ECSE 211 - Design Principles and Methods

HARDWARE DOCUMENT

GROUP 11
John, Durham, Alex, Ian, Ethan

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Abstract

This document is intended to outline 4 hardware designs and the differences between them. It will cover the input components (ultrasonic sensors and color sensors), the output components (motors), and the ball launching mechanism. These designs have been evaluated, and ultimately a final design has been chosen, revised and refined in order to best complete the competition's task on *April 5th, 2017* .

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1 EDIT HISTORY

- March 8th 2017:
  - **Ethan Lague:** Initial set up of document sections (including table of contents), completion of first draft of sections 1 through 7.
- March 9th 2017:
  - **Alex Lam:** General Re-Formating
- March 14th, 2017
  - **Durham Abric:** Updated abstract and ball launcher sections to reflect progress and design decisions the team has made.
- March 23th, 2017
  - **Ethan Lague:** Added **design 4**, the final hardware design to the document and added methodology section.
- March 29th, 2017
  - **Ethan Lague:** Added changes to **design 4**, added to methodology section, and added introduction section.
- April 8th, 2017
  - **Ethan Lague:** Modified **design 4**, reasoning, and abatract. Vectorized Figures.
- April 9th, 2017
  - **Alex Lam:** Redesigned the layout of the document, added section 3 and a version system for the different hardware designs (section 4)
  - **Ethan Lague:** Added LDD models for versions 0 through 3

2 INTRODUCTION

2.1 Purpose

Our vehicle is a fully autonomous robot that is capable of localization, navigation, obstacle avoidance, odometry, and retrieving a ball that can be shot into a target. In addition, the robot is capable of defending all the listed capabilities. The purpose of this document is to provide a detailed overview about the Hardware designs of the robot. A detailed description of the components of each of the 4 hardware designs is covered as well as the reasoning for the hardware decisions made for the final design.

2.2 Context

See requirements document included in the reference package.

2.3 Audience

This technical document is intended for parties who are interested in maintaining, testing, or extending the hardware that is included with the project. It is assumed that all readers have a sufficient understanding of the EV3 components such as ultrasonic sensors, color seonsors, motors, and the EV3 itself.

2.4 Scope

The scope of our project will be limited to only achieving the list of requirements specified by the client. Therefore, no additional features will be added.

3 DESIGN PROPOSALS

3.1 Proposal 1

The robot in this proposal uses 2 ultrasonic sensors for localization and obstacle avoidance. The first ultrasonic sensor is placed static horizontally facing the front. The second ultrasonic sensor is placed vertically on a motor where it will rotate to either face the left or right side. It will only be engaged once the first motor sees an obstacle and will turn either left or right to face the obstacle.

The robot proposed also uses 2 color sensors for odometry correction. The two sensors are placed underneath the Ev3 brick at the same levels as the wheels and at a height of 3mm from the ground. Each sensor is placed on either side of the robot.

This proposed design utilities 4 motors. 2 NXT motors are placed on either side of the robot each attached to a wheel for movement of the robot. 1 EV3 motor is used for the ball launcher. Another EV3 motor is placed horizontally in the middle of the robot for the rotating Ultrasonic sensor.

The ball launching mechanism in this design uses a single EV3 motor placed vertically towards the back of the robot. A long arm is extended from the motor with a claw like basket to hold the ball. The motor is oriented so that the arm rotates perpendicular to the robots velocity to increase the overall stability when firing.

Refer to figures 1 through 4 for illustrations of the design presented.

3.2 Proposal 2

The second proposed design uses 3 ultrasonic sensors for localization and obstacle avoidance. The first is placed static horizontally facing the front. The two others are placed static facing the left and right sides of the robot. Similar to design 1, the two sensors facing either side will only be engaged when in the process of obstacle avoidance.

This design uses 1 color sensor placed at the front of the robot facing the ground with 3mm of separation.

This design utilizes 3 Motors. 2 NXT motors are placed on either side of the robot each attached to a wheel for movement of the robot. 1 EV3 motor is used for the ball launcher.

The ball launcher for this design is the same as in proposal 1.

Refer to figures 5 through 8 for illustrations of this proposed design.

