Urban Search & Rescue Proposal

Lil' Dragon Runner

Team 1

Introduction

After the completion of the Gates Center for Computer Science there was a terrible accident that left the building in ruins and various individuals trapped inside. Carnegie Urban Rescue Force (CURF) has petition team 1, amongst other teams, for the rapid prototyping, development, and deployment of a small urban rescue robot. This robot, through teleoperation, must be able to traverse rubble and urban terrain in its search for survivors. Towards this purpose Team 1 is ready and enthusiastic about developing this small mobile platform to search for survivors as quickly and effectively as possible.

In this proposal we will outline the objectives of our robot as well as present our main design along with some other, secondary designs. We will also present a set of criteria which we will use to objectively rate our designs.

Objectives

As our robot's name suggests, our design was inspired by Carnegie Mellon's Dragon Runner. This robot is a small and tough machine that can quickly cross all kinds of terrain with little regards for its safety. We find this to be extremely important in any platform that aims for speed and traversal of adverse terrain.

The objectives of our robot will be to find as many survivors as quickly as possible. For this we will need to be able to traverse adverse environments quickly. We will also need to be able to survive some rough handling in order to be able to travel through the terrain quicker via a need for less teleoperated precision on the part of the human operators.

Towards this, the set of criteria or metrics used for evaluations are: speed, ruggedness, ability to function flipped over, complexity of the design, percent of powered ground points, and visibility, ground clearance, and ability to traverse adverse terrain.

Speed

We find that the speed of the robot is essential to its success. This is due to the small time-window the survivors have to be found. Per this we put a lot of emphasis on the speed of our designs.

Ruggedness

Although speed is important, ruggedness is key for quick execution. If a robot is fragile it cannot clear obstacles easily since it must slow down in order to be cautious. We propose a rugged build for the robot in order to allow for a larger margin of error in human operation and thus increase the speed the robot can achieve in operation.

Ability to Function Flipped Over

Important to this metric is center of gravity. Given a low center of gravity this ability turns less important but towards our policy of ruggedness we find it essential to be able to effectively function no matter the orientation of the robot.

Complexity of Design

The complexity of the design is greatly tied to the robot's overall ability to take damage. If a design is complex, there are many points of failure and thus more caution must go into its operation.

Percent of Powered Ground Points

If a robot has n points of contact with the ground, a large number of these must be powered. This allows the robot to have a lower chance to be caught up in any obstacles.

Visibility

The robot's ability to locate survivors is greatly dependent on its ability to see. This ability to see is characterized by the amount a robot's camera can vie at any given time.

Ground Clearance

A robot's ground clearance is crucial for it to be able to go over rubble as well as bumps.

Ability to Traverse Adverse Terrain

This metric is a key to our entire design since it is a good summation of a robots complexity, ground clearance, and ruggedness.

Design Alternatives

While designing Lil' Dragon Runner we came across a few concepts and design ideas that helped us reach our final design for this proposal. Some of these designs were:

Original Robot

Our first and original design was based on our current robot design for previous challenges as shown in Fig.1. This robot has two wheels directly driven by the NXT motors with a third caster wheel on the back. The NXT controller was mounted vertically in the middle of the robot. The camera would also be mounted on top of the wheelbase next to the NXT controller and would be panned via a third motor placed in the base as well.

