Sonar Sensor Interpretation for Ectogenous Robots

WEN GAO

College of William & Mary, Department of Applied Science, 2005
Field: Nondestructive Evaluation   Degree: Ph.D.

Advisor: Mark K. Hinders, Associate Professor of Applied Science

Abstract

We have studied the physics of full-field sensor interaction with materials, structures and components in order to develop the brains for useful robots. Four generations of sonar scanning systems have been developed to automatically interpret surrounding environment. The first two are stationary 3D air-coupled ultrasound scanning systems and the last two are packaged as sensor heads for mobile robots. The data acquisition and motion control subsystems have been improved at each stage.

For the indoor objects, three methodologies have been discussed to tell different objects and materials. Among these, template matching is the most effective one. It is conducted by comparing the tested echo with the reference echoes. Important features are then extracted and drawn in the phase plane. The computer then analyzes them and gives the best choices of the tested echoes automatically.

For cylindrical objects outside, an algorithm has been presented to distinguish trees from smooth circular poles based on analysis of backscattered sonar echoes. The echo data are acquired by a mobile robot which has a 3D air-coupled ultrasound scanning system packaged as the sensor head. Four major steps are conducted. First, a series of scans (?9) for one object are done by the mobile sonar system. Second, a backscatter vs. scan angle plot is constructed by a 5th order polynomial fit. Then, Asymmetry and Deviation features are extracted from the interpolation plots. Finally, further feature extractions are done based on the Asymmetry-Deviation graph. Average Asymmetry-Average Squared Euclidean Distance phase plane is segmented to tell a tree from a pole by the location of the data points for the objects interested. Results located in the small area near the origin represent poles while those located away from the origin represent trees.

For extended objects outside, we successfully distinguished seven objects in the campus by taking a sequence scan along each object, obtaining the corresponding backscatter vs. scan angle plots, forming deformable template matching, extracting interesting feature vectors and then categorizing them in a hyper-plane. Results show that this approach to distinguish different objects is promising.

We have also successfully taught the robot to distinguish three pairs of objects outside. Multiple scans are conducted at different distances. Instead of the previous backscatter, amplitude vs. scan angle plots are obtained for analysis. A two-step feature extraction is conducted based on the amplitude vs. scan angle plots. The final Slope1 vs. Slope2 phase plane not only separates a rectangular trash can from a cylindrical trashcan, but also separates a flat brick wall from a convex brick wall, a square lamppost from a round lamppost.