3.3 Proposal 3

The robot in this design uses 2 ultrasonic sensors for localization and obstacle avoidance. Both sensors are placed horizontal with an angle of 90 degrees between them on a motor. One sensor will face the front, and that will be used for localization. During obstacle avoidance, the motor will rotate the sensors so that one is facing the front while the other is facing the side that the obstacle is on.

The color sensors in this proposal are placed the same as in proposal 1.

The design proposed incorporates 4 Motors. 2 NXT motors are placed on either side of the robot each attached to a wheel for movement of the robot. 1 EV3 motor is used for the ball launcher. Another EV3 motor is placed horizontally at the front of the robot to turn the two ultrasonic sensors.

The ball launcher for this design is the same as in proposal 1.

Refer to figures 9 through 12 for illustrations of this proposed design.

4 DESIGN STAGES AND MODIFICATIONS

4.1 Version 0

The first build of the robot was initially only intended for testing purposes but was finally integrated into the final design. Version 0 of our robot consisted of the base of our final design and of a front ultrasonic sensor. A small metal ball is also placed at the back of the vehicle in this build to allow for added stability. Refer to figures 13 and 14.

4.2 Version 1

While developing the localization method and working on other early software, we developed version 1 for hardware. Version one was still a primitive design using one US sensor and no color sensors but we added a throwing arm to the base. The throwing arm was erected from a motor standing vertically above the base, with a rotation that would propel the ball over the robot perpendicular to the robots travel velocity. Refer to figures 15 and 16.

4.3 Version 2

After testing version 1 of the hardware it was determined that a single motor mounted at the base of the robot would not be powerful enough to shoot the ball as far as required (see testing document section 6.1.1). To fix this problem a tower was built at the top of which two motors were horizontally attached. A long shooting arm the length of the tower extended from the motors and had a claw at its end on which the ball could be held.An additional metal ball was also added to the front of the robot to restrict the forward tilting motion of the robot when it fires a ball. The US sensor was also moved to be under the EV3 brick for this version. Refer to figures 17 and 18.

4.4 Version 3

Once we realized that the robot could not maintain precise odometry after traveling a far distance, we added two color sensors to implement odometry correction. We placed each sensor just in front of each respective wheel. Refer to figures 19 and 20.

5 REASONING

In this section the reasoning behind the choices that lead to the final design of the robot is discussed.

5.1 Ball Launcher

After brainstorming ideas (see System Document section 8) it was decided that we would go with a simple, low centered robot build with a single motor to power the throwing arm which would be facing the side of the robot rather than straight ahead. The reason this was chosen above the other brainstormed ideas is that it was the simplest, most time efficient idea. The crossbow idea discussed in the referenced document was indeed judged way too complicated for the little benefit it added. The tower idea also involved more work than simply attaching a motor to the base of the EV3 and thus was set as a fall-back idea in case the chosen idea did not work. The 3 proposals showcased above were the 3 initial designs we had in mind. However, once we realized that the ball luncher we had in mind could not generate nearly enough torque the throw the ball the distance required, we decided to scrap those models and create an all new design for the ball launcher using two motors (a more detailed thought process with test data to back this decision is described in section 5 below). Both motors are placed at the top of a tower like structure. This decision is made because being able to bring the throwing arm down so that is perpendicular to the ground allows it to swing the ball from there enabling it to release the ball at a more optimal angle and throw it farther. We chose to design a very simple claw-type mechanism where the ball sits while being transported. This is because we know from the labs that too many excess pieces can inhibit the release of the ball while launching.

5.2 Color sensors

After testing the odometry without correction, we realized that using two color sensors was optimal for navigation. We put the color sensors just in front of the wheels so that whenever one sensor passes over a line, the corresponding wheel stops until the other sensor passes over the same line. Since the hardware is faulty and every so often one of the color sensors misses a line, we implemented a correction where if 1 second passes after the first light sensor hits a line and the second sensor has still not passed the line, the wheel corresponding to the second light sensor will stop and travel back to where it was when the first light sensor hit the line and then the robot will continue forward. The color sensors are also used in ball retrieval and in the aiming process for the shooting of the ball. For both cases the robot will line up to two perpendicular lines using the light sensors so that its odometry is as accurate as possible. This will allow us to be precise when retrieving and shooting the ball.