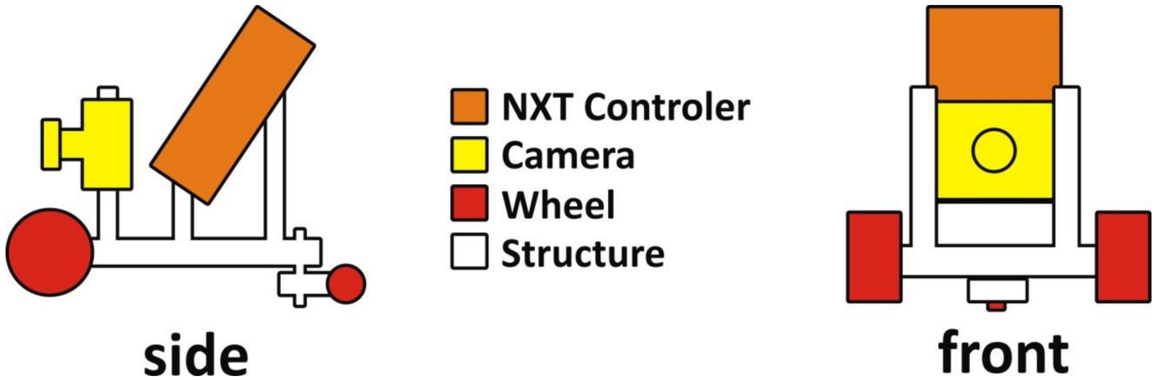


Fig. 1: Original Robot Design

Advantages of this design included its low level of complexity as well as its speed. Due to its direct drive it could operate the wheels at the motor's top speed. It also receives good visibility markings due to its high placement of the camera and ability to pan it.

The drawbacks to its design are based on its caster. The caster proves to be a point of failure since it is very possible for the caster to get stuck while going over rugged terrain. The caster is also a non-powered ground point and looses merit in that metric as well. The robot has a very low ground clearance and does not function flipped over at all. We find this design to be less rugged than desired since its caster gets in the way and its single set of wheels prove to be less than adequate for going over obstacles.

Finally, due to all the above, the robot does not have a very good ability to traverse adverse terrain. We did not choose this design due to its low ground-clearance and lack of ruggedness. Given our dedication to these ideas, we chose to go with an alternate design

Plate of Wheels

Given the drawbacks of our original design we tried to build one that provided more points of contacts with the ground and allowed us to traverse more rugged terrain while still keeping high speed and visibility.

Towards this end we came up with the plate of wheel design as represented in Fig.2. This design is basically the NXT controller and a panning camera mounted on top of the plate of wheel. This "plate of wheels" is a set of 4 wheels on each side where two center wheels are in contact with the ground. The other two wheels are slightly elevated over the center wheels allowing room for tilting while keeping the robot in control.

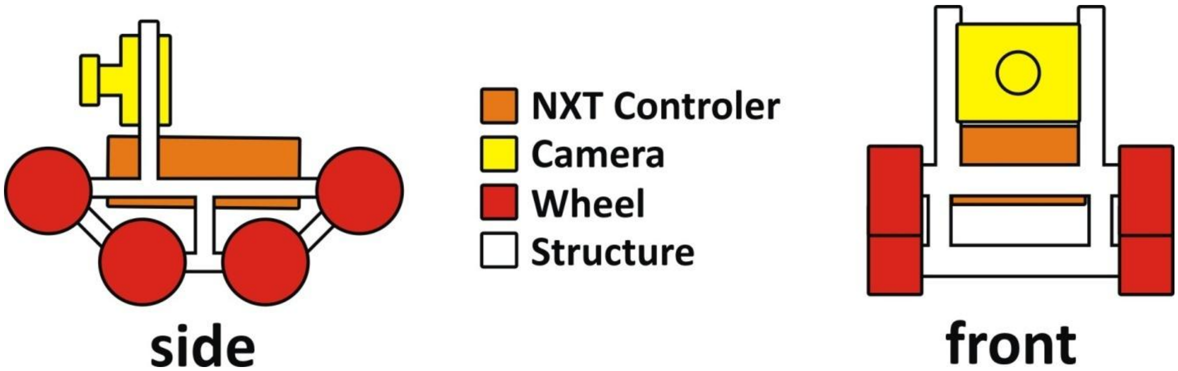


Fig. 2: The Plate of Wheels Design

This design had the advantage of being more rugged than the original one. It has good visibility due to its panning camera and had a high speed due to its direct-drive strategy as well. The robot had the ability to go over rougher terrain due to its more advanced wheel setup. It also exhibited 100% power of ground contacts.

