# Surface-Trace Feasibility in Use of IR-Based Position-Sensing Devices



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# Surface-Trace Feasibility in Use of IR-Based Position-Sensing Devices

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## Abstract

Feasibility of using IR-based position-sensing devices to trace the surfaces of objects encountered by robots, wheelchairs or other vehicles is examined. Experiments demonstrate the successful capture of the outline of several objects.

## I. Introduction

Advanced robots, such as humanoid robots, are attracting a lot of attention, given the increasing demand for persona (or public) security and factory automation. One remaining barrier is the current weakness of sensor devices; robots will need to know far more of their surroundings to be effective. Other social needs include bio-medical applications of sensors in hospitals and security applications at home. Such needs have not yet been satisfied because the industry still believes that their market size is too small, in spite of its importance.

The purpose of this study is to advance research towards meeting the above social needs[1, 2]. This paper describes the feasibility of determining the coarse surface outline of objects without using direct imaging. The authors examine the potential of IR-based position-sensing devices (PSD's). Since these PSD's do not use imaging data, signal processing speed is inherently fast. Moreover, the circuit module is quite compact. The authors believe that this technique is suitable for electrically-powered wheelchairs for the handicapped as well as for the harnesses of guide dogs.

## II. Sensor Block and Implemented Functions

### A. Sensor block

A schematic and a photograph of the sensor block are shown in Figs. 1 and 2, respectively. Fig. 1(a) shows a front view of the sensor block and Fig. 1(b) shows a side view. The PSD sensor is mounted on a plate that can be rotated by a stepping motor. The other stepping motor is used to raise or lower the PSD sensor. IR-based PSD sensors are frequently used for distance measurements[3] and LED-based range sensors have recently been developed[4]. This study used an IR-based PSD sensor[5]. The first stepping motor is driven by the micro

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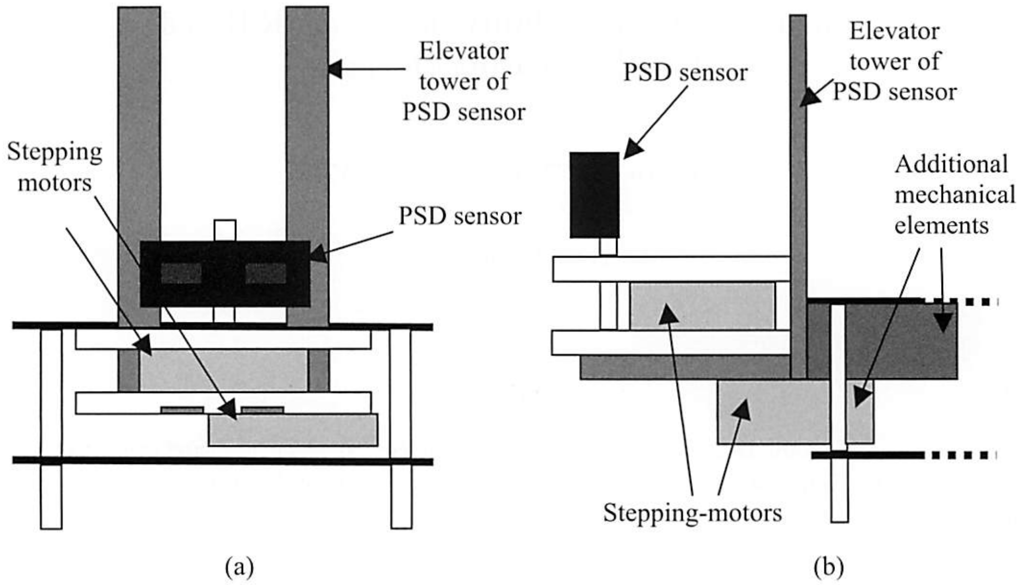