5.3 Ultrasonic sensors

Since two motors were used for the ball launcher and two color sensors we were used for odometry correction, we were limited in our design for ultrasonic sensors due to the limited number of ports in the EV3. Since there were no output ports available we could not manipulate the ultrasonic sensors with a motor in any way and since there were only two input ports available we were restricted to maximum two static ultrasonic sensors. We decided to use only one front-facing sensor to minimize the number of threads since the EV3 brick can only run so many. The sensor is used for localization and obstacle avoidance. We decided to place the sensor under the EV3 brick in this design for two reasons. First, it allows the sensor to see obstacles that are much lower to the ground than it could if the sensor was above like in designs 1, 2 or 3. Second, it allowed us to attach a ball bearing beneath it touching the ground so that when the robot launches the ball the bearing touches the ground stopping the whole robot from swinging forward. This allows the robot to throw the ball much farther, and reduces the error in odometry after every shot.

6 FINAL HARDWARE DESIGN

After testing of Version 3 of the design it was determined that having a second ultrasonic sensor on the side of the robot was detrimental to it's functioning as the precision of the ultrasonic sensors did not permit accurate distance readings to be taken and the robot would map obstacles in the wrong square. The decision was thus made to remove the second ultrasonic sensor and use a single ultrasonic sensor for both localization and obstacle avoidance purposes. The final robot design therefore uses a single ultrasonic sensor placed statically facing the front extending out from under the EV3 brick. The changes made from version to version were also implemented in the final design. A description of the final design follows.

The 2 light sensors of the final design are placed laterally along the front of the robot, as close to each respective wheel as possible. They also hang 3mm off the ground.

The final design of the robot uses 4 motors. There are two EV3 motors placed horizontally on top of a tower built up vertically from the brick that are used in the ball launcher mechanism. 2 NXT motors are placed on either side of the robot each attached to a wheel for movement of the robot. Additionally, a metal ball is attached at the rear of the vehicle for added stability and to ensure the rear of the robot does not drag on the ground when the robot travels.

The catapult arm will rotate down perpendicular to the ground along the back of the robot. There, the ball can be loaded. The robot can travel with the ball since two small Lego pieces are placed on the sides of the claw where the ball is held. When launching, the motors rotate the arm to throw the ball over the top of the robot. After testing of version 3 of the robot it was also determined that the two motors powering the shooting arm still wernt powerful enough to consistently make the 8 tile shot (see testing document section 6.1.2). The use of rubber bands to increase the strength of the shooting mechanism was thus integrated into the final design build. Three rubber bands are stretched from the middle of the throwing arm to the top of the tower to add torque when throwing the ball. A second metal ball is also placed at the front of the robot to stop it from tilting forward when a shot is taken.

Refer to figures 21 through 24 for an illustration of the final design of this project.

