Crisis Response Autonomous Vehicle (CRAV)

Engineering 111: Foundations of Engineering 1

Team 23

SUBMITTED BY

JOSEPH GERULES

HUNTER HAZZARD

LEILANI HORLANDER-CRUZ

TAYLOR WEBER

Instructor: Rainer Fink

Associate Professor of Engineering Technology and Industrial Distribution

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DWIGHT LOOK COLLEGE OF ENGINEERING

TEXAS A&M UNIVERSITY

TABLE OF CONTENTS

SECTION	PAGE #
EXECUTIVE SUMMARY	3
COVER MEMO	4
INTRODUCTION	5
DESIGN CONSIDERATIONS	8
DESIGN PRODUCT	10
RESULTS AND DISCUSSION	12
CONCLUSIONS & RECOMMENDATIONS	13
REFERENCES	14
APPENDICES	15

EXECUTIVE SUMMARY

Over the past couple of decades the annual frequency of natural disasters has increased a significant amount. In 1980, around 100 natural disasters were reported to emergency disaster databases, and by the year 2000 that number had more than tripled. This staggering increase also brings up another issue: What needs to be developed to compensate for the numerous hazardous conditions resulting from these catastrophes? The solution would have to be a product that offers an efficient and safe way for response teams to navigate and rescue people from potentially deadly situations.

The creation of a product to assist response teams could not only help to save the lives of the people affected by the disaster but could also help ensure the safety of the men and women who bravely volunteer to search for and rescue these individuals.
Our objective was to develop the prototype for a vehicle that is able to analyze a situation and determine the most effective way to reach its target and activate the necessary systems to account for the condition of the environment.

The product we developed is a modified version of an EV3 robot. It includes a movable arm that changes position to fit the instructions is it given. Structurally it has two large wheels and flat pieces as a tail that resembles a fin to help it overcome various types of terrain. It utilizes color and light sensors to help it stay on course to get it to its destination and a sound sensor for audio commands to help it progress through the course to prevent running into potential problems.

Although the EV3 was just intended to be a prototype to use for testing, it might be useful to invest in a more reliable product. We ran into several problems with motor performance, as well as extreme sensitivity to lighting changes. The color sensor was consistent for the most part, however, the color yellow was very unreliable when the amount of light in the testing room was changed. Another factor to consider is the placement of the light and color sensors and what distance they should be from the object to get an optimal reading. We concluded that approximately 1.25 Lego Units was the best distance for the tests we completed.

COVER MEMO

DATE: December 8, 2015

TO: The Management of Your Company

FROM: Team 23

Joseph Gerules

Hunter Hazzard

Leilani Horlander-Cruz

Taylor Weber

SUBJECT: Crisis Response Initiative

This project is focused on creating a product that is capable of navigating different terrains and situations without the help of a human controller. We are marketing this product for companies and organizations that are responsible for crisis response and rescue in the event of a disaster. We have developed and tested a small-scale version of this vehicle that has been overall successful in the situations we've put it in. This testing has allowed us to adjust and account for new circumstances we wouldn't have thought of without it.

What we plan to accomplish with this project is:

- Self navigating vehicle – a vehicle that can operate and perform accurately without assistance
- Navigation system – follow a pre-designated path to reach a target object
- Control Arm – a movable appendage that will change position depending on what it needs to activate
- Code Scanning – scan a code to determine what the target is to choose a route to take

Our next goal will be to re-create our product on a much larger scale and begin improving our design with the data we have collected from our prototype. We will have to translate our findings with the small robot to fit with the full size model of the response vehicle. Furthermore, we will continue to run tests and experiment with different situations to develop a product that is extremely versatile as well as reliable.

INTRODUCTION

As a part of the Crisis Response Initiative, our project was to design and program a Crisis Response Autonomous Vehicle (CRAV) that could navigate through difficult and dangerous situations to safely and efficiently rescue civilians. To model and test our design in different environments we used various test tracks and sensors that were compatible with an EV3 robot. An EV3 is a brick shaped product that can be programmed and operated using Labview. It includes several different parts and sensors that can be used to detect external input such as color, light, and touch. The prototype we were able to create with this allowed us to gain a more comprehensive understanding of how the performance of an actual CRAV could be affected by diverse factors. For example, this experimentation was necessary to determine a design that could efficiently navigate through most environments. In the event of a natural disaster, a self-controlling vehicle opens up the possibility for more rescue missions to be performed than was previously possible. Not only does this vehicle provide a more efficient way of accessing civilians, but it can also decrease the number of response members injured or killed by unexpected circumstances.

This vehicle was put through a series of trials in order to update the design to be able to overcome a multitude of obstacles based on real-world environments. Sensors and motors were placed or removed for each challenge, resulting in our final design for the vehicle for the final project. One of the first iterations of our robot simply involved adding light and touch sensors, motors and wheels to model a Roomba® style machine that was able to push a number of blocks off of a surface in a timely manner. Our final design of the vehicle includes motors and wheels, light, color, and sound sensors, and a pivoting arm. This design was constructed in the context of being able to follow a track, vault multiple "terrain obstacles" in the form of small wooden dowels, and read the value of a barcode and press the correct button which corresponds with the barcode.

The assignments and tasks for the robot required our team to evaluate the engineering design process and the necessary steps and procedures involved. The physical part of this project, building the actual robot, tested our ability to compile a box of scattered parts into the most effective and efficient design to complete the course. Although our team used supplemental information to build the base of the robot, there were many alterations performed to the base model to complete tasks effectively (Mindstorm Instructions). There were many hours spent writing the code and making changes and small calibrations in order for the robot to not only complete the course, but complete the course in the most efficient way possible. As will be outlined in more detail later in the report, many of our original ideas had to be thrown away and replaced with a more effective solution to the problem. One of the major lessons learned from this project was that the simpler a design is, the easier it is to make changes and redirect the vision of an entire project. This is one of the simplest yet most important fundamentals of creating a product, which is mentioned in the required text for this course (Stephan et al. 57).

Many of the calibrations we performed while constructing the robot involved making changes to the code rather than the design of the vehicle. Most of these changes were simply editing the input values for the various sensors used. For example, our robot was equipped with a color sensor to detect the color blue using the 'detect blue' function to follow a blue track, but we found that the actual track was a dull color and the function wouldn't detect blue. We swapped out the color sensor with a light sensor, which sensed white (with a value around 30, depending on the lighting in the room), black (with any value less than 30), and more importantly, blue (with a value of less than 45).

Over the course of this project there were many times that we realized our idea wouldn't work at all and needed to be scrapped. This was frustrating at first, but we've realized that a perfect design isn't produced on the first try. This realization was important and helped us to overcome the time constraints. With the experience of this first project under our belts, we have nothing but excitement for upcoming challenges in the world of engineering.

DESIGN CONSIDERATIONS

The design and construction of our robot was heavily based around the design process, implementing every one of the five steps outlined in the process: identify the need, understand the need, ideate possible solutions, and implement the solution. We were instructed to design and build a crisis response vehicle, a seemingly daunting task at first. As we began the project, however, we found that by implementing small, incremental changes to the robot we were able to slowly make our way towards a functional final product.

