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A SURVEY ON UNDERWATER TARGET DETECTION AND TRACKING METHODS

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Abstract: Active target detection and tracking is classical signal processing problem that arises in various applications like biomedical and military. In this paper different methods are using to detect and track the target in underwater. Underwater target detection and tracking attracts tremendous research interest due to various impediments to the estimation task caused by the noisy ocean environment. Target detection is nothing but detecting the target position and tracking is used to measure the target's relative position in range. In this case mainly used sensors to detect and track the target and these sensors can be classified for different approaches.
Index Terms: Target Detection, Target Tracking, Sensors, Sonar, Sonobuoy, Gabor filter, Kalman filter, AUV, Forward Scan Sonar.

I. INTRODUCTION

Underwater object detection is critical in lot of applications in maintenance, marine sciences, repair of undersea structures, and homeland security. For example inspection and surveillance of underwater pipelines with optics camera presented. With people's increasing passion to exploit the ocean resource and the demand of military development, more and more attention is paid to how to acquire and comprehend the information of underwater scene exactly. Sound is considered as the most suitable form of energy that propagates through the sea, as it is the most robust form of energy against attenuation by underwater conditions, especially when compared to other sources of radiations such as electromagnetic waves. Electromagnetic waves do not propagate over long distances underwater except at extremely low frequencies and is prohibitively expensive because of the large and powerful transmitters required. Over the past few decades, ocean exploration activity has been steadily increasing. The data collected by sensors placed underwater is transmitted to the surface of the ocean, from there, it is possible to relay the data via dedicated communication systems or satellites to a data collection centre. The technique that uses sound propagation underwater to navigate, communicate or detect objects underwater is SONAR (SOund NAvigation and Ranging). Applications of Underwater sound can be classified into civilian and military applications. Civilian applications of underwater sound include acoustic devices for navigation and localization, remote control and monitoring of underwater equipments, location and identification of underwater mammals and emergency communications. These devices are being used in scientific, commercial and recreational exploitation of the oceans. Military applications of underwater sound include acoustic mines and detection of underwater objects. This research focuses on the application of underwater target tracking in ASW.

II. RELATED WORK

Detection, tracking and classification of underwater targets bear immense significance and has attracted great attention in the past few decades due to its growing importance in various spheres critical to mankind like oceanographic as well as fisheries studies, sonar operations, military applications, research, etc. The Target detection and tracking in underwater is very important hence here more methods are used i.e Forward scan optical imaging, Forward scan sonar imaging, AUV, Active sonar, Passive sonar, Side scan sonar, Synthetic aperture sonar, Bottom mounted sensor, Sonobuoy, etc. In the section III we enumerate major challenges in the design of underwater acoustic network. In section IV we compare the different methods for underwater target detection and tracking. In the V section we conclude this paper by using sonobuoy method.

III. MAJOR CHALLENGES IN THE DESIGN OF UNDERWATER ACOUSTIC NETWORKS

A. Path loss

Attenuation: Is mainly provoked by absorption due to conversion of acoustic energy into heat, which increases with distance and frequency. It is also caused by scattering and reverberation (on rough ocean surface and bottom), refraction, and dispersion (due to the displacement of the reflection point caused by wind on the surface). Water depth plays a key role in determining the attenuation. Geometric Spreading: This refers to the spreading of sound energy as a result of the expansion of the wave fronts. It increases with the propagation distance and is independent of frequency. There are two common kinds of geometric spreading: spherical (omni-directional point source), and cylindrical (horizontal radiation only).

B. Noise

Man made noise: This is mainly caused by machinery noise (pumps, reduction gears, power plants, etc.), and shipping activity (hull fouling, animal life on hull, cavitation). Ambient Noise. Is related to hydrodynamics (movement of water including tides, currents, storms, wind, rain, etc.), seismic and biological phenomena.

C. Multi-path

Multi-path propagation may be responsible for severe degradation of the acoustic communication signal, since it generates Inter-Symbol Interference (ISI). The multi-path geometry depends on the link configuration. Vertical channels are characterized by little time dispersion, whereas horizontal channels may have extremely long multi-path spreads, whose value depend on the water depth.