7 FIGURES

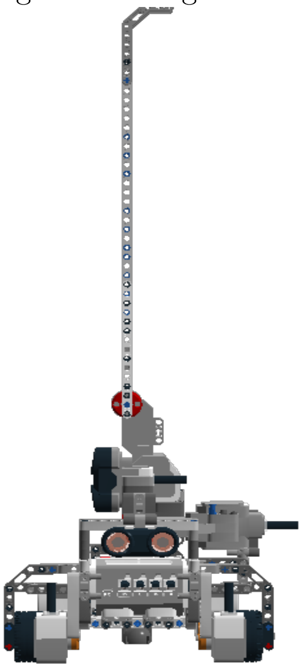


Figure 1: Design 1 front

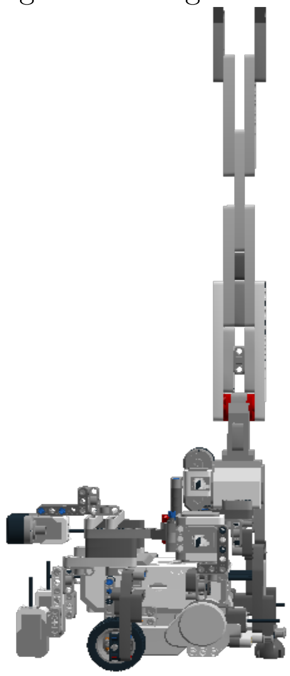


Figure 2: Design 1 side 1

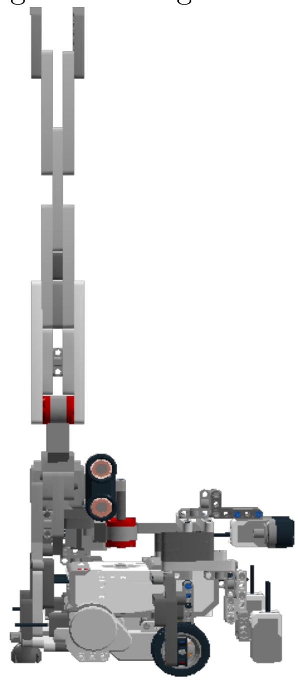


Figure 3: Design 1 side 2

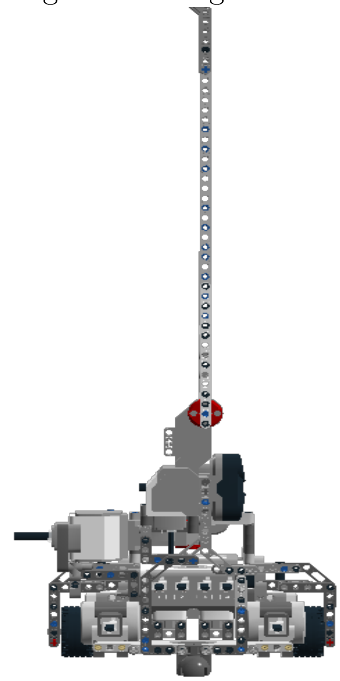


Figure 4: Design 1 back

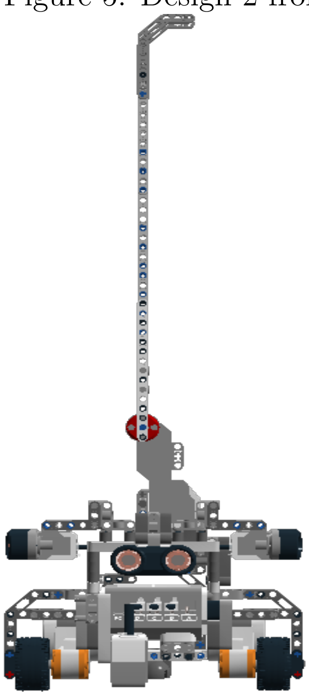


Figure 5: Design 2 front

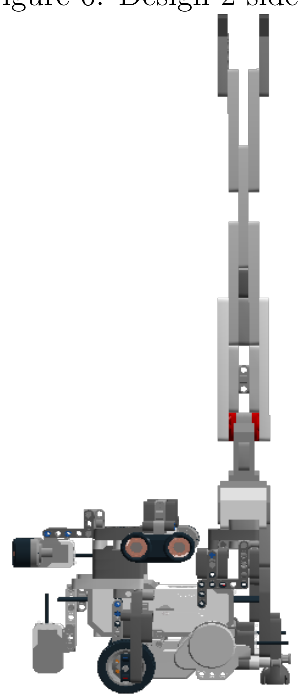