This robot had a low ground clearance as well as a more complicated design due to its large number of powered wheels. This design is unable to operate flipped over. It is also less rugged than desirable since there are a large amount of positions from which it cannot move. Finally, it does not properly traverse adverse terrain due to its lack of ruggedness. This, in turn, does not allow it to reach its top speed.

We decided not to pursue this design since it lacked the ability to flip over and it had a large number of angles from which it might not be able to recover. If it tipped forwards too much it could possible never get up again. This was of particular concern when the robot would be traversing inclines or stairs.

Tank/Car

This design builds from the plate of wheel with some additions. We started to take the ability to flip over as a more important aspect of ruggedness and thus used it thoroughly in this design.

This robot has a vertical tank tread in the front. It functions as a wall of treads in front of the robot and a wheel at the point where it contacts the floor. On the back, the robot has a set of small wheels. This robot was designed to rely on its treads to traverse obstacles front-first. There is a fixed camera in the center of the robot.

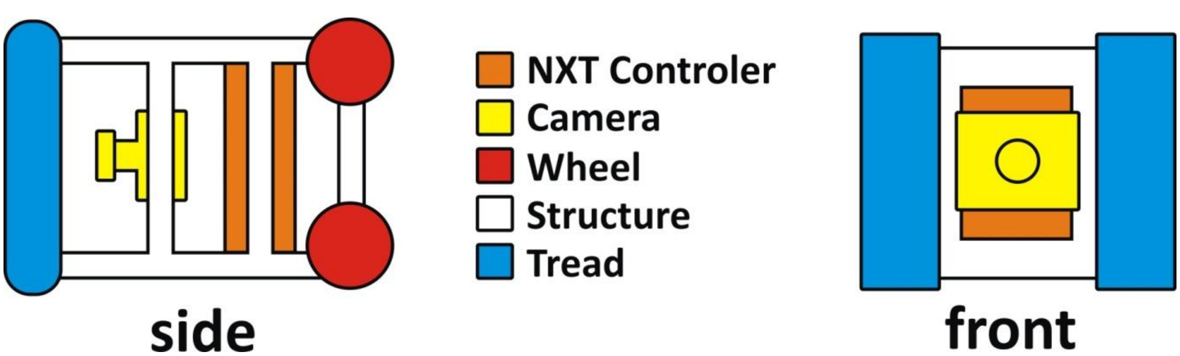


Fig. 3: Tank/Car Design

The advantages of this design start with its ability to go over many terrains as well as its ability to function flipped over. This greatly increased the ruggedness of the design. It also has 100% powered ground contacts.

However, this design has some major disadvantages. The speed was greatly decreased by the use of treads. These treads also forced us to have an even lower ground clearance. The visibility of the system was greatly decreased by the fixed camera. The design was also perceived as rather bulky. It took up all available space in the dimensions. Finally, this design was rather complex due to the necessity for a level of tightness in the treads.

We did not choose to pursue the development of this design since we seemed to lose a lot of ground clearance and visibility while gaining some ruggedness.

8-Wheels

This design's main goal was ground clearance and speed while still maintaining the ruggedness we had achieved before. To do this we chose to get rid of the treads and to increase the diameter of the wheels.

This design features four wheels on each side. One left one right and a second pair on the "top" of the robot. The same setup was achieved in the "back" of the robot. The camera was still held in place however, but it was moved to the front-center of the chassis.

