LawnShark: A New Platform for Autonomous Mowing and Navigation

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Abstract

The LawnShark is an extension of the previous work done with the LawnNibbler® at the Machine Intelligence Laboratory at the University of Florida. The LawnShark uses an electric rechargeable push-mower as a mobile platform, as shown in figure 1. Its goal is to efficiently and intelligently mow grass in an environment typical of a person's lawn.

Figure 1 The LawnShark

Introduction

The LawnShark borrowed from the ideas already used on the LawnNibber. The LawnNibber is an autonomous lawnmower and navigation system developed by Prof. Keith L. Doty and master's student Kevin Hakala. It uses a weed-eater cutting attachment to cut the grass. It has an active beacon navigation system that uses sonar and infrared light to allow the mower to obtain the distances from itself to 3 stationary beacons. Once these three distances are obtained, the mower uses trilateration to calculate its current position in the *xy* plane [Arroyo and others, 1998]. Its mobile platform was designed in the lab. It has two drive motors, one for each side of the mower, each of which drives a chain linking both wheels. The LawnNibber™ is a registered trademark of Mekatronix.

The philosophy behind the LawnShark is to eliminate some of the mechanical problems encountered in trying to build a mowing platform. It instead uses a platform that was designed for cutting lawns and adapted to be suitable for an autonomous agent. The LawnShark's body is an electric rechargeable pushmower donated by the Toro Corporation.

The LawnShark currenty uses an array of four infrared (IR) emitter-detector pairs for obstacle avoidance. It also has a sonar transceiver pair on a panning head on the top of the mower that will be used for both collision avoidance and navigation.

Experimental Platform

As stated before, the platform for the mower is a rechargeable electric pushmower donated by the Toro Corporation. This allows the mower to have a body designed by lawn-cutting experts. This body was then altered as necessary to suit an autonomous agent. The most significant alteration was to add drive motors to allow the mower to be self-propelled.

Most of the mechanical work done on the mower has been the attachment of motors, gear-boxes, and wheels to the original frame. This has been accomplished in a way that preserves the previously tested and proven internal structure and design of the Toro lawnmower. The goal was to mount a motor/gearbox combination and wheel on all four points originally occupied by a single wheel. These four points were to provide all the power and steering for the lawnmower. In addition the mounts would support the original weight of the lawnmower plus any additional considerations, i.e. sensors, batteries, circuitry, etc.

The most straightforward design was to attach the motors directy to the body of the mower. This would keep the wheel base to a minimum. This turned out to be impossible due to the flimsy plastic outer shell and the angles of the shell in relationship to proper alignment of the wheels. So a design was conceived that integrated the load bearing rod (LBR), which supported both the wheels and the plastic frame. Although this increased the wheel base and made the turning radius greater, problems with stuctural integrity of the future design were immediately solved.

In order to mount the motor/gearbox, a rectangular plate was designed that used the 0.5 inch hole already drilled in the LBR. This provided a main mounting point for the plate, motor/gearbox, and wheel all in one place. The motor/gearbox luckily used the same size diameter hole, which made connection with the LBR and wheel simple. The next problem was keeping the plates from spinning around the main mounting point. A crossbar was then designed that would connect the two front plates together and the two rear plates together. Both crossbars would also be mounted to the thin metal undershell that protects the mower from the blade and flying particles. Now the plates were held in place and able to hold the motor/gearbox. To ensure that the motor/gearbox would not spin on the plate the molded mounting points on the gearbox were used. A bolt through each of these and then the plate solved this problem.

The mechanical designed was conceived and implemented by Brett Spooner, Florida State University.

Electronics

The main processor for the LawnShark is a Motorola 68HC11. The circuit board containing the 68HC11 is a Mekatronix MRC11 board. This board contains 32K of SRAM and an expansion header for connection to external circuitry. On the LawnShark this expansion header was used to connect to a Mekatronix MRSX01 sensor board. This board contains digital input and output ports and analog multiplexers that allow multiple digital and analog sensor readings to be taken from the outside world. The digital output ports allow external devices to be controlled, for example IR LED's for collision avoidance and H-bridge circuits to control the drive motors.

Two H-bridges and their accompanying circuitry control the four drive motors. Each side of the mower is controlled by one H-bridge. Therefore, the mower drives and turns like a tank. This has turned out to be a serious limitation in the mobility of the mower. Specifically, it has great difficulty turning. A steering system for the mower is currently being designed.

