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Title: Investigating necessary sensors required for metal debris collector to navigate and interact with terrain autonomously

Introduction

In order for a metal debris collector to autonomously navigate and interact with an environment, it must know its surrounding. The collection of data via environmental detection technologies provides the necessary information to the robot about said surroundings. With regards to navigation, camera sensors and distance sensors are needed to tell the robot how to move while a metal detector sensor allows for interaction by informing the robot on what debris is to be collected. This technical review summarizes commercially available camera, distance and metal detection sensors, how the technology for these sensors works, and it suggests placement of the sensors on the robot.

Commercial application of environmental sensors

In the automotive industry camera sensors are a vital part of autonomy. Eight camera sensors [1] are fitted all around Tesla vehicles to allow for a 360° view of the surroundings. The images from these multiple cameras are used to create a 3D model of the surrounding environment allowing the car to navigate itself on the road [2]. Adaptive Cruise Control (ACC), Automatic High Beam Control (AHBC), Traffic Sign Recognition (TSR) and Lane Keep Systems (LKS) and all use camera sensors for reliable autonomous vehicle operation [3]. Cameras can be used to see, and more importantly identify objects; this identification is necessary in determining what an autonomous vehicle should do (it is likely be just as necessary for an autonomous metal debris collector). There is a vast array of reliable, cost effective cameras, such as the OpenMV Cam M7, a low cost embedded vison camera that can be used on a small low power microcontroller; it costs $65 [4].

Options for distance sensors include LIDAR, RADAR and SONAR. Both LIDAR and RADAR are also vital to avoiding obstacles in vehicle autonomy. The most widespread RADAR usage is for military purposes; airplanes can precisely measure altitude and detect other planes in their vicinity [5]. Submarines use SONAR to detect other vessels. The main differences between the three ranging sensors are price and precision. LIDAR is the most expensive of the group but considered the most accurate, RADAR sensors are less expensive but still highly accurate while SONAR sensors are the cheapest and most widely available (despite being the least precise they are sufficient for many applications). SONAR sensors like SparkFun's HC-SR04 Ultrasonic Sensor priced at approximately $4 are ideal for a metal debris collector that does not need high precision distance sensors [6].

At least one metal detector is needed to identify what the robot needs to collect. Traditionally metal detectors have been used for security to reveal weapons such as knives and guns, they have also been used at crime scenes to find clues. Metal detector ICs that can be readily attached to microcontrollers are not readily available however the circuit consists of cheap and easily available parts and can be built without difficulty.

Technology behind environmental sensors

Images collated by camera sensors are run through computer vision algorithms to identify details of objects. The robot knows that a specific object is in its view due to previous training on the objects features via machine learning. Machine learning inputs a huge amount of data, in this case photos of a specific object, and recognizes patterns in the images in order to identify the sign in new previously unseen images.

LIDAR, RADAR and SONAR all work by emitting pulses of waves toward a target and detecting a small portion of those waves reflected back to a receiving antenna. The difference in operation of these sensors is the waves used. LIDAR uses light waves (highest speed and frequency), RADAR used radio waves (same speed as light with lower frequency) and SONAR uses sound waves (slowest speed).

A metal detector contains a coil of wire that creates a magnetic field when electricity flows through the coil. As the detector moves, the magnetic field moves around too. The magnetic field coming from the detector induces a magnetic field in the metal; it is this second magnetic field that is picked up by the detector [7]. The person is informed of the second magnetic field (i.e. metal detected) through a beeping sound.

Suggested placement of environmental sensors

The camera needs to provide a view in the direction of the motion. The freedom of motion and the ability to collect the debris will determine the front of the robot (if there is one). Assuming there is a front, it is sufficient to have one camera mounted on or on top of the robot with a clear line of sight of the front surroundings.

Two SONAR sensors, one in the front and one at the back, should be sufficient for detecting obstacles when in forward or reverse motion. Two of these sensors will only cost $8 (approximately).

The metal detector should be placed at the front of the robot (with the collection mechanism behind it). This likely prevents having to change direction of the robot between detection and collection.

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