Remote System for Oil Spill Detection Based on ZigBee and GIS

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Abstract—**In order to solve the problem of long delay time and low data precision, a remote system for oil spill detection based on ZigBee and GIS is designed in this paper. This paper analytically summarizes the results obtained from surveying spectral characteristics of spill oil film at sea. M along use of AVHRR and TM data, the image of oil spill in several marine accidents has been processed and identified, and the place and area of oil spill in obtaining images are the same as investigation in the scene of accidents. Simulation results show that the proposed system which bases on the ZigBee and GIS can thus improve overall system performance substantially.**

Index Terms—**remote system, oil spill detection, ZigBee frame, GIS**

I. INTRODUCTION

Recently, as the oceanic activities are more and more frequently carried out, marine oil spill accidents bring to enormous harm to the economy and society in China, especially in the Offshore China. Marine oil spill is one kind of serious disasters which severely damages the marine environment. Oil spill at sea normally results in negative economic and social consequences over time. It is therefore essential to acquire information about oil film accurately and timely in order to reduce risks. Remote-sensing surveillance constitutes an important component of oil spill monitoring and contingency management system.

With the current maritime cause, offshore oil development and rapid economic development along the coast, oil spills accidents and illegal oily discharge occur frequently on the sea, and these situations represent a serious threat to the marine environment and cause great losses of energy sources. Early detection, monitoring, containment, and cleanup of oil spill are crucial for the protection of the environment. It is possible to monitor and identify oil spill with the rapid development of remote sensing technology, and many image processing techniques of remote sensing have come into being. In particular, the technology of edge detection is an important tool for the location and acreage calculation of oil slick on the sea by aerial remote sensing[1-2]. Whenever we need to identify oil spill, confirm the location or get the shape and acreage of oil spill, we have to get the edge information of oil slick images firstly. Due to the complexity of oil spill remote sensing image, it is very difficult to gain accurate edge detection results by conventional edge detection methods. Therefore, further research is still needed. In this research, we mainly focus on a new method based on the ZigBee and GIS technology which can overcome the shortage.

With the development of economy in China, the requirement of energy resources becomes more and more, which accelerates the development of marine transportation and petroleum exploration. However, the more human activities probably enlarge the risks of marine oil spill accidents, especially serious marine oil spill accidents. As a result, these marine oil spill accidents will damage the offshore marine environment, and affect people's life and hinder the economic development of China. Therefore, it is urgent to carry out the research on oil spill emergency response technologies, and improve the emergency response system as a technology platform which provides not only technical support for protecting the offshore marine environment safety but also provides necessary protection for the development of marine transportation and exploration industry of China. Recently, as the oceanic activities are more and more frequently carried out, marine oil spill accidents bring to enormous harm to the economy and society in China, especially in the Offshore China. Marine oil spill is one kind of serious disasters which severely damages the marine environment. Aiming at the improvement of the emergency response system and response ability for the oil spill, the relative technologies on oil spill response are developed. This paper briefly introduces the developments and achievements of the oil spill numerical models, including the oil spill spreading model, the oil spill transport model, the oil particle model as well as the oil spill weathering model, which provide the theoretic criterions for the future work on the oil spill predicting and response.

Once the oil spill accident happens, there will be a serious threat to ecological environment. In order to limit the oil spill and promote clean work smoothly, it is needed to get the knowledge of the motion path and the extent of the oil spill. In addition to the monitoring work about the oil spill in the sea, it is also needed to forecast the oil drift trajectory by an oil spill model with currents and winds data of the oil spilled region. Since the1960s, scientists have paid lots of attention on the research of oil spill pollution problems. A lot of researches have been done and many achievements have been obtained but the fate and the transport of the spilled oil is a very complex process and is difficult to be described with a single model, therefore there are many topics left still to be studied[3-4]. In the previous research some semi-theory and semi-experimental formulae have been obtained and established under the condition of oil spill happened on static water or steady fluid flow mostly.