The prototype that we'd decided to construct was expected to perform tasks similar to the actual product, just on a smaller scale. Our final robot was expected to follow a track, be able to run over rough terrain represented by wooden dowels, and then read a barcode and press the correct button on a switch which corresponds with the barcode value.

With these goals in mind, we were able to begin construction of the robot. There were two preliminary models of our robot that did not resemble our final product at all, but only because the requirements for the first tasks were very simple: rotate a motor to follow a light and rotate a motor in correspondence with a certain color reading. The first iteration of our robot that resembled the final product was a simple vehicle consisting of an EV3 brick, a couple of motors attached to two front wheels, and a ball bearing acting as a third wheel in the back of the robot to provide balance.

The next challenges for our robot all used the vehicular design, and they were simply for the purpose of practicing using different sensors and motors to our advantage and performing calibrations in preparation not only for upcoming tasks, but also the final product. These preliminary tasks involved using touch, light, and color sensors to overcome obstacles in an efficient manner. Creating a Roomba® type machine to push blocks off a table was one of the first memorable products that allowed for multiple solutions to the problem. Our team initially used a light sensor extended in front of the robot to sense when it had reached the end of the table, but we found that different environments often had very different light levels, and the functionality was compromised.

The following tasks were all in final preparation for our final product. We first utilized a light sensor to follow a black line and differentiate between colors to output the correct response. The following task was altered slightly to include reading a series of black lines (barcode) and output the correct response and there were two wooden dowels added to the track for the robot to ride over. The final project combined these two challenges and added a few new ones. The CRAV needed to begin in its "crate", follow a colored line instead of a black one, and after reading the barcode, it had to press the correct button on a tower that corresponded with the barcode value. The first robot design that we constructed for the final project ran into a multitude of problems, one of which was difficulty riding over the dowels.

The first solution we devised for the dowels was a simple yet effective "tail" that touched the ground behind the robot. This tail acted as a lever to provide more stability and enough upward force on the front of the robot and friction to clear the dowel. Although this design was effective, we found difficulty finding the perfect speed for our robot to both clear the dowels and turn sharp corners. This problem led to yet another simple yet effective solution, which was to add a sound sensor to the robot to toggle its speed in response to a clap, either for clearing the dowels or making sharp turns. The negative side to using the sound sensor is that this design would be far too impractical to exist in a crisis situation. Nevertheless, the design with the sound sensor made the cut for our final robot simply because the time slot was too narrow to find the perfect speed the robot would need to maintain in order to complete the track successfully.

DESIGN PRODUCT

Our final product is made up of various components and included some that were necessary to any design as well as other features that were specific to our robot. The foundation of our robot comprises a Mindstorms EV3 complete brick connected to two large motors. RJ12 Connector Cables are used to link the motors to the brick electrically and various Technic Liftarms, Pins, and Axles were used to physically hold it together.

Other features the robot has to offer are unique to this design. We fixed several different types of sensors on the robot to expand its functionality. On the front in the middle we attached a Light Sensor to allow it to follow lines based on light values. We also used a Black Technic Axle to extend a color sensor off to the side to read information given to it in the form of a barcode. We also included a sound sensor on the back right to increase the capacity for commands the vehicle could be given. All of the sensors are also connected using the same RJ12 Connector Cables and physical supports.

A major problem we had when it came to mobility was the inability of the Ball Pivot Socket and Steel Ball to overcome certain obstacles. It would very commonly get caught on raised objects in the terrain and make it impossible for the robot to continue on its path. We replaced this with a two Left Panels that we positioned at the back of the robot to create a fin-like object. We used tape to ensure that the two pieces would stay together. This allowed the robot to smoothly transition through different landscapes with minimal issues.

In order for the robot to effectively respond to the barcodes it was reading we needed to create an arm of some sort that would be able to rotate to different angles depending on what material it was given. To do so we attached a medium motor to the underside of the vehicle. The actual arm included two Technic Liftarms connected to a system of parts with a Technic Axle passing through one of the ends that allowed for rotation. The Axle that connects to the Lift Arms on the opposite end is used as an extra support to help turn the desired button. There were also several experimental elements we added to the robot in order to test the accuracy and reliability of the various parts. A good example of this is our addition of a White Bionicle Tooth with Axle Hole in the middle of each of our wheels to better see how they turned each time we would run our program. It permitted us to more-easily analyze how consistently the motors would turn the wheels for the time needed in our program. Failure to calibrate this could lead to errors in execution of the track. If the wheels turn too much or not enough the robot could potentially get off track, which could lead to major problems regarding the reading of the barcode. Our final product so far includes all of the elements that we have found to be the most effective through our experiments. However, that does not mean there is not room for improvement. We plan on continuing to experiment and perfect our product.

RESULTS AND DISCUSSION

Our robot was mostly successful in completing the tasks it was given, but there were times when irregularities occurred and the robot failed to complete the tasks. Several factors could have contributed to this failure: sensitivity to slight lighting changes, motor inconsistencies, and background noise were the most common annoyances we came across. We originally calibrated our light value at 35, but we found that this value changed depending on the room we tested in. The value would range anywhere from 35 to 50, and this was too much of a variance to ensure success in all environments.

Another issue we encountered was irregularity in motor performance. Every time we ran the robot, the motors performed slightly differently. Most of the time the discrepancies were small enough that the performance was unbothered. However, there were occasions where the vehicle would pass the line it was assigned to follow, and that would in turn affect how well the robot could read the barcode. If the motors would move too much it was very possible for our robot to miss a section of code all together.

The sound sensor was also difficult to work with at times. We used claps to activate various parts of code, however this proved to be difficult in rooms full of people. We tried to set the original response level at 40 but quickly learned that although it was perfect for hearing the clap command, it also was perfect for hearing other noises present in the room. The adjusted value we set it on was too high and resulted in missing cues because it wouldn't recognize sound unless there were several people making the noise together.

Although we had some difficulty, there were also several features that proved to be successful. One of which was the way we designed the back of the robot to easily slide over rough terrain. The fin shape we gave it proved to be quite useful in getting over objects that were not flat with the ground, like sticks and rocks. Also the placement of our sensors was effective in reading the light and color values on the ground in front of the vehicle. We had to experiment with different distances to find what distance gave the most accurate readings the largest percentage of the time.

CONCLUSIONS & RECOMMENDATIONS

There's absolutely no denying that there was a considerable amount of stress, frustration, and doubt that accompanied this project. We all had to come to terms with the fact that true success is to be found from the mistakes of the past. Our final robot met expectations, albeit with a few quirks and hiccups, but it's very conceivable that a new iteration of the robot would be much more successful given our experience from the past semester.

A simple way to improve our design process would be to cut down on 'dead time' spent not working on the project. One of the major setbacks we encountered as we built the robot was an inefficient use of time. If we were to maximize the efficiency in which we worked on the project, we would ideally focus on maximizing the use of our time.

As our deadline approached, we found that our robot didn't move fast enough to vault the wooden dowels. When we increased the speed, however, we found that our robot would then be unable to make sharp turns at such a high velocity. We 'engineered' a quick solution to the problem: toggling speed using claps read by a sound sensor. Although this solution technically completed the course, it would not be practical for the real-world CRAV because the core function of such a device is to perform without outside input from an operator. A better solution for this problem would have been to find the perfect speed at which the robot could execute all sections of the track while maintaining the same speed.