D. High delay and delay variance

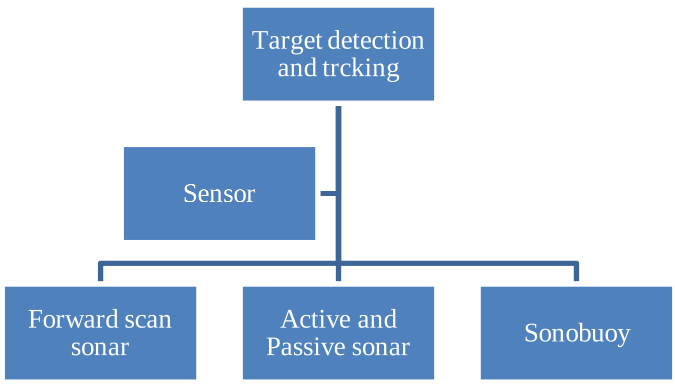
The propagation speed in the UW-A channel is five orders of magnitude lower than in the radio channel. This large propagation delay (0.67 s=km) can reduce the throughput of the system considerably. The very high delay variance is even more harmful for efficient protocol design, as it prevents from accurately estimating the round trip time (RTT), key measure for many common communication protocols.

E. Doppler spread

The Doppler frequency spread can be significant in UWA channels, causing degradation in the performance of digital communications: transmissions at a high data rate because many adjacent symbols to interfere at the receiver, requiring sophisticated signal processing to deal with the generated ISI.

IV. CLASSIFICATION OF TARGET DETECTION AND TRACKING

Sonar is a device used for remotely detecting and locating objects underwater.



Gabor filter Time of arrival GPS and DIFT
Kalman filter Target motion analysis

Fig.1 classification of target detection and tracking

They play a key role in ocean research due to the ease with which they can be used as instruments for detection of noise sources underwater. Since its introduction during the early half of the 20th century, it has been undergoing various evolutionary stages and has remained as one of the priority areas of research in developed, developing as well as underdeveloped countries. Sonar uses sound propagation underwater, to navigate, communicate or detect other vessels or targets of interest.

A. Active Sonar

Active sonar involves the transmission of an acoustic signal which, when reflected from a target, provides the sonar receiver with a basis for detection, estimation and localization of targets underwater as illustrated in Fig.2 A signal, in the form of a sound pulse called ping, is emitted and the wave then travels in various directions and hits the objects on its propagation path. Some of the energy reflected will travel back to the transmitting system.

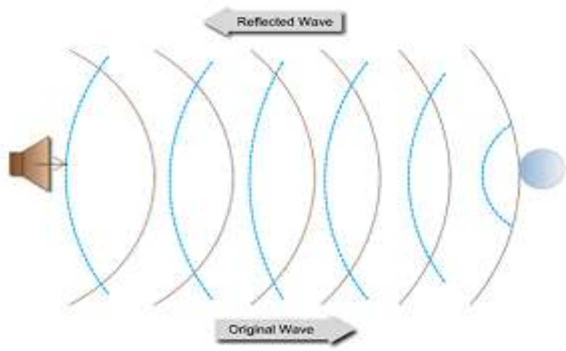


Fig. 2 Principle of Active Sonar

The echo, along with other factors such as the frequency, energy of the received signal, depth, water temperature, etc., will enable the sonar system to compute the position of the target of interest, with vanishingly small errors. Ping of acoustic signals generated using a Sonar Projector working in conjunction with the signal generator, power amplifier and transducer array, possibly with a beam former helps in target detection and estimation as depicted in Fig. 3 Acoustic signals can as well be generated underwater by other means such as detonation of explosives. The time elapsed between the transmission and reception of a signal is converted into the range parameter to estimate the distance of the target of interest using the velocity of sound. To measure the bearing, several hydrophones are used, which measure the relative time of arrival (TOA) of the reflected signal to each, or by measuring the relative amplitude of beams formed through beamforming, with an array of hydrophones. Beamforming is a technique that is used to manipulate the directionality, or sensitivity of a radiation pattern. When receiving a signal, it can increase the receiver sensitivity in the direction of the desired signals, while it decreases the sensitivity in the direction of interference and unwanted noises. The use of an array reduces the spatial coverage and hence to achieve wider coverage, multi-beam systems are used. The echo returns together with noise is then subjected to various types of signal processing, which for simple sonars may be just energy detectors. It is then presented to some form of decision device, which will interpret the signal, within certain allowable tolerances. This decision device may be an operator with headphones or a display, or in more sophisticated and fully automated sonar systems, this function may be implemented by special purpose tools or platforms. Simple sonars generally use the TOA technique with a filter, wide enough to cover possible Doppler effects, while more complex ones generally employ the beam forming technique.

