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Evaluation of Complex Robots and Necessity of New Parts in Botball

Mechanical Engineering

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Abstract This paper discusses disadvantages and advantages of complex robots and presents ideas on new parts in the Botball competition. In the first main section complex robots are being analyzed, the second main section gives an insight to which problems teams in Botball have to face due to a lack of proper parts and how this could be avoided.

Keywords Botball, Complex, Robots, mechanical, parts

1. Introduction

The international educational robotics program “Botball” encourages middle and high school students to participate in a team robotics competition. Participants design, build and program their robots. Moreover, they have to document their progress, which should help them to get used to research project structures. When it comes to building, some teams tend to implement complex ideas, which are not necessary in most cases. Designing, building and using complex robots makes Botball more interesting. However, they should reach some kind of criteria – they should be successful in competition. Some complex structures are necessary, however, due to a lack of proper parts. Ideas on which parts would make these workarounds obsolete are presented in the 3rd section.

2. Complex Robots

In most cases simple solutions do not work for a task and therefore a complex method is necessary. However, in some cases teams design robots, which are way too sophisticated, even though simple ways of completing a task would work as well. In general, a robot should only be as complicated, as successful it is.

2.1 Rattlesnake

In 2013, Team iBot used their robot Rattlesnake. One of the tasks was to pick up PVC pipes with a big diameter (Booster Sections) and stack them on an almost 3’ high, thin PVC pipe (launch pad). Most teams used a claw attached to a crane, which was a really simple way of building a robot capable of completing this task.

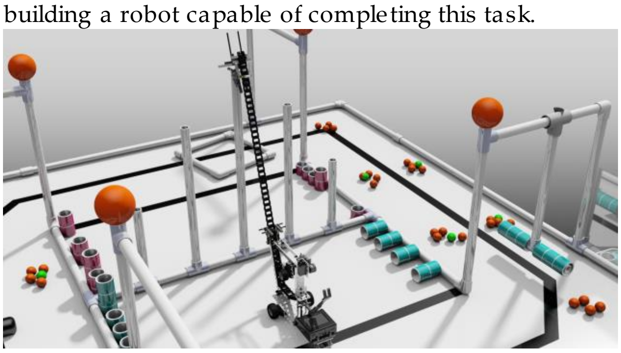

Figure 1. Rattlesnake aligned with highest launch pad, Booster Sections in turquoise and pink.

However, Team iBot used a cable carrier which can move in and out to a maximum height of more than three feet. The angle of the U-profile metal piece, which works as the guidance for the IGUS chain, can be changed. Thus, the robot is able to lower the arm to pick up the Booster Sections. In order to stack the sections on the launch pad, the arm would raise and the cable carrier move out, as one can see in Figure 1. After the Booster Section has reached over the top of the thin PVC pipe, the IGUS chain moves downward again. This causes the launch pad to be inside of the Booster Section. One of the reasons for not using a claw at the end of the cable carries was, that the Team would have to use a lot of servo extension cables. It is a really sophisticated idea, but unfortunately, not successful enough. Rattlesnake scored zero points in all of the three seeding rounds at ECER12. However, the team made it to the finals of Double Eliminations, just with the help of Rattlesnake.

Figure 2 shows some of the most important parts of Rattlesnake. The tire, which was attached to a motor, creates enough friction to move the cable carrier. An IR sensor in combination with pieces of white paper is used to let the robot know how long the motor has to turn until the chain has moved all the way out or in. The sensor returns a high value as longs as only the black cable carrier is in front of it. As soon as the white paper appears in front of the sensor, a low value is returned.angle of the guidance can be changed with the help of a rope winch.

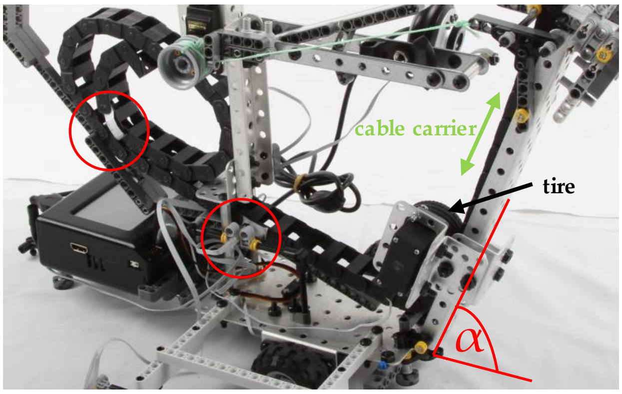

Figure 2. Mechanism of Rattlesnake.

