BB-8 Robot

Mechanical Design:

Creation of VEX robotics BB8

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In the summer of 2017, following my last full year at Ivy Tech, I joined a group to work on a project creating a robot. The robot in question is the BB8 robot from the Star Wars franchise. My job for this project was to work on the internal design of the robot as well as the drafting of all the components for the SolidWorks assembly of the robot.

The first task of the design process was to figure out how the internals of the robot will be created. To create a fully functional BB8 similar to the one seen in the Star Wars films a large budget and team of designers would be necessary. The technology used in the real BB8 robot is far too advanced for the size of this project. What is needed is pre-made robotics parts that can be assembled together to mimic the functionality of the BB8 robot.

There are several different pre-made robotic kits to choose from, each with their own pros and cons, but the one that was chosen is VEX robotic parts. VEX parts were chosen to be the internals of the robot for a number of reasons. To start with, we already had a large selection of VEX parts at our disposal at the Ivy Tech Northeast campus. Second, VEX robotics has an omni directional wheel that is essential for the creation of the BB8 robot. An omni directional wheel is needed to rest inside the shell of the BB8 to allow the robot to move. If the mechanism that moved the robot didn’t consist of omni directional wheels the design wouldn’t be possible with the parts that we had at our disposal. Therefore, the BB8 was to be constructed using VEX robotics parts.

These parts are easy to use to build different robots, generally types of cars. Although VEX robotics has all of their parts listed online, there is no library of parts that can easily be downloaded and edited through the VEX robotics website. This met the first task I had was to create a library of parts to use for our assembly. These parts are separated into a few different categories.

The most important of these parts are the set of plates, channels, and omni directional wheels that are included in the VEX robotics library. The plates start with a 5x5 grid of holes for fastening parts of the robot together, and increase the number of rows for each successive part by 5. This means that there are 5x10, 5x15, and so on for sizes of the VEX robotics plates. The channel pieces are similar to the plates, but with a two 90-degree bends that shape the part into a U shape. These pieces are the core structural pieces of the BB8 internals that we have to work with. Things like spacers, stand-offs, rods, motors, and gears also had to be created. In Figure 1 below you can see a sample set of the parts that were created for the VEX robotics library for this project.

