Octagon 2.0 Design Report
Nabtesco Sponsored Project

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Introduction

The purpose of this project continued with what it started as, an opportunity for students to design and build a machine that incorporated a Nabtesco Motion Control Inc. product. An autonomous robotic base was chosen to be built utilizing Nabtesco right angle gear boxes. The hope for this project was that it would not only allow the current students to get some hands on experience developing the robot, but also that the robot would continue to be used as a learning tool by future students. The IGVC would be an added goal for the project although the intended use of the robot would be indoors. The modular base of the robot was constructed from 80/20 in the shape of an octagon. The 80/20 would allow for easy adjustments and changes, while the octagon shape was ideal for its simplicity and maneuverability indoors.

Many hard lessons were learned during the previous year and this was applied to the new design. The original design was refined in all three areas of mechanical, electrical and software. A much more robust platform was attained and we are pleased to mention that there are plans to add an ABB robotic arm to Octagon 2.0 in the near future.

Figure 1, above: Octagon

Design Process

The inexperience of the team during the previous year caused the timeline of the project to fall far behind, and the quality of the work suffered. Therefore, a concerted effort was made to start improving Octagon the day after the IGVC competition of 2015. The improvements focused around safe/stable wiring, decreased size, decreased noise, increased speed. By getting an early start we hoped to be able to spend more time on the software and increase the overall capabilities of the robot. The following refinements were added to the original design:

- Smaller frame
- Lower center of gravity
- Lower gear ratio differential drive
- Larger wheels
- Improved safety features(enable button)
- New motor controller
- Voltage & Current monitoring capability
- Complete re-wiring
- New simplified charging circuit
- Stereo vision camera
- New laptop
- Further development of software

Item	*Original Description*	*New Description*
Dimensions	37 x 30 x 66 inches	36(25 indoor) x 25 x 66 inches
Safety Considerations	Mechanical and electrical safety measures	-New latching E-stop circuit with enable button -Current limiter for motors -Voltage & current monitors
Payload	At least 300 lbs	At least 300 lbs
Runtime	2 – 3 hours	2 - 3 hours
Weight	Approximately 200 lbs (w/ IGVC module)	Approximately 200 lbs (w/ IGVC module)
Top Speed	Safe around humans, 5 mph	8 mph(limited in software)
Operating Environment	Relatively flat all terrain operation	Indoor use & moderately uneven terrain operation with outdoor suspension

Figure 2, above: Comparison of the original design parameters to the current year.

MECHANICAL DESIGN

Octagon was designed to be a modular robot that could navigate both indoors and outdoors. To achieve this goal a main platform was designed with all of the necessary components for simple indoor navigation. The base is designed so that different modules can be attached to the top of the base. For outdoor navigation a module with a camera and a GPS was designed. These components are crucial for the IGVC competition. The cameras and GPS are placed high on the module so that the cameras have a bigger field of view and the GPS is centered for more accurate positioning.

The base of Octagon was designed with differential drive, so that the robot could perform zero-point turns. This greatly improves the robot's ability to steer away from obstacles. It also simplifies the drivetrain of Octagon, since turning is solely achieved by the drive wheels. It was also desired that the shape be as close to a circles as possible, to minimize the chance of hitting objects while turning. A compromise was reached between the mechanical structure and the ideal shape which resulted in an octagonal base. New gear boxes from Nabtesco were installed. The new gear boxes reduced the gear ration from 103:1 down to 51:1. This would increase speed, reduce noise but still leave ample torque for the system. The base was also completely redone to reduce the outside dimensions from 30 x 30 inches to 25 x 25 inches. This would make the robot much more capable of maneuvering not only the IGVC course, but also tighter pathways indoors.

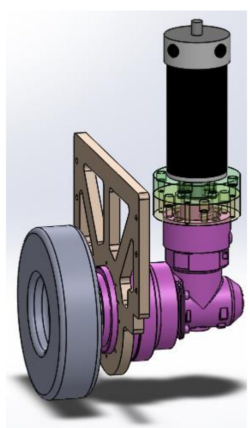

Figure 3, above: Wheel mount, 51:1 gearbox and motor configuration.

The material used for the robot, again was 80/20 extruded aluminum. This material made it relatively easy to not only reduce the dimensions, but also to position the batteries to a lower more centered position. It is also a relatively light and strong material that can withstand substantial loads. The robot also has polycarbonate siding which helps with weatherproofing.

From a control standpoint it is relatively easy to calculate the path of a differential drive platform. That, coupled with the maneuverability on grass led our design to the drivetrain arrangement of two drive wheels on the sides with two supports on the front and rear. This geometry allows Octagon to rotate about its center, in effect greatly simplifying the path planning and control.

