PROJECT BETSY

2017 IGVC DESIGN REPORT

UNIVERSITÉ DE MONCTON – ENGINEERING FACULTY

IEEEUMoncton Student Branch

I certify that the design and engineering of the vehicle by the current student team has been significant and equivalent to what might be awarded credit in a senior design course.

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FACULTÉ D'INGÉNIERIE

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1. Introduction

IEEEUMoncton, founded in 2013, is a student branch of the IEEE association situated in Moncton, New Brunswick, Canada. This year's group, consisting of 14 undergraduate students in electrical engineering and computer science, are proud to present Betsy, the improved version of the previous Breakpoint vehicle. Using the same frame as Breakpoint, and most of the same physical components, the goal was to keep costs to a minimum by recycling components. Thus, the vehicle looks like its predecessor, but the bulk of the work accomplished is in the programming of the vehicle, with a complete overhaul of the system from previous years. This report will document the changes made to the mechanical design, as well as the transition from a priority-based C design to an intelligent decision-based system.

2. Design Process and Team Organisation

This year's team consists of 13 electrical engineering students and a computer science student, all ranging from 3rd year to 5th year. Most of the work was accomplished during class projects by 4th year students during the last two years, meaning the now 5th year and 4th year students. The tasks were divided into 2 categories: Machine vision and Navigation. The lead of the project was student IEEEUMoncton chair Alain Roy, while under supervision by faculty supervisor Dr. Gabriel Cormier and faculty para-academic supervisor M. Novona Rakotomanga. For each category of work, the group leads were varying each week, as per class requirements, but always reported to the project lead. Student communication was encouraged throughout completion and proved to be crucial to the completion of the project.

3. Mechanical Systems

As per our design decision, the base of the robot remains built from the basic structure of an electrical wheelchair, with an electric motor for each front drive and swivel wheels in the back. Le chassis upon the base was built by measure by the groups from previous years.

3.1. Structure

The structure consists of an aluminum frame while a plexiglass cover secures and seals the computer as well as the components inside to ensure that they will not be damaged by rain or other weather conditions.

Figure 1: General view of the robot

The electrical components are fixed to the base of the structure. To promote airflow, the cabling has been strategically separated for each component inside the frame of the robot. To be noted, the upper supports for the cameras have been changed due to using a single camera now, compared to three before. For this reason, figure 1 is not up to date with the current design, but remains from a lack of updated pictures.

4. Sensors

4.1. LIDAR

The robot uses a Hokuyo UTM-30LX-EW for its measurement system. The LIDAR has a sensing range of 30 meters with a +/-50 millimeters of tolerance. The sensor also has a field of vision of 270 degrees. It is the robot's primary obstacle detection sensor.

Figure 2: Measurement system : Hokuyo UTM-30LX-EW

4.2. Cameras

Part of the changes present on Betsy is the use of a new tool for computer vision. The new camera used is a Kinect for Xbox One. Instead of the 3 cameras used previously, the Kinect is equipped with a 1080p color camera, depth sensing capabilities and infrared capabilities. Coupled with the new memory that is included in the robot, a single Kinect with depth sensing can replace 3 cameras, creating an image of the lines as it goes in the memory to recognize them even when it doesn't seem them. A new camera mount has been fabricated as well to secure the Kinect in position.

Figure 3: Kinect for Xbox One

4.3. Global Positioning System

The robot is equipped with a Ag Leader 1600 for its Global Positioning System. This GPS has a 0.6m accuracy at a 95% confidence interval. The GPS automatically finds and connects to the GPS and SBAS signals and outputs them as a standard NMEA string at 5 Hz through serial communication. The Ag Leader 1600 is robust and can withstand any operating conditions.

Figure 4: AG Leader 1600

4.4. Odometry

To calculate the position of the vehicle, two encoders were purchased and attached onto the shaft of each motor. These encoders allow the vehicle to record every rotation of the wheel since the initial start period. The count of each of these encoders can be used to perform a navigation technique called “Dead Reckoning”. This technique allows the vehicles to know how far it has travelled from the starting point while considering its direction.

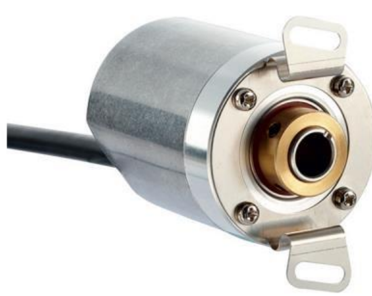

Figure 5: Encoder SICK DBS36E

The combination of the LIDAR and encoder can be used to obtain the raw data necessary to create a map of the surrounding of the vehicle. The creation of this map can be done by implementing SLAM in the vehicle. The SLAM algorithm is already implemented in ROS, which is how the laptop onboard the vehicles can generate a map while also completing the course. This method of navigation will be useful to remember the location on lines and obstacles to optimize the trajectory. Figure 6 demonstrates the robot in motion, at the same time creating a map of walls seen by the robot.