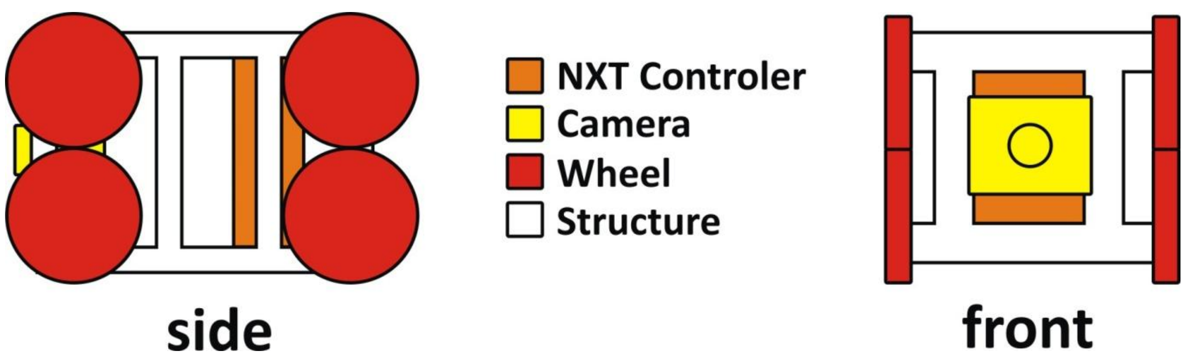


Fig.4: 8-Wheels Desgin

This robot's larger wheel allowed us to have a much larger ground clearance. We also directly drove the motors so we were able to once again attain good speed. We had a rugged design able to function flipped over. It was also less complex that the treaded approach and had the same 100% powered ground contact.

This design was also rather bulky and large. It also had the failure of lacking functionality if it was tipped onto its side due to wheel of small width. It had bad visibility since it had an unmovable camera that resided on a fixed point.

We thought we were close with this design but chose to pursue one final redesign in order to decrease the size of the chassis, to increase the visibility of the design, and allow for the robot to function if tipped to the side. We wanted a smaller chassis for us to have more room to move the robot.

Proposed Design

Lil' Dragon Runner has 8 wheels. Three are small and wide wheels and two are large and thin wheels. The thin wheels are in the back of the robot while the six large wheels are in the front with a center wheel placed further forward than the other two. All wheels are powered direct drive from two NXT motors.

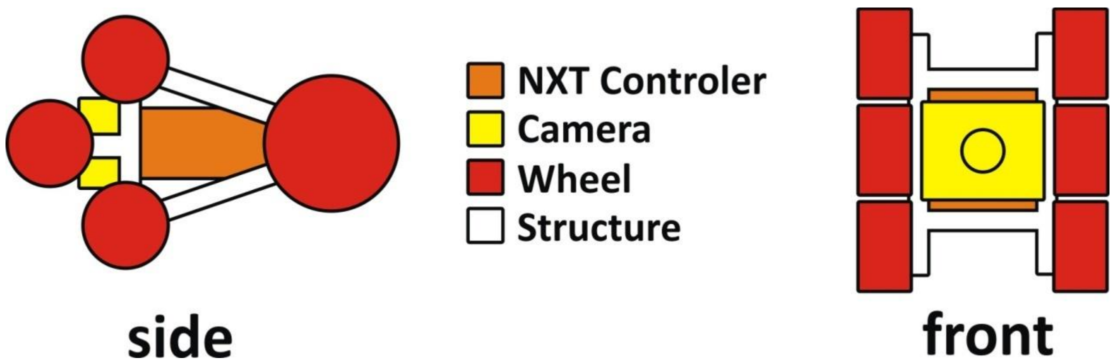


Fig. 5: Proposed Design

Advantages, Drawbacks, and Pitfalls

This design allows Lil' Dragon Runner to traverse adverse terrain easily. It is able to climb over obstacles with it's from wheels and the width of these allows for good traction. The one offset wheel is especially good for scaling obstacles. It has great speed due to its direct drive. It also has a high ruggedness thanks to the full-wheel design and the compactness of the robot. There is no weak point in the frame; it is all one connected piece. The robot does have the ability to function flipped over. It also has 100% powered ground points; all 4 wheels that touch the ground at any point are powered. The robot has a much higher degree of visibility than the above designs. It can tilt its camera and look forward. The camera is also placed at the front of the robot and thus has an unobstructed view of its path. This robot has a high ability to traverse adverse terrain due to its large number of wheels and their placement all around the robots. The wheels are the only thing to contact the floor no matter how the robot is positioned. This allows the robot to have the ability to recover if it is tipped from a side. This final revision features a smaller chassis than the above designs. We believe this has added to the compactness of the robot and thus to its ruggedness.