**Fig. 1** Sensor block.
(a) front view, (b) side view.

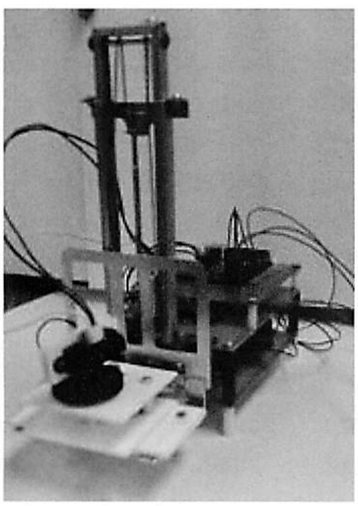

**Fig. 2** Photograph of sensor block.

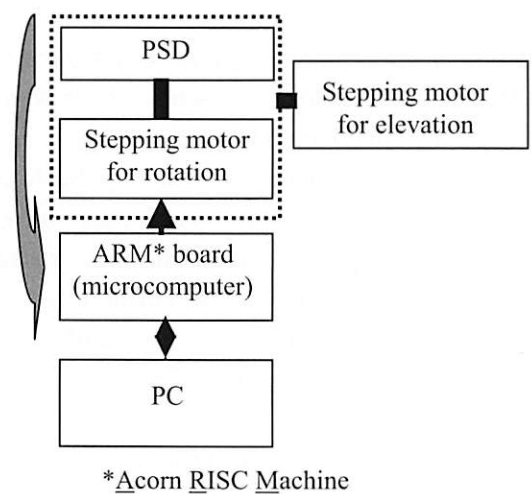


**Fig. 3** Schematic illustration of system for test the functions.

controller. An overall view of the sensor is shown in Fig. 2.

### B. Functions of the sensor block

The sensor block is composed of PSD sensor, ARM board, two stepping motors, and mechanical elements for sensor rotation and sensor elevation, as shown in Fig. 1. The system is controlled by a microcomputer on the ARM board, as shown in Fig. 3. The process flow is summarized as follows. The stepping motor rotates the PSD sensor through 180 degrees with a certain angular velocity under the control of a software module. Since the PSD sensor outputs the distance between the sensor and first reflection point at each angle, an edge is detected when the distance changes abruptly. When an edge is detected, the second stepping motor lifts the PSD sensor by a certain amount, and the PSD sensor is rotated in the other direction. This sensor-scan process is repeated till the PSD is lifted up to the top of the elevator tower.

## III. Results of Experimental Sensor System

### A. Detection of object edges

We first detected the edges of a box-like object. When the stage of the PSD sensor is rotated in front of the object, the sensor begins to measure the distance between the sensor and the obstacle surface. This sequence of PSD sensor data yields the two sets of results shown in Fig. 4, where the distance from the object to the sensor is 30 cm, W stands for the front width of the object, and the IR sensor scans from 0 degrees to 180 degrees so that the sensor can search for the edges of the object. In the case of W=15.2 cm, the IR sensor catches the edges of the object at an angle of ~80 degrees and ~110 degrees. This confirms that the method can properly detect the location of the object.

There are, however, two impediments to accurate edge detection. One is the deflection of

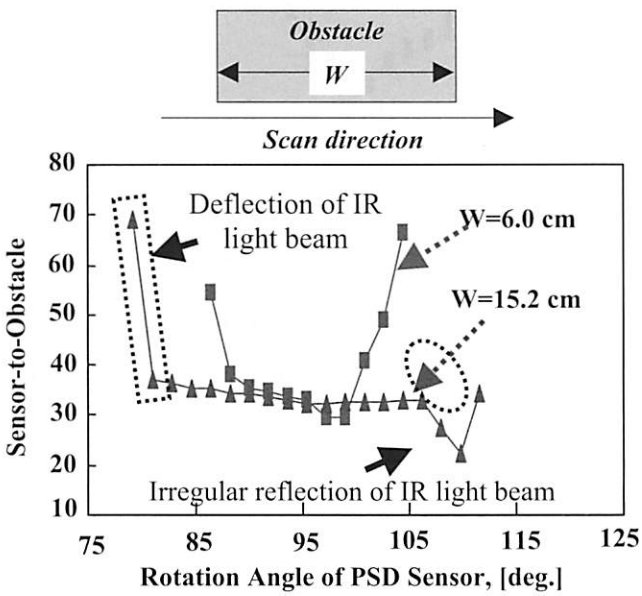


Fig. 4 Detection of two edges of a rectangular object. W = width of object.