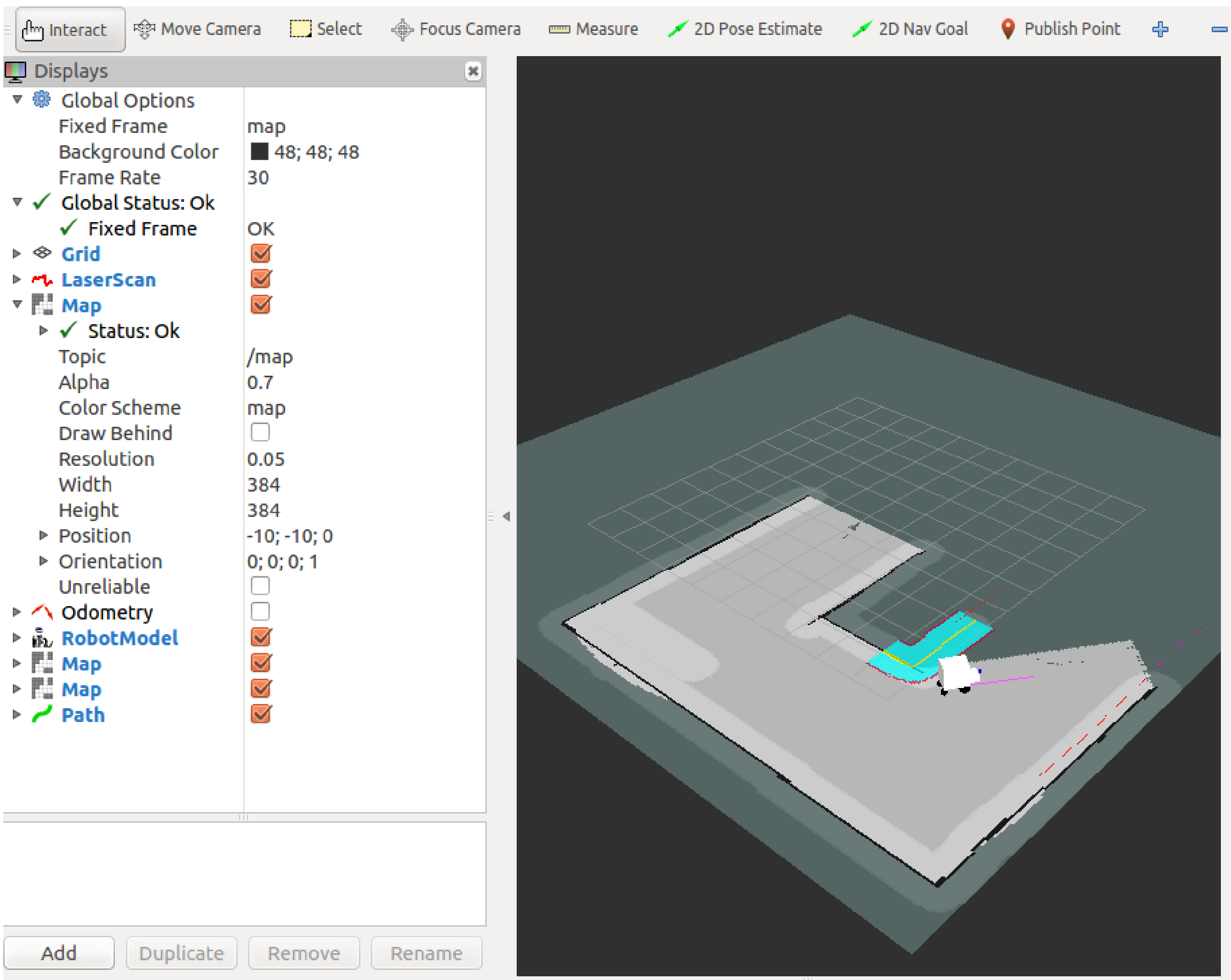

Figure 6: Map generated in real time

5. Power Distribution and Battery Systems

The vehicle is powered by two 12V DC batteries in series. Only the Motors and the GPS are connected by a direct 24V DC input. A DC-DC converter is used to ensure both batteries drain at the same rate and that there is an almost perfect voltage of 12V DC. The converter powers the wireless E-stop, the LIDAR, the USB hub and the 120V AC Inverter which power the laptop. The remaining components are connected by USB with the USB hub. Utilizing the old schematic, the section in red is added hardware. The remote-control section is all new and is new done by Bluetooth with a PlayStation3 controller, and there is an additional relay separating the remote-controlled section and the computer-controlled section.

