Lessons from an Autonomous Rover

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Abstract

The development of autonomous vehicles is of extreme importance in the mission of exploring the galaxy. The process of developing one small version of an autonomous robot is detailed in this paper, in addition to the components used for the robots. The final section develops ideas for future improvements to the robot. The robot never made it to the field; however, plenty of useful data came from the process.

1. Introduction

The development of fully autonomous vehicles is a constant process for many industries, especially with the space and automobile industries. This paper focuses on the efforts of one team to create an autonomous robot capable of navigating around obstacles and making it to a beacon. The process and components of the robot will be detailed here, and ideas will be provided for continuing and finishing the project.

The robot was intended to maneuver around the Great Sand Dunes. The location is used to simulate the terrain of Mars; both places are dusty, sandy, and very cold for the time the competition would occur. The main goal is to create a robot that can withstand such conditions and still complete a mission. In this manner, more can be learned about the pitfalls of rover design and what errors can be avoided next time.

2. Structure

The structure of the robot began with the chassis of the 6WD Yahboom robot[1]. While the electronics were discarded, the structure of the robot was sound and was utilized for the final design. In the end, the robot came together as a six-wheeled, very boxy design.

2.1. Chassis

The robot was originally designed to have two metal plates, with all electronics in between the two, according to the original Yahboom design[1]. While this works fine in a lab environment, it quickly became clear that more would be required to protect the electronics inside the robot from the harsher environment of the Sand Dunes. Therefore, a shell was planned to be added. This shell was designed to keep the majority of the sand kicked up by wind or wheels from getting near the electrical components of the robot. Finally, a tower was added to the top of the shell, to separate the compass from the largely metal body of the chassis. Unfortunately, the shell was never added to the robot, but the plans will be listed below in figure 2.
2.2. Locomotion

The robot runs with six wheels; three on either side. The decision to use six wheels was fueled by the idea that if even one got stuck, the other five would be powerful enough to pull the robot forward again. This did work, as unintentionally tested by one of the wheels falling off during a different test. Each set of three motors was run as if it were one motor with a H-bridge[2]. Several interesting problems appeared when working with 6 wheels instead of 4. Turning was especially challenging, as it was quickly proven that without enough power, the robot would not turn at all. The robot was very quick, even at the lowest settings; therefore, more attention was given to the power put out by the motors. By the end of the experiment, the robot could climb slopes of 20 degrees or less.

Unfortunately, the connection to the robot was suspect, and the wheels would fall off or jam somewhat frequently as more testing occurred. The jams were solved by using screws with smaller heads to connect the wheels to the robot. The wheels falling off was not completely solved, but a few ideas for solving it could be to use a lot of hot glue or drill through the connection point on the motors and insert a screw all the way through the shaft.

2.3. Battery

A nickel metal hydride battery or NiMH, designed by RadioShack has been used for powering the robot with a voltage at 9.6V and a current rate at 2000mAh[3]; the battery has been used to power all electrical components. Also, it can be recharged through a charger.

One issue that was discovered was that once the battery was connected to the Arduino, the high voltage could potentially destroy the Arduino board. To solve this issue, a step-down power converter was introduced and used for the robot to reduce unwanted power surges from the battery.

2.4. Arrangement of Electronics

Most of the electronics fit easily between the two plates of the chassis. Three pieces needed to be further away from the body of the robot to perform their necessary functions. The ultrasonic and infrared sensors were placed in front and behind the robot for obstacle avoidance. The compass was placed well above the chassis to ensure that the metal and signals coming from the rest of the electronics would not interfere with the signal sent by the beacon.

All parts of the electronics were secured by attaching small pieces of foam board to the bottom and attaching the foam board to the robot itself. The foam board prevented any unfortunate surges of static from frying the circuitry, and made the process of designing the positions of the circuitry easier by providing more mobility in the planning phase.