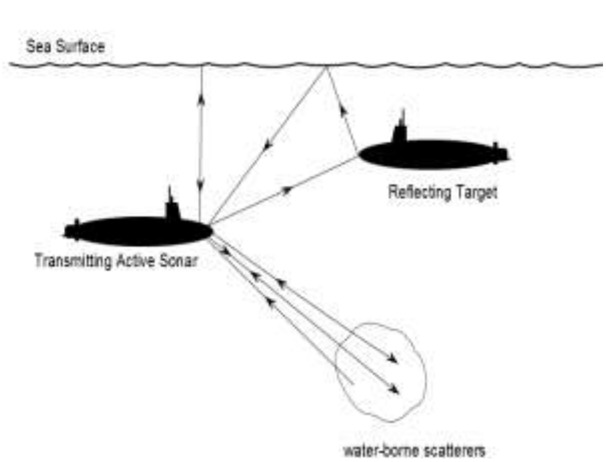


Fig.3 Scenario using Active Sonar

Military sonars often have multiple beams to perform the surveillance of the entire space, while the simple ones only cover a narrow area. When single frequency transmission is used, the Doppler effect can be utilized to measure the radial speed of a target. The Doppler shift, which is the difference between the transmitted and received frequencies, is estimated and converted into a velocity term. Since Doppler shifts are caused by either the motions of the receiver or target platforms, appropriate correction terms deemed fit need to be taken into account to compensate for the radial speed of the sonar platform. The use of active transmissions from sonars, especially during war time, need to be analysed on the strategic point of view. Active transmissions from such sonars will help the enemy vessels, around the radiating sonar, to infer the clues about the presence of active sonar, its transmitting frequency and its position making use of the received acoustic levels. Since active sonar platforms are very noisy, such sonars will not allow target identifications with significant success rates. Thus, this type of detection is used by fast platforms such as planes and helicopters and by noisy platforms like surface ships, but rarely by submarines. When active sonar is used by surface ships or submarines, it is typically activated very briefly at intermittent periods, to reduce the risk of detection by the enemies. Depending on the number and position of the transmitters and receivers, the active sonar operation can be classified as mono-static, bi-static and multi-static. When the transmitter and a receiver are in the same place, the operation is called mono-static, while in bi-static, they are separated. When more transmitters or receivers are used, it is referred to as a multi-static operation. Generally, most sonars are used mono-statically with the same array often being used for transmission and reception. In certain mono-static system installations, if the platform is moving, it may be considered as bi-static. Multi-static operation is preferred in active sonobuoy field applications.

B. Passive sonar

The passive sonar which is quite frequently referred to as listening sonar is essentially a listening device that records the sounds emitted by the objects underwater. Such device can be used to detect seismic occurrences, early warning of ships, submarines, torpedoes, etc. and marine creatures that emit characteristic sounds of its own. A passive sonar scenario is depicted in Fig.4 Passive sonar systems, unlike the active sonars, do not radiate any signals. They detect the targets and perform estimations by analyzing the sound signals emitted by the target itself. The passive sonar has a much greater detection range than active systems and helps in performing the identification of the targets, estimating the range and bearing as well as tracking of targets. The noise generated by mechanized objects underwater is made use of, for performing the target detection. Once a signal is detected in a certain direction, referred to as broadband detection, it is possible to zoom in and analyze the signal received, referred to as narrow band analysis. Identification of the target is made possible, as every target generates its own characteristic noises and Fourier Transform techniques can be used to analyze the various frequency components in it. Another use of the passive sonar is to determine the target's trajectory by a technique referred to as Target Motion Analysis (TMA), which will provide the target's range, course, and speed.