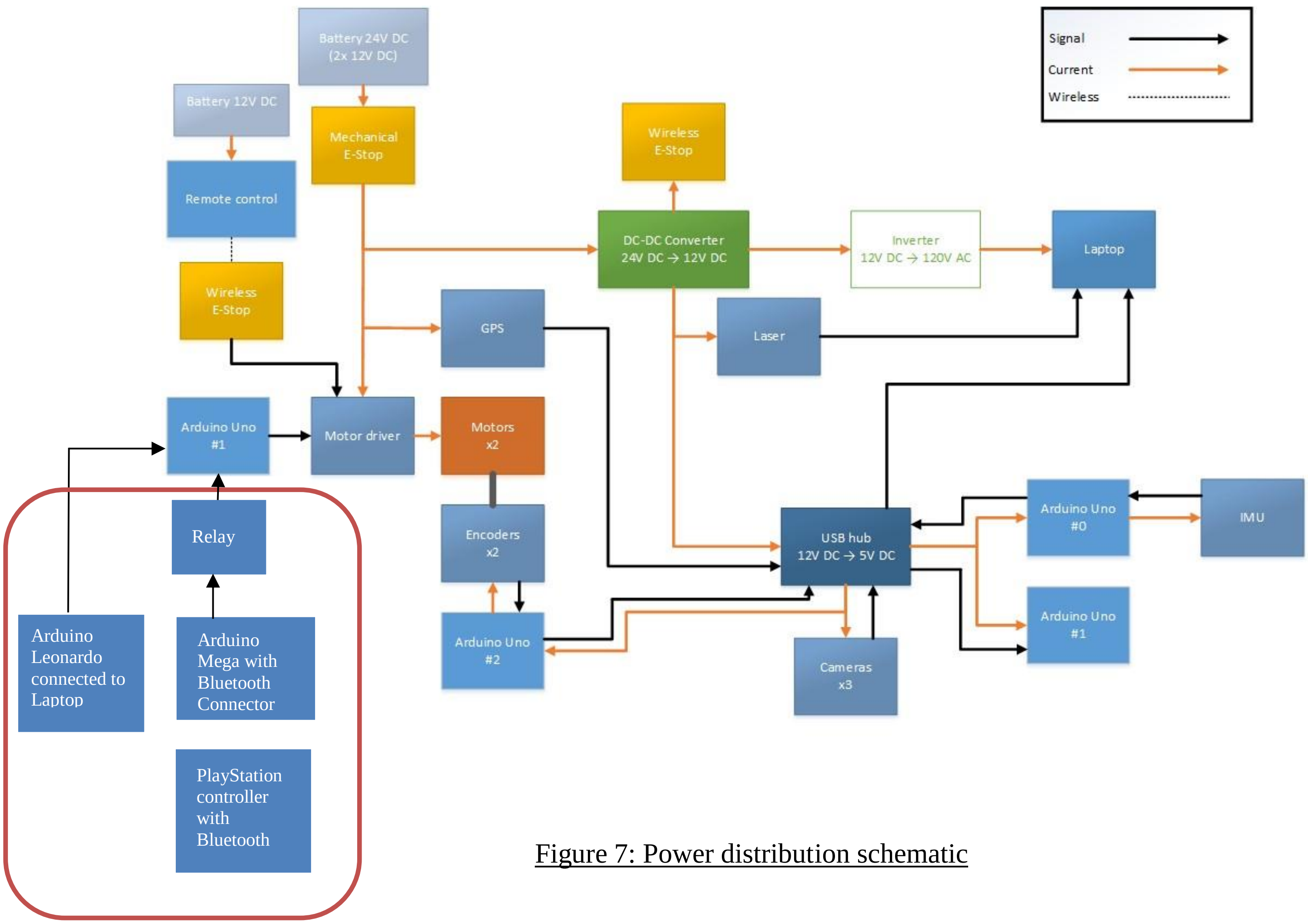

Figure 7: Power distribution schematic

6. Electronics and Computer Systems

6.1.Main Computer

The main computer of the robot is an MSI CX62, chosen because it successfully met all our requirements while being relatively inexpensive. It is composed of i5-6300HQ processors with 6 MB of cache clocked at 2.3 GHz with 4 physicals cores and 4 threads. It is also equipped with an NVidia GeForce 940MX graphical processor and 8GB of RAM, all of which is useful for both performing real-time action and decision making as well as video processing.