Although our robot completed the project, it didn't run as smoothly as we wanted. This irregular performance comes down to two factors: limited time to adjust sensor values and differing environments resulting in unexpected malfunctions. With the experience from this project, our team now possesses the necessary experience to complete future projects with more confidence. As has been mentioned in the report previously, the engineering process isn't a simple equation you can solve immediately. Failure is necessary, though sometimes ill-received, in order to adapt to the fast-paced and highly competitive field that is engineering.

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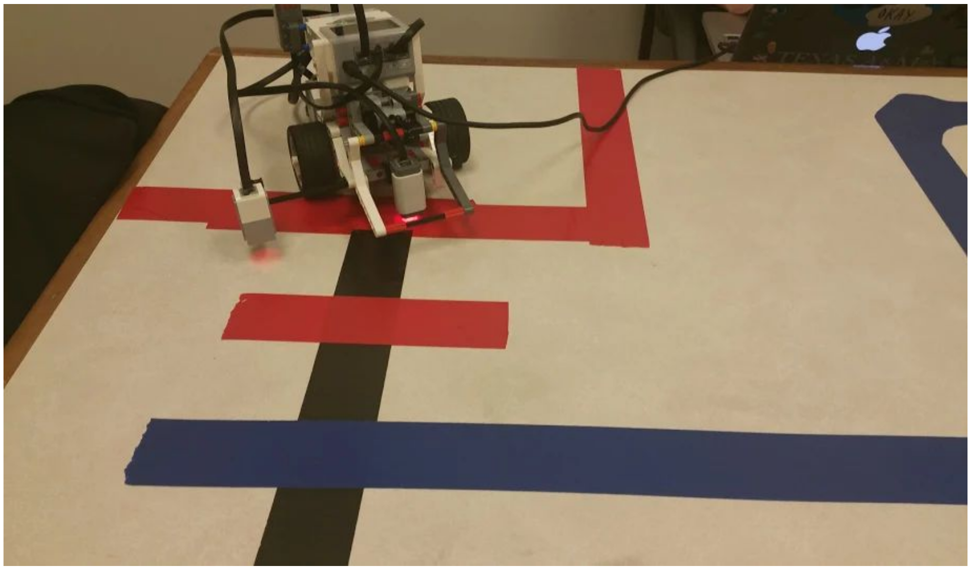
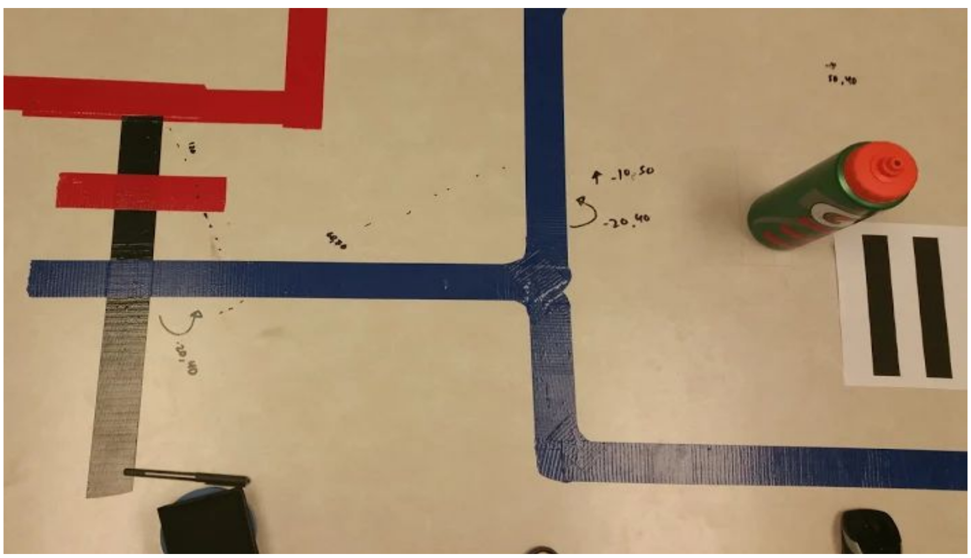
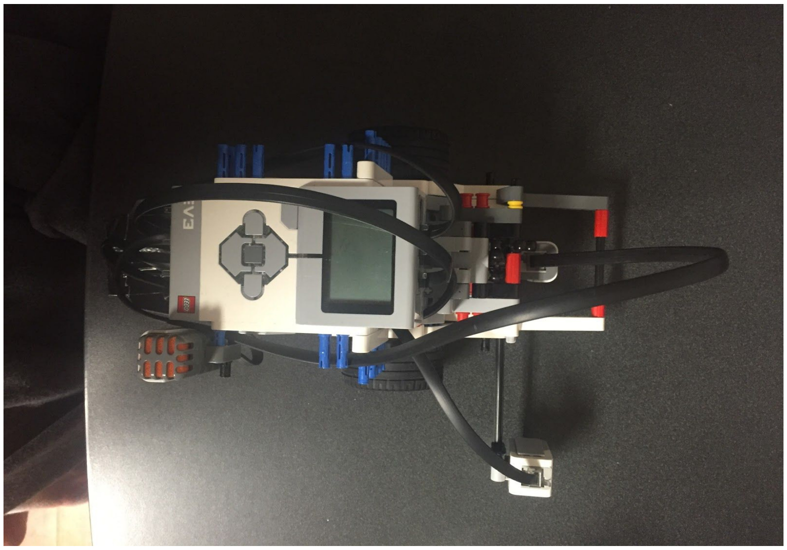
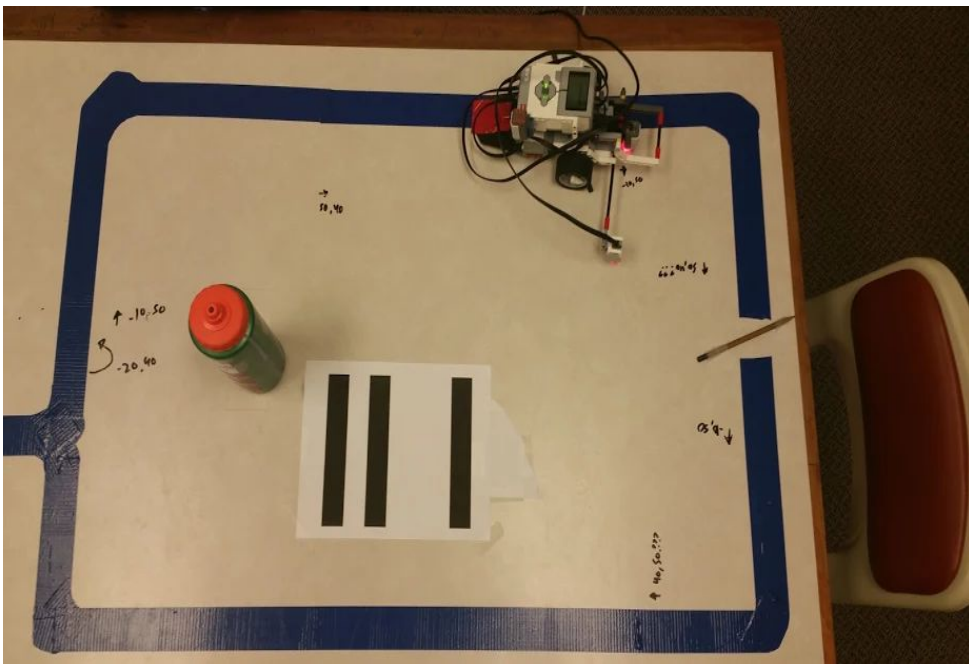
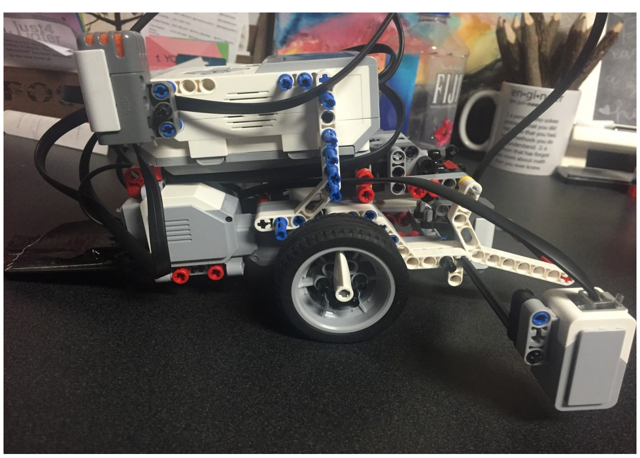
APPENDICES