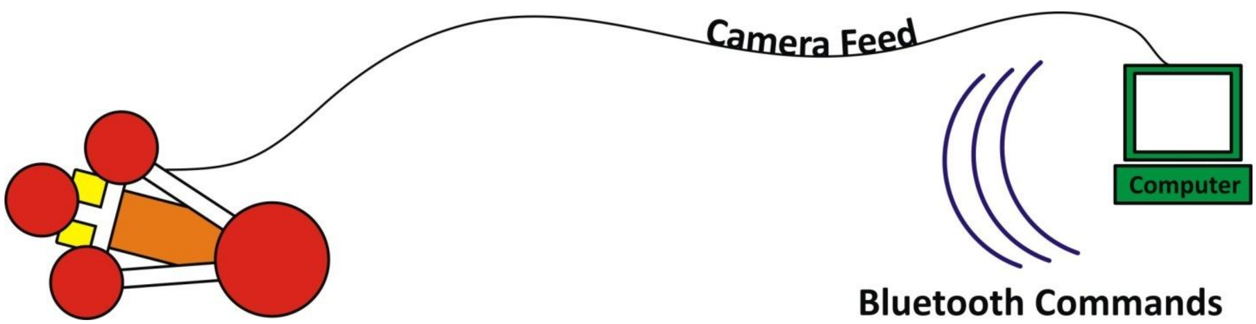
The three main pitfalls of this design are low ground clearance, no panning of the camera, and relatively high complexity. The robot has a somewhat low ground clearance, it is the same or higher than most of the above designs but we fear that it might still be too low for some obstacles. We do not have the ability to pan our camera, we believe that this lowers our overall visibility but given our 3 motor limit we do not foresee this being fixed. Finally, the high complexity of the design is a detriment to the reliability of the system. However, due to all the other advantages of this design, we chose to use this design anyways.

Theory of Operation

Lil' Dragon Runner will be deployed into a building to seek out survivors. Its main goal is to find as many people as possible as fast as possible in order to increase the likely hood of the survivors being alive. In order to do this, Lil' Dragon Runner is designed to quickly traverse any terrain and in doing so cover as much ground as possible while looking for survivors. Lil' Dragon Runner was designed with ruggedness in mind and thus can quickly traverse obstacles with little or no regard for its well-being.

The robot will climb stairs whenever necessary. Given doors, it will attempt to open them with force. Rocks, cars, and other obstacles are either climbed or avoided depending on their size.

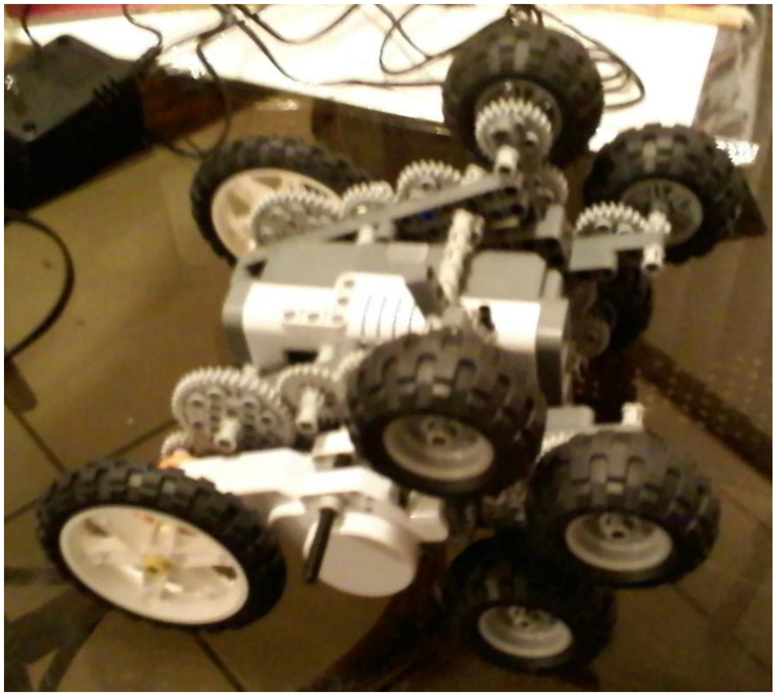
Lil' Dragon Runner will be remote controlled via Bluetooth. He will also transmit real time images from its current position via a 50*ft* tether. This tether will be connected to a computer that is also controlling the robot via Bluetooth.