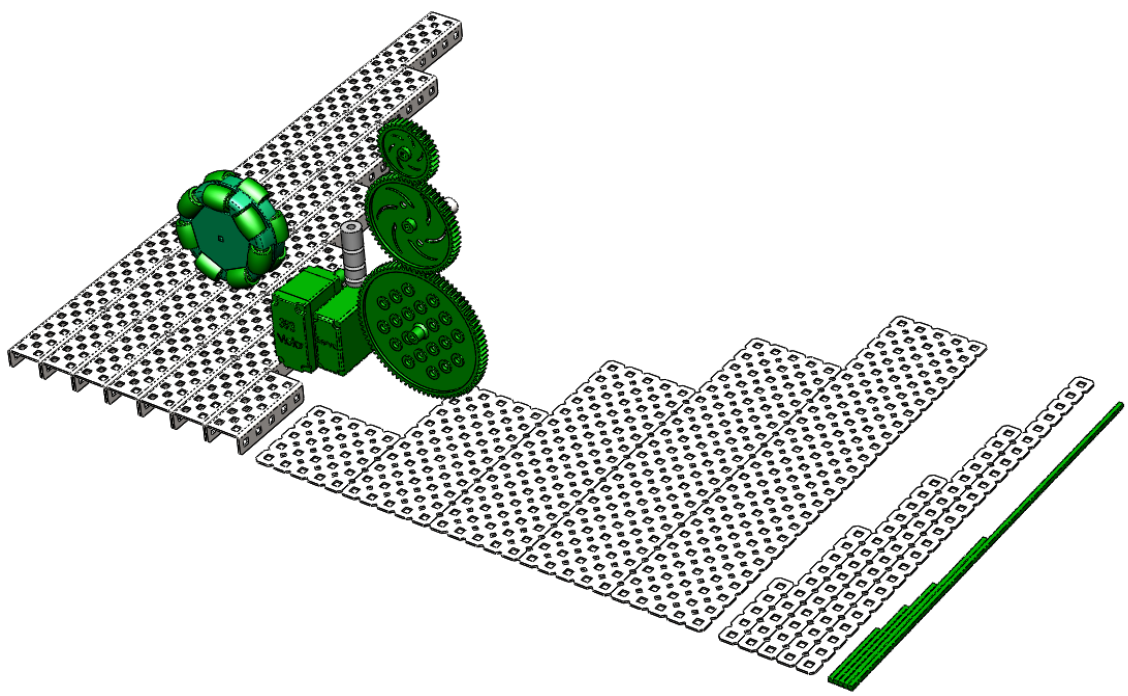

Figure 1: First part library for BB8 robot (Spacers and standoffs not included)

After the creation of the parts the next task was to figure out how we wanted to assemble the BB8. Some constraints existed before this step. A Styrofoam ball with an internal diameter of 10.25in was already in possession of the group before I joined, so the assembled robot had to fit within this space. Another constraint was our use of VEX parts. Unlike the advanced robot that uses expensive equipment and gyroscopes for a working BB8, we only had Omni wheels to work with. This should still work well enough functionality wise for the robot. The design relies on two drive wheels that rest parallel to the ground while resting inside the shell of the BB8. The top view down of the internals would be an X shape as the turning wheels were positioned to touch the sphere on the top side while being perpendicular to the drive wheels. This general shape is the easiest way to simulate a functional BB8 design without the advanced electronics found in more expensive builds of the BB8. However, the only way this would work is if the internals of the robot were bottom heavy. This would mean when it comes to a rest the sphere would naturally want to orientate itself to the drive wheels are close to parallel with ground and remain in the bottom half of the sphere. This means my design had to be bottom heavy, and had to consist of two sections, a drive wheel chasse and turning wheel chasse.

These sections would have to be connected in some way using either VEX parts or 3d printed parts. Initially a channeled metal piece with 3 sections was selected to act as the turning wheel, but there were some problems and design choices that reversed this decision. In Figure 2 below you can see my first attempt at the turning wheel configuration. I decided to stop where I did for a number of reasons.

