Automatic Underwater Multiple Objects Detection and Tracking Using Sonar Imaging

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Publications

1. Shi Zhao, Amir Anvar, and Tien-Fu Lu, "Automatic Object Detection and Diagnosis for AUV Operation Using Underwater Imaging Sonar", presented at Industrial Electronics and Applications, 2008. ICIEA 2008. 3rd IEEE Conference on, pp. 1906-1911, 2008.
2. Shi Zhao, Amir Anvar, and Tien-Fu Lu, "Automated Mapping and Localization for Autonomous Underwater Vehicle's Navigation Using Imaging Sonar", presented at IAENG International Conference on Control and Automation, 2009. International MultiConference of Engineers and Computer Scientists IMECS 2009, pp. 1361-1367, 2009. Best Student Paper Award
3. Shi Zhao, Tien-Fu Lu, and Amir Anvar, "Automatic Object Detection for AUV Navigation using Imaging Sonar within Confined Environments", presented at Industrial Electronics and Applications, 2009. ICIEA 2009. 4th IEEE Conference on, pp. 3648-3653,2009.
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6. Shi Zhao, Tien-Fu Lu, Amir Anvar, "Multiple Objects Detection and Tracking for AUV Navigation using Imaging Sonar within Confined Environments", in preparation for *IEEE Transactions on Robotics*
7. Shi Zhao, Tien-Fu Lu, Amir Anvar, "Automated Mapping and Localization for Autonomous Underwater Vehicle's Navigation Using Imaging Sonar", IAENG Transactions on Engineering Technologies Volume 3 - Special Edition of the International MultiConference of Engineers and Computer Scientists 2009, published by American Institute of Physics for the IMECS 2009

Abstract

The exploration of oceans and sea beds is being made increasingly possible through the development of Autonomous Underwater Vehicles (AUVs). This is an activity that concerns the marine community and it must confront the existence of notable challenges. These include, for example, mining minerals, inspecting pipeline and mapping oceans, sampling in contaminated water. Also, there has been another growing interest for security forces in precluding submarines or intruders from a beach or harbour entrance as well as hunting shallow water mines. However, an automatic detecting and tracking system is the first and foremost element for an AUV or an aqueous surveillance network. Since accurate surrounding information is essential in order to manoeuvre the AUV efficiently and economically, while corrupt information can jeopardize an entire mission. By extracting the space information form sensors, an AUV can achieve the localisation and mapping which are currently two primary concerns in the robotics research. Meanwhile, such information will provide a fundament of protection for surface vessels or troops, harbour infrastructure and oil plant against the enemy and terrorism.

Acoustic sensors are commonly used to detect and position underwater obstacles, suspicious objects or to map the surroundings because sound waves can propagate more appreciable distances than electromagnetic and optical energy in the water. The measurements from these sensors, however, are always bound up with noises and errors. Various underwater activities may further pollute sound signals and then threaten the AUV navigation process. To simplify the detection procedure, some researchers make use of acoustic beacons or apparent obstructions (such as rocks, concrete walls) because they have distinctive characteristics. Point or line features are extracted from the acoustic signals or images for localization and mapping purposes. The long propagation range of sound waves can present new problems when acoustic sensors operate in confined environments, such as water tanks, rivers and harbours. The multiple reflections will be recorded by the sensor and result in false alarms. Furthermore, with advances in manufacturing techniques, the downsizing in marine explosive ordnances is progressing

significantly, making it more difficult to discriminate between surface reflections and explosive ordnances. Finally, under the consideration of cost effectiveness, a mechanically scanned sonar has been introduced for the AUV in this research. However, the sensor beam cannot cover a large region simultaneously and a moving object may be distorted in the acoustic image because of the relatively low scanning speed. Due to such distortions in the data flows, objects may be indistinguishable from random noise or reverberation in acoustic images.

The research presented here addresses the afore-mentioned problems relating to the theme of automatic detection from acoustic images. It is concerned with the detection and tracking of small underwater objects in order to protect autonomous underwater vehicles using sonar (SOund Navigation and Range). In the present study, these vehicles operated in laboratory water tanks or natural river environments.

This research made use of self provided analytical studies that differentiated between reverberation and real object echoes. Detections were achieved automatically by using signal and image processing techniques. This research consists of three important and linked strategies. Firstly, a simple and fast reverberation suppression filter was provided, based on the understanding of the mechanism of the sonar sensor. Secondly, a robust detection system was developed to perceive small suspended obstacles in the water. Thirdly and finally, arc features were successfully extracted from the acoustic images and mathematical maps were generated from those features. The majority of experiments were derived from the elliptical water tank and the River Torrens, Adelaide, South Australia. For this project, a sequence of sonar images was taken from the same sonar location in the elliptical water tank. Further, a sequence of sonar images was taken from a sequence of sonar locations in the natural river. They provided different data sets for the assessment and evaluation of self developed algorithms. Results shown in this thesis confirm the favourable outcomes of the investigation and applied methodology.

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Abbreviations

AUV	Autonomous Underwater Vehicle
CFAR	Constant False Alarm Rate
CML	Concurrent Mapping and Localization
CHIRP	Compressed High Intensity Radar Pulse
DSTO	Defence Science and Technology Organisation
DGPS	Differential Global Positioning System
DVL	Doppler Velocity Log
DOF	Degree of Freedom
DSP	Digital Signal Processor
EKF	Extended Kalman Filter
ESIS	Electronically Scanned Image Sonar
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FIS	Fuzzy Interface System
FPGA	Field Programmable Gate Arrays
GM-PHD	Gaussian Mixure Probability Hypothesis Density
INS	Inertial Navigation system
KF	Kalman Filter
LBL	Long Base Line
LS	Least Square
MBES	Multibeam Echo Sounder
MF	Matching Filtering
MFP	Matched Field Processing
MOD	Maritime Operations Division
MSIS	Mechanically Scanned Imaging Sonar
MSP	Mechanically Scanned Profiler
MTI	Moving Target Indicator
NNSF	Nearest Neighbour Standard Filter

PCI	Principal Component Inverse
PF	Particle Filter
ROV	Remote Operation Vehicle
SLAM	Simultaneous Localization and Mapping
SNR	Signal to Noise Rate
SSS	Side Scan Sonar
TOF	Time of Flight
USBL	Ultra Short Baseline