II. OVERVIEW

In recent several decades, a lot of numerical models have been presented to simulate the fate and transport of spilled oil. Oil transport and fate in the water is a complex process, including the physical expansion by gravity, surface tension, inertial force and viscosity force, chemical change resulted from weathering process, such as evaporation, dissolution, emulsification, photo oxidation and biodegradable, drift motion caused by current and wind, as well as the randomness. The development of hydrodynamic models, such as the application of the two-dimensional hydrodynamic model ADCIRC, the three-dimensional hydrodynamic model FVCOM, and the three-dimensional hydrodynamic model HYCOM, provides a good basis for numerical simulation of oil spill accidents. For a rapid response to the oil spill accident occurred, An easy using two-dimensional oil spill model with a friendly interface of NOAA, GNOME (General NOAA Operational Modeling Environment),is used to simulation oil spill accidents.

Mera's paper [5] summarized the international studies of current conditions on the response to oil spill emergency on offshore platform and indicated their limitations, and designed the general framework and functional requirement of the decision support system for oil emergency in offshore platform of Bohai, which constructed according to the achievements of scientific research projects in progress and the physical circumstances of Bohai, based on the combination techniques both of Geographical Information System (GIS) and Decision Support System (DSS).

Fustes [6] constructed the Strategy Decision Model for the removal and recycling of spilled oil in offshore on basis of production knowledge rule combining the structure and characteristics of expert system through the practical problem analysis of the removal and recycling of spilled oil. Particularly, introducing the artificial intelligence mean into the response to oil spill emergency, constructed the expert system directing towards the process decision on removal and recycling of spilled oil offshore, further studied the construction of knowledge base, realization of processor, information acquisition and so on, and put the emphases on the aspects such as types and expression of knowledge, structure design of knowledge, the realization of processor.

Eason [7] studied the optimizing allocate and transport of emergency supplies in limited conditions using Fuzzy Optimization Method and Ideal Point Method and proposed the optimizing allocate and transport model of emergency supplies for offshore oil spill, following the guidance of system science and combining number of subjects such as applied transportation science, operational science, and geographical information system. This applied model was characterized by two patterns of single resource transport and multi resource transport both of which had the two emergency objects of the shortest beginning time for emergency and the best system stability, which could provide the aid decisions for emergency personnel, improve the emergency efficiency, and reduce the costs of supply allocate and transport.

Sun's paper [8] put forward the dynamic damage model for the offshore oil spill against the practical needs for the oil spill emergency due to the enormous damage of the marine oil spill accidents to the marine ecology environment, which was mainly on assessing the damage caused by oil spill. Comprehending the current achievements on the ecology damage of marine oil spill, the corresponding disaster loss evaluation formulas were constructed to realize the functions of loss evaluations on marine environment capability, marine ecology service and natural fishing.

Wang [9] established the pollution level assessment model for oil spill on offshore platforms through the application of analytic hierarchy process into the discrimination on the contamination degree of offshore oil spill. In detail, the corresponding oil spill parameters were selected to construct the risk hierarchical structure of oil spill pollutions which determined the corresponding object layer, criterion layer and program layer, and defined the membership grade of each parameter, finally, set up the total sort table of risk level assessment for the oil spill contamination on oil platform of Bohai.

In Gong's [10] paper, five levels were classified for the pollution risk of oil spill and each level corresponded to a certain numerical range, and the pollution level was determined through the corresponding value calculated by the model. Pisano [11] pointed out the advantage of the application of SDSS technique in the field of oil spill emergency by comparing the development and characteristics of the techniques of GIS, DSS and SDSS, and established the decision support system of oil spill emergency on oil platform of Bohai named OSCOP-DSS adopting C# language and ArcGIS Engine 9.2 with Visual studio.NET as the platform and the MSSOL Server of SOL Server 2005 as the basis, together with the research and development achievements of four decision-support models. In addition, the development requirement, design object and principle, system framework, development application platform and database management platform of the OSCOP-DSS were detailed described in this paper, along with the structure and function design of the six main modules of OSCOP-DSS. Finally, the functions of this system were demonstrated with the emulated data of the oil drilling platform of Bozhong.

The spill oil information monitored by radar will be transmitted from the oil platform to the land remote data processing center, then the data will be saved to the local hard disks, and the paths will be recorded in the database. When querying, if a piece of oil is selected, then the system will read the relevant pollution from local hard disks, then doing single channel AND operation between the image matrix and background image matrix, and can be combined with sub image matrix.

