Research on Marine Oil Spill Pollution Detection Based on Image Recognition Algorithm

Kun Zhang, Chong Shen*, Haifeng Wang and Xiaoyan Chen

ABSTRACT

With the development of offshore oil exploration and transportation activities, the threat of oil spill disasters to the marine ecological environment and even human beings is increasing. How to deal with the harm caused by oil spill is urgent. This paper introduces and analyzes the marine oil pollution situation and the current situation of marine oil pollution in China, analyzes the sea surface and sea surface marine monitoring technology, through marine monitoring technology and based on pattern recognition technology marine oil pollution detection technology, seeks to solve the oil spill pollution in time detection and image processing recognition based water quality monitoring technology, in order to assist in rapid intelligent recovery and clear oil pollution treatment.

Kun Zhang: State Key Laboratory of Marine Resources Utilization in South China Sea, Hainan University, Haikou, Hainan, 570228, China; College of Ocean Information Engineering, Hainan Tropical Ocean University, Sanya, Hainan, 572022, China; College of Information Science and Technology, Hainan University, Haikou, Hainan, 570228, China; Sanya Key Laboratory of Computer Vision, Hainan Tropical Ocean University, Sanya, Hainan, 572022, China, kunzhang@hainu.edu.cn

Chong Shen: State Key Laboratory of Marine Resources Utilization in South China Sea, Hainan University, Haikou, Hainan, 570228, China; College of Information Science and Technology, Hainan University, Haikou, Hainan, 570228, China, chongshen@hainu.edu.cn

Haifeng Wang: College of Ocean Information Engineering, Hainan Tropical Ocean University, Sanya, Hainan, 572022, China; Sanya Key Laboratory of Computer Vision, Hainan Tropical Ocean University, Sanya, Hainan, 572022, China, wyfxxz@163.com
INTRODUCTION

Marine environmental detection is not only important for the protection of marine environment, marine biology and ecosystem, but also an important guarantee for the earth's atmosphere, terrestrial water resources and ecosystem security. As an important frontier technology, the three-dimensional detection of marine environment is a strategic emerging technology for the cultivation and development of the country.

This paper is organized as follows. In the next section, the severity of marine oil spillage is introduced, and describes the situation where China’s oceans are polluted by oil spills in section 3. Introduced the sea oil spill monitoring in section 4. Describes the underwater leak monitoring technology in Section 5. In Section 6 opportunities and challenges facing this research. In Section 7 introduces the application of pattern recognition algorithms. In the final structure made a brief summary.

THE HARM OF OIL SPILL IS SERIOUS

The frequent occurrences of marine oil and gas leakage in the world not only seriously pollute the ecological environment of water area, endanger land water resources and biological safety, but also cause huge economic losses, even affect human health and life safety. Among them, the oil spill in the Gulf of Mexico oil spill in 2010 caused tens of billions of dollars in economic losses, contaminating more than 5180 square kilometers of marine waters. Although the sea water has the ability to purify pollution, the oil film will greatly reduce the oxygen exchange between the sea water and the atmosphere, thus affecting the sea water purification and destroying the marine ecological balance. Therefore, the impact of a large oil spill will continue for more than a decade or more.

THE PRESENT SITUATION OF OUR COUNTRY IS WORRYING

From the 2005 China marine environmental quality bulletin, the land-based pollutants discharge is the main cause of environmental pollution and ecological damage in coastal waters of China. But from the perspective of marine biodiversity protection, the harm of oil pollution is the biggest factor: One is that the oil film floating on the sea can reduce the marine oxygen production, directly cause the suffocation of marine life, while the surrounding marine fisheries and aquaculture is a devastating disaster. The second is that toxic substances enter the marine food chain, and the dispersed state and emulsion state of the dissolved fuel will produce a variety of toxic compounds, which will cause serious harm to the food users while poisoning the marine life. Three is the oil film condensed matter is the long-term
killer lurking in the sea, including the floating tar balls and residues in the sediments, are the energy accumulation and accumulation of unsafe factors.

