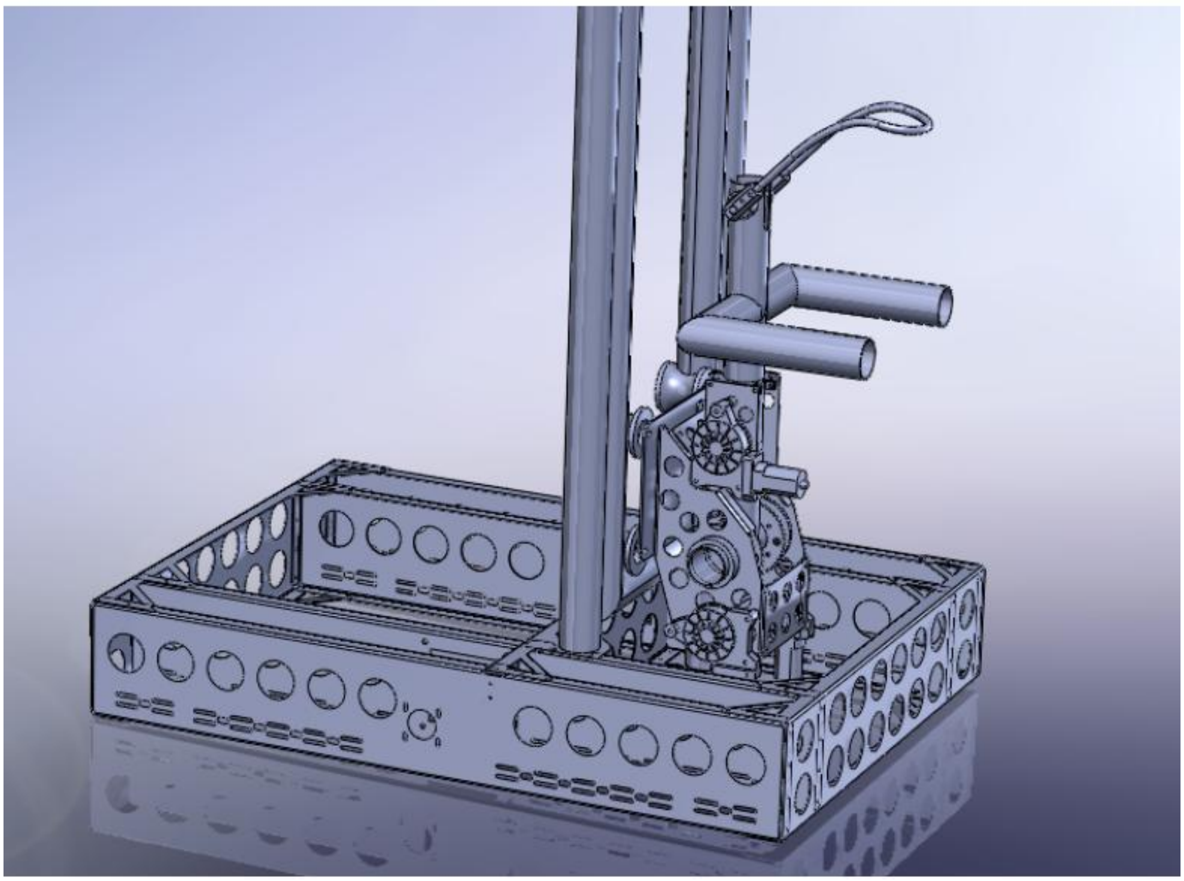
Team 67

HOT



Design Portfolio

Design Intent:

The HOT team set out to build a main robot that could place the uber tubes on the top row during the autonomous mode, pick up logo tubes from any location and placing them in any location on the scoring rack, and deploy a minibot that could reach the top of the 10 foot pole in less than one second. It needed to have simple and robust components that had offensive and defensive functions.

Main Robot:

Before we began our main robot design, we reviewed previous robot design concepts to look for ideas we could use in this year's robot and included these concepts to the list of ideas we had come up with for this year. Based on the information in the game manual, the team created a weighted decision table to prioritize each function. We worked on calculating a weighted scoring analysis to create a Robot Function priority list that our lead mentors Jim Meyer and Adam Freeman came up with. Weighted analysis took into account Importance, Complexity, Limiting Function, and Winning Functions. Each function was ranked for the criteria and then assigned a value. Each criteria was then assigned a multiplier value. At this point we were not sure if our weighted list was really dictating the basic robot design and function any more than a general robot function list ranked by importance. All rankings were generated based on intuition and experience, not prototyping at this point. The use of this table allowed us to focus and concentrate on key functions during the design process.

