:1 and the third motor is used to drive the two wheels at the same time with a total gear ratio of 9:1. This setup allows the robot to move at 15 times the normal speed of a motor while having controllable steering behavior.

Making it possible to build advanced drivetrains like this one allows experienced teams to build robots on a par with the iRobot Create. These require more complex movement algorithms due to their mechanical behavior, thus offering a new type of challenge to advanced teams. This could be interesting especially in regard to a Botball challenge which requires long driving distances while being limited to the round time of 2 minutes.

3.2 Adding shock absorbers to the set

Another type of parts team BotFusion discussed were shock absorbers by Lego (see Figure 8).

Figure 8. Small and large Lego shock absorber

These springs could serve for multiple purposes, for example holding something in place in a loose manner, building flexible drivetrains or even adding extra force to an effector. These parts would be a great addition to the existing Botball kit in general. Until now, teams would use rubber bands to achieve a similar effect. A big problem of those is that they tend to loosen over long time, making them an expendable part. Another problem is that you can only stress them by extending them, and not by pushing them.

In general, this part is not necessary for the set itself since one can construct workarounds using rubber bands in most cases, but it gives the user more freedom while building a moveable part. When considering including shock absorbers into the set, it is recommended to take the large and not the small ones, due to the longer effect distance and the larger force.

3.3 Including a new type of Lego wheel

Traction is a crucial part of proper movement. The best effector does not help if a robot cannot properly move to the position where it needs to be. In the current Botball set, teams can decide between 4 types of parts which they can use for traction: the wedge belt wheel tires, which are pretty small and do not provide proper friction, the flat tires, which have an acceptable size but do not have a defined contact point on the ground, the balloon tires, which in turn have a better defined contact point but change their wheel diameter depending on the weight of the robot, and the tread, which can be used for chain drives, although using those is not recommended, since they have pretty undefined behavior and bad traction. As one might see, none of these parts are perfect for a general traction application.

Due to all the reasons mentioned above, team BotFusion looked for alternative types of traction components. Concluding, one wheel came up with outstanding properties. The decision fell on the Lego parts with the Lego part numbers 32077 and 32078 (see Figure 9).

Figure 9. Lego parts 32077 and 32078

These so called futuristic wheels consist of 2 parts: the triangular plastic rim (part number 32077) and the full rubber tire (part number 32078). The next few sections will give a brief overview of the positive and negative attributes of these parts.

First and foremost, one of the key factors to why these wheels were chosen is that the wheel diameter is defined really well. The rim obviously does not deform at all and the full rubber tires only yield by a maximum of one millimeter when put under pressure. Another positive aspect is the round profile of the tires. This gives the wheel a defined connection point to the ground and makes calculation of turning radii possible. Last but not least, the material used for the tire provides a tremendous amount of friction considering the small contact area, regardless of force used to push the wheel on the ground.

The only real drawback is that one cannot properly mount the wheel on a servo horn directly due to the triangular rim. However, this way of mounting cannot be recommended anyways since it creates unbalance.

3.4 Including threaded bolts

Figure 10. Example of a threaded bolt [2]

Lego parts and metal parts are allowed during robot construction for the Botball competition. Obviously, the higher the occurring forces are, the more one will tend to choose metal parts over Lego parts. However, there is one type of metal structure that cannot be built using the current kit parts: an axle that is hung up multiple times and can be turned by 360 degrees. To make that possible, we suggest adding threaded bolts (see Figure 10) into the metal kit. Those can be used to join multiple standoffs and nuts to build a single turning axle.

It is recommended to consider adding a few threaded bolts of the same dimensions as the 8-32 screws, which are already included in the set. The threaded bolts are a norm part (for example ISO 4766), so they can be bought prefabricated and do not need to be produced separately.

4. Conclusion

As one can see, there are quite a few points which could be improved regarding the Botball kit. Although most of the points brought up in this paper are optional, some would provide great enhancement to the set.
One has to keep in mind, that the problems addressed in this paper only cover parts of the mechanical kit though. Similar considerations should be made regarding the electronic components used in the Botball set. One example would be the trimmer potentiometer which was added in the Botball season 2013 but removed again the year after. Its usefulness should not be overlooked although a smaller form factor may be convenient.

5. References

[1] Figure 6.
http://www.toypro.com/media/cache/my_thumb_super_detail/uploads/images/custom/extra/3513-extra.jpg
(23.03.2014)

[2] Figure 10.
http://www.tracepartsonline.net/(S(n31lii45xv41c0q42hz3zt3o))/partdetails.aspx?Class=BENE_INOX&ClsID=/BENE/BENE_BV/SER_10_b_1/SER_10_b_2/S_10_b_3/&PartID=10-05052009-134855
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