Oil and gas leakage detection and tracking technology is urgently needed in China. First of all, China's sea area is wide, the number of facilities and equipment engaged in the operation of offshore petroleum drilling, mining and transportation is huge, and there are a large number of oil storage equipment distributed along the coastline of thousands of kilometers, and the explosion accidents occur. Secondly, the offshore oil and gas industry in China has developed rapidly in recent years, while offshore oil exploration has entered a period of rapid development [4], about four-fifths of the output comes from the oil and gas fields developed 70 years ago. With the expansion of offshore oil and gas exploration and development, the aging of equipment facilities and the continuous growth of drilling depth, the oil spill incidents in the sea have increased year by year.

At present, the monitoring of oil and gas leakage of offshore platforms such as drilling platform depends mainly on the manual periodic inspection or regular inspection of the robot, it is difficult to find the small oil and gas leakage at the early stage. If the offshore oil and gas operation platform and its facilities and surrounding areas are monitored online 24/7, the oil and gas leakage risk or safety threat can be detected in time, preventive or remedial measures can be taken in time, so as to avoid large-scale oil and gas leakage accidents, and thus lead to huge economic losses and serious marine environmental pollution. Unfortunately, the early online monitoring and prediction research of offshore oil and gas leakage has just started, and there is no effective technology. The several oil spill contaminated seawater surface images are as shown in figure 1.

![Figure 1. Several Oil Spill Contaminated Seawater Surface Images.](image)

**MONITORING OF SPILLED OIL ON THE SEA SURFACE**

The research of oil spill monitoring has a history of several decades, mainly focusing on the technology of oil spill monitoring, oil pollution recovery and ecological restoration. The traditional marine oil spill monitoring system relies on
the surface, air and underwater independent equipment to collect the data of the monitoring area and send it to the shore base station or onboard equipment through satellite communication or underwater cable. The existing sea oil spill monitoring technology mainly includes satellite remote sensing monitoring, aerial remote sensing monitoring, ship remote sensing monitoring, CCTV monitoring and buoy tracking. Satellite remote sensing and aerial remote sensing oil spill monitoring are the most commonly used technologies in developed countries, but the satellite remote sensing monitoring has a long repetition period and low spatial resolution, which has some limitations. The cost of aerial remote sensing and radar monitoring is high, and is vulnerable to weather and environmental conditions, and cannot be implemented in harsh conditions such as smog. Although the ship oil spill monitoring equipment can monitor the oil spills at night, it is not realistic for staff to cruise at night, so it is often used in daytime patrol monitoring and tracking monitoring after oil spill accidents. The technology of fixed point CCTV monitoring and buoy monitoring is limited by location, and the monitoring range is relatively small.

Marine oil spill monitoring research has been a few decades of history, mainly focused on sea oil spill monitoring, oil recovery and ecological restoration technology. The traditional marine oil spill monitoring system relies on water, air and underwater equipment to collect data from the monitoring area and send it to shore base stations or onboard equipment via satellite communications or underwater cables. The existing sea oil spill monitoring technology mainly includes satellite remote sensing monitoring, aerial remote sensing monitoring, ship remote sensing monitoring, CCTV monitoring and buoy tracking. Satellite remote sensing and aerial remote sensing oil spill monitoring are the most commonly used technologies in developed countries. However, satellite remote sensing monitoring has long observation period and low spatial resolution, and has some limitations. Aerial remote sensing and radar monitoring are high weather factors and environmental conditions, in the haze and other harsh conditions cannot be implemented. Ship borne oil spill monitoring equipment can monitor the oil spill at night, but let the staff cruise at night is unrealistic, so commonly used in daytime inspection and monitoring of oil spills after the occurrence of tracking and monitoring. Fixed point CCTV monitoring and buoy monitoring technology is limited by the location, the monitoring range is relatively small.

The existing oil spill monitoring technology has the following disadvantages: (1) Relying on sea buoys, potential beacons and shore stations can monitor the ocean's limited point or level continuously, but cannot monitor the large area of the sea or underwater outside the site. (2) With the help of ship and ship-borne equipment, the monitoring of limited space and time coverage can be carried out in the scheduled sea area, but the cost of manpower and material resources is high, and the long-term and continuous observation cannot be carried out. (3) Using marine remote sensing technology, the sea surface environment can be observed by satellite or aircraft, but
also by the limitation of working time and weather conditions, and cannot monitor the early oil leakage of the underwater operation platform.

