Lego Mindstorms Guide Robot

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Abstract

Service animals undergo rigorous and lengthy training to fill many difficult and dangerous roles for the benefit of their human counterparts. With existing technology, a subset of these roles that depend on the ability to learn and intelligently respond to a variety of external stimuli can also be filled by robots with less training time and maintenance cost. This paper explores such an approach with a guide robot for the blind that is trained by feedback from both humans and the environment using a reinforcement learning model. This model will allow the guide robot to selectively obey human commands depending on its understanding of the safety of doing so. We expect the robot will quickly learn when to disobey after exposure to a diverse set of environments.

Introduction

The primary goal of this research is to create a robot that models the basic functionality of a guide dog by responding to its owner's commands and safely navigating the path requested by the owner. To achieve this functionality a guide dog must be able to learn to associate specific commands with specific actions, follow a route as instructed by its owner, selectively obey the owner's commands based on its own safety assessment, and avoid any impediments to the owner's movement (Harris 2008). The goals of the guide robot are to address the two-dimensional aspects of a guide dog's duties without addressing three-dimensional challenges such as handling stairs, curbs, or other changes in elevation.

Background

Robots capable of learning to interact with humans and safely navigate unfamiliar environments could fill the roles of most service animals including the more dangerous roles of search and rescue dogs. Many of the benefits of a robot guide become apparent in relation to the difficulties of interactions between animals and people. Many animals require additional training to desensitize them to distractions such as toys, people, and food. Additionally, specific breeds must be chosen that have little to no history of causing allergies and those animals may still be restricted from entering public and private places based on health, religious, or personal concerns ("Guide dog" 2008). The guide robot's ability to be quickly retrained using any arbitrary set of commands would allow new owners to customize the robot's behavior to their liking and current owners to update their robot's behavior as their needs change. As the physical capabilities of the guide robot increase, new actions can be added to the robot's physical vocabulary and new commands can then be associated with those actions. Finally, to perform selective obedience, the guide robot must interpret the validity of a human command based on its awareness of its own environment (Harris 2008). Such learned decisions are similar to decisions made daily by humans and suggest another level of cognition beyond that of a non-learning robot.

Methods

The scope of this research is defined by the capabilities of the robot guide and its owner. While the authors are aware that 12% of the potential owners in America are both blind and deaf, it is assumed for this paper that the owner has limited vision, satisfactory hearing, and the dexterity to operate a touch sensor (“Statistical Snapshots” 2008). Correspondingly, the guide robot is expected to have satisfactory vision to detect obstacles to its movement, respond to its touch sensor, produce feedback for its owner, and disobey its owner when it believes that obeying a command would be dangerous.

The guide robot is constructed from a single Lego Mindstorms NXT kit that includes ultrasonic, sound, light, and touch sensors and the ability to playback sounds. The buttons on the NXT core, or “brick”, are used by the owner to issue commands. The orange center button is used to issue the forward and stop commands. The left and right arrow buttons are used to issue the left and right commands, respectively.

Training mode allows the owner or another trainer to teach the robot guide the proper response to each command in the owner's vocabulary. This command/response mapping is stored in a table built from a reinforcement learning algorithm and a trainer who provides positive reinforcement for favorable responses and negative reinforcement for unfavorable responses. An alternative to

teaching the robot the command/response mapping is to program the mapping directly into the robot's behavior. For initial tests of the robot's behavior in its environment, the direct programming approach is used. However, the training approach will allow each new owner to customize the robot's behavior to suit their specific needs.

An ultrasonic sensor fills the role of the guide robot's eyes by detecting and measuring the distance to objects up to 255cm away. The ultrasonic sensor searches its environment by sweeping from left to right in about a 120 degree arc. Two light sensors, one on each side of the robot, detect the presence of objects to the robot's sides using reflected light.

When the guide robot is given a command to move, it searches its environment for objects and passes the results to its learning model. The learning model tracks whether a given a command in a given environment increases or decreases the robot's proximity to an object that could endanger the owner. If a the given command has sufficiently increased the robot's proximity in a similar environment, the robot disobeys the command by stopping and issuing a sound signal to alert the owner. The learning model is based on a reinforcement learning algorithm which rewards commands that do not endanger the robot and owner and punishes commands that do.

Conclusion

It is expected that the guide robot will match a guide dog's performance when navigating a two-dimensional environment with selective disobedience. The robot guide's performance will be measured by the number of times it obeys an owner's command in an unsafe state. This performance can be compared directly to corresponding values of a guide dog at different stages of its training.

In addition to matching a guide dogs performance, the guide robot is expected to cost less than a guide dog in terms of cost of purchase, training time, and maintenance cost. Although it cannot be easily tested, the robot's lifespan is not expected to match the guide dog's lifespan due to hardware limitations of the NXT kit.

The guide robot provides an easily trained, inexpensive, and flexible alternative to an animal guide which will benefit anyone for whom an animal guide is not a viable solution because of cost, health concerns, or personal beliefs.

References

"Guide dog." Wikipedia, The Free Encyclopedia. 20 Mar 2008, 00:43 UTC. Wikimedia Foundation, Inc. <http://en.wikipedia.org/w/index.php?title=Guide_dog&oldid=199482509>. 20 Mar 2008.

Harris, Tom. “How Guide Dogs Work.” How Stuff Works. 07 Dec 2000. <http://people.howstuffworks.com/guide-dog.htm>. 20 Mar 2008.

“Statistical Snapshots.” American Foundation for the Blind. <http://www.afb.org/Section.asp?SectionID=15>, 2008.