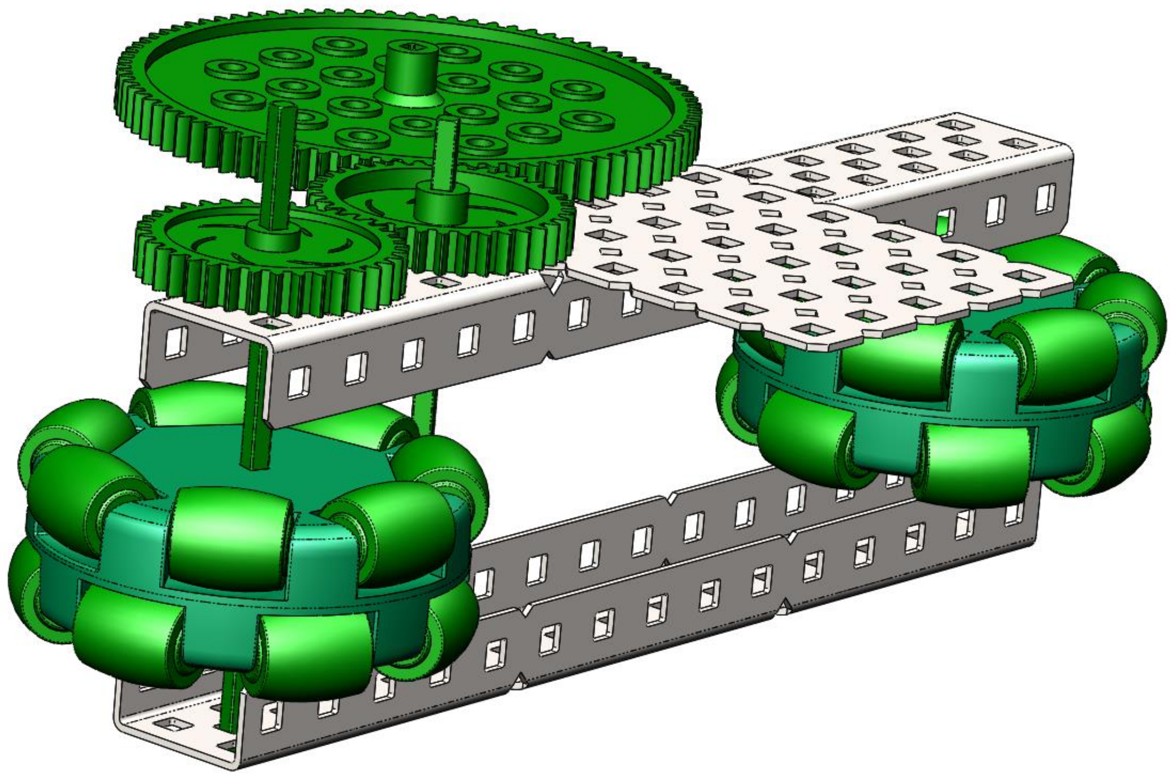

Figure 2: BB8 driving wheels, first attempt.

The channel piece that is 3 sections long (as seen in Figure 2) has a length of 7.5 inches. The distance of this piece as well as the diameter of the omni-directional wheels means that this piece would rest right around the middle of the sphere. Another section of this size wouldn’t be able to fit within the sphere we have, this means that the driving wheel section must be short enough to fit underneath the turning wheels to ensure the robot is bottom heavy. Unfortunately, that wouldn’t be possible with this design for the turning wheels. Another benefit about changing from this design is that the gear setup involved different sized gears. Having the same size gear throughout the mechanism will make it easier to put together in an assembly as well as allowing better symmetry of the robot. A new design was then created to fix this issue. Having the driving and turning wheel sections use smaller channel pieces would allow them to stack on top of one another within the sphere. I made two separate assemblies for both the driving wheel and the turning wheel sections.

The new design had two separate chasses that would hold the driving and turning wheels. A large 3d printed piece would have to be made to connect the two chasses in the right position to fit into the sphere as intended. While this design technically worked for the goals we had in mind, the amount of material needed to 3d print the block that would hold the two chasses together was much larger than anticipated. This is because the piece would also be structural as it is the only thing holding together the driving and turning wheels. If it deformed at any point the robot would cease to function properly. This design also didn't really have a use for the plates from the part library, which means spots for fastening electronics to the robot would be minimal. For this reason, I decided to scrap that design and start over. The next design that was created solved this problem by not having two separate chasses, and this design was created by Veronica and Dakota. Unfortunately, it wasn't symmetric so this design would also have to be scrapped, but one aspect of it became a staple in future designs.

By only having one chasse the only parts that would need 3d printed for this robot are electronics holders as well as potentially spacers. It is easier to create a shell of the robot without wheels initially and fit its size into the constraints specified by the project. Once the shell was created in SolidWorks with VEX parts, the actually components of the robot (gears, wheels, shafts, electronics) could then be put inside the shell and moved around indecently until pieces were in stable and correct positions. This made keeping the wheels contacting the inner surface of the sphere much easier than the previous design with separate chasses. This design also reduces the amount of VEX part cutting needed in the overall creation of the robot. Having a singular body piece made out of vex parts is a design choice that will stick around. Below is a figure of the frame created for this new design.