Robot Functions	Weighted Score
Handle all Game Pieces	397
Able to Push (Defense)	328
Fast / Agile	314
Pick from Floor	285
Auto Top Row	258
Tele-op Top Row	254
Minibot Capability	241
Tele-op Mid Row	238
Reposition Tubes	230
Load from Human Player Station	213
Tele-op Bottom Row	153
Hold Pieces within bumper perimeter	131
Self Righting	52

The main robot design that the team decided on, composed of three different design functions: a minibot deployment, drive train, and an arm on an elevator for placing the tubes. We reviewed several different robot designs from previous years and other teams. Using this benchmark data, we evaluated each of these three functions to determine their importance. Every component was designed for its functionality and robustness.

From our benchmark data, we looked at several designs from teams. We studied roller designs from 67 and 148, clamp style manipulators from 1114, and elevator designs from 254 and 968 through pictures and videos. From these ideas that the team looked at, team members Alex Garrigo and Greg Ponti presented a claw concept that had two stationary posts separated at a specific distance that would line the tubes up to the robot as the claw grabbed the tubes from the hole in the middle. This claw idea would be put on an arm so that the tubes can be pivoted to the point where we could hang them. The arm would be placed on an elevator instead of a more complex arm. An elevator with a simple one point pivot arm would ensure that we did not break the 80 inch perimeter around the robot, where as a multi-pivot arm would not be as effective to stay within this restraint.

<u>The Claw and Elevator:</u>

We decided to use this claw/elevator concept because of its simplicity and robustness but more importantly it could pick up any game piece from any angle and would be able to release them quickly and smoothly. Although our first idea was to make another roller manipulator like we had in 2007, but we rejected this concept because we had issues with tubes getting stuck in the rollers and we wanted to avoid this issue this year in order to hang as many tubes as possible. With Alex and Greg's claw idea, the tubes would be grabbed by adding enough pressure to the tubes to be able to manipulate them in any manner necessary. This would also provide an easy release since all that needed to be done was release the pressure on the tubes.

Inspiration for potential robot designs:

1114 Clamp Claw

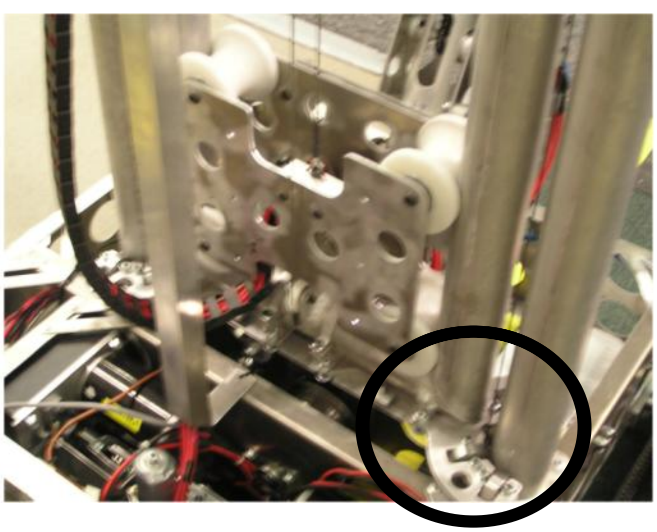
254/968 Elevator

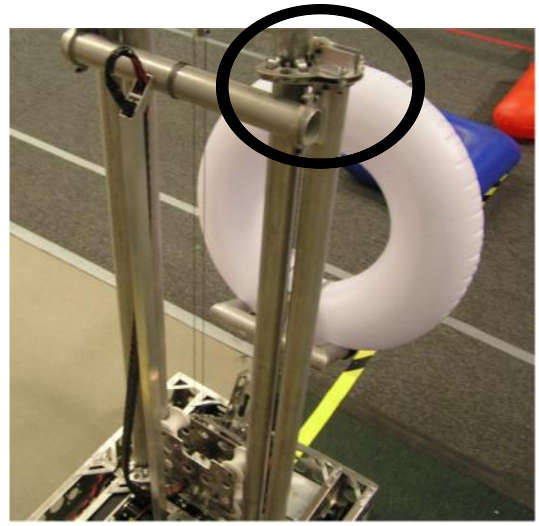
We created a prototype of the three point claw to check its geometry. The prototype proved that it would work for all of the game pieces and at any orientation. Based on our prototype, we knew some geometry changes of the stationary posts and profile of the claw were necessary to optimize the grip it had on all of the tubes. After testing this prototype, we noticed that the distance between the two stationary posts needed to be increased by about two inches.