Extruded slotted aluminum channel was used to build the frame. The extrusion allowed for easy assembly and nearly limitless flexibility. If any additional modules, components, or sensors need to be added it is a simple task to do. The main contributions to Octagon's mass are the batteries, gearboxes, and motors. All of those components are symmetrically distributed and low to the ground. This makes Octagon a balanced and stable platform even when driving in an uneven field. The driving brushless motors are securely mounted to Nabtesco Gearboxes with custom adaptor discs. The gearbox is then mounted to a plate which is bolted to the frame. The front and rear spaces allow for several configurations of supports to be used. For example in a hard flat industrial setting smaller castor wheels may be exchanged for the swivel supports. The electronics are housed beneath a large plate with the 270 degree LIDAR sensor sitting on top of that plate. In order for cameras and GPS to get a higher vantage point they are mounted on an elevated platform.

Electrical Design

We encountered many problems with the wiring during the previous year, so when the decision was made to reduce the frame it was also decided to completely rewire the robot with more caution and improved features. The first improvement was a new simplified battery charging circuit that allowed the use of a single charger, as seen in figure 4. The previous year it was necessary to charge the batteries at three separate connections.

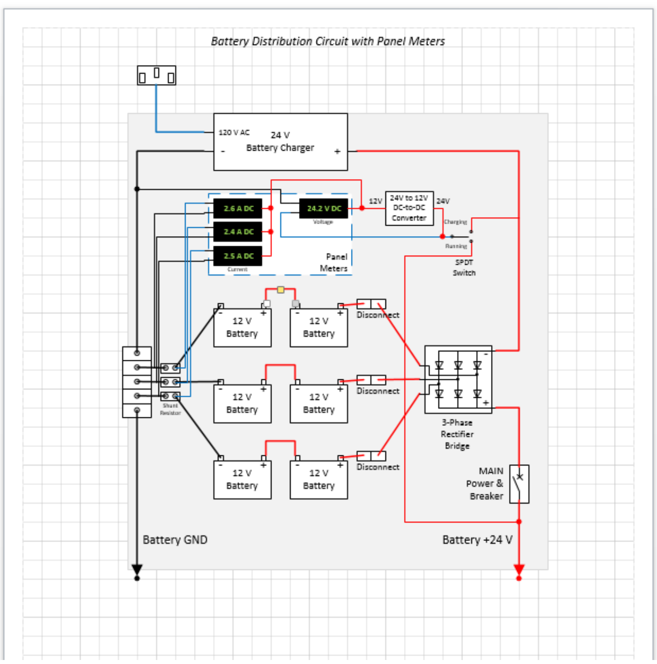

Figure 4, above: Schematic of the new charging system with voltage and current monitoring displays.

The new charging circuit would allow the batteries to be charged with 3 separate chargers or only one single charger. It also included displays that would show the voltage level of the batteries and the current flow during charging or operation. This circuit also included a 3 phase rectifier bridge that would help to create a balanced flow of current and equal charging for the three sets of two batteries.

The second improvement was a latching circuit and start button that was added to the E-stop. Pr. Mirza came from an industrial robotics atmosphere and suggested that the edition of the start button would help to create an extra layer of safety to the system. Power to the motors would not be reintroduced just by switching the E-stop back on. It would essentially force the operator to take an extra step and have an extra mental awareness that they are indeed ready to reintroduce power.

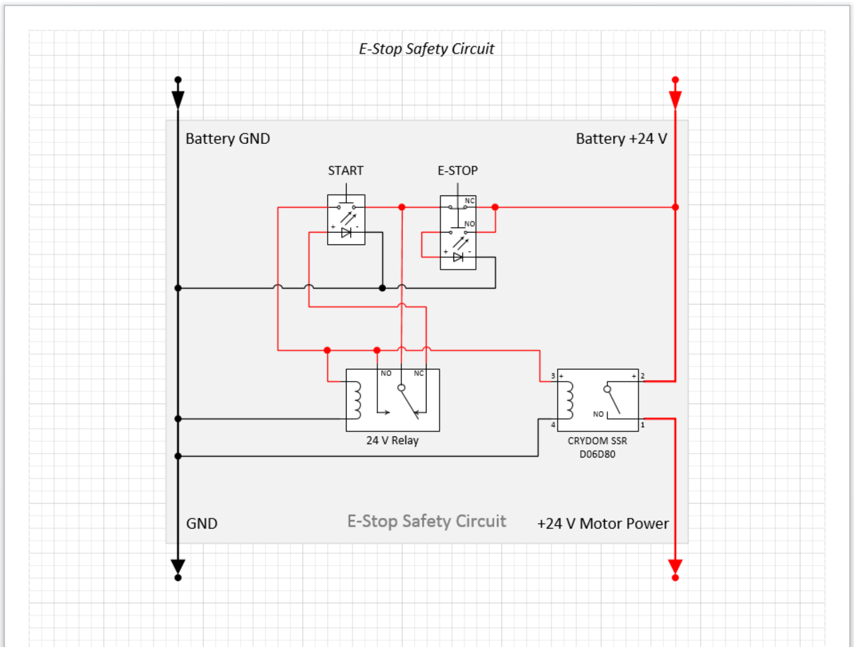

Figure 5, above: New latching E-stop circuit with added start switch.

While wiring up the two previously mentioned circuits, stesp were taken to wire up the remaining components in cleaner and neater fashion than the previous year. Wiring is a bit of an art form and it was not perfected during this second attempt, but it is much better and has provided consistent safe operation for the last few months.