Therefore, the existing oil spill monitoring technology can only be used in large-scale oil and gas leakage, resulting in a large area of oil slick, cannot detect early and small range of leakage accidents. The distribution status of oil spills and its drift cannot be tracked, and the long-term on-line monitoring cannot be applied to the key areas where the leakage may occur, so as to provide early warning of oil spills so as to eliminate the hidden dangers of oil spills and to avoid the huge ecological damage and economic losses caused by the major oil spill accidents.

At present, there are two kinds of better machinery and methods for the recovery of marine oil pollution: One is to use a gap in the front of the oil tanker, so that the oil can be collected directly into the ship. A cleaning brush collection method consisting of buoys, motors, drum housings, drive shafts, wheels, brush seats, bristles, and cleaning brushes and sump. In comparison, the first method causes pollution to the ship. Because the oil is driven by the water wave, the oil spills on both sides of the ship, resulting in incomplete cleaning and slow speed. Using the second method, because the oil has a strong adhesive force, the working time is not long must get rid of the grease on the cleaning brush, so the clean up speed is very low. The intelligent marine oil pollution fast scavenging system designed by this project is designed, and a high resolution camera is installed above the oil collector to recognize the oil pollution. After the image processing, the data are acquired, and then the MCU controls the oil collector in front of the oil storage tank to collect oil in the movement. Through the hose to the oil pump, oil the oil on the oil tanker on the oil and water separator, oil and water separation methods to improve the traditional oil collection equipment deficiencies, and thus greatly improve the efficiency of oil recovery.

At present, the oil pollution in the oil tanker is relatively difficult, such as the use of the previous method is slow, pollution is not timely treatment, in order to quickly clean out the oil pollution, to protect the marine clean and sanitation, this project for the first time to study the design of the intelligent oil pollution rapid removal system. This paper mainly proposes that a high resolution camera is installed above the oil suction device to recognize the oil. After image processing, the data is obtained, and then the single chip microcomputer collector in front of the oil storage tank is collected in the movement to collect the oil. Through the hose to the oil pump, oil and water separator on the oil storage tank is pumped into the oil and water separator, oil and water separation is carried out. This method is more efficient, clean and less polluted than the conventional method, so it can be used to clean up the oil pollution in large area.

**UNDERWATER LEAKAGE MONITORING**

Relative to the sea surface floating oil monitoring has formed a more mature technology system, the underwater oil and gas leakage monitoring and prediction
research has just started, and received more and more attention. In 2010, Norway's Stinger and Marine oil and gas enterprise joint LeakRoV project, launched to study underwater oil and gas leakage monitoring mechanism, the project evaluated the performance of the existing underwater oil and gas leak detection sensors, and developed a new type of monitoring techniques. At present, the underwater oil and gas leakage monitoring mainly focuses on the numerical modeling and simulation of underwater leakage, the detection of leakage points based on underwater autonomous underwater vehicle (AUV), the diffusion process of submarine pipeline oil spill in water body, the trajectory and diffusion of submarine oil spill, the estimation of underwater diffusion source based on special network, the location and tracking, the 3d distribution of oil and gas leakage, and the underwater oil spill detection and analysis system based on image processing and machine learning, etc.

In recent years, the low cost and low energy consumption sensor network technology provides a new method for the underwater oil and gas leakage monitoring. Through the underwater acoustic communication or optical communication system network sensor combined with underwater autonomous underwater vehicle AUV, forming dynamic monitoring network, according to the planned monitoring sampling path for three-dimensional large-scale repeated observation, is the ideal choice for real-time information collection and monitoring of underwater environment. In the 1980s, the United States navy developed the wireless underwater equipment network sea web, including autonomous underwater vehicles, gliders, buoys, echo, and ships, and between equipment through sonar, radio and satellite channels (see figure 2).

![Figure 2. Seaweb network in the East Gulf of Mexico.](image)

In 2012, the researchers of the Stevenson Institute of Technology, with the support of the United States natural science foundation, proposed the concept of underwater oil spill monitoring and tracking based on heterogeneous marine robot network. The literature proposed the idea of the safety monitoring of underwater oil
and gas pipeline using sensor network. At present, there is no underwater oil and gas leakage monitoring network system, and the related basic theory and method system need to be improved.