We decided to use an elevator lift style due to the 60 inch rule that limited the swing of a traditional arm. For our elevator, we utilize a unique two-stage design allowing the arm to rise at twice the rate it would in a single stage elevator design. This is accomplished using two series of pulleys each running through one stage of the elevator. The elevator frame contains two crab claw shaped linear bearings with four wheel bearings to locate the first stage with minimal friction inside a stationary tubular frame. The first stage, on the other hand, includes two lobster tail shaped linear bearings to maintain it on the same horizontal plane as the outer tubes. Two banebots mounted in a tough box extend the first stage to its full height. As the banebots power the first stage upwards, the second stage (containing the arm/claw) moves up at the same rate. The banebots are connected to jaguars for speed control. This allows the elevator to ascend quickly to place tubes; and because the jaguars are on break mode the elevator descends slowly on its own. The second stage itself is not connected to these banebots, but its pulley system includes a part of the elevator frame so that as the first stage moves upwards, the second stage moves upwards at the same rate. The second stage has four hard plastic rollers that hold it securely to the first stage.

The claw motor assemblies are attached to the elevator platform. Because the elevator is set back from the front edge of the robot, after the claw grabs a tube, it has an arm that rotates the game piece up into a vertical position ready for hanging. There are three window motors wired to the arm. Two of the window motors allow the arm to rotate up and down. The third window motor controls the claw and its rotation. Because the game piece is held within the robot frame it makes it difficult for an opponent to grab and steal the piece away from our robot. This also allows our robot to maintain solid control of the game piece during both transport and placement.

The elevator system is positioned by feedback control from a standard quadrature encoder mounted on the banebot driven tough box. The position of the elevator mounted arm is monitored with a potentiometer. The drive system is also monitored by encoders. The information from the encoder and potentiometer enables the HOT Bot to place uber tubes during the autonomous period. Another autonomous option is to use light sensors to follow tape lines to the scoring grid. These controls are used in the teleoperated period as presets for arm and elevator positioning. The controls can be overridden by the driver to provide more precise tube placing capability.





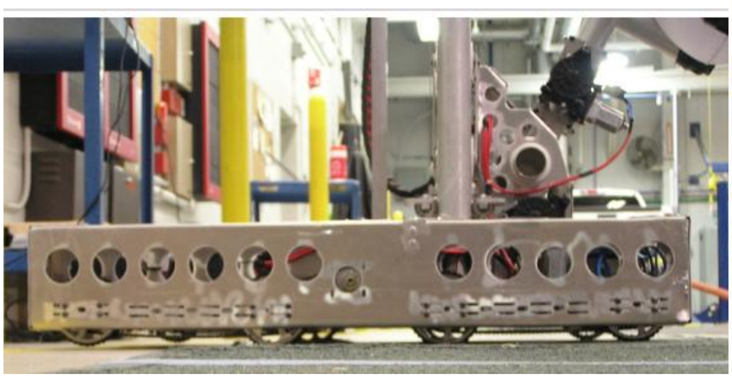
The two stage elevator with its lobster tail bearings on the left, and crab claw bearings on the right

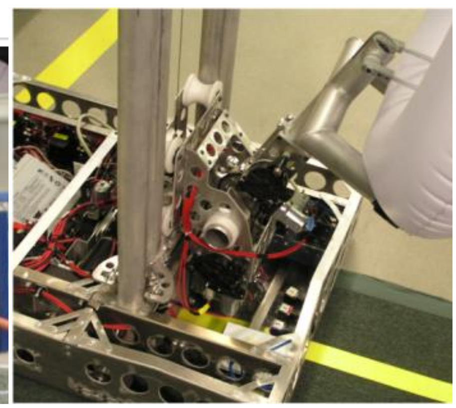
Frame and Drivetrain:

We needed a drive train that was able to maneuver around opponents, get across the field quickly, and push other robots out of our way if need be. We decided to use a similar 8 wheel tank drive train from our 2010 robot but instead of using two different sized wheels, we had eight 4 inch treaded aluminum wheels. The outer four wheels are elevated 1/8 inch off of the ground so that 4 wheels would always be in contact with the floor. We did this so that when we are being pushed, the robot would have six wheels contacting the ground to provide extra traction for defense. Their tight spacing of the center four wheels gives the robot a tight turning radius, making it very agile.