2.2 GearBot

The La Quinta HS Boys' Team planned to use a robot in 2014, which could raise its main platform from the bottom to a maximum height of 6 inches. The goal of this design was to be able to operate in two different levels with no need of an attached arm, but only a claw. As a result of this, the robot can drive in raised position to the rack and grab one of the yellow and orange cubes, since the height of the rack corresponds to the height of the claw, when GearBot is raised. Afterwards, the robot drives in lowered position to the equivalent bin of the cube and drops off the cube.

The idea of this robot sounds valuable, but in Botball it is rather useless.3 shows when GearBot is lowered. The gear system, which is attached to two motors, has a ratio of 1:25. This creates enough torque to raise the main platform.

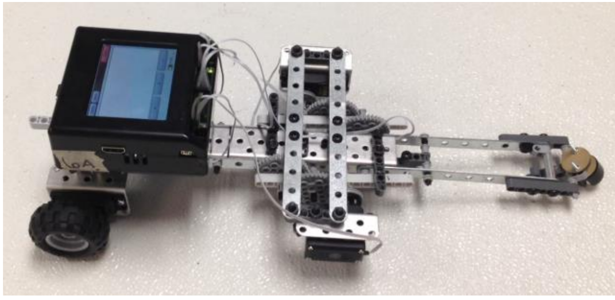

Figure 3. GearBot, lowered

The motors will keep turning until the push sensor on each side returns 0. This prevents the motors of turning, even though the legs cannot be moved anymore.

The Link is not attached to the platform, since this would increase the weight which has to be lifted. Instead, it is located at the back leg of the robot. The front leg is touching the ground only with the caster, which does not create a lot of friction. Figure 4 shows GearBot in raised position.

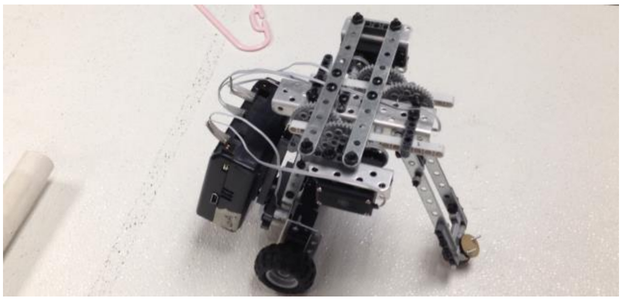

Figure 4. GearBot, raised.

2.3 ParallelBot

Since GearBot was not successful enough, the La Quinta HS Boys' Team used ParallelBot for the competition in 2014 instead. In opposite to the previous robots, this one was complex but also very successful. At the Los Angeles Regional, it scored more than 200 points in average during the seeding rounds. , so the team got 1st place.

Even though the overall design of the robot is simple, the most important part, the claw, is rather complex. Since the task was to pick up cubes, the team decided to build a parallel closing claw. Two sets of gears are connected to two gear plates, which causes a parallel movement. In order to be able to use a small servo, a gear system had to be implemented to create a certain gear ratio. Otherwise the gears would not turn long enough and the claw could not open all the way. An IR sensor, which can be seen in Figure 5, is attached at the tip of the claw, so the robot knows when the claw is located exactly above the cube.

When there is no object below the sensor, it will return a high value, caused by the big distance between sensor and object. As soon as a cube appears below the sensor, the distance between sensor and object decreases, so a lower value is returned. With this technique, ParallelBot drives along the rack until a cube is recognized, then the robot opens the claw, lowers the arm and finally grabs the cube.

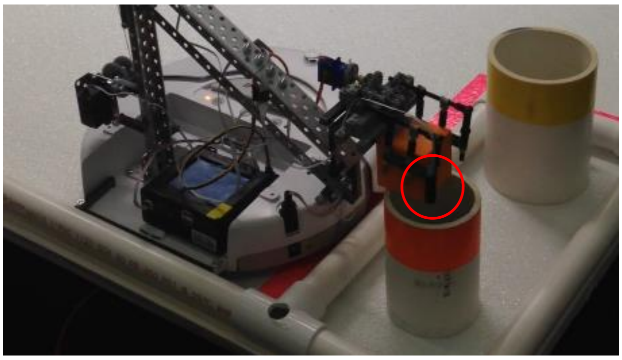

Figure 5. ParallelBot droping off cube.