Figure 6: Design 2 side 1

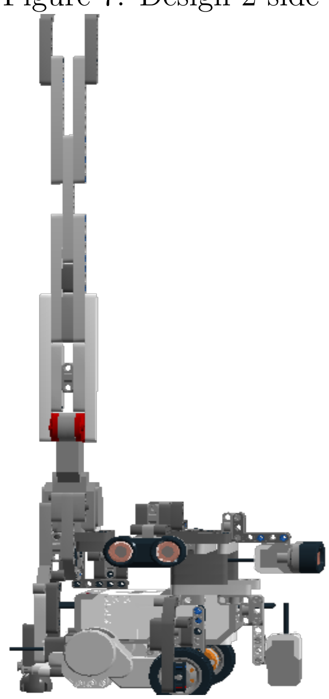


Figure 7: Design 2 side 2

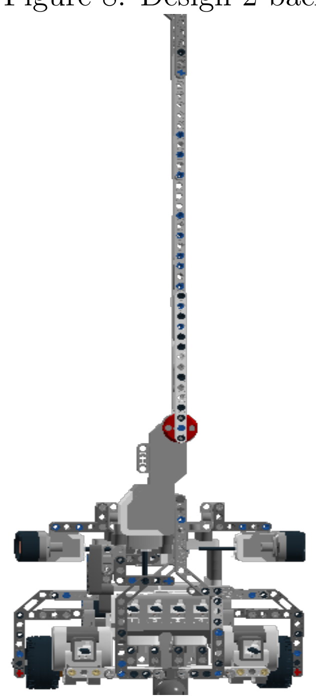


Figure 8: Design 2 back

Figure 9: Design 3 front

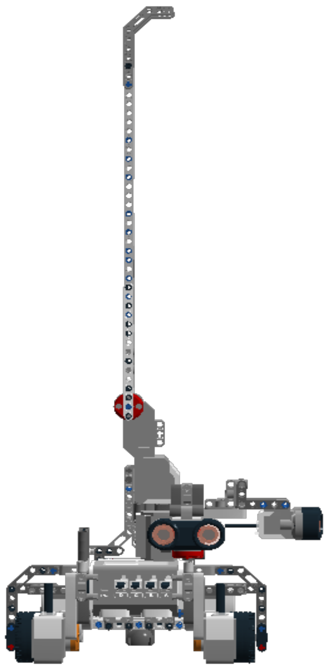


Figure 10: Design 3 side 1

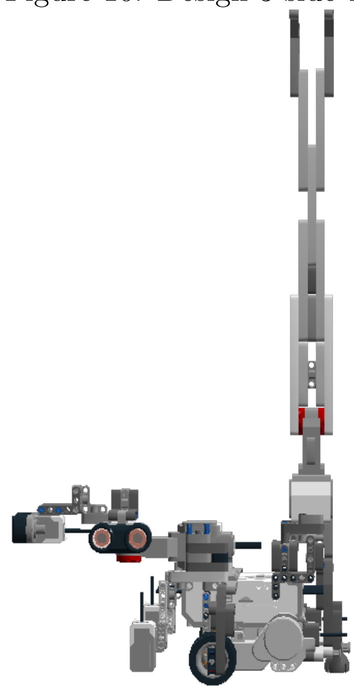


Figure 11: Design 3 side 2

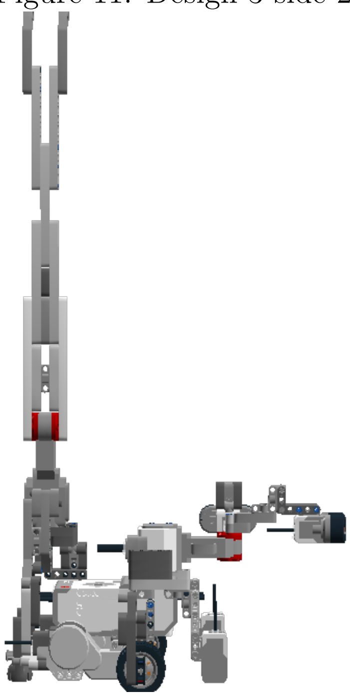
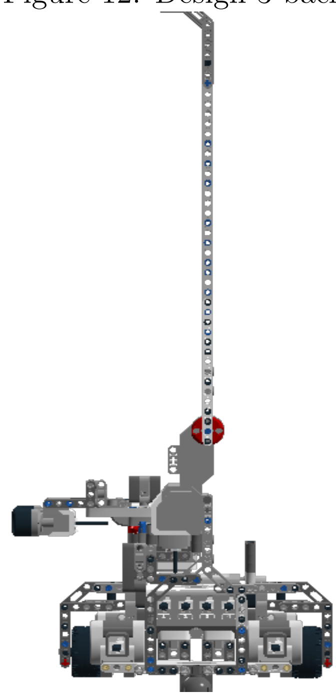