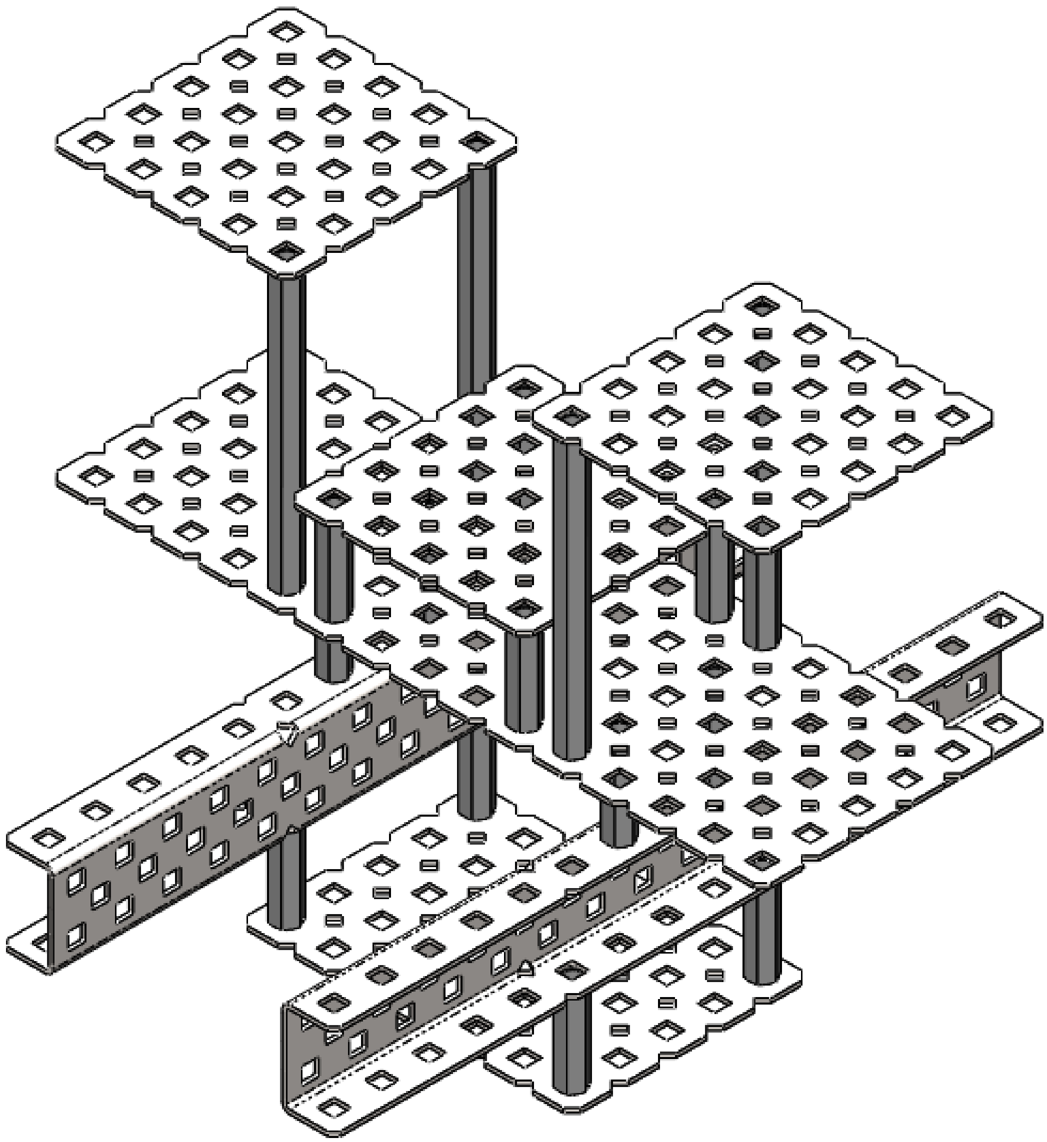

Figure 3: Final frame design for BB8 robot.

As seen in figure 3 the frame itself has 3 main sections. Starting from the top of the frame down we first have the spot for turning wheels. This section is the largest one on the frame for reasons that will be explained later. The next section involves the channel pieces, this is where the drive wheels and drive motors will be resting. This space was made very similar to previous drive wheel designs with one difference, which is the 3rd part of the frame. The final section is the 5x7 plate on the bottom that will be used to help support the batteries that will be resting at the bottom of the robot. This piece will need to be cut from a larger plate piece.

Once the frame was created the next part was how to fit the wheels at the exact level needed for the robot to function properly. To have full control the four internal omni wheels need to be touching the inside of the shell at all times. This means the drive wheels should be resting against the ball while the turning wheels are also being pushed up against the right side up section of the sphere. The small rollers on the omni wheel make this set-up possible. The motors for these wheels can sit symmetric about the center axis of the robot to maintain stability. Two drive motors are positioned about 1/3rd down the drive wheel channel piece that the driving omni wheels rest on. They are positioned close enough to the center so that the corner of the motor isn’t rubbing up against the sphere while it moves. The motor for the turning wheels is settled in between both of the drive wheels. This is done so that the weight of the motor helps keep the center of gravity lower than the center of the sphere. By keeping a majority of the weight of the internals lower down, the robot will naturally sit right side up when in a resting position. To help ensure that the center of gravity sits in the lower section of the robot, most of the heavier components inside the robot will be positioned on the bottom. This is a win win situation for the design we settled on. It was already decided that the drive wheels will be powered by two separate motors. These will sit in the bottom side of the robot next to the batteries that will power the BB8. With this positioning of the motors and the battery the robots center of gravity should be lower than the center of the sphere.