2.4 Platform

In 2015, Team iBot αlpha uses a robot called Platform, which collects green and red poms and sorts them by color. Figure 6 shows the robot while it is sorting. The robot collects the poms with the claw and drops them into the container made of foam board. If one of them gets stuck, the jammer pushes it farther down until it hits the conveyor belt, which carries the poms to the hub. Since the robot waits in one end zone while sorting, green poms are disposed immediately. Red poms will be stored until Platform has arrived at the other end zone. After arrival, the gate will open and the poms simply roll out of the storage area. If some of them do not leave the storage area immediately, Platform will spin right and left, which will cause the last poms to roll out as well.

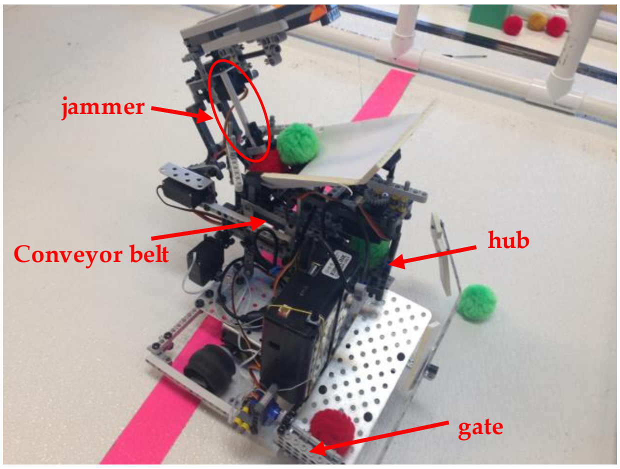

Figure 6. Platform sorting poms.

The design of Platform is already quiet sophisticated. However, the programming makes this robot really complex, but very useful. Platform is using the "Robot Positioning System" (RPS), which was written by Christopher Zwölfer, one of the members of Team iBot αlpha. This system lets the robot know exactly where it is located on the game table. Moreover, it is possible to simply type in coordinates, which Platform will drive to. In order to make programming and troubleshooting easier, a graphic output on the Link is provided.

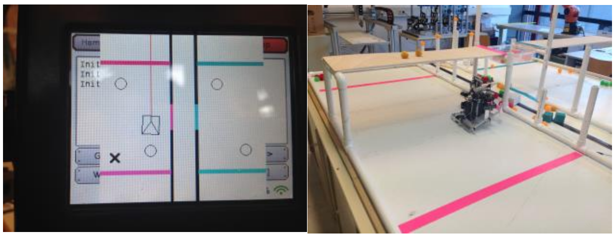

Figure 7. Graphic output of Robot Positioning System

Figure 7 shows the graphic output of RPS compared to where the robot is actually located. The red line indicates where Platform is driving to right now and the circles represent the starting position of the red and green poms. This type of programming is quite complex, especially at the beginning. However, it makes programming easier and the robot has been very successful during practice.

3. Suggestion of additional parts

In the following section it is described which parts should be added to the Botball set.

3.1 Adding LEGO axles made of metal

In the 2015 Botball set there are 12 axles included in various lengths, styles and colors. However, all of them are made of plastic. Plastic axles have multiple disadvantages.

First of all they are not resistant against torsion.

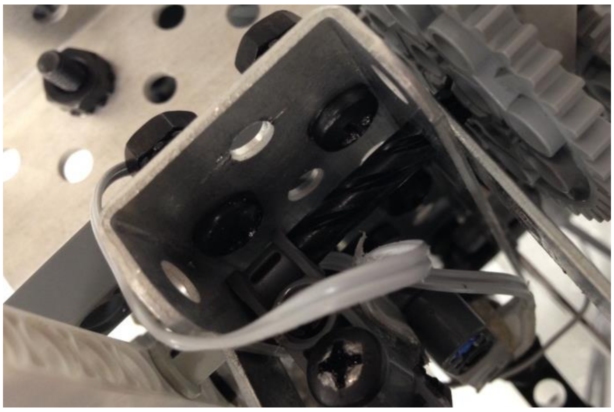

Figure 8. Axle on GearBot turned by 360°.