6.2. Security Systems

Given the IGVC requirements, the vehicle has an emergency stop fixed on top at the back of the structure for easy and rapid access. The vehicle also has a wireless emergency stop which only stop the motors driver and not all the power of the vehicle. The remote has a range of up to 200 fee within a line of site.

The vehicle has two different modes, only the laptop on the vehicle can control it or only the wireless remote. It is possible to switch from one mode to another by remote control, activating a relay, choosing where the signal comes from to be fed to the driver. A beacon was placed on the top of the vehicle to signal that the vehicle is in operating mode. If the light is blinking the laptop is controlling the vehicle and if the light is solid the remote is in command.

7. Software Strategies

The IEEEUMoncton student branch is made up of undergraduates electrical engineering students that have an interest in robotics and similar topics. In consideration of future students, it is necessary that the work done is simple and robust so it is easily alterable and can be rapidly assimilated.

For the success of the project, many control strategies were studied, and are showed in figure 7. Based on our first participation, it was discovered that ROS was a good choice. Regardless, a study was made to compare options, all with ROS being the baseline. In the end, ROS is the solution that will be used.

System considered	Advantages/drawbacks
- New system made from scratch	Drawbacks: - No feasible in terms of time and skill - A lot of the work is already done by other solutions
- Microsoft Robotics Developer Studio (MRDS)	Advantages: - Flexible - Can be used on Windows. Drawbacks: - Not open source. - Little community - Not a lot of packages available
- Mobile Robot Programming Toolkit (MRPT)	Advantages: - Open Source - Used in academic situations Drawbacks: - Few users, limited documentation - Limited functions
- CARMEN (Carnegie Mellon Robot Navigation Toolkit)	Advantages: - Open Source - Used in academic situations Drawbacks: - Few users, limited documentation - Limited functions
- Orocos (Open Robot Control Software Projet)	Advantages: - Better real-time control than ROS - Older than ROS Drawbacks: - Significantly harder to use than ROS - Small community

Figure 8: Operating system study

8. Systems Integration

8.1. Vision

As lines and flags make up obstacles in the course, the job of the computer vision part is to recognize these obstacles and mark them as obstacles to be avoided in the generated map To do so, the first crucial part is to prepare an algorithm so recognize certain colors and mark them as either obstacles or directions. The process of doing this is by using the popular OpenCV library and interfacing it with the brain of the computer, ROS. As a result of online research and by reading other student team reports, we noted that the HSV color space is most often used for color detection. It is advantageous to have the detection in the hue, saturation and value fields because the light variation has lesser effect on the received image. If the detection would be completed in the RGB field, the light variation would have an effect on the color detected. For instance, a red flag may be perceived as darker when placed in the shade. Ultimately, because the vehicle will be outdoors where light variation will occur, the HSV system will offer the best results. The way that the transformation to an obstacle will work is by pixelating the image, where every pixel of the desired color will form a point cloud. This cloud, if dense enough, will be perceived as an obstacle and will therefore represent a boundary. For the obstacle detections, the LIDAR gives highly accurate measurements, at a wide degree or sweep (270°) with a high speed of detection, that can be used directly to demonstrate obstacles in the map.

8.2. Navigation

The navigation of the vehicle is measured by three different components, the GPS, the encoders and the IMU. To detect if the vehicle has arrived at a waypoint, the GPS gives the latitude and longitude measurement which is used to determine its location. Also, while the vehicle is in motion speed and orientation data can be collected. The disadvantages of the GPS is that it only work outdoors and can possibly have a bad connection. The encoders help balance the negative effects of the GPS, which allows for proper measurements in the result of a failure of the global positioning system. The information received by the encoders is identical to that of the GPS, except for the position that will be in meters instead of the latitude and longitude. Another important use of the encoder is that the rotation count is directly used in the mapping program to be able to recreate the environment in the appropriate scale. The IMU is currently only used for the orientation of the vehicle, but has the potential to be used for the acceleration, speed and position with the proper calculations.

As for the navigation as a whole, ROS has a package called "Navigation Stack" that will enable the robot to receive information and process it on its own. How this stack works is expressed in figure 9.