the IR beam at the left edge and the other is the irregular reflection effect at the right edge. So, we need to categorize the profile of as-measured sensor-to-obstacle distance data.

When the PSD sensor approaches the left-side edge of the obstacle from the left side of the obstacle, the PSD sensor integrates the reflected light that is weakened by the deflection of light as the incident light traces the obstacle surface. This does not yield an abrupt step in the distance data.

When the PSD sensor approaches the right-side edge of the obstacle from the left side of the obstacle, the PSD sensor integrates the irregularly-reflected light near the right-side edge. This results in enhancement of reflected light and the sensor outputs a range which is shorter than expected.

This problem is more clearly observed when the surface of a rectangular obstacle is tilted relative to the sensor face. Experimental results are shown in Fig. 5. Points B and B' are the peaks in distance tracks used to detect the edges. Lines B-C and B'-C' are almost parallel to the incident light beam, so the reflected IR light that the PSD sensor can receive is very weak, and correct detection becomes problematic. Both difficulties can be eliminated by using paired PSD sensors. Here, we assume that the second sensor is stacked upside down on the first sensor.

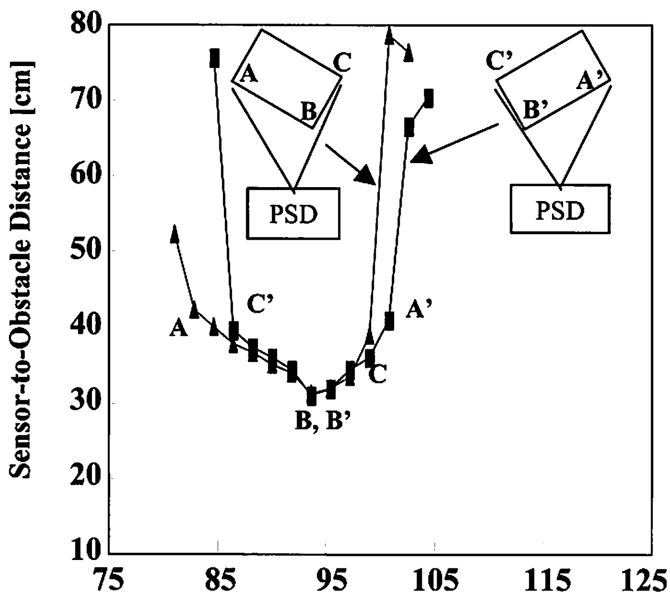


Fig. 5 Detection of two edges of a tilted box-like object.

## B. Outlining an object

Work has already been reported recently on using on-vehicle millimeter-wave radar to outline objects; the goal was road-shape recognition[6]. Unfortunately, the system is too power-hungry for many common applications. Since our target is short-range detection with low power consumption, we used an IR-based sensor.

Fig. 6 shows the outline of an obstacle; the inset shows a photograph of the object. In the experiment, the PSD sensor was elevated in 1 cm steps. The edge of the obstacle was automatically determined by the abrupt change in obstacle-to-sensor distance (see Appendix).

It is seen that the outline curve successfully reproduces the shape of the object. Therefore, this technique is useful in acquiring the rough outline of objects.

## C. Measurement of Surface Outline

We are now exploring the potential of this technique for roughly measuring an object's surface outline (3-D outline). This experiment is carried out in order to evaluate how easily the technique is applicable to the detection of rough surface image[7].