Figure 8 shows an axle which has been used on La Quinta HS Boys' Team's robot GearBot (see: "2.2. GearBot"). As one can see, the axle is turned by more than 360 degrees. This was caused by too much weight, which caused that the axles were turning but the legs of the robot did not. With axles made of metal, the applicability of axles in Botball could be increased, since metal axles are more stressable.

Secondly they are not resistant against sideward forces. In Figure 9 one can see an axle which is currently being used on team iBot αlpha's robot Platform. Together with another axle on the other side of the tread it is supposed to stretch the tread so that it does not sag in the middle. Due to the distance between the holes in the LEGO liftarms the stress applied is very high. In this case the tread does not expand more, but the axle gives in and bends.

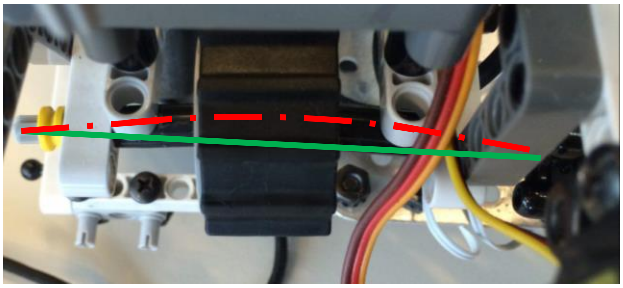

Figure 9. Tread of Platform with bent axle. Green line: axis of axle in normal position; red line: actual axis of axle.

Although here the flexibility of the axle is an advantage because stretching the tread would not be possible if the axle did not bend, most of the time it is a big disadvantage.

Therefore it is recommended to add an axle made of aluminium alloy to the Botball set.

Since there are no metal axles available for purchase, it would be necessary for KIPR to produce them on their own.

LEGO plastic parts are produced using injection molding. This method is also possible for metals, however, it is not the exact same process, of course. For injection molding of metals there is the PIM method (Powder Injection Molding). This process makes it possible to injection mold metals by transforming the raw material into a powder first and mixing it with binder. Then the mixture is melted and injected into the mold. In order to remove the binder, the part is being heated up to about 400°C. In the last step the part itself gets heated up to approximately 85% of the melting temperature of the metal so that pores get eliminated. [1] This process is only cost efficient for quantities larger than 10.000 units. Therefore using CNC milling machines for the production would be recommended.

Moreover, during research it was found that there is a high demand for metal axles in the LEGO Technic hobby sector. There are very few producers of metal axles and all of them produce small quantities.

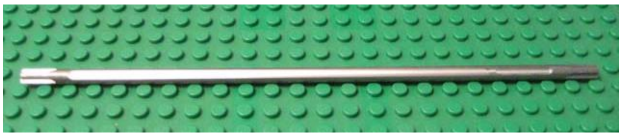

Figure 10. Metal axle by Brick Machine Shop. [2]

Figure 10 shows a metal axle produced and distributed by Brick Machine Shop. This model only has the cross-shaped diameter at its ends, which makes it suitable only for drivetrains. This model comes at $4.10 each, which is fairly expensive. Therefore KIPR could consider producing more axles than the Botball sets would take up and selling the excess on the internet.

3.2 Adding a modified LEGO part

Since LEGO parts make up for most of the Botball set and there are many different models included, it is possible to build almost everything using these parts. However, sometimes one has to create a complex and parts-consuming workaround because the part originally used misses one little detail.

Therefore one of the LEGO parts has been modified. The design is presented below using the 3D software Autodesk Inventor.

The original Axle Joiner Perpendicular 3 Long has one hole for an axle on each end and one hole for a pin in the middle. If one would like to fix, say, a sensor cable to the robot using this part, the second axle holes is downright useless because one axle is sufficient to secure the Axle Joiner in place and secure it against torsion. If one wants to press the Axle Joiner against another LEGO piece and using the axles would not create enough pressure, the pin hole has to be used. There is only one pin hole, however, so the Axle Joiner is not secured against torsion. In both cases the inverted Axle Joiner would be a better option:

Figure 11. Left: new part, Right: old part

As can be seen in Figure 11, the newly designed inverted Axle Joiner Perpendicular 3 Long has a pin hole at each end and one axle hole in the middle. This makes it possible to secure the Axle Joiner against torsion in any way. The old version has two axle holes, even though only one would be necessary.

