Creating a robot: From design to testing

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This paper is going to be an exploration of the thought and design processes which I go through when designing and building a Lego robot for Botball. It will be a look at the six or so different "stages" I go through when I design and build robots and the different ways that I look at these stages. If I write in third or second person read it as if I'm talking to myself. Some of this will not be incredibly insightful, and I'll try not to focus on this, but I think it can be helpful to making successful robots. Next I will provide some general design/building suggestions, and then finally a list of some cool examples of Lego to non-Lego connections and other construction tidbits. This paper is not designed to be anything more than my attempt to describe my design process and show some random things I have learned, hopefully it can be helpful.

(1)The Building and Design Process:

(1.1) Stage One: Strategy idea

The first thing to do of course is to get a basic idea for a strategy. How I usually do this is to try to think of the largest amount of points which are either: close together physically, or in a standardized form so that it can be collected easily. At this point I also try to think of what physical structure will collect the points and exactly where they are going to be placed to score. This stage can go easier when a group of people work together and discuss different strategies. This often allows for other people to see problems with the design that the original creator might not have seen. However if this method is followed too heavily, sometimes every idea gets shot down, and often it is worth it to continue working on an idea others have ridiculed if you think it can still work. At this point I have usually not determined the exact workings of the robot, just important areas such as whether or not the robot can move, or is stationary, and which points it will try to capture and where it will take them, etc. It is helpful to have a basic idea of how the robot will work, for example it will have an arm here, and a basket here, etc.

(1.2) Phase Two: Design details

After I have the basic strategy worked out I then start thinking about the actual design of the robot seriously. This can be hard since a design on paper or in the mind never quite works the same as it does in reality. I start out by deciding simple things such as if the robot will have wheels, how many wheels? How many motors will these wheels have? How will the robot steer? How many arms will the robot have? And so forth. Then once I have a basic idea of these things I can focus on the most important part of any robot, the moving parts. Moving parts are important for several reasons; the first is that they actually perform the motion of the robot, and the second is that most problems occur at these places so special care should be given to designing them.

The actual places where pieces move are special and require the most care in designing. When designing these a few things ought to be kept in mind. When building a robot, try to make the "core" area (chassis) and the base movement-places of arms the strongest and most solid parts of the robot since they support the rest of it. Before going too far into further design, lock down what actuators will actually move the part. Make sure that the force of these actuators and range of movement are appropriate for the desired range of motion and expected force. For example if something needs a lot of force, I usually use a pulley and fishing line because this can produce a very large amount of force and is very flexible. Investing time thinking through these moving places can prevent many problems down the road caused by weak or impossible-to-design, yet very crucial pieces.

During this design phase I usually work outward from the center of the bot, thinking through the details of the joints and then leave the rest, like lengths of various sections, exact shape and size of chassis to later. The important thing is to make sure that all of the necessary joints are physically possible and plausible given the motors and servos that are available. At this point if I honestly cannot think of a way to make one of these work I will go back and rethink the whole strategy instead of starting to make something that probably won't work well in the end anyway.

(1.3) Phase Three: Beginning Building

Ok, so now once I have thought through all of the joints and wheel patterns, basically how every motor/servo is going to be used, I actually start building. I usually start by building the chassis and adding the wheels and motors. I always make sure that this is very solid and is not going to be too weak or break constantly. This is very important because if the base can't drive correctly, all of the fancy arms and baskets you have designed are useless.

After I have the base worked out I start by building the cores of the moving joints and any important pieces and then I add random "filler" pieces to connect these pieces together. The point of the filler pieces is to have a prototype where I can test to make sure that all of the joints work together and that any special pieces, such as claws, actually work. Essentially I test each piece individually and then in relation to the other parts with out worrying too much about the pieces in-between.

(1.4) Phase Four: More building…

If all of the important pieces (Joints, claws, etc) seem to work, I will then start refining the "filler" material and making connections between the different joints and other important pieces. This usually consists of changing the lengths of beams, adding more pieces to arms and the chassis to add strength, and finalizing the mounting of the motors/servos and the controller. The important thing to do here is just basically connect all of the pieces together and make the whole structure more solid. Sometimes arms need to be tested with the robot running through what it will actually do to get exact lengths for arms and pieces. I basically just try to crudely put all of the pieces together until I have something that appears to do what is required of it.

