Navigation Control Systems and Sensors

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Introduction

On Earth navigation and localization systems are present and utilized throughout every day. Navigation and localization systems are everywhere, whether it is navigating the fastest route from point A to point B, using the "find my iPhone" feature to determine where a friend or an Apple device is, or even tracking a plane to determine where a family member is to time your arrival at the airport for them. By utilizing satellite networks and known locations on Earth's surface, Apple can locate your iPhone within meters and Google maps is able to tell what road you are on and the speed you are traveling. Unfortunately, the accuracy of these localization and navigation systems relies on Global Positioning Satellites (GPS).

Overview

Our Project

The focus of our team's (Outer Space) project is to develop a system that will allow for autonomous navigation and obstacle avoidance on foreign bodies. These systems will not have access to GPS, or other known locations they can use to aid in their localization. The topic discussed in this paper is the systems and sensors which make up autonomous and semi-autonomous navigation systems and the conclusions we can draw from them.

Current Technologies

The first autonomous vehicle was created in the 1980s. By combining a variety of sensors and cutting edge computing, a car was able to drive on a road without any human input (Reilly, 2016). From this point, autonomous vehicle technology has grown massively. LiDAR, enhanced GPS, computer vision, and increased processing capabilities have led to current innovations such as Tesla's autopilot and other companies' entrances to the autonomous vehicle market. Even on Mars, the latest Perseverance rover has capabilities which allow for autonomous driving on the red planet.

Types of sensors

Satellite Imaging

While there is no GPS network on Mars or other foreign bodies, there often are satellites photographing the surface. By using images of the surface, localization systems can update the location of the rover or vehicle to where it resides instead of where the system believes it resides.

This technology, while primitive and untimely, is one of the more effective ways we currently have of confirming location. In addition, satellite imagery, when combined with computer programs, can detect, and predict optimal routes utilized in path planning and navigation (Marc et al., 2020).

IMU and Motor Encoders

Another useful technology is the Inertial Measurement Unit (IMU) and motor encoders. These sensors measure the physical movement of the rover or system. The IMU can be thought of as a device that detects the forces and accelerations acting on the rover. By doing some complex math, it is able to determine the speed and then the distance traveled. Another physical sensor is motor encoders. These devices measure how many rotations of the wheel have occurred. These sensors can prove useful for identifying how far the bot has traveled based on the size of its wheel. When combined with the IMU data, it can even detect when the bot's wheels were spinning, but the bot did not move.

Cameras

Cameras provide the opportunity for the rover or vehicle itself to detect objects in its desired path through use of computer vision algorithms. These algorithms track features within the photo and can discern whether there is an obstruction in the frame. Stereoscopic cameras use two cameras to gain more useful information about the surroundings. By using stereoscopic cameras, software can identify the distance from surrounding objects in the frame by noticing differences between the images captured on the cameras. (R. Lasser, personal communication, 2021)

LiDAR

LiDAR technologies allow for accurate object detection of a surrounding area. The premise of LiDAR is simple: it measures the amount of time needed for a laser to bounce off an object and return to the sensor. By doing some simple math, comparing the time it took between the sensor sending and receiving its signal, LiDAR can detect the distance from the sensor to the object.

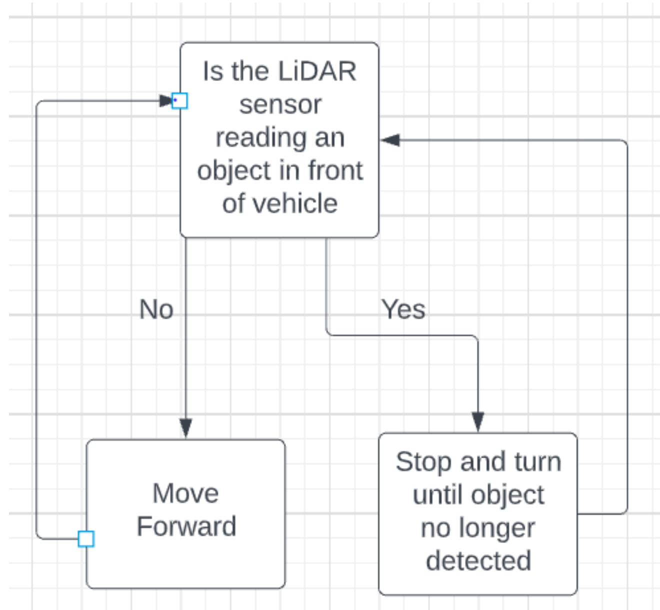

Figure 2. A diagram illustrating a simple object detection system (Hartano et al., 2020)

Movement Systems

In addition to sensors, rovers need a system to control their movement. These systems can best be thought of as if and while loops. If an object is detected, then move in this way avoid it. While no object is detected, then continue to move forwards. The simple diagram above would be this control system.

Example Control Systems

As you can see, the system in figure 1 utilizes sensors and their responses to determine the part of the flow chart should be followed. In the grand scheme of things, this chart would be a block in the larger control system, but it becomes possible to see the utility in utilizing flow charts to illustrate parts of a control system. (Hartano et al., 2020)

Another example of a control system is one that would drive the motors of the rover. By utilizing motor encoders, the system receives feedback, letting the flowchart decide whether or not it wants to sped up or slow down. Based on the information provided by the motor encoders, the motor control unit can determine whether the bot should increase power supplied to the motors or decrease it. (Sharma et al., 2021)

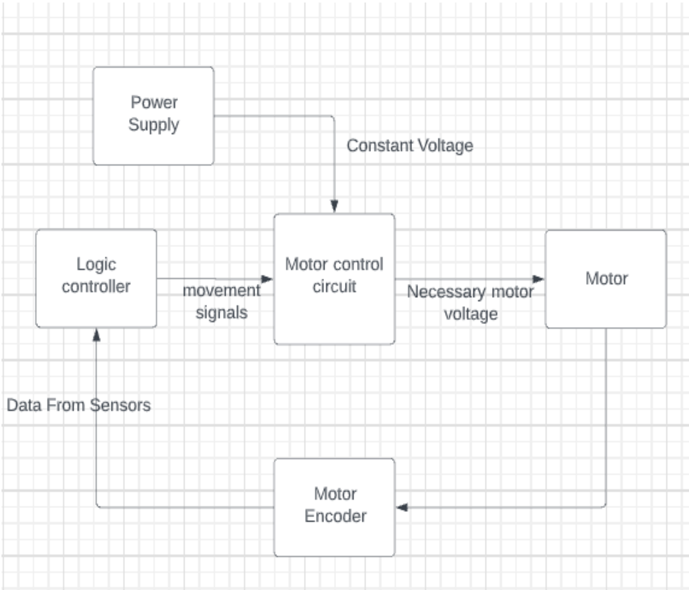

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Figure 2. A motor Control system showing the flow of information (Sharma et al., 2021)

Conclusion

Students, scientists, and engineers have made progress towards developing autonomous vehicle systems which do not rely on GPS and instead can be supported by sensors on the vehicle itself. While some groups are utilizing localization and mapping, a technique which has the system develop a map of its environment to place itself, others are pursuing methods which involve less focus on generating a surrounding map and a larger focus on planning a path with limited data and available inputs. Our project specifically looks to explore this area by utilizing a simple path planning algorithm and utilizing only LiDAR, Visual Camera and IMU sensors. We hope that by the end of this project we will be able to correctly identify our distance traveled relative to our origin and detect obstacles in our planned paths.

References

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