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Modeling of High-Resolution 3D Sonar for Image Recognition

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Automated underwater 3D sonar image recognition has great potential to simplify many underwater tasks. Sonar modeling is necessary to recognize 3D object images. We propose a 3D sonar model that can predict what an object is based on by recognizing similarities to objects that pre-exist in a database. The sonar's displaying mechanism and characteristics of the 3D sonar image are studied. Due to the nature of acoustics, a sonar image is not necessarily always an accurate depiction of an object. The proposed model enables mapping of a 3D world onto a 2D sonar screen. This modeling framework enables the implementation of various optical vision techniques for recognition. Recognition experiments were conducted to evaluate the model's accuracy.

INTRODUCTION

Underwater, the sonar image and the optical camera are both feasible sensing methods for object recognition. They are essential to carrying out tasks such as object finding, environmental monitoring, and underwater structure installation and maintenance.

The optical camera provides the highest underwater image resolution, but it has restricted applications due to its limited visibility (Sisman, 1982), especially since many of the tasks take place in shallow water with visibility distances of less than 1 m.

The sonar image is also a feasible method for recognition. Recently, the quality of the sonar images has improved dramatically. The latest 3D sonar image such as DIDSON (Dual frequency IDentification SONar: Belcher, 2002; DIDSON website; Kim and Neretti, 2005; Negahdaripour et al., 2005) provides high-resolution 3D images.

Automatic sonar image recognition has great potential in many underwater fields such as mine detection, and maintenance and safety inspections. However, both automated sonar image recognition's displaying mechanism and the very nature of acoustics present challenges. These difficulties cannot be overcome simply by the optical camera model-based approach. We studied the sonar's characteristics and display mechanism and proposed this model to recognize objects from any viewpoint.

SONAR ANALYSIS

Displaying Mechanism and Characteristics

Sonar images have large differences from optical images because of their acoustic characteristics. Figs. 1∼12 show examples of both optical and sonar images. In this study, DIDSON (1.1/1.8 MHz) is used as the 3D sonar image. The images were taken from the surface at a distance of about 1 m. Here are described the sonar's displaying mechanism and the concrete difficulties in image recognition. In contrast to the optical vision, the sonar image has the following representative characteristics.

Different geometry. Despite showing the same concrete cone, Figs. 9 and 11 look very different. The disparity in these 2 images highlights how identical geometry looks very different when seen through sonar imaging. Fig. 13 illustrates the sonar's displaying mechanism. The sonar projects acoustic beams toward an object and then displays the returned beams on the screen. The beam's source and sink locate at the same point DP. In optical terms, this would correspond to a light source being at the same point as the camera taking the image. When the projected beam hits on either the cone surface or the bottom (XY plane), it returns 2 kinds of data: the acoustic reflection's strength and the distance from DP to the point of reflection. These 2 types of data are then translated into the image on the screen, with each returned acoustic beam representing 1 pixel. The distance covered determines the position of the pixels, and the reflection intensity determines the brightness (higher brightness = higher intensity).

As shown in Fig. 14, the sonar image displays as the cylindrical coordinate. The upper area in the image shows the increased distance from the sonar.

As shown on the left side of Fig. 13, the distance from DP to the cone's vertex B is closer than the bottom area A. B is mapped into the image's lower area. In the sonar image, the shadow indicates the area which has no returned beam data. The cone's shadow is not the area from C to D. The shadow is the area from B to D. The cone's front surface area A and B stops the beam from moving forward resulting in no data. The beam's data reappears from the left side of the line BD. It is the bottom XY plane's reflection. The right side of Fig. 13 shows the different geometry between the optical and the sonar images. Both images have the same viewpoint and lighting direction, but the sonar's cone shape is upside down but with a similar triangle shadow shape. The sonar's characteristic displaying mechanism brings out the different geometry of the object in the image.

Partial loss or modification of object. Figs. 5 and 7 show both the optical and sonar images of a concrete cylinder model. The cylinder shape in the sonar image is different from the optical image. Fig. 14 illustrates the sonar's displaying mechanism. It is more complicated than the cone model. As noted above, the

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