In a marine environment, the oil pollution will eventually disappear after a series of complicated physical, chemical and biological changes. The fate and behavior of oil can be divided into the processes as follows: (a) Spreading process: the enlargement of the oil slick on sea surface due to the intrinsic character of oil. (b) Transport process: the movement of the spilled oil, including horizontal transport as well as vertical mixing and suspension. (c) Weathering process: all of the processes that can lead to the composition property changes, including evaporation, dissolution, emulsification, dispersion, sedimentation, oxidation, biodegradation and so on. Normally, evaporation and emulsification are closely related to the oil spill emergency response and economic damage assessment in a short term, but oxidation and biodegradation, which the final destination of the spilled oil depends on, are directly related to the marine environment impact assessment.

III. METHOD

Zigbee is a kind of wireless communication technology proposed in recent years. It is provided with many advantages like short-distance, low-complexity, low-power, low-rate and low-cost. This wireless technique is built upon IEEE802.15.4 protocol; the 802.15.4 workgroup is responsible for the establishment of PHY layer and MAC layer protocol, and the application and exploitation above are taken charge of by Zigbee Alliance [9].

The IEEE802.15.4 defines a total of three frequency bands of operations: 2.4GHz global, 915MHz Americas and 868MHz Europe. All of these frequency bands are free. The bit rate of protocol is decided by the chosen frequency, different frequency has different rate and channel numbers.

Compared with other wireless communication technology applying Zigbee to Fitness data acquisition system is superior, and advantages are as follows:

①Using free ISM as its operation frequency bands, and module price will be lower and lower along with the maturity of market. Therefore, Zigbee is suitable for the popularization and application of Fitness data acquisition;

②The transmission distance is decided by transmitted power and it can transmit from 0 to 100m in usual, this transmission range is enough for normal family network;

③Zigbee network can contain 255 nodes and also can extend the network max to 65000 nodes, so it can fulfill the needs of the families that own lots of home applications;

④The data integrity and authentication function are offered, AES-128 is used as enciphering algorithm, and each application can choose proper safety mechanism neatly. It provides guarantee for family network security.

The tree and mesh topology is respectively shown in the following figure 1 and 2. A wireless sensor network is comprised of sensing, computing, and communication technology, which can be utilized to control and observe the events and phenomena in the specified environment. There are four basic components in the WSN: a mass of distributed sensors, an interconnecting wireless network, a central point for cluster information, and a set of computing resources at the central point.

The ZigBee protocol was specified by the IEEE 802.15.4 task group and the ZigBee Alliance, which targeted the low-powered, low-cost wireless networks. Although the ZigBee protocol was not specified for the WSN, it had some features such as low data rate, low power consumption, and low cost. These features typically fit the requirements of the WSN. So we can establish a WSN based on the ZigBee protocol.

In this paper, on the basis of analyzing the ZigBee protocol, the author implemented the main functions of the ZigBee protocol based on the nesC and TinyOS.

The paper implemented the main functions of the Physical layer, MAC layer and Network layer of the ZigBee protocol respectively. Then the writer designed and implemented an embedded wireless data acquisition system based on the ZigBee protocol that had been implemented in the paper. The whole system was composed of one data acquisition node and some sensor nodes, and the communication protocol between the two nodes is the ZigBee protocol that had been implemented in the paper. The author designed a validation system, which was composed of two MC13192SARDs. And the system's value was to validate the correctness of the ZigBee protocol that hand been implemented.