The production of this part is not possible by modifying the already existing parts. In order to implement the this idea, the part would have to get injection molded or 3D-printed. It is assumed that this production method is too complex and would not be cost-efficient for the Botball kits.

3.3 Adding already existing parts

3.3.1 Adding a second caster set

Currently, there is only one caster set included in the Botball set. This is useful for stabilisation of the robot, if the team uses only two motors for the drivetrain. However, the robot often loses its track when it drives over the divider which is used to connect the large FRP pieces. Moreover, stabilizing the robot directly on the divider is impossible due to the divider's triangular cross section.

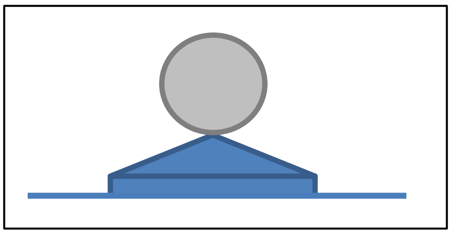

Figure 12. Approximate cross section of the divider including caster. Blue: divider and FRP pieces; grey: caster.

As one can see in Figure 12, the caster always slips down on one side of the caster, making it impossible to drive straight forward on the exact middle of the table. This made getting Botguy extremely difficult in last season's Botball competition.
Therefore it is recommended to add another caster set to the Botball kit.

3.3.2 Adding a worm gear box

When trying to use the worm gear in Botball, one has to face one main problem: the pressure the gear is pressed against the worm gear with is never enough – the gear keeps on slipping out, creating major failures during tournaments. Especially when the worm gear is used for lifting the main arm of the robot and then all of a sudden the arm does not lift anymore at all.
LEGO offers a solution to this problem: the LEGO worm gear box.

Figure 13. LEGO worm gear box. [3]

Because this box is one piece of plastic, it is very stable and the pressure applied to the worm gear is sufficient at any time. That is, given that the force transferred is not too high. In this case the flexibility of plastic axles might be a problem again (see also "3.1 Adding LEGO axles made of metal").

3.3.3 Adding the Rotary Sensor

The potentiometer which is able to measure turns by giving back a certain analog sensor value depending on how many degrees it has been turned was included in the Botball set for many years. However, from season 2013/14 on it was removed from the set and only the Linear Slide potentiometer was left. For team iBot αlpha this is a big disadvantage, as can be seen in Figure 9.

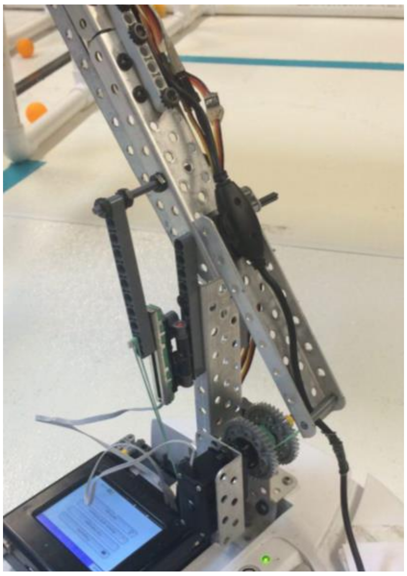

Figure 14. Picture of robot Chicken by team iBot αlpha.

The system used for the lifting mechanism of the on this robot would have made it easy to implement the Rotary potentiometer. It simply would have been mounted to the axle which leads through the cable pulley. Since it is not included in the set anymore, a rather complicated workaround had to be built, which consists of the Linear Slide potentiometer mounted to the base stand, an axle mounted to the arm itself and a liftarm connecting them.

4. Conclusion

This paper presented a discussion about disadvantages and advantages of complex robots and ideas on new parts for the Botball kit.
The experiences made with complex robots are very subjective and there might be teams in Botball who enjoy building advanced structures and perfecting them. One should keep in mind though that, as stated before, the most important part in Botball is that the robot scores points reliably. The ideas on new parts presented are only

suggestions, of course, but most of them would certainly provide a great enhancement to the set.
The authors hope to have made their point regarding additional kit parts and would like to see the 2015/16 kit including some of them.

7. References

[1] http://www.amt-mat.com/Powder_Injection_Molding_PIM.html

[2] http://www.bricklink.com/myImg/97665.jpg

[3] http://i.ebayimg.com/00/s/MTIwMFgxNjAw/z/s0IAAOxyZzlTeKni/$_35.JPG