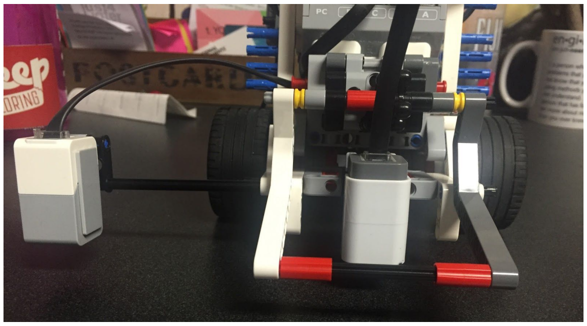


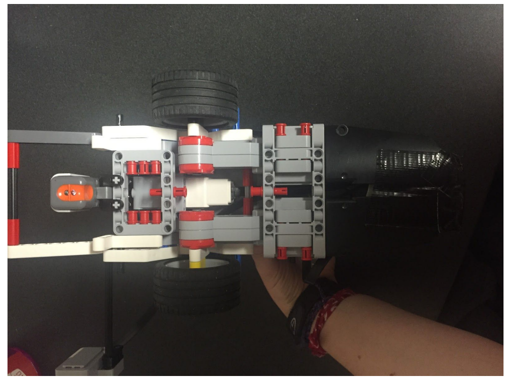


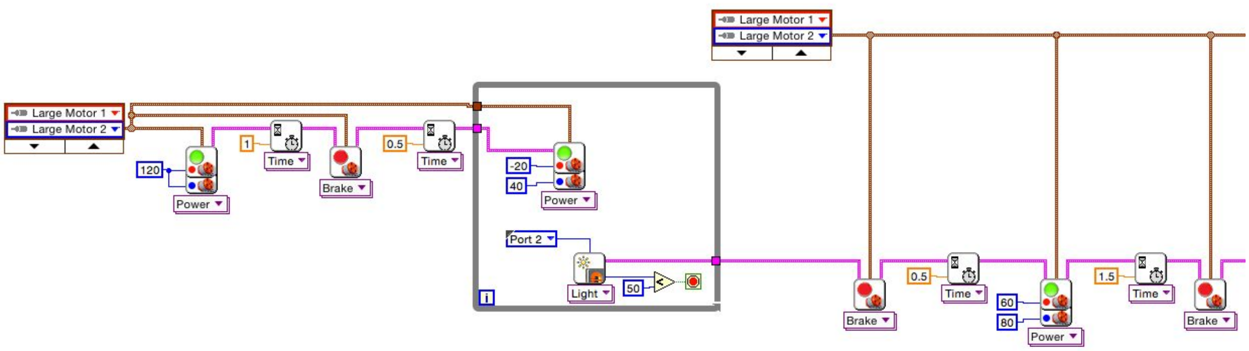








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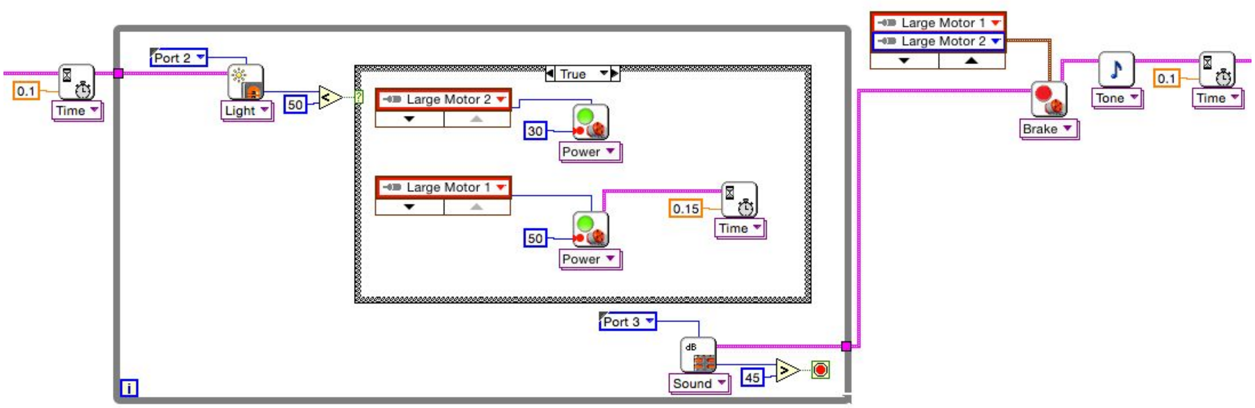
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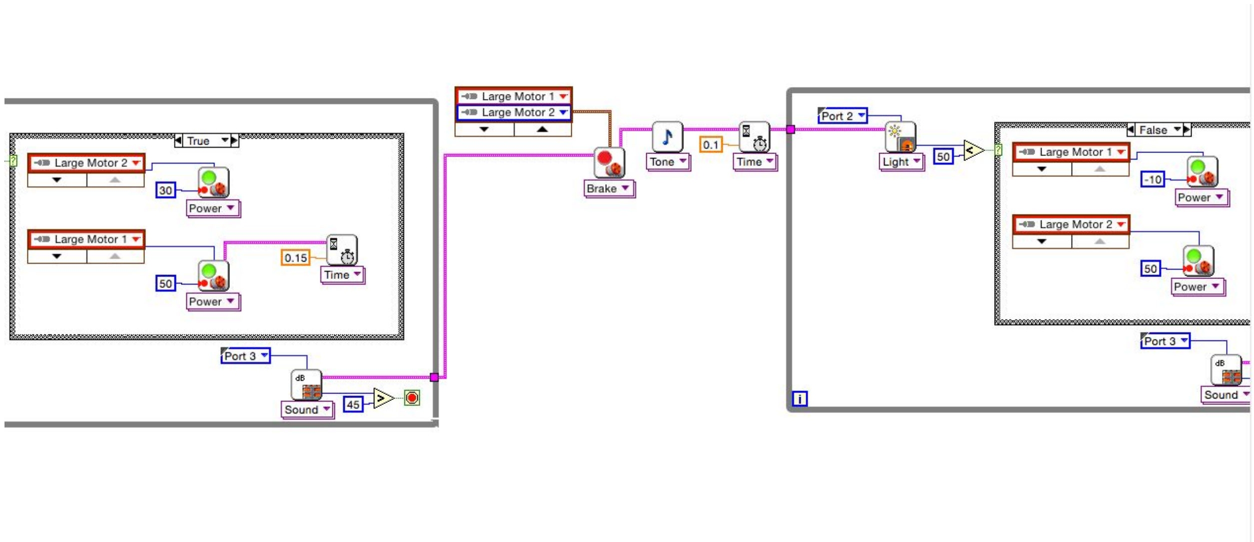
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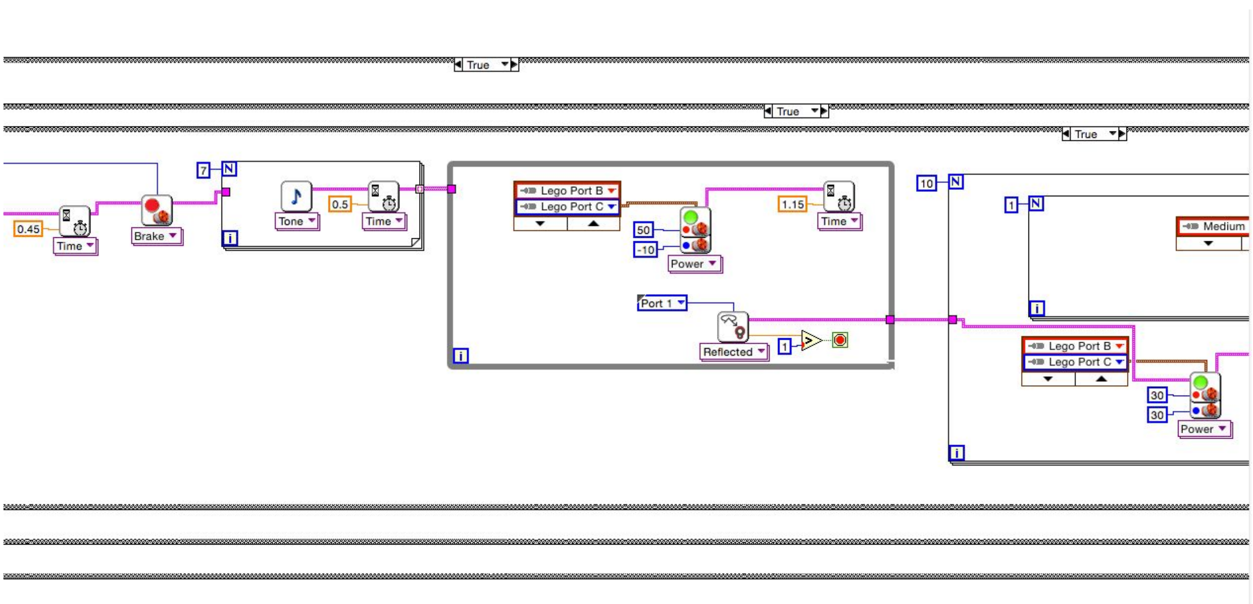
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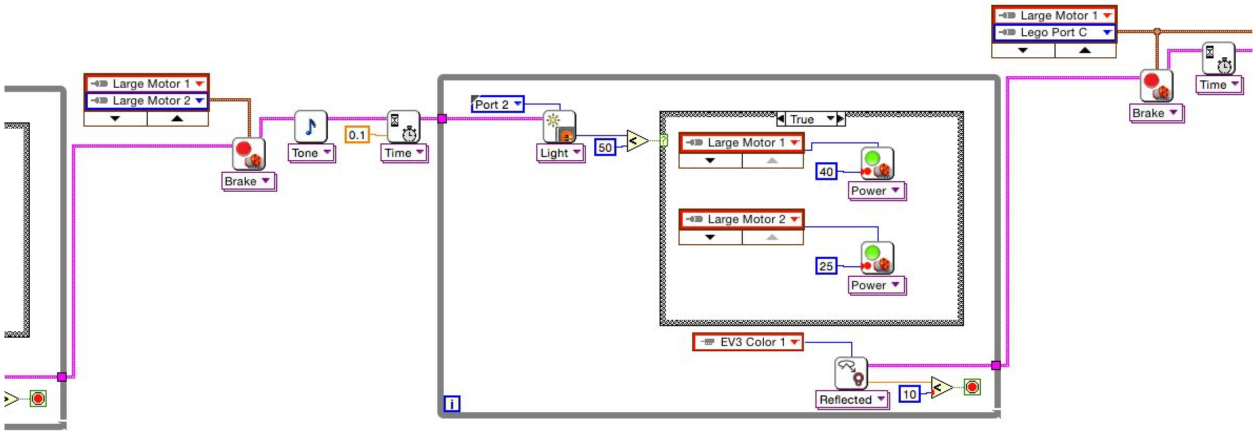