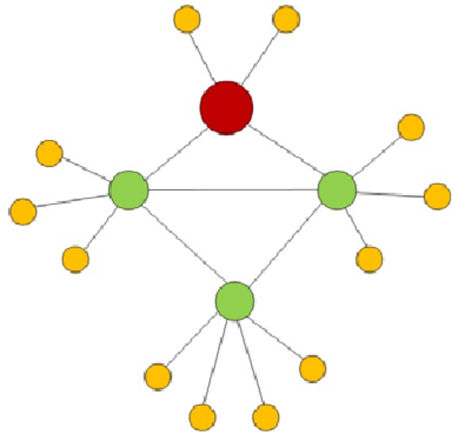

Figure 1. The tree topology

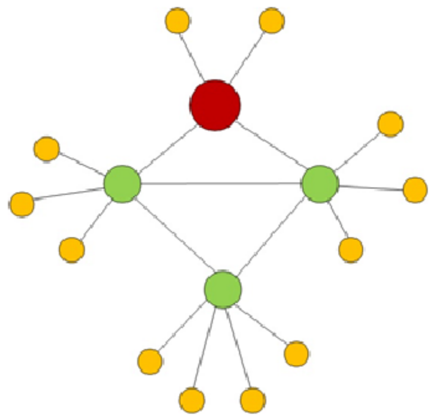

Figure 2. The mesh topology

The author designed the sensor application program based on the nesC/Tiny OS and the accelerometers of the MC13192SARD.Utilizing the main functions of the ZigBee protocol that had been implemented in the thesis, the author implemented the commutation between the two MC13192SARDs successfully. And it validated the correctness of the ZigBee protocol that had been implemented.

The basic equation of key algorithm is shown as the equation (1):

$$(N, sk) \leftarrow Key(1^k) \quad (1)$$

This formula is used to generate file checksum parameter which is denoted by:

$$r \leftarrow \{0,1\}^k; sk \leftarrow \{e, d, r\}; \\ Output\{N, sk\}; \quad (2)$$

The Euler function is:

$$\phi(N) = (p-1)(q-1) \quad (3)$$

Then choose an integer e to satisfy the following equation 4:

$$\begin{cases} 1<e<\phi(N) \\ \gcd(e,\phi(N))=1 \end{cases} \tag{4}$$

Then finally export (N, sk) in Tag algorithm, we can get the optimization equation (5):

$$(T_0,T_2,...T_{n-1}) \leftarrow Tag(pk,sk,m) \tag{5}$$

The formula generates labels for each file block.

$$for(j=0; j \le n-1; j++); \tag{6}$$

$$\{W_j = r*(j+1); T_i = [h(W_j)*m_j]^c \bmod N\}; \tag{7}$$

$$Output(T_0,T_2,...T_{n-1}); \tag{8}$$

And local fractional integral of $f(x)$ defined by Eq.9.

$${}_aI_b^{(\alpha)} f(t) = \frac{1}{\Gamma(1+\alpha)}\int_a^b f(t)(dt)^{\alpha} = \frac{1}{\Gamma(1+\alpha)}\lim_{\Delta t \to 0}\sum_{j=0}^{j=N-1} f(t_j)(\Delta t_j)^{\alpha} \tag{9}$$

It is well known that when oil is spilled, it starts to spread out over the sea surface, initially as a single slick. The speed at which this takes place depends upon the viscosity of the oil to the great extent. Fluid, and low viscosity oils spread more quickly than those with high viscosity. Nevertheless, slicks quickly spread to cover extensive areas of the sea surface. It is developed the three-stage oil slick spreading model considering gravity, inertia, viscous and surface tension forces. The model could be divided into three equations according to the different roles of those forces at different stages: gravity-inertia spreading equation, gravity-viscous spreading equation and surface tension-viscous spreading equation.

After the proposition of Fay spreading model, several improvements on the model were made. It should be mentioned that a new Monte Carlo model had been developed for the study on the oil slick spreading process, which was based on the theory that under the effect of turbulence the diffusion of oil particles is random as a series of disordered movements. The directions of those particle movements at any time are random, and the randomness is controlled by the turbulence. Therefore, to any target particle, if the random number, the intensity of turbulence, the time range and the number of particles can be identified, the moving distance of the target particle can be calculated.

IV. EXPERIMENT RESULT

ESRI ArcGIS software has been the major tool for High Consequences Area (HCA) analysis. Many GIS software companies and pipeline operators have done serious software development to automate the GIS workflow for HCA analysis. The 49 CFR 19_5 requires that pipeline operators to respond and repair their pipeline anomalies under different time frames based on whether the anomaly is in HCA segment or not. Figure 3 shows the pipeline integrity management. Data gathering is an important part of the whole process and GIS has been widely used in the data gathering and analysis processes for pipeline integrity management process. In the past ten years, GIS has also become a major tool for pipeline integrity management and all the pipeline service and operating companies are using GIS to conduct data integration and risk assessment and modeling. What's more, many database models have been developed for pipeline integrity management such as Pipeline Open Data Standard (PODS) and ArcGIS Pipeline Data Model (APDM). However, remote sensing technologies have not been widely used in pipeline integrity management. There is a huge research gap between remote sensing and pipeline integrity management. Our case study wants to focus on the potential application of SAR imagery technology in pipeline integrity management.