Our ground speed target was 16 ft/sec with no load. We set this target based on our review of previous robots and the max speeds and their correspondence with their efficiency during competitions. With this gathered info we decided that a faster robot allowed for more points to be scored during competition. In order to accomplish this goal, we powered our drive train with 2 CIM motors per side with super shifters.

Our frame base is made from 1/16" 6061 aluminum sheet metal. We use a water jet to cut the frame out and to reduce weight, holes were cut out. Then the frame was bent to give it its strength and then riveted together. This provides us with a very light and robust frame that can contain all of our components.





Mini Bot:

We worked on ten different basic mini bot designs. Most of the designs contained versions of a hook structure that used gravity to create grip on the pole as the mini bot climbed. On one side of the pole two small wheels were stationed at slight angles, in opposition to the main drive wheel on the other side. The main drive wheel was powered by two direct drive motors, placed on each side of the wheel. The battery was placed behind the main drive wheel on an extension, away from the pole, to provide leverage for the wheel to grip the pole.

The Textrix kit of parts supplied gearboxes that had a 52:1 gear reduction, and peak torque output of 0.86 ft-lbs. We did a spreadsheet to show optimum torque/weight ratio to find our final gear ratio based on estimated weight. We estimated weight by placing motors and battery on a scale and adding switches, sheet aluminum, etc. Original weight was about 3.5 lbs. This got us a ballpark to start building for a 12" equivalent wheel direct driven. Since we were using either a 4" or 3" wheel from the kit, this meant a 3:1 or 4:1 ratio. A 3:1 ratio with the tetrix gears was possible by driving a 40T gear with a 120T gear, so we used that. This was the design that used the cantilevered frame, and it confirmed the stated torque output of the motors.

					Bot total weight (lb)			
		2	2.75	3	3.25	3.5	4	5
	4			0.25	0.27	0.29	0.33	0.42
Wheel Dia	5			0.31	0.34	0.36	0.42	0.52
	6			0.38	0.41	0.44	0.50	0.63
	8			0.50	0.54	0.58	0.67	0.83
	10			0.63	0.68	0.73	0.83	1.04
	12			0.75	0.81	0.88	1.00	1.25
	13			0.81	0.88			
	14		0.80	0.88	0.95	1.02	1.17	1.46
	15		0.86	0.94				

It was then revealed that the supplied gearboxes were indeed able to be modified within the rules. So instead of using the gearbox to gear 'down' the motor and then use big gears to gear it back 'up' accordingly, we decided to set up the gearbox to simply gear down less and use a 3" wheel. So we multiplied the 52:1 by the 4:1 and came up with a desired 13:1 for a 3" wheel.

Minibot						
gearbox	52.0	: 1				
gear ratio	3.0	: 1				
wheel diameter	4.0	"				
Ratio for 4" wheel	17.3	: 1				
Ratio for 3" wheel	13	: 1				
Kit TETRIX Gearbox						
Motor	10	26				2.6
2nd stage		10	30			3.0
3rd stage			15	25		1.7
4th stage				10	40	4.0
						52.0
						17.3
67 Custom Gearbox 1						
Motor	10	26				2.6
2nd stage		15	25			1.7
3rd stage			10	40		4.0
						17.3
67 Custom Gearbox 2						
Motor	10	26				2.6
2nd stage		10	40			4.0
						10.4

The 10.4:1 would provide a faster time, given we could cut a little weight, so we went with that. We then removed the extra gears and cut down the gearboxes and fabricated parts to fit from the existing components. This resulted in a much faster, more efficient drive train, cutting time from 2.7 seconds to about 2 seconds.

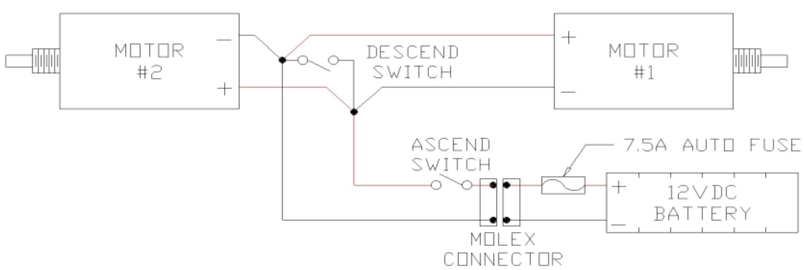
Our prototypes that was able to achieve 2.7 seconds, tended to fall off the pole. By mini bot prototype number nine, we were able to achieve a mini bot that climbed the pole in 1.5 seconds. Unfortunately by that point, the velocity became too great for the structure of the mini bot. This required us to make some structural modifications to the mini bot frame.

