Real-Time Obstacle Avoidance for Tele-Autonomous Mobile Robots

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Introduction

A real-time obstacle avoidance algorithm for local mapping has been implemented to provide autonomous navigation capabilities to a mobile robot. In addition, the integration of an Inertial Measurement Unit (IMU) provides localization to the mobile robot for the construction of a permanent global map.

Research Question

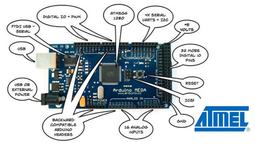
How reliable should a real-time obstacle avoidance algorithm be when the mobile robot is controlled by an operator?

System Overview

A modular system was chosen to provide the best results possible in a short period of time (100 hours).

A PICkit™ 3 development kit from MicroChip is used as the main controller for the IMU unit.

An Atmel® Atmega1280 microcontroller is used for the array of ultrasonic sensors and for communication to the iRobot® Create platform.



A wireless iRobot Create platform provides adaptive video streaming when operating remotely.

3-Axis Rate Gyroscope

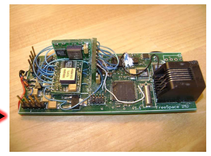
The ITG-3200 consists of three independent vibratory MEMS gyroscopes, which detect rotational rate about the X (roll), Y (pitch), and Z (yaw) axes.

3-Axis Accelerometer

The function of this device is to measure the proper acceleration, which is the acceleration relative to freefall and the acceleration felt by people and objects. Such accelerations are typically measured in terms of g-force.

3-Axis Magnetometer

This device is used to measure the strength and/or direction of the magnetic field in the vicinity of the device. This device can be used to help reduce the reading error of the accelerometer in the yaw direction.

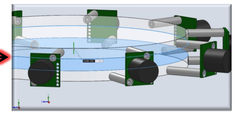


Inertial Measurement Unit Controller

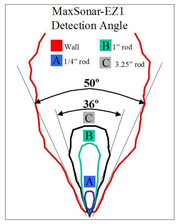
The IMU is a device that measures and reports back a craft's orientation or attitude in 3-D space, using a combination of MEMS (Micro Electro-Mechanical Systems) sensors such as gyroscopes, accelerometers, and magnetometers.

MaxBotix LV-EZ1

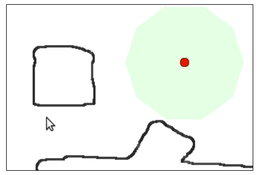
An ultrasonic sensor measures the time interval between sending a signal and receiving an echo to calculate the distance to an object. The Field of View (FOV) of the MaxBotix LV-EZ1 unit is 36 degrees and has a conical shape.



An array of 10 MaxBotix LV-EZ1 sensors suspended on two circular plates.



Each MaxBotix sensor provides a 36 degree FOV.



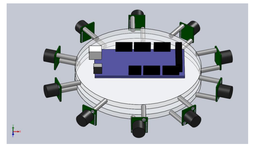
Panoramic view of the iRobot Create in a 2D Simulation environment.

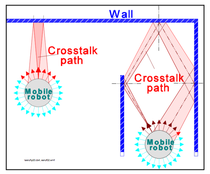
Research Method

- The iRobot Create platform is controlled by a human tele-operator.
- The chosen algorithm was Johann Borenstein's Virtual Force Field (VFF) method.
- The IMU provides estimation of the orientation to the tele-robotic platform.
- The design of the IMU was based on an algorithm by Terence J. Bordelon.
- Bordelon's algorithm is based on quaternion transformations, which is a mathematical tool that represents quantities in four dimensions instead of three.

Data and Results

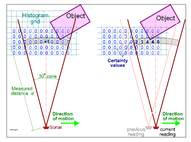
The iRobot Create platform is equipped with a circular array of ultrasonic sensors. The main controller (Atmega 1280) queries the ultrasonic sensors in a Daisy chain mode.

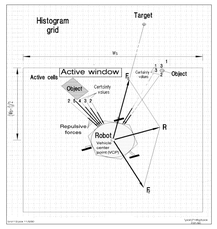




Unstable readings from ultrasonic sensors are one of the main problems with these units. For example, crosstalk causes unstable readings when running multiple sensors.

The VFF method uses histogramic in-motion mapping (HIMM). HIMM represents data in a two-dimensional array (called a histogram grid) that is updated through rapid, continuous sampling of the onboard range sensors during motion.

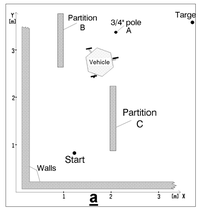


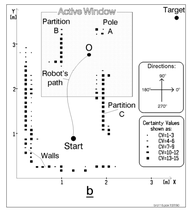


Each cell in the histogram grid contains a Certainty Value (CV) that indicates the measure of confidence that an obstacle exist inside the affected cell.

The CV is used as an input to the Potential Field (PF) method.

Each occupied cell inside the active window applies a repulsive force to the robot. In this way, a virtual pushing force is applied to the robot. The magnitude of this force is proportional to a cell's CV, and inversely proportional to the squared distance between the cell and the robot.





A constant attractive force pulls the robot toward the target. A resultant force is produced by adding the repulsive force with the attractive force, which represents a new direction for the robot.

As a result, a map of the robot's trajectory can be constructed.

Conclusion

- The primary goal of this project is to improve the performance of mobile robots by introducing new components that will help robots in self-guidance mode.
- The difficult part about the design was the integration of all the components to produce an accurate estimate of the robot's orientation.
- The algorithm developed by Bordelon was employed; in particular, the main processing chip was programmed to take various sensor data and fuse the information in an efficient manner.
- The research is an on going project. Selection of the hardware will be finalized by the end of the summer and the project will exceed the assigned 100 hours.
- Working on a team was a very helpful experience that enabled us to be team-oriented and team-players.
- The research emphasized multidisciplinary work in various fields within Electrical and Computer Engineering.

Acknowledgements

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