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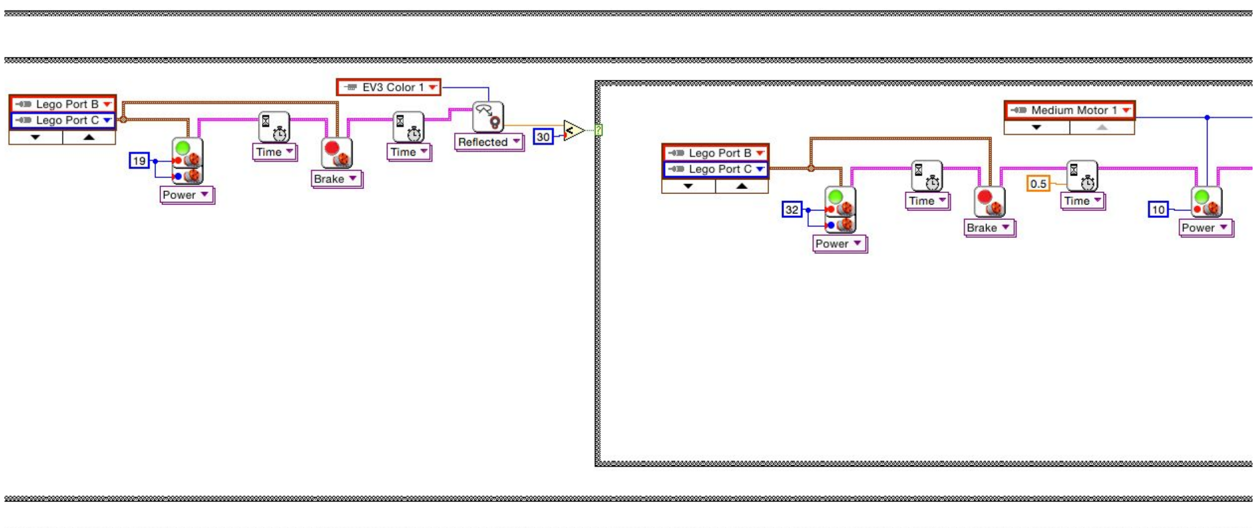
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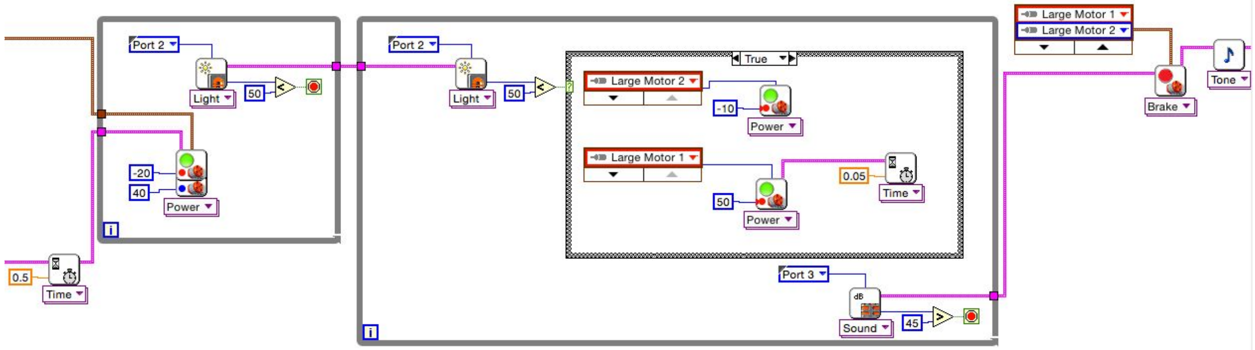
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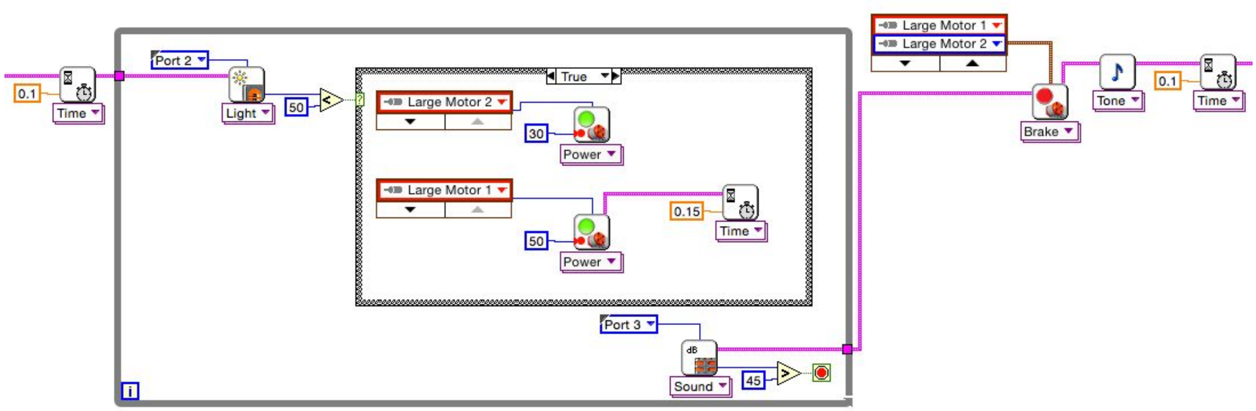
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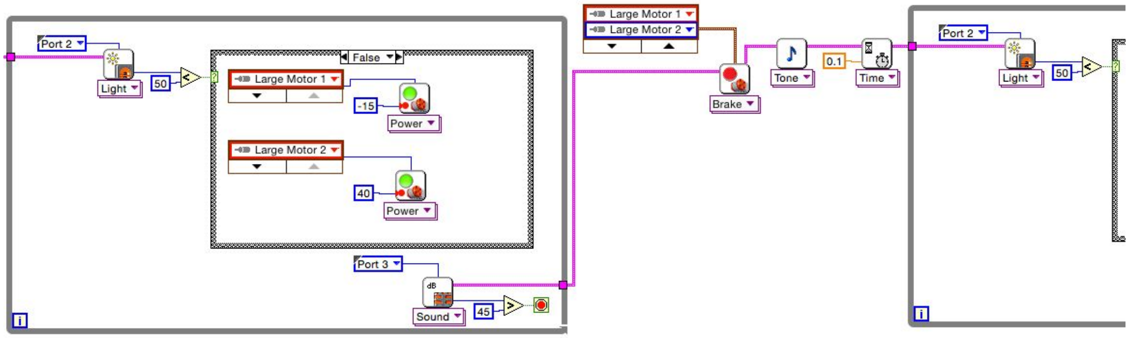