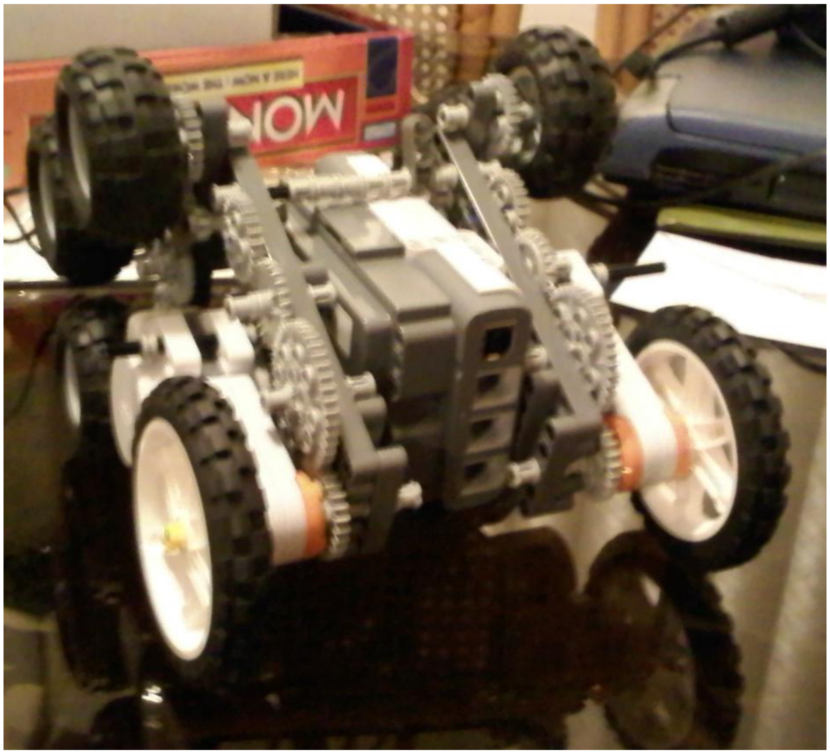
The human operator team will operate Lil' Dragon Runner as he goes room by room finding survivors.

The physical design calls for two mirrored sides connected by the NXT controller. These two sides have an NXT motor driving the back wheel and then a set of gears transferring power to the front three wheels. All of the wheels spin in the same direction, thus when the robot flips over the direction the motors spin must change as well.

One of the robot's side modules. Notice the 4 wheels, the set of gears, and the NXT motor

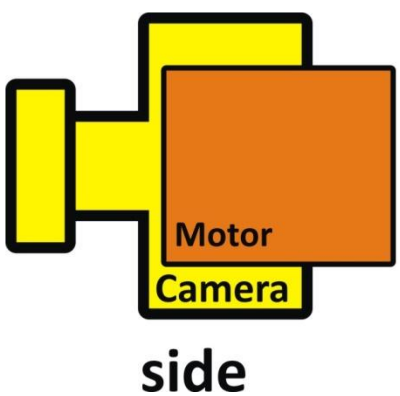

Current prototype. Notice the NXT controller in the center.