Figure 12: Design 3 back



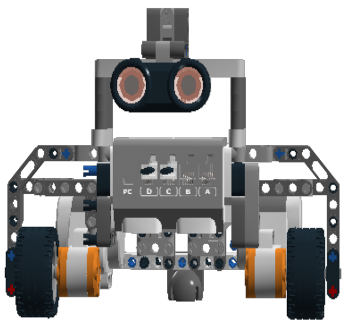


Figure 13: Version 0 front

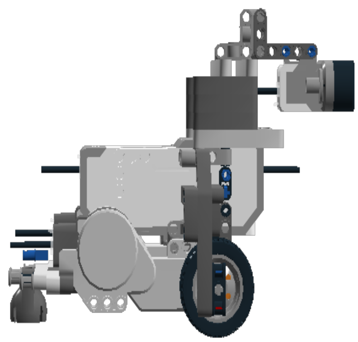


Figure 14: Version 0 side

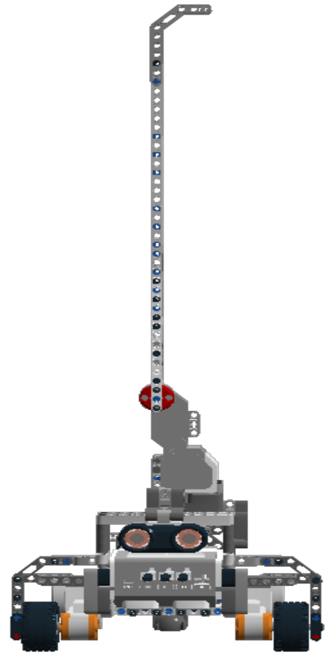


Figure 15: Version 1 front

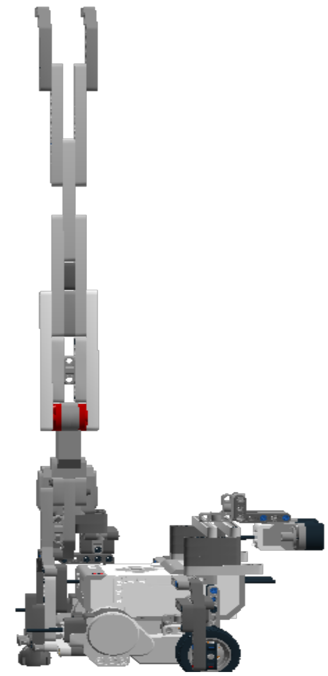


Figure 16: Version 1 side

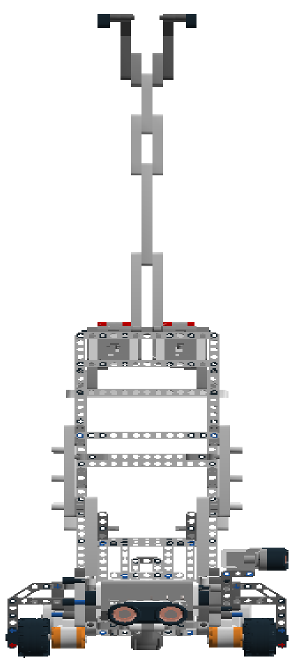


Figure 17: Version 2 front

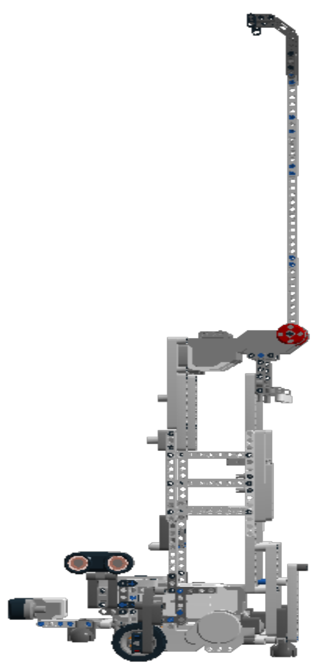


Figure 18: version 2 side

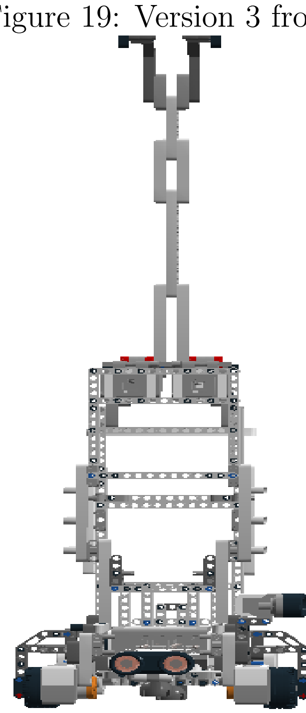


Figure 19: Version 3 front

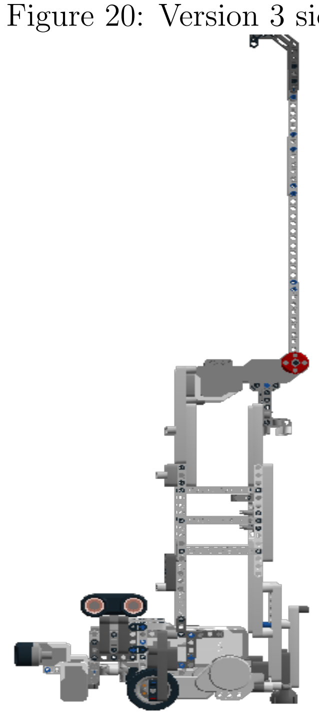


Figure 20: Version 3 side

Figure 21: Final build front