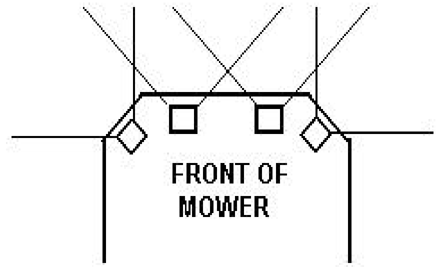
Eight of the digital outputs of the MRSX01 have in-line resistors and can be modulated at 40 kHz. These outputs are used to connect the IR LED's for the collision avoidance system.

A sonar transceiver board was also designed for the mower. This board uses a large inductor to generate the high voltages necessary for the transmitter (gives an approximate 120 V output from a 12 V input). The sonar can be used for collision avoidance as well as in part of an active beacon navigation system.

Sensors

The collision avoidance system consists of four of the IR LED's paired with four 40 kHz receivers. The receivers are connected to the analog inputs of the MRSX01. The orientation of these four pairs on the front of the mower are shown in figure 2. This orientation allows the robot to have a good idea about where an obstacle is located based on which of the four detectors registers the object.

Figure 2



The LED's emit a continuous stream of 40 kHz IR light. When an obstacle is encountered, the light bounces off of this obstacle and enters the detector. By constantly monitoring the outputs of the detectors, the mower can decide which direction it is safe to move in.

This collision avoidance system was used for quick and easy testing of the circuitry and the mobility of the platform. It works very well indoors. However, outdoors the range of IR is very limited. As a result, an alternative system is needed.

The sonar transceiver is located on a panning head on the top of the mower. It will be used as the permanent collision avoidance mechanism. The principles used in this collision avoidance system are similar to the ones in the IR system.

There is one transceiver pair that is rotated on the panning head. The servo controlling the head can be moved to a known angle. At this angle, a single sonar pulse is emitted. If the receiver hears an echo back, the robot knows there is an object in the direction the transmitter is pointing.

Future Work

The LawnShark project was started in May of 1998 and is still very much a work in progress. There are several design goals that will be implemented in the future.

The first goal is to utilize the sonar as the principle collision avoidance method. The IR sensors will remain as a backup system.

The sonar will also be used as part of a beacon navigation system. The current plan is to emit a single, brief sonar chirp when doing collision avoidance. When the sonar is being used for navigation purposes it will send and receive a bit pattern of chirps.

A network of stationary beacons can be set up in the mowing area. Each beacon will have a sonar transceiver. When the mower wants to know its position, it will stop and send out its sonar bit pattern (which all of the beacons will recognize) in a certain direction and wait for a response from a beacon. Each beacon will have a unique bit pattern that it responds with when it receives the mower's pattern. The mower will have a table of beacon coordinates and their corresponding bit patterns in memory. If the mower receives a response from a beacon, it makes note of which beacon responded, what the angle of the mower's panning sonar head was at the time, and the time it took from the time the mower transmitted to the time it received (time of flight). The mower continues to move its sonar head in increments until it gets a response from three separate beacons. Once it does, it can use trilateration to calculate its position in the *xy* plane.

Another plan is to use a more powerful processor to control the 68HC11. The current plan is to use the Motorola MC5206 ColdFire processor. Experimentation is currently being done with an evaluation board developed in the lab. Possibilities for a real-time operating system for the processor are being developed. The 5206 is a 33 MHz processor with a DRAM controller, 2 serial ports, an MBUS module for fast synchronous serial communication, and a complicated chip-select module.

A more powerful processor can be used to implement machine learning algorithms for intelligent mowing. One possibility is to have a training period of supervised mowing where a human being provides negative and positive feedback via remote control. This could allow the mower to learn to stay out of areas such as flower beds.

Another problem is with limited battery life. The mower should be able to tell when its batteries are beginning to get low. It should then make its way to a recharging station and recharge its batteries.

The final future plan deals with safety. The dangers of a fully autonomous lawnmower are obvious. So it is desirable to take every possible precaution to avoid accidental human injury. One idea is replace the metal cutting blade with a rubber blade that would only cause a person a nasty welt instead of a severed limb. Another plan is to have the mower shut itself down if it unable to determine its position. This will prevent it from wandering out of its mowing area.

The LawnShark is a promising project that hopes to revolutionize the way people take care of their lawns.

Bibliography

[Arroyo and others, 1998] Arroyo, A. Antonio and Doty, K. L. and Hakala, Kevin and Jantz, Scott and de la Iglesia, Erik, "LawnNibber: An Autonomous Lawnmower and Navigation System", 1998 Florida Conference on Recent Advances in Robotics, Florida Institute of Technology, March 26-27, 1998.