SID: A 'Seeing Eye' Robot

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Abstract

Although Seeing Eye dogs are widely used, current artificial intelligence and robotics technology may be able to create a better guide dog. In order to simulate a guide dog robot, SID has a suite of sensors to detect various danger conditions in a world consisting of a sidewalk and crosswalk. The actual performance of SID may not reach the level of a true Seeing Eye dog, but it does provide a good benchmark to which future robots in this area may be compared.

1 What is a Seeing Eye dog?

A Seeing Eye dog is a dog specially trained to help the blind or visually impaired. Although often thought of as used only by the blind, Seeing Eye dogs also help those with other eye problems and vision poor enough to be detrimental. On a vision scale, legally blind describes someone whose vision is 20/200 or worse.

The Seeing Eye, the foundation which trains Seeing Eye dogs, was founded in 1929 in order to provide dog guides to those visually impaired individuals who did not like having to depend on others to get around. The Seeing Eye breeds its own dogs, seeking certain traits such as teachability and endurance. Once born, a litter of prospective guide dogs are raised by families for a year and a half, being taught basic obedience and other standard training while becoming accustomed to being around both adults and children. Once the dogs are old enough, they are returned to The Seeing Eye, where the actual guide dog training begins, lasting four months.

2 Why a 'Seeing Eye' robot?

Although it is unlikely that a robot would be able to match a trained Seeing Eye dog at the same job, the possibility still exists. With sufficiently advanced AI, a robot can think, learn, and perform based on past experience and training, as trained dogs can.

Robots have two main advantages over dogs when it comes to training of this sort. First, the construction cost of a robot is much less expensive than the cost to breed, raise, and feed a dog and keep it healthy. Time is the second advantage, since, even with one trainer able to train a group of ten Seeing Eye dogs over the span of four months, training for robots comes much more quickly, and sharing of knowledge and experience makes training even faster.

Robots, however, have several disadvantages when compared to dogs. At the present time, robot AI is not yet advanced enough to fully emulate the intelligence of a trained Seeing Eye dog. In addition, a robot has limited sensors. If a situation arises where something such as scent might be an indicator for a desired reaction, a robot designed to operate solely on sound and vision would be completely helpless. Also, while not a functional flaw, robots are less desirable than dogs to many people. While a robot, even an expert one, may be able to operate perfectly as a guide, most humans may prefer an actual companion rather than a robot which can do nothing more than the job for which it was designed.

Still, the design of a 'Seeing Eye' robot is a worthwhile one. Even if a 'Seeing Eye' robot never replaces true Seeing Eye dogs, a sufficiently advanced guide robot can give a convenient standard by which actual Seeing Eye dogs may be measured.

3 SID: An overview

When one thinks of a Seeing Eye dog, the image that often comes first to mind is a dog leading a visually impaired person down a sidewalk and across streets. The design of SID (Seeing 'I' Dog) follows this general worldview. By using sensors specifically chosen to interact with a sidewalk and street environment, SID can navigate safely while leading a human partner.

4 The world of SID

SID's world must match the requirements for the general purpose of the robot. As such, the world is a controlled area which simulates a sidewalk and crosswalk.

A large white sheet of paper functions as the ground, with black electrical tape marking off the boundaries of the sidewalk. For test purposes, SID's world is an L-shaped region of sidewalk, containing a crosswalk at the corner (figure 1).

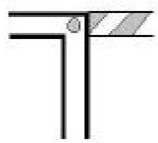

Figure 1
SID's world

5 Behaviors: The basics

SID has two main modes of behavior, mirroring the job of a Seeing Eye dog in a similar situation. The first of these two behavioral modes is to simply lead a partner around while remaining on the sidewalk. The second behavior mode is for crossing the street, in which SID must make sure the crossing light is on and that there are no oncoming cars.

6.1 Sensor suite

The SID robot utilizes a sensor suite made up of several different kinds of sensors. It uses the standard bump switches and IR detectors for obstacle avoidance, as well as a flex sensor to simulate a leash and several CDS cells which perform various functions, from line detection to color vision. In addition, SID also uses a sensor designed to detect car horns.

6.2 Leash sensor

As a guide robot is useless if its partner is unable to keep up with it, SID must have a sensor to detect when it is getting too far from the person it is leading. This is accomplished by a leash attached to a Jameco flex sensor (cat. #150551) (figure 2).

Figure 2
Flex sensor

As the leash is pulled, the sensor flexes, changing the resistance, which ranges from 10k ohms at no flex to 30k-40k ohms at 90 degrees of bend.

6.3 Sidewalk edge detection

Since the edge of the sidewalk in SID's world is represented by a black line, detecting the edge is a simple matter. Using a CDS cell, which changes resistance based on the wavelength of light hitting it, SID can easily tell the difference between white and black. An example of sidewalk edge detection can be seen in figure 3.

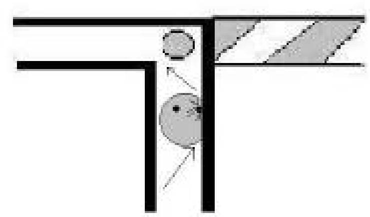

Figure 3
Detection of sidewalk edge

As seen in figure 3, the right sidewalk edge detector has triggered upon sensing black. In order to remain on the sidewalk, SID changes direction away from the sidewalk edge.

6.4 Traffic light detection

When SID's behavior is to cross a street, it must first determine if the way is safe. Since real streets have crosswalks with walk and don't walk signs, SID's world also has indicators. Rather than using red and white as real walk / don't walk signs do, the indicators in SID's world use red and green for simplicity. See figure 4 for an overview of the traffic light indicators in SID's world.