(1.5) Phase Five: Even more building

At this point most of the robot's structure should work and all of the moving parts' functionality should be tested. Now I usually just sit around and yell at the programmers to hurry up. Also I try to figure out what sensors the programmers want and where they want them (sometimes I give suggestions). I then integrate these sensors into the rest of the design. About this time I also usually go over the robot and try very hard to find places where either pieces are used inefficiently, or places that are poorly engineered. I spend a whole lot of time changing out pieces such as axels that are unnecessarily long, or extra pins. Also if I ever find a place that looks like it needs some added strength or is a little weak I always spend the time to try to rebuild it. Basically at this point I spend time just perfecting the design and adding any more necessary pieces.

(1.6) Phase Six: Tweaking/Testing

I have finally made it to the last stage! This is the tweaking and testing stage. Here I usually run the robot with whatever program the programmers have coughed up and try to find anything that goes wrong. I also look for wear in pieces or structures that keep coming apart after use. These are signs that something needs to be redesigned. So in this last phase, I again redesign and rebuild anything that has any sort of problem whatsoever and also test the robot as many times as possible.

(2) General Design Suggestions

I have been playing with Legos since I was two or so, and I have been working on a Botball team since I was in sixth grade. In doing all of this I have learned many valuable things along the way. The following are just simple ideas that I have learned that can help make designing and building robots more successful.

2.1. Always rebuild/redesign constantly. This is probably the most important thing I can tell anyone wanting to design great robots. What I mean is to always rebuild something if you see an obvious way that it could be better, or something that after considerable building you think “I wish I had done it this way.” There have been times when I have a robot that is very compact and very difficult to take apart and then I realize there are two beams at the very center that would be better if they were two holes longer, or something similar to this. I will *always* go back, spend an hour or whatever it takes rebuilding the robot to fix this. Sometimes I will realize that the beams were better the way they were, but most of the time it helps. When you adopt this habit as a general rule you end up with robots that you are satisfied with instead of pieces of junk with more junk added to them which break all of the time. Always rebuild regardless of how much time it might take.

2.2. Spend as much time possible observing other teams' robots. This is almost as important as the first suggestion. It always surprises me how differently and intelligently teams solve problems on their robots. I spend a very large amount of time at tournaments looking closely at other teams' robots, most of the time the other teams are more than willing to let me do this. I have learned more about how to build robots from this than any one other thing. So look at other teams' robots, and when you discover any cool ideas, shamelessly adopt them and use them as soon as possible.

2.3. If you use gears, try to use them with the spacing they were built for. Maybe this suggestion is sort of lame, but I have seen countless robots which had random gears connected together in non-standard forms that produce the dreaded "clicking" sound whenever stress is applied to them. I almost always use standard spacing, and also hear very few "clicking noises." This clicking happens because Lego gears are designed to work in very specific arrangements, and work very well in these specific arrangements. While occasionally non-standard configurations work, it usually is a much more secure connection to put them they way they are supposed to be. By "the way they are supposed to" I mean along one beam with the right number of holes in-between (for example the 24-tooth gears this is two holes)

2.4. If you can help it, don't use glue or tape. I pride myself on having not used any glue or tape on the vast majority of robots I have built over the last four years. The reasons I recommend this is that connections involving just Legos (I will give some examples in the next section) are a whole lot easier to change, usually are stronger, and simply look better. I have thought up many different of these ideas in my head but I have probably learned more from looking at the other people's robots.

(3) Section Three: Fun Non-Lego to Lego connections

There are too many of these that I have learned to show them all here but I will try to get to some of the most important. This is very hard to do without pictures (I might get them later) but I will try nonetheless.

3.1. Mounting servos to Legos

One great way to do this is by putting black Lego pins through the two top holes on the sides of the servo. I then put two short beams in them going up. After this a regular beam just so happens to fit across the whole servo with a perfect spacing of 5 holes in-between.

or

you can put 3-long pins in all four holes and take two length beams and put them on the pins so that their two open holes line up. Then put an axel through this and the servo has mounting places on the same plane as its rotation.

3.2. Mounting stuff to servo horns

Using screws is the best way to do this. My favorite way to do this is to take the white round horn and put two screws into either a 24-tooth gear or one of those weird four-pointed rounded gear-type pieces. This configuration allows for an axel to be securely mounted right at the center where the servo rotates.

3.3. Mounting various sensors.

ET: One interesting way I have seen to mount ET's is by using that flexible tubing and putting it through the two holes, which happen to be about six Lego holes apart.

Medium Touch sensors: try placing the square part of the sensors between two axels with one space between them and beams on either side.

Large Touch sensor: Use three-long pins and put them into the areas between the metal pieces and the glue and then attach the pins to beams.