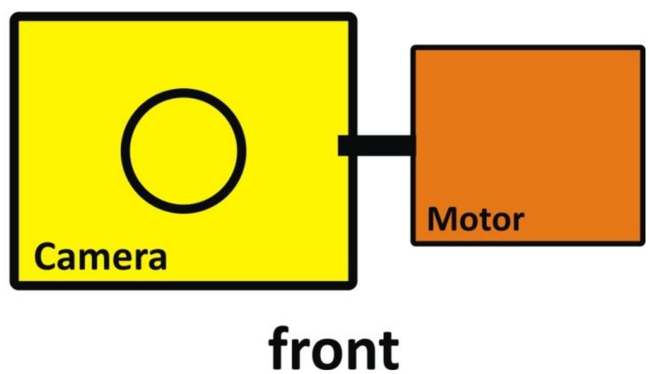

Current prototype. Front view. The vision system will go in between the two front-most wheels



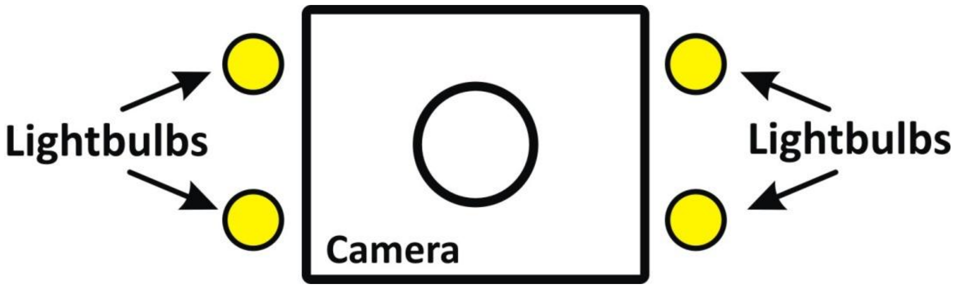
Current prototype. Back view

Lil' Dragon Runner's camera system is comprised of an RCX motor directly attached to a small webcam (see Requested Parts Budget). This allows the camera to be tilted according to the rotation of the motor. The RCX motor was chosen due to its smaller size given the size constrains on our robot.

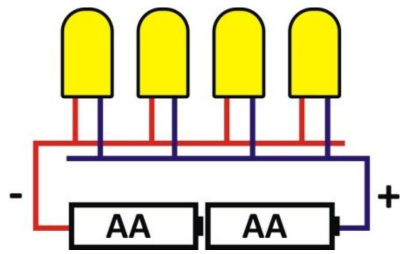




The light system is focused on the robot's camera. The robot will be equipped with a set of 4 light bulbs placed around its camera. These light bulbs will be wired together to a set of AA batteries.



Setup for the lighting system



Light system wiring

Plan of Implementation

Lil' Dragon Runner is currently in a Beta build phase. The chassis is designed and built but some small improvements can be made that do not affect the overall design. We will start with this Beta build and go through a test iteration method until we reach the final desig. What this means is we will run our tests (see Evaluation) and evaluate how well the robot did in these tests. We will decide what can be fixed and what will stay the same. Then we will fix the current design to match the fixes we planned to make. The fixes we will make do not affect the design as a whole; rather they will affect the way in which we carry out our design decisions. For example, currently we transfer powers through gears, testing might prove that a chain might be more effective at this power transfer; we would then change our design to use these chains.

On the software side, we will develop it first since the testing requires it to function before the iterative test process can begin. We will develop the control system with the ability to function backwards along with finding a webcam application that allows for an image to be flipped.

Control Architecture

Lil' Dragon Runner will be controlled by a human operator team comprised of two team members: a navigator and a control operator.

The navigator keeps track of Lil' Dragon Runner's progress and plans its future route. He is equipped with a map of the building before the collapse occurred; he must use this map to make sure the robot completely covers the environment at least once.

The control operator does the actual controlling of Lil' Dragon Runner. He interacts with the robot through the above mentioned computer via Bluetooth and tether. He uses the webcam to view live images of Lil' Dragon Runner's environment. He then controls the robots movements through simple commands he sends through the computer. Using the arrow keys, up and down go front and back, while left and right turn the robot left or right. This allows Lil' Dragon Runner to work in any given direction yet it only runs in straight lines. It either turns or goes straight. This will allow it to more easily attain its top speed and also allows for ease of moving straight.