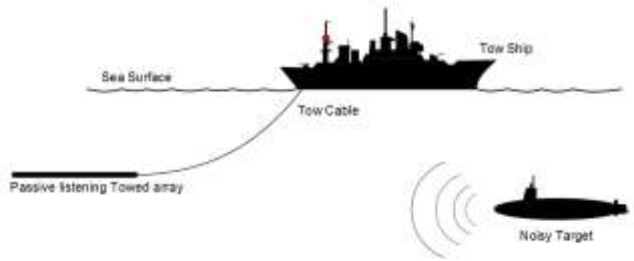


Fig. 4 Typical illustration of Passive sonar

Performance limitations arise as a result of the propagation loss and additive noise at the receiver, even though passive sonar is stealthy and very useful. Major limitations result from the imprecise knowledge of the characteristics of the target emanations, and from dispersion in time and frequency of target emissions by the undersea medium.

C. Sonobuoy

Sonobuoy is mainly a microphone that is deployed from a platform to become submerged in the water and provides information about the local sound amplitude, as a function of frequency and time. Figure 5 shows loading of an aircraft with sonobuoys for future deployment in water. Sonobuoys are used to estimate and track the position of underwater objects that emit sounds. The platforms that deploy sonobuoys are usually helicopters or airplanes from fig.6 but they can also be surface ships. In order to determine the position of a submarine, it should be within the detection range of at least three sonobuoys. However, the bearing of the submarine can be detected if the submarine lies in the detection range of one sonobuoy if equipped with a compass. The advantages of sonobuoys over other acoustic measuring systems include its relative low cost, ease of deployment and the fact that they are not disturbed by the noise from the deploying platform. An advantage of passive sonobuoys compared to active sonobuoys, which emit a sound signal, is that they do not reveal their presence. The main factors that affect the operation of sonobuoys are interference from surrounding sources and background noise. In order to use the data received from the sonobuoys to provide a target position, the location of the buoy must be known in the aircraft. Present buoy geolocation schemes involve a variety of radio direction finding schemes to home on the RF transmission of the sonobuoy.

Figure 5 Sonobuoy loaded on aircraft

These methods require the ASW aircraft to maneuver to obtain a sonobuoy position, and also in most cases require the use of some form of directional antenna. These methods also mean the aircraft cannot stand-off at any distance from the buoy pattern without degrading localization accuracy.

Figure.6 Aircraft launched sonobuoy

Recently global positioning systems (GPS) were introduced to sonobuoys for accurate knowledge of their geographic locations. The sonobuoys system employing GPS for positioning of deployed sonobuoys is known as "GPS Sonobuoys". Figure.7 shows a GPS sonobuoys system. The floating part of the sonobuoy carries a GPS receiver which is used with another GPS receiver mounted on the platform to apply differential GPS for the sonobuoy position. This will lead to highly accurate position of the sonobuoy and hence the detected source can be accurately localized.

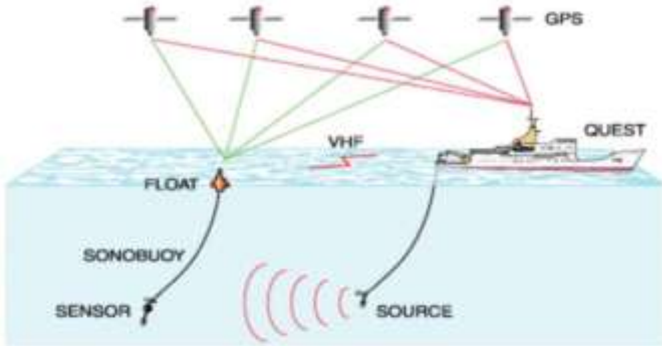


Figure .7 GPS Sonobuoys

D. Forward scan sonar

Underwater object detection is critical in lot of applications in maintenance, repair of undersea structures, marine sciences, and homeland security. Therefore, forward-scan sonar is widely applied to the underwater object detection in recent years. Firstly, the sonar images are enhanced by the gaborfilter. And then underwater objects are extracted. Finally the tracking method is based on kalman filter is adapoted.

V. SUMMARY

Underwater target detection and tracking attracts tremendous research interest due to various impediments to the estimation task caused by the noisy ocean environment. In this case mainly used sensors to detect and track the target and these sensors can be classified for different approaches. The floating part of the sonobuoy carries a GPS receiver which is used with another GPS receiver mounted on the platform to apply differential GPS for the sonobuoy position. This will lead to highly accurate position of the sonobuoy and hence the detected source can be accurately localized.

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