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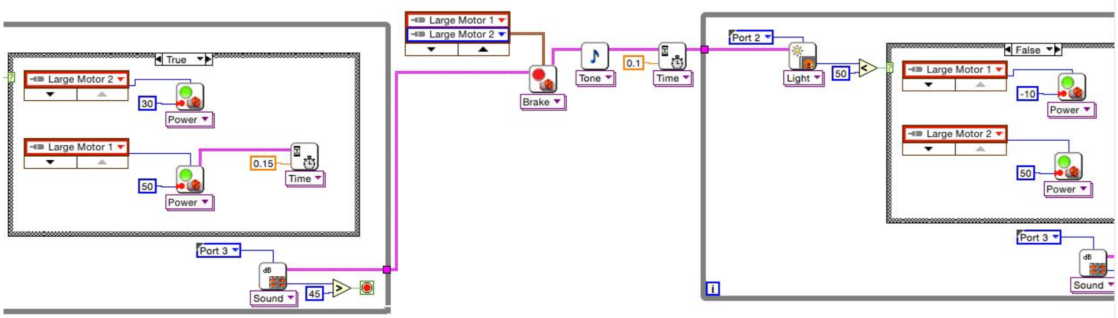
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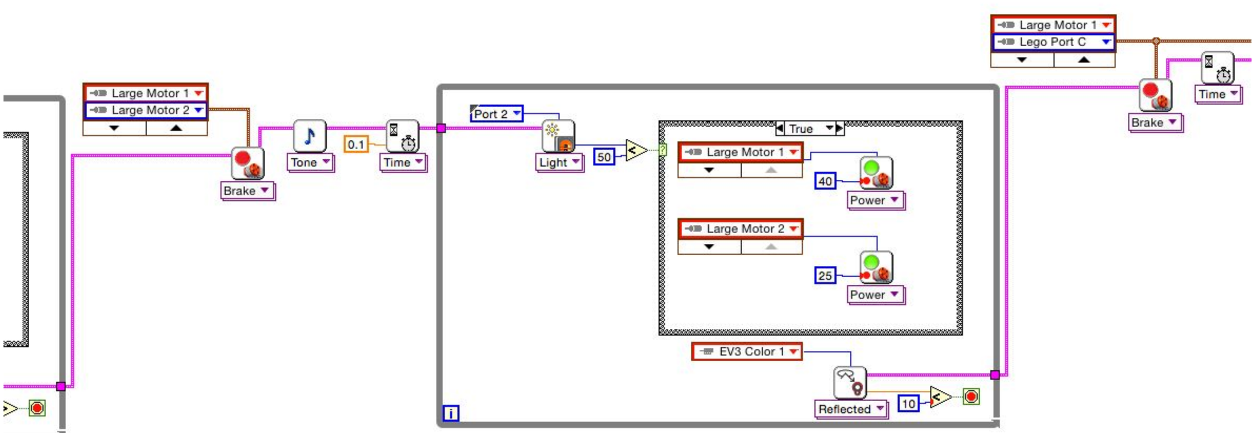
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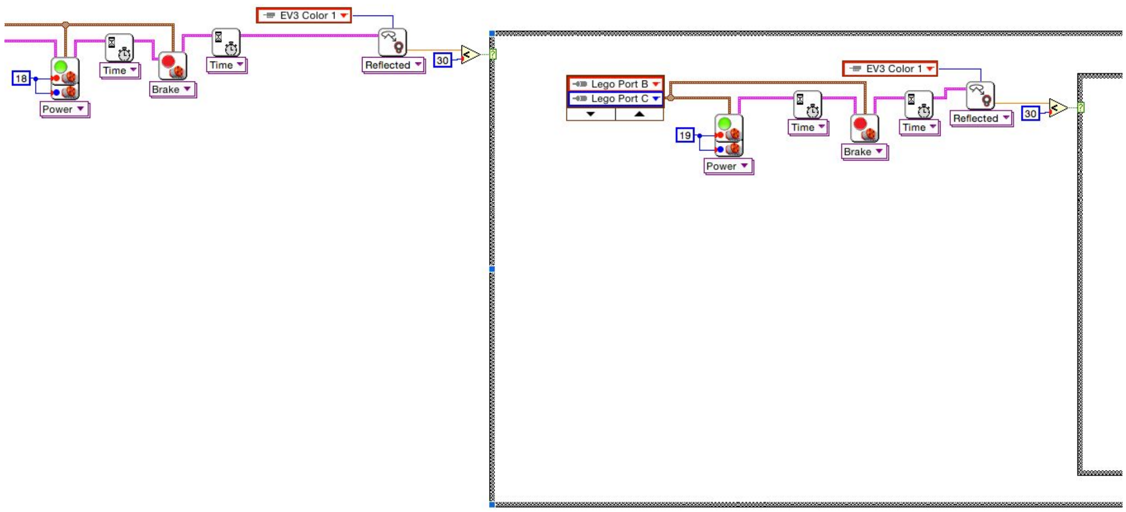
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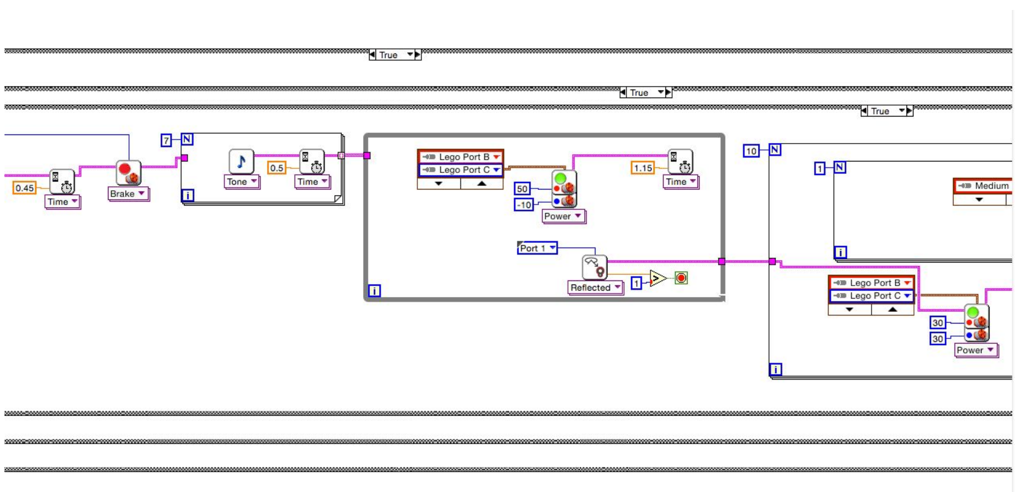
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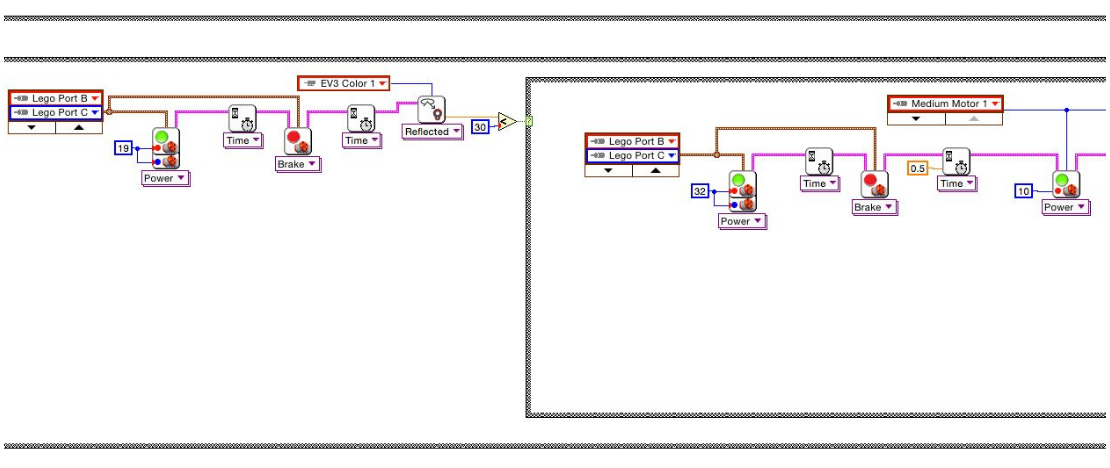
