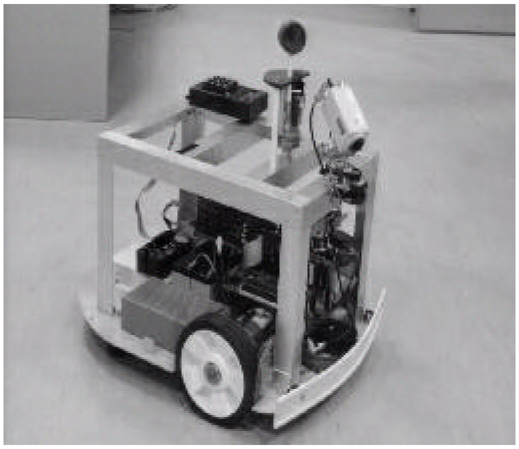
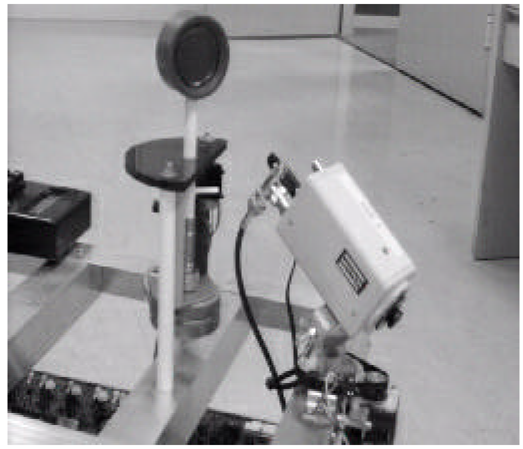
Generating Sonar Maps in Highly Specular Environments



(a) Robot J.Edgar



(b) Closeup of sonar head

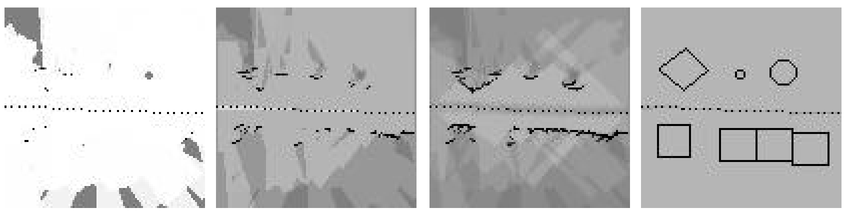
Figure 1

Building environment maps from sensory data is an important aspect of mobile robot navigation, particularly for those applications in which robots must function in unstructured environments. Ultrasonic range sensors are, superficially, an attractive sensor modality to use in building such maps, due mainly to their low cost, high speed and simple output. Unfortunately, these sensors have a number of properties that make map building a non-trivial process. In particular, standard sensors have very poor angular resolution and can generate misleading range values in specular environments. The first of these problems can be largely overcome by combining range measurements from multiple viewpoints. Elfes [1] and Moravec [2] describe an approach in which range measurements from multiple viewpoints are combined in a two-dimensional `occupancy grid'. Each cell in the grid is assigned a value indicating the probability that the cell is occupied. Unfortunately, the occupancy grid approach does not work well in specular environments. Specular reflection may occur whenever an ultrasonic pulse encounters a smooth extended surface. In such cases the pulse may not be reflected back to the ultrasonic sensor; in effect, the surface may appear to be invisible. In ordinary office environments which contain smooth walls and glass doors specular reflection is common. In this research, we have improved on earlier grid-based approaches by introducing the concept of a `response grid'. The intent of the response grid framework is to produce an approach which has the advantages of the occupancy grid framework, but also performs well in specular environments.

The response grid framework attempts to model the behaviour of ultrasonic range sensors in a more physically realistic fashion. The basic notion that the response grid encapsulates is that a cell may generate a response (ie appears to be occupied) when viewed in one direction, but will not generate a response when viewed from another. For example, a smooth planar surface will only generate a response when the angle of incidence between the surface normal an the beam emitted by the sensor is close to zero. At larger angles of incidence the surface will generate no response. In the original occupancy map framework, this would present a contradiction, since this approach assumes that an occupied cell should generate responses in *every* direction. A full description of the response grid framework can be found in [3] and [4].

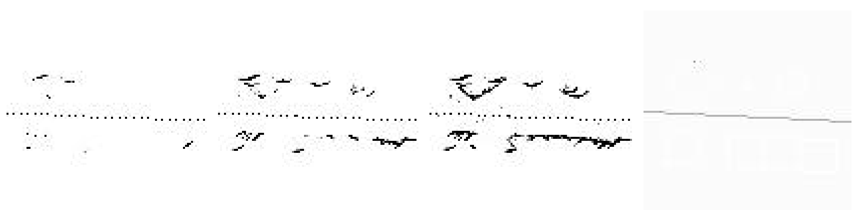
Some results are shown below. These results where obtained using a small mobile robot equipped with a single Texas Instraments/Polaroid ultrasonic range-finder attached to a pivoting head (Figure 1). The sensor has an unobstructed view and can rotate through 360 degrees in 7.5degree increments. Consequently, 48 range readings are generated by each `sweep' of the pivoting sensor head. The experiments where conducted in a relatively complex environment containing a number of boxes, a hatstand and a chair. The robot travels in a more-or-less straight line between the obstacles, taking range readings as it goes. The results shown in this section include readings from about 30 complete sweeps of the sensor head, about 1440 individual readings. The robot's location is determined by simple odometry. The robot has an on-board 486 processor which is easily fast enought to generate maps in real time (i.e. it can incorporate new range measurements at the rate at which they are acquired).

Figures 2 and 3 show the maps produced for varying values of n (i.e. varying numbers of response directions). Each cell represents a region 4 centimetres square. In these maps, cells which are probably occupied (or for which we have strong support) appear darker than cells which are probably unoccupied. The dotted line shows the path of the robot. Note that the technique described by Elfes [3] corresponds to the n = 1 Bayesian occupancy map shown in Figure 2a.



(a) n = 1 (b) n = 4 (c) n = 8 (d) Ideal

Figure 2: Bayesian Occupancy maps



(a) n = 1 (b) n = 4 (c) n = 8 (d) Ideal

Figure 3: Dempster-Shafer Occupancy maps

References

[1] Alberto Elfes, "Occupancy grids: A stochastic spatial-representation for active robot perception", in *Proceedings of the Sixth International Conference on uncertainty in AI*
[2] Hans Moravec, "Sensor fushion in certainty grids for mobile robots", *AI Magazine*, pp 61-74 Summer 1988
[3] Andrew Howard and Les Kitchen, "Generating Sonar Maps in Highly Specular Environments", *Proceedings of the Fourth International Conference on Control, Automation, Robotics and Vision* December 1996.
[4] Andrew Howard and Les Kitchen, "Generating Sonar Maps for Mobile Robots", *Tech Report 96/34* Novermber 1996.

Last Update: 06/08/1997