OPPORTUNITIES AND CHALLENGES

Based on the underwater three-dimensional detection network, the offshore oil and gas operation platform and the surrounding sea area can be monitored in real time, and the leakage signs or leakage sources can be determined as soon as possible. Monitoring and tracking the risk of oil and gas leakage through different depth and water surface location monitoring nodes can better grasp the diffusion rules of oil spill in water and water, and take remedial measures at the beginning of oil spill and diffusion to reduce the pollution caused by oil spill and the economic loss caused by the ecological environment. Such monitoring network can also provide long-term online monitoring for offshore operation platform and surrounding sea area, and form a perfect underwater - sea - sea - air integrated ocean detection technology.

Oil and gas leakage monitoring based on offshore 3d detection network is facing many difficulties and challenges. The main technical challenges are summarized as follows: (1) The acoustic communication bandwidth is very narrow, the data transmission rate is low, the transmission delay can reach more than ten thousand times the radio communication delay, and the temperature and salinity changes in the sea area affect sound speed and detection performance. (2) The relative motion of the acoustic communication node results in a significant Doppler effect. (3) The sensor is not easy to charge frequently, so the data processing, communication, positioning and other algorithms on the sensor are simple and efficient to ensure low energy consumption. (4) The reflection of sound wave in the sea and the seabed will lead to multi-channel transmission effect, and the reflection characteristics vary with the sea water temperature difference and salinity, so the acoustic communication link quality is poor and the bit error rate is high. Therefore, the research of underwater oil and gas leakage monitoring network is very challenging and has great research value.

Application of Pattern Recognition Algorithm

Applied national standard as standard sample, selected the monitoring data of three sample regions with oil spilling as to-be-assessed sample, used Vague set pattern recognition method based on similarity measure for recognition assessment, with concrete practice as follows.

Established index set. Established index set, here the first level factor was taken for example, took \( X = \{ x_1, x_2, x_3, x_4 \} \), where \( x_1 \) is hydrocarbon compound, \( x_2 \) is
colioid, $X_3$ is asphaltene, $X_4$ is soluble paraffin, which are part of indices of national standard.

Establish to-be-assessed sample set and standard sample set. Established standard sample set $\mathcal{A} = \{A_1, A_2, A_3, A_4, A_5\}$ on index set, where the water quality $A_1$ is category I, $A_2$ is category II, $A_3$ is category III, $A_4$ is category IV, $A_5$ is category V, which correspond to pollution degrees of extremely light, light, medium, heavy pollution, and grave pollution respectively.

Established to-be-assessed sample set $\mathcal{B} = \{B_1, B_2, B_3\}$ on index set, where $B_1$ is region sampling point 1, $B_2$ is region sampling point 2, $B_3$ is region sampling point 3.

Enter Vague environment. Entering Vague environment means translating raw data into Vague value data. The literature presents the formula translating non-negative single value data into Vague value data, which takes the following form in this case:

$$x_{ij} = \left[ I_{ij}, 1 - f_{ij} \right] = \left( \frac{x_{ij}}{x_{j_{max}}} - 1 - \left( \frac{x_{ij}}{x_{j_{max}}} \right)^2 \right)^{\frac{1}{2}}$$

Where $x_{j_{max}} = \max\{x_{1j}, x_{2j}, \ldots, x_{kj}\}$, $j = 1, 2, 3, 4, 5$.

CONCLUSIONS

With the development of offshore oil development, the development of offshore oil transportation and oil industry is rapid; the oil spill accidents are common, and resulting in serious environmental pollution and economic losses. At present, China’s oil spill treatment technology is still very immature. Based on the research of marine monitoring technology of marine oil spill, this paper provides an effective method for the clear and processing technology of sea oil spill with the application of image processing and pattern recognition. Therefore, the basic law and the related treatment system of the oil spill are not only instructive to the oil spill treatment, but also provide the direction for the future research and improvement.

ACKNOWLEDGEMENT

This research was financially supported by the National Natural Science Foundation of China (No. 61461017); the Hainan Natural Science Foundation Innovation Research Team Project (No. 2017CXTD004); the Scientific and
Technological Cooperative Project for College and Region of Sanya (No.2013YD36); the Hainan Provincial Key Research and Development Plan (No.ZDYF2016002); the State Key Laboratory of Marine Resources Utilization in South China Sea; the Innovative Research Project of Postgraduates in Hainan Province (No.Hyb2017-07); the Open Topic of State Key Laboratory of Marine Resources Utilization in South China Sea of Hainan University (No.2016013A); the Key Laboratory of Sanya Project (No.L1410).

REFERENCES