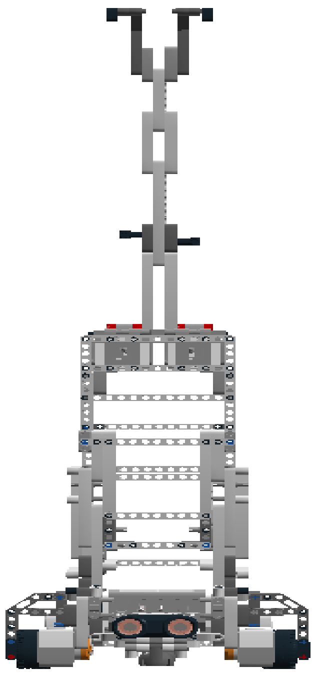


Figure 22: Final build side 1

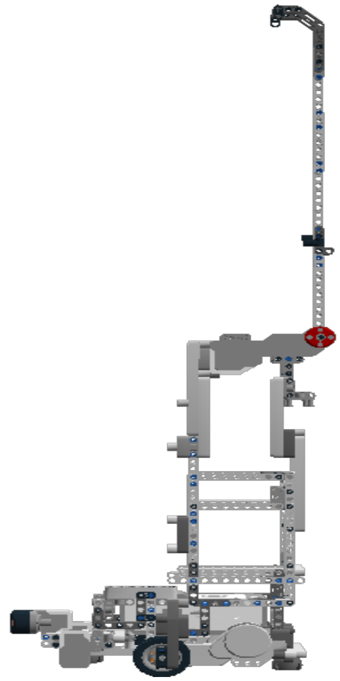


Figure 23: Final build side 2

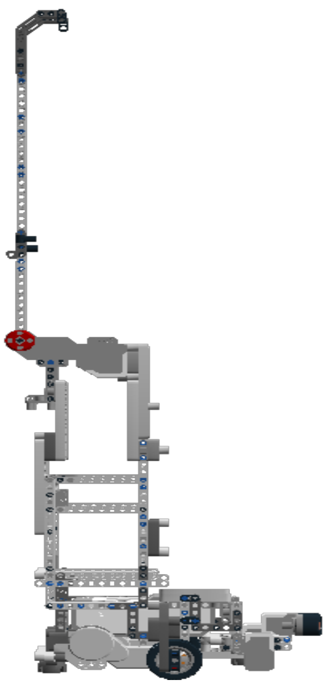
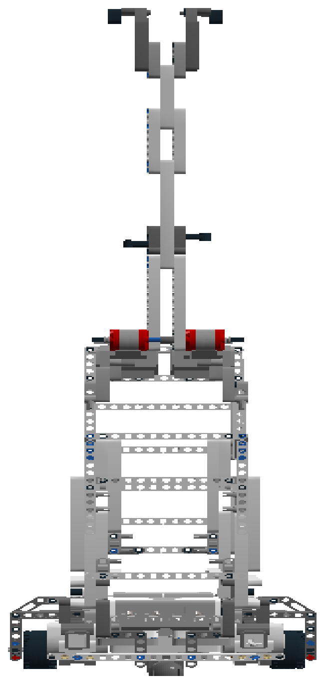


Figure 24: Final build back



8 GLOSSARY OF TERMS

- Ultrasonic sensor: A sensor which emits sound waves to pick up its proximity to an object.
- Color Sensor: A sensor which picks up on the color of an object which given the black lines on the field can help the robot know where it is.
- "The client" in this document refers to Professors Lowther and Giannacopoulos giving this course.