Since the robot has the capability to function while flipped over, the system displays which direction the controls are currently configured. If the robot is flipped, the operator will notice through the reverse image sent by the camera. The operator then chooses to flip the controls which will adapt all of the controls to the current direction. This includes flipping front, back, left, right, and flipping the image that is received.

Specifications

Size (L x W x H):	8.5*in* x 7*in* x 6*in*
Centroid:	3 inches off the ground and behind the front wheels
Top Speed:	16*cm/s*
Turn Radius:	0 (on the robot's center)

Innovation

We believe that the main innovations of our designs are the ability to function flipped over, the compactness of the design, and the focus on ruggedness.

Our design has the ability to still function even if the robot flips over. This allows us to go relatively anywhere and takes away the fear that an operator might have when considering climbing a large obstacle. Also, if the robot falls or is tipped, regardless of the position Lil' Dragon Runner will still be able to complete its mission.

Our design is also very compact. We have 8 wheels and the NXT motors and controller all tightly packed in the design. Our design was so compact that we even had to opt for a smaller camera. This camera is considerable smaller and allows us to have the ability to pan while still fitting in a small footprint.

Our focus on ruggedness allows us to have the operators focus on what matters: finding survivors. Rather than think will the robot fit? Can it climb that? The operator is just encouraged to try it and see. Lil' Dragon Runner can take it! We believe that this gives us a considerable advantage since the robot can truly operate at a faster velocity.

Evaluation

We have developed a series of tests through which we will test Lil' Dragon Runner. These tests are based on the conditions we expect the environment to contain. These tests include:

Stair climbing test: This test calls for Lil' Dragon Runner to climb a set of stairs. We find this to be crucial since most building will not be a single floor

Rough terrain test: The robot will be run through a rough terrain as fast as the robot can. This rough terrain is defined as a series of small obstacles that the robot can traverse with a medium level of difficulty. The terrain will also contain small items that might get stuck on the robot. This will cause the robot to be tossed up and down and to the sides as it tries to quickly go through these obstacles. This tests the ruggedness and build of the design. How well the design holds up with speed and frequent impacts.

Incline test: The robot is driven up a series of inclines with increasing angle. First a 25 degree incline followed by a 35, 45, etc until the robot cannot climb the incline.

Flip test: The robot is driven into a wall and attempts to climb the wall but ends up flipping over. This is done n times and it is timed. This test allows us to see the effects of a flip on the chassis and on the operators and their ability to control the robot.

Side test: In this test the robot is put on its side and the operator must attempt to right it once more.

Close obstacle test: This tests the finesse of the driving along with the operators. The robot is driven through a small opening through which the robot almost fits through. This tests how well the operator can see and understand the robot in relation to the environment.

Large obstacle: In this test there is a series of large obstacle the robot will attempt to traverse. These large obstacles are 6, 8, and 10 inch ledges. This tests the ability of the robot to clear a large obstacle and how it reacts to a large fall.

Requested Parts Budget

Here are the parts we plan to purchase and their costs along with their use:

Item	Cost	Use
Webcam	\$10.73	See what the robot sees
4 Light Bulbs	\$4.00	Light the robot's path
50*ft* Wire	\$2.02	Carry the camera's image and work as a tether
Total:	*\$16.75*	

There will also be a few AA batteries that will power the lights along with the required cabling. We are using one RCX motor in place of our third NXT motor.

Conclusion

We believe that in order to maximize the amount of ground covered by a robotic search team, the human operators must have little to no regard for the robot's safety. Rather the operators must first focus on their goal of finding survivors and second to think whether the robot has the ability to traverse any given terrain. In order to accomplish this goal we have designed Lil' Dragon Runner. He is capable of function regardless of what angle he lands in. He is also designed with a high level ruggedness that allows it to survive a large amount of abuse. We believe that Lil' Dragon Runner has the ability to quickly search a building and find survivors. The key to his speed is the operator's ability to assume the safety of the robot regardless of the beating it might take. Lil' Dragon Runner is truly a rugged and versatile platform with the urban environment in mind.