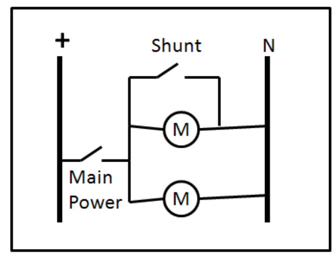
In the midst of this change, we found the cantilever design to require a more complicated deployment. Although it was more robust at staying on the pole, it took longer to deploy, so we moved to a hinged finger design using surgical tubing.

This design proved to be too difficult to keep on the pole and also resulted in numerous problems with the modified gearboxes (gears breaking, press fit bushings coming loose, etc). Traction also was an issue in the non-cantilevered setup.

So we moved to a direct drive design with a very small diameter 'wheel' made from neoprene cord over aluminum rod. We also experimented with using magnets to hold the minibot on the steel pole, and eventually went with a hybrid finger/magnet set up where the magnets are mounted at the ends of the fingers to hold them together, thus holding the bot on the pole.
We continue to look for ways to cut weight and increase the gear ratio by using larger rods inside the neoprene cord.

Another development challenge was finding a way to turn off the minibot and bring it slowly down the pole. We experimented with the switches that were supplied and found that if mounted at the very top at a 10-15 degree angle, they would flip when hitting the top plate of the pole. A second switch was added to 'shunt' the motors at the top, making them spin slower on descent. A 'finger' was also added to the deployment setup to turn on the power switch as it moves out of the host bot.





“Shunt” open at start, then set to closed by hitting top plate.
“Main Power” open at start, then closed by ‘finger’, then open again by hitting top plate.

As the season progressed we realized that the aluminum frame of our minibot caused surplus friction between our ‘wheels’ and the pole by not allowing the ‘wheels’ to flex outwards accordingly. We realized that this friction actually slowed our minibot climb rate so to fix it and reduce some weight, we substituted the aluminum frame with a Lexan frame. Now that we had fixed this friction problem, another problem arose. Originally the two switches we had on the top of the frame were more towards the center. With the Lexan frame, they would flex down once the minibot hit the top of the pole and probobly not trigger both switches. To accommodate for this, we moved the switches to the sides (of the top) of the frame and added a triangle support to strengthen the frame.

Deployment:

Our deployment consists of two stages, the first stage provides a rough alignment to the pole and the second stage actually deploys the minibot onto the pole. The first stage made of the same 1/16 inch thick, 2 inch diameter aluminum tubing used for the elevator that is welded together to give it its stability. To deploy this stage, we trigger a servo which opens the latch of a trunk latch releasing two 30 Ib gas struts (one on each side) that push the first stage out six inches. These six inches allow the vertical poles of the deployement frame to contact the base of the tower and provide the minibot its rough alignment to the pole.

The second stage is a little more complicated since it is powered by both constant force springs and surgical tubing. Inside the deployment frame we had two 20 inch drawer slides where we have attached our lexan tray that holds the minibot. The bottom of this tray is attached to a piece of 20 inch aluminum that stretches the constant force springs when the second stage is loaded. These springs alone gave us incredible speed and accuracy but in order to be competitive with other top robots we decided to utilize surgical tubing at the top of the tray to increase the speed of the deployement by another half second. On both sides of the deployement tray we half riveted two rivets so that the aluminum rod would be locked in place. We tied one end of a 4 inch long piece of surgicale tubing to a ¼ inch washer with zip ties and then zip tied the other end of the surgical tubing to the vertical tubes of the deployement frame. The advantage of utilizing these rivets and washers this way allows the surgical tubing to help accelerate the try to the pole but once the tray nears the pole, the washers fall off the rivets and do not hinder the deployement at all.

Summary:

As you can see, simple but efficient shapes and designs were used to achieve our targeted capabilities. We used methodical evaluations and processes, utilizing fundamental engineering practices based on the basic laws of physics. By using sturdy tubing, light weight materials and components, and simple shapes, we were able to achieve a high degree of reliable functionality resulting in an efficient platform and a very robust design.

Here are Pictures of our completed robot.