The large amount of space that the turning wheels sit inside is also a useful and practical design choice. The frame seen in Figure 3 was made this way to allow the turning wheels the space to be pushed up until they rest on the internal parts of the sphere. This design choice was done for a few reasons. First, the creation of the frame first was done so that the structural components of the BB8 would all be VEX parts. This is useful because it allows use to use metal sturdy parts for its structure instead of 3d printed parts. This helps fix the design error in an earlier design where the connecting section between the drive and turning wheels would be made with a 3d printer. Another useful aspect of this design is that the top and bottom parts are separated far enough to allow maintenance on parts already assembled without having to take out a bunch of parts. Earlier designs would require a near complete disassembly of the robot in order to replace or adjust existing parts. With the new design of the frame this problem isn't nearly as big. At its worst the drive and turning wheel sections might have to be separated in order to adjust the turning wheel motor. Lastly, the resting top plate in the middle of the frame as seen in Figure 3 allows extra space for control of the BB8 head. Although our primary goal is to create a rolling dome first, thinking ahead to how the final product would have to work is important. This plate allows a servo motor to sit inside the shell with enough room to create an attachment that will allow a head to rest on top of the shell eventually. The idea behind this is magnets in the head of the BB8 and underneath the shell would attract the head of the BB8 to the shell, thus keeping the head attached as the robot rolls. The magnets inside of the shell would be attached to some sort of mechanism that is further attached to the servo motor that will rest on top of the plate. At the moment this section of the robot isn’t a priority, and most of the focus will be on making the robot actually move first.

With the new frame the turning wheels all get to have the same size gears. This make assembly of the robot easier sense the pieces now follow a very obvious pattern. With all of the design choices in place the last thing that is needed is custom parts.

Custom 3d printed parts will have to be made to allow the robot to function as intended. For the turning and drive wheels’ custom spacers need to be created that position the wheel to touch the inner surface of the sphere constantly while the robot rests inside the shell. The spacers that come with the VEX parts come in pre-determined sizes that don’t allow the wheels to fit as intended. The overall design and structure of the robot could have been adjusted to fix this issue, but the tradeoff is 3d printed structural parts. Instead of printing structure parts it was decided that it would be easier to print of simple spacers.

Another custom part that had to be made was the bracket that would hold the servo motor on the top plate that will eventually control the BB8 head. Initial designs of this bracket involved several sections that would rest against the servo motor to keep it stable. It also had 6 separate holes that would be used to fasten the bracket onto the middle top place of the frame. I reworked the part to be much smaller for a few different reasons. Firstly, the servo motor isn’t going to shift too much when in use, so the bracket that keeps the motor stable doesn’t need to be too strong in the first place, it just needs to have enough points to anchor the motor in place. Also, creating a smaller bracket would save on 3d printing costs. The newer bracket has 4 holes instead of 6 that are used to fasten the motor to the plate, and the positioning of these is set up so it doesn’t take up most of the space on the plate as previous designs did. On the next page you can see in Figure 4 what the most recent design of the BB8 is in solid works.