In a past study, the resolution of surface outline proved unsatisfactory because the number of measurement points was limited[7]. However, the technique proposed here has no such

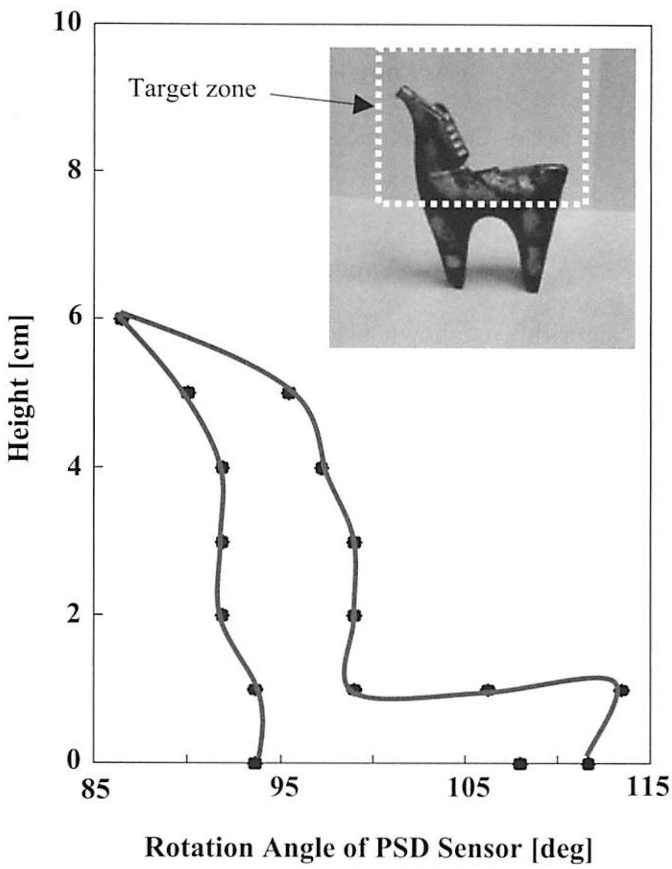


Fig. 6 Outline of object The inset shows a photograph of the object.

drawback because the number of detection points under sensor scanning is easily increased.

### D. Remaining Issues

This study is the first step in evaluating how easily the outline of a complex object can be determined by an IR-based PSD sensor. Our experiments suggest that the technique is useful, but the evaluation speed is not good enough to support practical applications because the elevation of sensor board takes too long. Therefore, the next step is to shorten the time spent scanning the sensor. One approach is to two-axis-rotate the sensor. This would also reduce the volume of the sensor block.

### E. Summary

This paper described the feasibility of determining the outlines of objects without the use of direct imaging. We examined the potential of IR-based position-sensing devices (PSD's) by scanning two objects. We successfully reproduced the outlines of both. Since this method does not process image data; its response speed is inherently high. The technique is quite promising because its circuit module is quite compact and offers low power consumption.

## Acknowledgment

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## Appendix

The edge detection algorithm is shown below. When the difference in distances at two adjacent points exceeds a critical value, the sensor circuit indicates that an edge has been found. In the present experiment, it is assumed that the critical value is 4.17 cm.

```
If (k <= 4.17){
          If (kp > 4.17){
          a = (100 - stepsl + 1) * 1.8;
          printf("%.1f\n", a);
          }
          }
if (k > 4.17){
          if (kp <= 4.17){
          b = (100 - stepsl + 1) * 1.8;
          printf("%.1f\n", b);
          }
          }
```

k: difference between latest distance values evaluated at two adjacent points (in cm.)
kp: difference between previous distance values evaluated at two adjacent points (in cm.)
a: rotation angle of sensor when the left edge is detected (in degrees.)
b: rotation angle of sensor when the right edge is detected ) (in degrees.)
(100-stepsl) * 1.8: rotation angle (in degrees.)

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