Ultrasonic Echoes Obtained in the Outdoor Environment


*Department of Mechanical Engineering, University of Idaho, Moscow Idaho 83844-0902 USA, †Intel Corporation, 5000 W. Chandler Blvd., Chandler, AZ 85226-3699

Abstract: Many, if not most, applications of ultrasonic transducers in air are for ranging systems used in a relatively structured environment. We describe the application of ultrasonic transducers to range sensing for a robotic autonomous vehicle that is intended to operate outdoors in a forested environment. Unlike the indoor environment, application of ultrasonic ranging outdoors involves a much more cluttered environment. The outdoor environment contains a large number of categories of objects and features, as well as a wide variation within each category. In this talk, a statistical summary of echoes obtained from features including ground contour, roughness elements, and obstacles common in the forest environment is presented.

INTRODUCTION

Ultrasonic ranging systems are often used for robotic machines that must characterize their surroundings. One application of ultrasonic ranging in robotic systems now being considered at the University of Idaho is the development of an autonomous robotic log skidder [1]. This robotic vehicle is intended for use in low-impact timber harvesting using techniques derived from horse-logging. The autonomous capability of this robot is to be provided by a fuzzy logic control system using several inexpensive sensors, chosen to obtain a certain degree of redundancy. This sensor system includes an array containing a small number of ultrasonic ranging transducers.

When used as a sensor in a control system, a small array of ultrasonic ranging transducers provides a low resolution image of the surroundings to the controller. Central to the design of the controller, and the performance of the robot, is the understanding of time-of-flight data that will be obtained in a complex environment. In this paper we describe an effort to get a quantitative understanding of time-of-flight data that is obtained from an ultrasonic ranging system in the outdoor environment.

METHODS

A wheeled instrumentation platform was pushed through the forest. At various locations, the instrumentation platform was stopped, and ultrasonic echo time-of-flight readings were recorded. Time-of-flight data was obtained for three orientations of the instrumentation platform relative to the surrounding obstacles at each location. Later, the obstacle content of the immediate surrounding at each location was measured using a tape, compass, and tripod.

The instrumentation platform consisted of a three wheeled baby carriage, outfitted with a computer and several sensor systems. Measurements of ultrasonic time-of-flight data from the three ultrasonic sensors in the ranging array were converted to distances and stored by the computer. The three ultrasonic sensors were mounted on the platform at -16.8°, 0°, and 16.8° angles relative to directly forward. Each sensor covered an experimentally determined half angle of 11.2°. Each ultrasonic ranging system contained a sensor that was 1.5 inches in diameter, electrostatic in type; and a ranging circuit board [2]. The outgoing chirp was a 16 cycle burst at a nominal frequency of 49.4 kHz. Time-of-flight is determined by this type of ranging system when the first echo signal exceeding a threshold is detected.

Ultrasonic echo data was collected in a forest environment. This environment contained evergreen trees, short grass (< 2-3 inch), tall grass (= 1.5 feet), leaves on the ground, and bushes (brush). As the data described below was collected in the winter, no leaves were on the deciduous trees or bushes.

RESULTS AND DISCUSSION

In this paper, we report on preliminary measurements obtained in the winter. Our intentions are to complete data acquisition over the change of a season.

An example analysis of ranging distance data obtained from time-of-flight information is shown in a scale
drawing, Figure 1. In Figure 1a,b,c, the platform is oriented at 11.1°, 0° and -11.1° relative to the surrounding obstacles. Each figure shows distance data from the three sensors, L=left, C=center, and R=right, in the ranging array. The orientation of each sensor is shown by a line intersecting the angular sector covered by the sensor. Twenty time-of-flight readings were taken at each platform orientation. The mean of the twenty corresponding distances is shown by the solid circle, and two standard deviations are indicated by error bars. The obstacle distribution at the platform location was two regions of brush bounded by the lines as shown. An opening between the brush, nominally at 0°, would be the intended path for the robot. The brush ranged in height from 28-60 inches, with a few branches exceeding 60 inches. No leaves were on the branches. The branches consisted of a relatively dense array of small twigs, all under 0.25 inches in diameter.

In general, the distance data obtained from the array corresponded to the contour of brush line with several exceptions. The statistical variation in distance obtained from a single sensor at a single location was observed to be reliable, as can be seen by the relatively narrow error bar deviations from the mean distance. Of the nine total distance determinations, five corresponded to the contour line of the brush. Three distance determinations, all from the right sensor, gave a range less than the distance to the brush line. This could either be caused by roughness elements on the ground; sensor misalignment or malfunction. One reading from the left sensor gave a distance beyond the brush contour line, most likely caused by a local lack of scatterers in the brush array.

CONCLUSIONS

It was concluded that ultrasonic ranging systems provide reliable distance information from an object when located at a fixed position. Determination of the nature of the object from the statistics of multiple readings is at this time unknown. It appears that the most difficult problem is the identification of ground contour and roughness elements.

REFERENCES