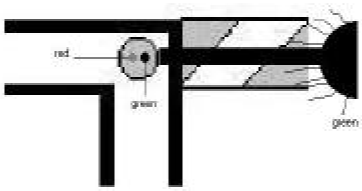

Figure 4
Traffic lights in SID's world

The circle indicates the region in which SID must sit in order to see the indicator lights. Within the circle lie two LEDs, one red and one green. These two LEDs function as the primary traffic light. In addition, a larger green light source, indicated by the black semicircle and 'beam of light,' acts as a backup in case the LEDs are out.

CDS cells are used in order to detect the color, as red and green have sufficiently different wavelengths on the spectrum to be easily discernable.

6.5 Car horn detector

SID's car horn detector is able to determine whether a car horn is sounded by measuring decibel levels. In order to do this, SID has a decibel meter with a microphone mounted on it.

The decibel level sensor of the car horn detector is the Radio Shack Analog Sound Level Meter (33-2050). The size of the meter is 160 x 62 x 44 millimeters, and the weight is 185 grams, without battery. This meter operates on a single nine volt battery.

Operating independently, the sound level meter is able to detect sounds ranging from 50 to 126 decibels, with an accuracy of two decibels at a sound level of 114 decibels. Although this measurement is not perfect, it is more than sufficient for its purpose, as the car horn detector only needs to determine if a sound is above or below a certain decibel level.

The sound meter has a dial which can be set from 60 decibels to 120 decibels, with ten decibel increments. An indicator on the meter displays the decibel level of the detected sound in relation to the current dial setting, from -10 decibels to +6 decibels.

In order to keep the sound level meter out of the way of other important components in the robot, it is mounted on the underside of the upper body panel (figure 5).

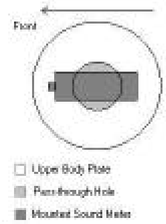

Figure 5
Mounting of sound level meter in SID

The presence of a car horn or similarly loud sound is indicated by the output of the decibel meter which, when compared to a constant value, can determine whether or not the sound is loud enough to register as a car horn (table 1).

Table 1: 'True' decibel values based on data found online.

Decibels	Sound
0	limit of human hearing
10	Breathing
20	whispering at 5 feet
30	soft whisper
40	library, quiet residential area
50	rainfall, refrigerator, large office
50-60	electric toothbrush
50-75	washing machine, air conditioner
50-80	electric shaver
55	coffee percolator
55-70	dishwasher
60	normal conversation, sewing machine
60-85	vacuum cleaner
60-95	hair dryer
65-80	alarm clock
65-95	lawnmower
70	TV audio, freeway traffic
70-80	coffee grinder
70-95	garbage disposal
75-85	toilet flush
80	toaster, doorbell, telephone ring
80-90	food processor, blender
85	heavy traffic, loud restaurant
90	tractor, truck, shouted conversation
90-115	subway
95	electric drill
95-110	motorcycle
100	factory machinery, woodworking class, snowmobile
105	snowblower

110	car horn ***
110	shouting in ear, squeaky toy
110	busy video arcade, symphony concert, power saw
110-120	rock concert
112	Walkman on high
117	football game in stadium
120	thunder, chainsaw, hammering
125	car stereo
130	jackhammer, air raid siren
135	noisy squeeze toys
140	airplane taking off
143	bicycle horn
150	jet engine taking off, firecracker
156	cap gun
157	balloon pop
162	fireworks at 3 feet
163	Rifle
166	Handgun
170	Shotgun
180	rocket launch

Of note, the most important readings in this table are for heavy traffic (85 decibels) and car horns (110 decibels). Using those two decibel levels, the sound meter's threshold can be calibrated to a value between 85 and 110 decibels, allowing for a margin of error of at least several decibels. If the threshold value is set to 100 decibels, then there is an allowable error of at least 10 decibels.

In order for the sensor to perform optimally, several assumptions must be made. First, since the decibel level of a motorcycle engine is 95-110 decibels, possibly within the threshold range, motorcycles must be either disregarded or automatically assumed as dangerous as a car horn, which is an acceptable assumption. Since the maximum volume of a car stereo exceeds the decibel level of a car horn, at 125 decibels, it will also trigger the horn sensor. Bicycle horns, in addition to car horns, will cause the sensor to trigger, as bike horns may be louder than car horns, at a maximum of 143 decibels. As many road construction tools and vehicles also exceed the threshold, topping off with a jackhammer at 130 decibels, road construction may also trigger the sensor. Finally, the weather must be clear, as thunder may reach 120 decibels, enough to cause the sound sensor to detect a horn.

7 Future work

As SID is primarily a sensor-based robot, most improvements which can be made to it relate to the sensor suite.

Although the leash sensor is somewhat functional, it still does not operate as the harness on an actual Seeing Eye dog. In order to function as a true harness, it must be able to take force and begin to pull the human partner forward, which the bend sensor is completely unable to do without signaling. Although it works in a limited way to keep SID from outrunning its partner, a true harness would need to both gently pull the partner and ensure that it is not outrunning the partner at the same time. This can clearly not be resolved with such a simple sensor.

While SID has sensors which can detect sidewalk edges and red and green lights, the addition of a camera for true vision would vastly improve its performance. With actual vision, as well as additional computing power to handle complex vision programs, SID may be modified to identify and avoid pedestrians, double-check on the identity of a car, and have greater accuracy in detecting walk and don't walk lights.

Currently, SID's car horn detector can only detect the presence of a car horn. It would be much more useful for the robot to be able to determine the location of the sound as well. In order to perform location tracking of sound, some kind of triangulation using two additional microphones must be integrated, allowing SID to focus on the position of the alerting sound.

8 Sources

Jameco: www.jameco.com
Noise Center: www.lhh.org/noise/decibel.htm
Radio Shack: www.radioshack.com
The Seeing Eye: www.seeingeye.org