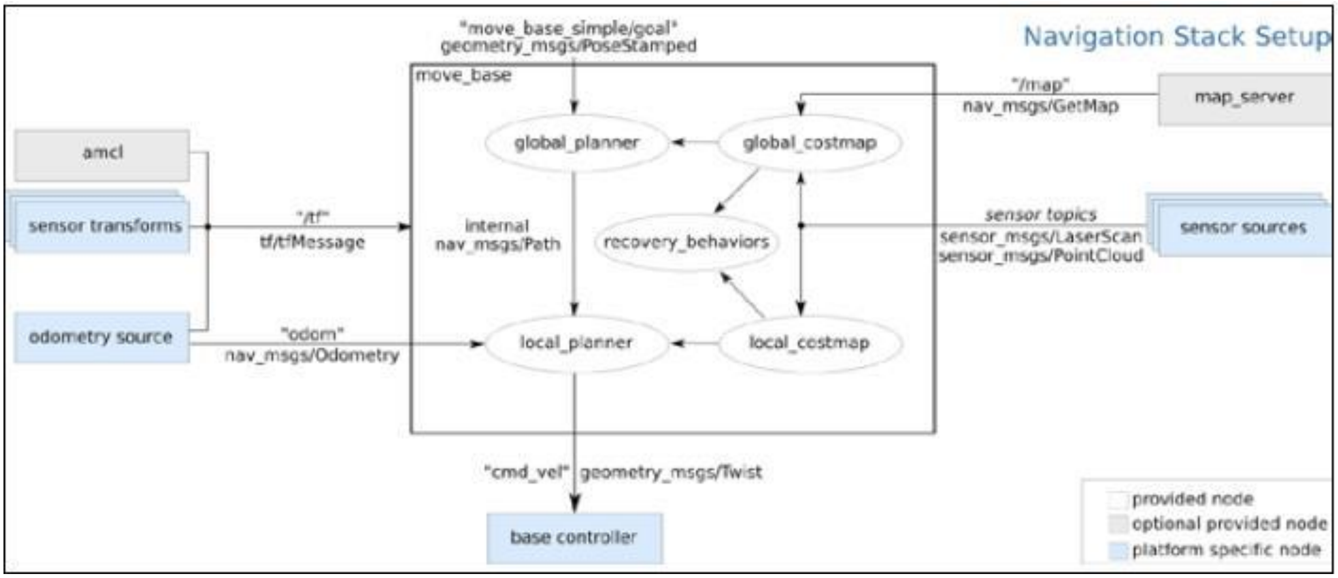

Figure 9: Navigation Stack

As seen in the figure, "navigation stack" takes the information from all the previously mentioned sensors and process it to send a single signal towards the base, being the main robot motor driver in this case.

9. Predicted Performances

As per the last appearance in this competition, since the motor drives didn’t change, the vehicle speed will be approximately 3.7mph at full speed, but the speed traveled when making the map is up to the robot’s smart system to take the time to gather and process the information needed. From tests however, this process can be done by going at least at 50% of the robot’s speed, making it meet the minimum speed requirement. The vehicle’s battery life is approximately 3 hour, and there is a backup battery pack and a charging station available for the convenience of being able to work for extended hours. At full speed, the vehicle needs 10A to operate properly. If the laptop’s battery is running low on power, this can be charged using the batteries on the vehicle.

Given the performance at the 2015 IGVC, and the intelligence upgrade that were performed on the robot during the last two years, the vehicle should be able to complete de basic course, as well as complete the advanced course.

10. Budget

The following table represents the additional costs that occurred between this year's competition and the 2015 competition Betsy project. As it is possible to see, the costs for the vehicle are very low, meaning that the initial goal of recycling parts and materials was accomplished, and proved to be an important factor in the group being able to make the trip.

Table 1: Cost of the components used in the Project

Component	Value	Cost	Comments
Microcontrollers	$182.11	$182.11	3 New Microcontrollers
PlayStation3 Remote	$39.98	$0	Donation
Xbox One Kinect & Accessories	$180.78	$180.78	
Total	$402.87	$360.89	

11. Conclusion

This year's group's focus was to improve on the performance delivered last time. By minimizing costs and reusing a lot of material, the changes to the software of the robot are significant enough to call it a new robot, for it is no longer a vehicle running on windows and C based programming working of a priority list, but it is now a vehicle working with ROS to intelligently create and navigate a memory of its environment as it moves. With the magnitude of the improvements, it is believed that last participation's best run of going halfway through the basic course will be shattered, and that the vehicle will be able to compete on the advanced course with much more elaborate and fancy robots.