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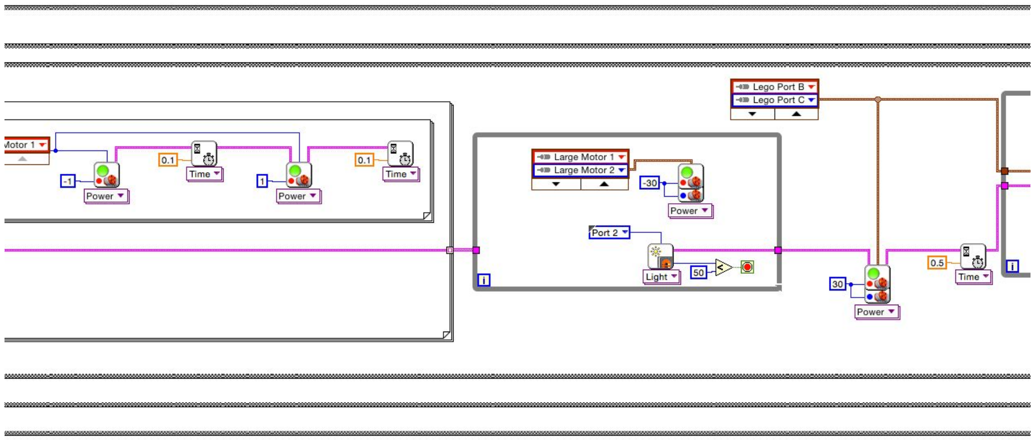
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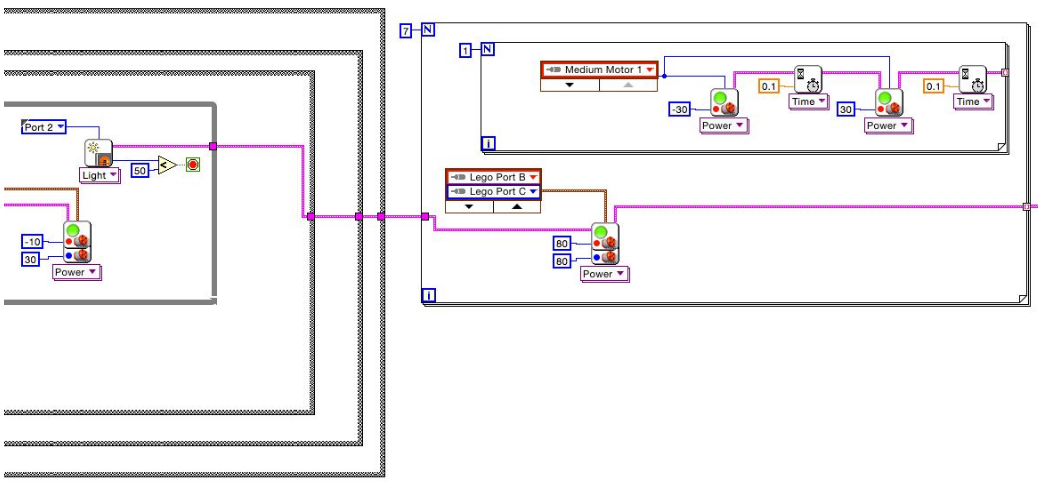
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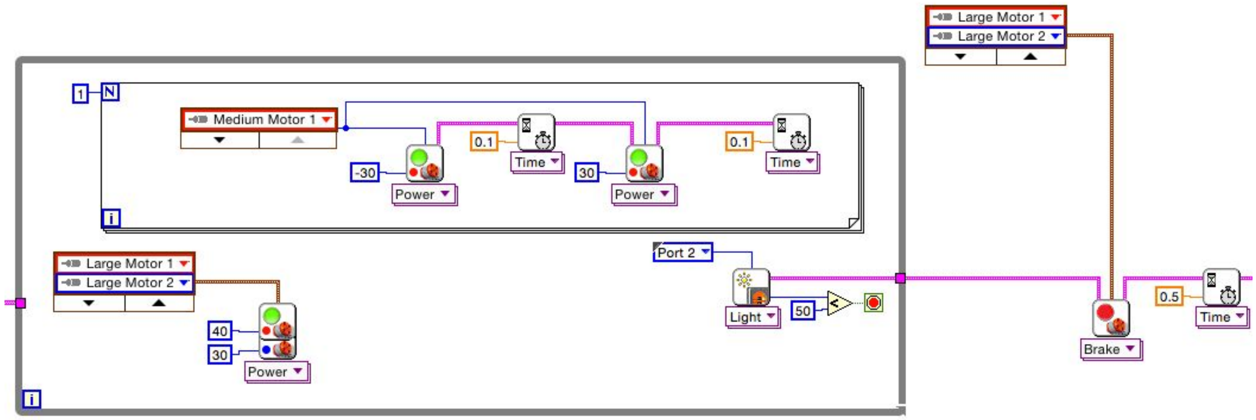
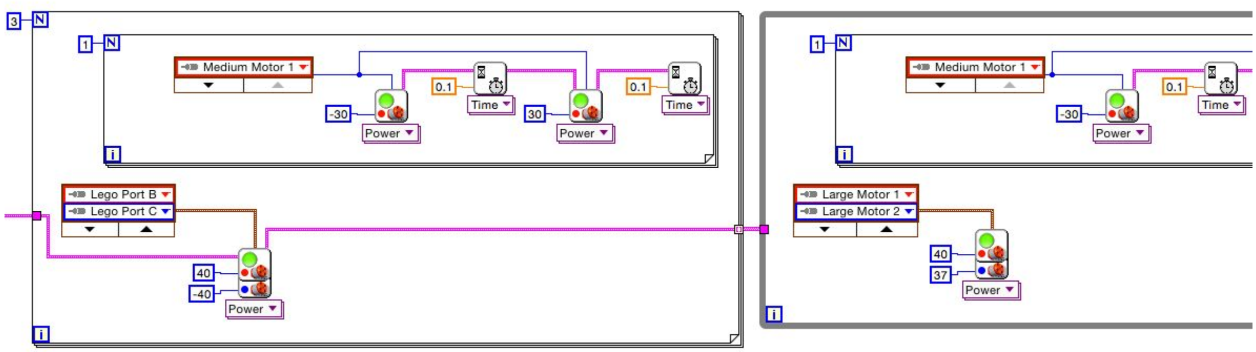
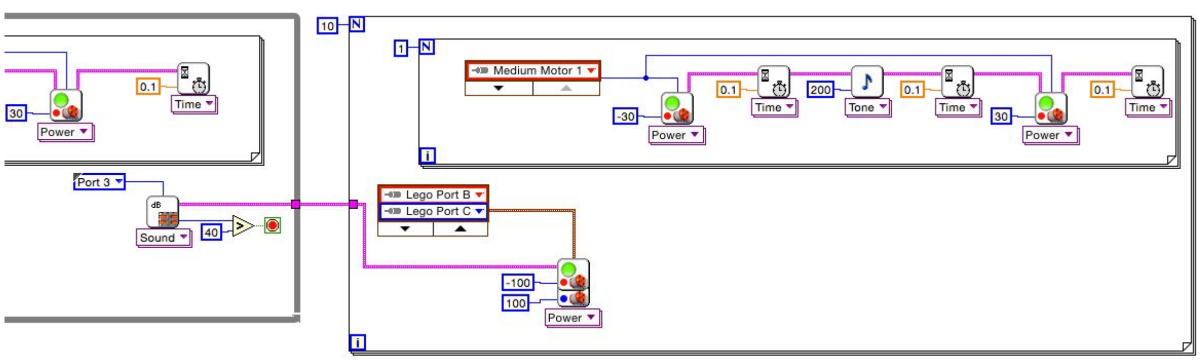
N
1
N
Medium Motor 1
-30
Power
0.1
Time
30
Power
0.1
Time
Lego Port B
Lego Port C
80
80
Power



Large Motor 1
Large Motor 2
1
N
Medium Motor 1
-30
Power
0.1
Time
30
Power
0.1
Time
i
Large Motor 1
Large Motor 2
40
30
Power
Port 2
Light
50
i
Brake
0.5
Time



3
N
1
N
Medium Motor 1
-30
Power
0.1
Time
30
Power
0.1
Time
i
Lego Port B
Lego Port C
40
-40
Power
i
1
N
Medium Motor 1
-30
Power
0.1
Time
i
Large Motor 1
Large Motor 2
40
37
Power
i



30
Power
0.1
Time
Port 3
dB
Sound
40
10
N
1
N
Medium Motor 1
-30
Power
0.1
Time
200
Tone
0.1
Time
30
Power
0.1
Time
i
Lego Port B
Lego Port C
-100
100
Power
i