3. Electronics

Several electrical components were required to create a functioning autonomous robot. All paths needed to lead to the Arduino Uno, as it was the communication hub and communicated instructions for all sensors and motors used in the construct. Depending on their function, the sensors send data along the analog or digital paths to the Arduino. All infrared sensors send data using the digital paths; all other sensors listed communicate through the analog side of the Arduino.
3.1. Infrared Sensor

The infrared sensors were tested extensively. Two different varieties were tested; of the two, the GP2Y0A21YK0F[4] sensors proved to function more consistently than the Gikfun EK1254[5] sensors did. Both sensors functioned in the same manner; they emit a certain wavelength of infrared light, and calculate the distance of an object from that position using the time it takes for the original wavelength to return to the sensor. In the lab setting, the sensors were found to be consistent to ranges of up to 70 centimeters. However, their performance changed drastically depending on the levels of light in an area and how reflective the object being sensed is. Once the sensor encounters sunlight at a horizontal angle or in a range of plus or minus 10 degrees, it constantly reads an object’s presence, regardless of the obstacle’s existence. However, when aimed at the ground, the infrared sensors continued to return accurate distances. Thus, the decision was made to use the infrared sensors in the capacity of sensing dangerous dips in front and behind the robot, to ensure it never would get stuck. Ultrasonic sensors would be used to sense obstacles directly in front of or behind the robot.

3.2. Ultrasonic Distance Sensor

The ultrasonic distance sensor that has been used on the robot is an ultrasonic distance sensor model HC-SR04[6]. The HC-SR04 sensor is capable of sending and receiving the ultrasonic wave in a range from 2cm to 400cm of measurement[6]. The HC-SR04 module consists of three small electrical components: a control circuit, a sensor receiver, and an ultrasonic transmitter[6]. So, the sensor gives the basic ability for the robot to detect that object that is reflective to the ultrasonic wave. Once the sensor detects the object, the robot can interpret and convert the received signals to the distance in centimeters that humans can read. Coding was required to convert the signals to an understandable unit. The connection between sensor and the Arduino was established by wiring and the sensors were powered by Arduino Uno.

3.3. Compass

The compass on the robot is a SparkFun 9DoF Sensor Stick 3.3v (LSM9DS1)[7]. It provides bearing or heading that is relative to magnetic poles. The LSM9DS1 consists of three main components: a 3-axis accelerometer, 3-axis magnetometer, and 3-axis gyroscope that make it function. As a result, the LSM9DS1 can detect and measure three properties of movement in three dimensions, such as heading, acceleration, and angular velocity[7]. The robot uses these readings and the data from the beacon to determine the path it needs to take. The LSM9DS1 was installed and set up far away from other electrical components because those components located near the LSM9DS1 may generate a small electromagnetic field that could slightly interrupt the LSM9DS1’s sensors.

3.4. XBee

XBee is a wireless-radio device that allows the robot to receive signals which are transmitted by the Robotics Challenge beacon[8]. The XBee module will inform the robot about a bearing that the robot needs to follow and let the compass determine the heading to the beacon. The communication between the XBee (a receiver) and the Arduino Uno was set up by wiring an Arduino Fio and the Arduino Uno together in a slave-master relationship[8]. IEEE 802.15.4 is a standard protocol that has been used for a network, and it allows the XBee receiver to communicate with another XBee that acts as a transmitter or beacon[8].

Powering the beacon and receiver and getting them talking took some time. Each was powered with a 9 volt battery for testing, and uploaded a few basic programs to get the two communicating properly[8]. The challenge was getting the receiver to communicate with another board. The Fio was the master board in the master-slave relationship, providing the essential data to the rest of the system.

4. Coding

The robot was programmed mainly on the Arduino Uno by using C++, which is considered a high-level programming language[9]. Moreover, built-in functions that come up with the Arduino Uno were used in coding. All codes were written and uploaded to the Arduino via the Arduino Integrated Development Environment or Arduino IDE. Not only did the Arduino Uno need to contain the main code, but other electronic components also needed to be coded. Foremost among these were the compass and the XBee transmitter and receiver. Each needed to be coded individually in order to communicate with the other components and send signals back to the Arduino Uno.

Once the code has been uploaded to the robot, it clearly creates the connections, and establishes the communications between electrical components. For example, the Arduino communicates with the H-bridge, the XBee, the Compass, and the Sensors to tell the robot
where and when to go. These connections enable the robot to perform tasks correctly, such as being able to detect objects, make decisions, and navigate to the beacon.

5. Plans

According to the original plan, the robot would be programmed with the capability to detect and avoid obstacles as well as navigate to a beacon. Also, the robot’s body would be modified or redesigned to have more defenses that can protect the robot from unexpected settings and extreme conditions. Moreover, the robot’s wheels had to be redesigned to handle any types of land surface, such as rough ground, sand dunes, or partially saturated soil.