A Roboteq motor controller was installed this year. The previous motor controller setup included three arduino unos with two h-bridges. Although they were very good h-bridges, because of faulty wiring the components were damaged and it was decided to go with a simplified set up that could be replaced quickly if damaged occurred again. The motor controller if very robust and exceeds the our worst case scenario of current draw of 80 amps. The motor controller also includes features that allow it to limit speed or current draw of the motors. The motor controller comes with it's own PID control loop and was very easy to adjust the parameters to get a smooth controlled response.

Sensor & Software Design

The task of the software team was to utilize Robot Operating System (ROS) to allow for autonomous navigation for indoor and outdoor use. The robot was required to navigate autonomously and avoid obstacles. This task was achieved by utilizing a LIDAR sensor, cameras, a GPS, a gyroscope, and the wheel encoders from both wheels. By taking the input from these sensors and analyzing the data continuously, Octagon was able to navigate autonomously. Using ROS libraries created for the sensors that were used helped ease the task of the software team.

The Intel NUC, running Ubuntu, is the onboard computer for Octagon. The NUC contains all of the ROS libraries and packages needed to run Octagon autonomously indoors or outdoors. Each package can be launched to complete a certain task by using a Microsoft Surface Pro that is connected wirelessly with the NUC.

Prior to allowing Octagon to navigate autonomously indoors, a map of a preselected area had to be created by collecting data from the LIDAR and wheel encoders as Octagon travelled through the area. During this time, Octagon had to be controlled by joystick to ensure an accurate and detailed map.

Utilizing the gmapping package allowed for use of simultaneous localization and mapping (SLAM) by Octagon. SLAM allows for Octagon to continuously scan its surroundings as it moves to avoid obstacles. SLAM also allows for Octagon to correct its position on a pre-collected map as it goes to a certain waypoint.

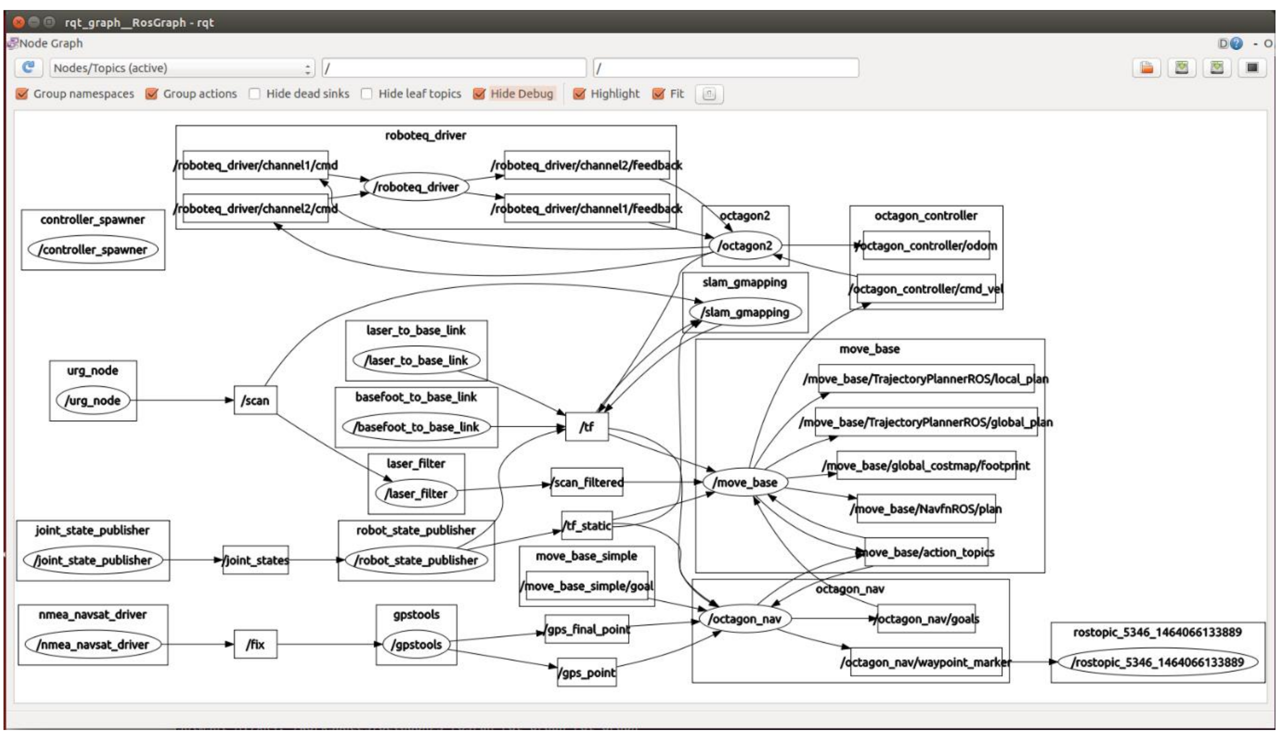

Figure 6, above: Rqt_graph(visual representation of software) of the entire software system developed in ROS.