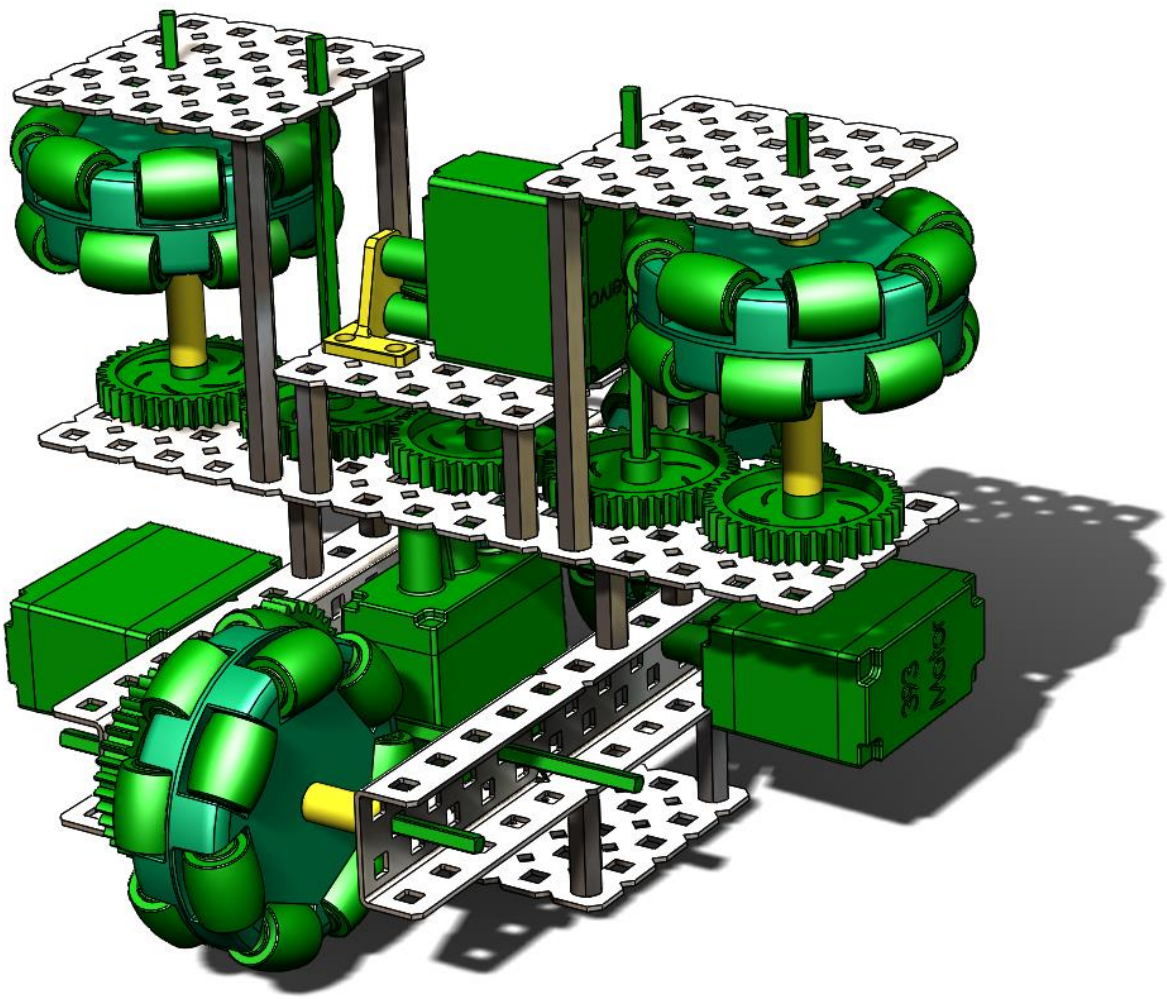

Figure 4: Most updated assembly of the BB8 VEX robot.

Things such as bolts and small washers are not included within the assembly that is shown in Figure 4. These pieces were functionally there with the use of the SolidWorks mating tool. This was done so any edits of the design wouldn't have as many parts, while still achieving the same intended goal.

Future goals for this BB8 robot is to create slots for the electronics that will control the robot (Arduino, motor drive, etc…) so they aren't rigged to the plates and channels of the robot. Personal decisions about the drafting process would also be changed if I had to create the VEX parts again. With my current library of parts, I didn't use any design tables to create subsects of the same part. This could have been done with several of the different sized but similar parts that the VEX library has. This would have cut down the number of parts that was created exponentially. Another useful aspect about creating the parts in this manor is that there would be less margin for error. If one of the plates wasn't the right size to match up as intended, then all the plates would be off by that same amount. This means that correcting inconsistencies within the measurements of the parts could be done much faster because the design table would automatically update the parts to the new specifications.

I would like to end this paper by saying thank-you to my advisor, Andy Bell, as well as the team members involved in the creation of the BB8 (Veronica and Dakota) for the advice on the design as well as the feedback received during this design process.