Unfortunately, unforeseen time constraints caused by the global health pandemic COVID-19 prevented the completion of the project. Therefore, this section will cover what can and should be done in the future to produce an even better robot than this one.

5.1. Goals

The final design for the robot was never carried out. With additional time, three more modifications would have been added on.

Three “arms” would extend in front of the robot, each with one ultrasonic sensor facing forward and one infrared sensor aimed at the ground. Each would be separated at the angle that most optimizes the robot’s range of “vision”. This would maximize the sensing of obstacles and more importantly, catch dips that might ground the rover if one side was too deep for the wheels.

A second addition would be to the shell. A third tier would be added to the structure to protect the compass and tower in case the robot does roll at any point. The final shell would be rounded and more flexible, with the hope that the robot would be able to return to an upright position if it did roll. This shell would also function as wheel wells for the robot, to ensure that no sand would get into or interfere with the functioning of the motors.

The final and most critical addition to the robot would be the final component of the compass. In order to properly read and communicate the signal of the beacon to the Arduino Uno, a second Arduino is required, an Arduino Fio. Unfortunately, the team ran out of time to get the two systems talking to each other. Therefore, adding the final critical Arduino Fio to the robot would successfully meet all criteria for a properly functioning, self-guided robot, and would allow it to successfully reach its objective.

5.2. Testing

A large volume of testing has already been completed for the robot. The range and capabilities of the infrared sensor has been conclusively examined. The minimum power to provide to the wheels is now known, and the methods of getting the robot to turn in a variety of ways with six wheels have been tested. The wheels have been tested on different terrain; they are effective on most. The robot will guide itself based on the heading from the compass. The Fio and the beacon communicate consistently with each other.

A number of tests revealed other issues that will need to be resolved in the future. For instance, the robot had issues sensing anything other than what was directly in front of it; it crashed into the wall several times because of this. The wheels on the left side were slightly more powerful than those on the right side, and the robot had a curved path whenever it moved. Due to the friction of these differing speeds, the wheels’ connections to the robot occasionally failed as well. All of these can be solved, but more testing is required to resolve them.

For instance, further testing on the ultrasonic sensors will be required to determine their range to a more exact point. Determining the angles at which the sensor can sense objects will also be useful. The infrared sensors will need to be tested running with digital data instead of analog data. The compass has been tested thoroughly, but its interaction with the beacon will need to be tested more extensively as well.

One problem that came up regularly was battery strength. Determining the point at which the battery fails to provide the appropriate power levels to the motors is absolutely essential, and may or may not prove a need for multiple back-up batteries to be ready for use in the field.

More testing needs to be done on the structure. It is unclear how much effect the additional weight will have on the robot; would a lighter, slightly less effective shell provide more function than a heavier, more effective one? The problem of getting through sand would become more pressing as the weight increases, so each shell addition would have to be tested before moving forward.

Finally, testing the robot’s capabilities of reaching a beacon would need to be tested. Once the entire system can communicate appropriately, it will need to be tweaked to ensure that the robot will not be going so fast as to crash into obstacles or go into ditches, but will also have enough power to successfully get over any hills required. Once this final stage of testing is in progress, the team will have a very functional robot.
6. Conclusion

Despite having a restricted timeline, the robot was a very useful learning tool and achieved many of its goals. It could successfully drive forward, turn, and otherwise perform all movements as required. With a little more time, the beacon would have been talking with the robot, and the project would have been mostly complete.

For future projects, working on the beacon sooner would be wise; it tended to be far more complicated than any other sensors. Starting with a base point of the structure of the robot works well, as long as it can be flexible and adjusted to various needs.

Autonomous robots are here. New developments will be constantly appearing, and projects like this will help push that forward.

7. References


[2] “L298N Motor Drive Controller Board Dual H Bridge”, Qunqi, Amazon. Retrieved from https://www.amazon.com/2Packs-Controller-Stepper-Arduino/dp/B01M29YK5U/ref=pd_sbs_60_t_0/137-6457474-88137262?_encoding=UTF8&pd_rd_i=B01M29YK5U&pd_rd_r=701a1bfc-fb3a-63a7-43b6-b917-5696af8270b&pd_rd_w=Y6jCB&pd_rd_wg=86979g&pf_rd_p=5efce89-300f-47d2-b1ad-a4e27203a02a&pf_rd_r=SK49SBG31WKF8J3PK0TR&psc=1&refRID=SK49SBG31WKF8J3PK Accessed 6 April 2020.


