GEONAVOD
(Geo-Registration, Navigation, and Object Detection)

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The Origins of the Project
A mobile robot can perform important and useful functions especially when presented with the right kind of sensors. The need to self-localize can present valuable information to robots that are required to navigate and to better understand their environment. Therefore, a robot that has navigating capabilities and an object detection system can provide far greater usefulness in hostile environments. By registering a target’s location, it can then perform inventory checks, improve the organization in a crowded warehouse or even save lives on the front lines of battle. The goal for this project was to make a mobile robot autonomous using geo-registration, navigation, and object detection (GEONAVOD).

Geo-Registration System
To calculate the position of the robot, the ranges are calculated from the ultrasonic receiver near the back of the robot to three active ultrasonic beacons, with frequencies of 40kHz. The timing synchronization between the beacons and the robot is brought about by the robot’s radio frequency (RF) receiving circuit. The robot identifies which beacon it “hears” because of the pulse order. The ultrasonic pulses travel at approximately 344 m/s, in dry air at 21°C, and thus, the elapsed time between the transmitted pulse and received pulse can be used to calculate the distance between each beacon and the robot receiver. The equations used to calculate the time delay of each received pulse are:  
Distance to each beacon = 344 m/s * (ultrasonic signal propagation time) 

The Beacon Pulse Method

Navigation System
Once the robot has localized itself and the heading has been determined, the robot can then navigate towards a predetermined waypoint. Using dead reckoning, the robot navigates until it reaches the specified point.

The Heading correction angle is calculated as follows:

\[ \alpha = \tan^{-1}\left(\frac{y_N}{x_N}\right) \]
\[ \gamma = \alpha - \beta \]

Object Detection System
The purpose to perform object detection is to detect and register the target’s location with respect to the robot’s environment. This system will run on another microcontroller so it can actively scan for an infrared emitting target without interrupting other routines such as positioning and navigation. Upon IR detection, the turret stops and registers the target angle. The CMUCam vision sensor detects the laser reflected off the target, and the pixel that is lit determines the range.

Experimentation Data
Plots of positioning system and complete system integration test:

Left: First and second stage of ultrasonic signal amplification
Right: Peak detector and voltage comparator output

Ultrasonic Receiver Circuit Outputs of Each Stage

Experimentation Results
Target Angle, Robot Heading, Robot Position