Figure 4 shows the integration of ArcGIS Desktop/Server, PODS and SAR Imagery and it will provide a huge help to the pipeline operators. This work flow can provide support to multiple aspects of pipeline integrity management and practice. This integration will bring the pipeline integrity management into another level. This case study will provide pipeline operators a guideline for their future GIS management and data integration. The pipeline leak was caused by a weak weld and directional drilling conducted by another pipeline operator. The construction activities were an indirect cause of the pipeline release. The coast guard noticed the spilled oil in the Galveston Bay. The pipeline operator also noticed the pressure change through their SCADA system. Finally the operator identified the location of spill.

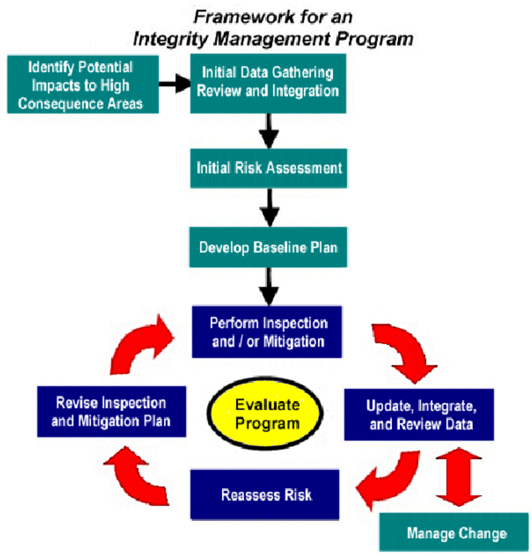

Figure 3. Pipeline integrity management framework

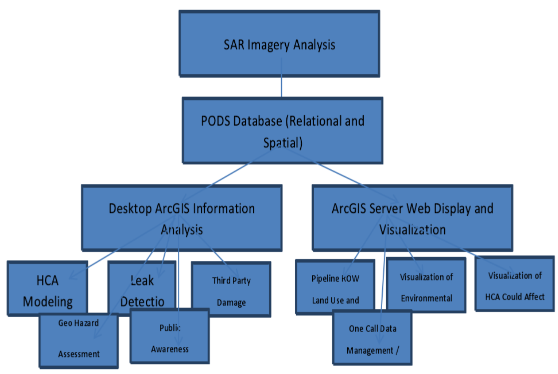

Figure 4. Integration of ArcGIS Desktop

Totally more than 800 barrels of crude oil were leaked into the soil and water ways nearby. It was very costly to clean up the spilled oil. Some of the spilled oil was recovered, but some of the oil was never recovered. Soil remediation was conducted by URS Corporation.

Figure 5 shows the target pipeline and release site location. The release site is very close to the Bayou, so the spilled crude oil went into the waterway and travelled all the way to the Galveston Bay area. That's why the coastal guard was able to spot the spilled oil during their daily cruise. After the accident, the pipeline operator and Texas Railway Commission conducted a complete investigation on the cause of the accident. They found the major cause of this accident was a weld failure. However, the welder was qualified for welding. The directional drill conducted by another pipeline operator disturbed the soil and increased the external force on the weld.

Figure 6 shows the Landsat8 natural color image for Houston region, May 13, 2013. The study area is bounded by a rectangle in red color. The blue line represents the West Columbia pipeline that had oil leakages in the end of March 2013. The red star pinpoints the site of the oil leakage.

The study area on the Landsat8 natural color image is zoomed in and shown in Figure 7. Figure 8 shows the study area of the Rapid Eye images, which are on the top of Landsat8 natural color images. There are four images taken by different dates before and after the oil leakage. The site of oil leakage on Rapid Eye images at a 1:1 resolution is shown in Figure 7.

V. DISCUSSION

They show that the incident site was clean and plain on Feb. 1 2015, before the oil leakage while it became rough and blur on May 4 after the incident, especially in the areas close to the West Columbia Pipeline. The comparison of images clearly shows the traces of cleanup work done for the oil spill. This study fused the black-and-white panchromatic image at a resolution of 15 meters and the multispectral color images from Channel 4, 3, 2 at a resolution of 30 meters to create relatively high resolution natural color images by using the Pansharp2 function in PCPs Geomatics 2015.

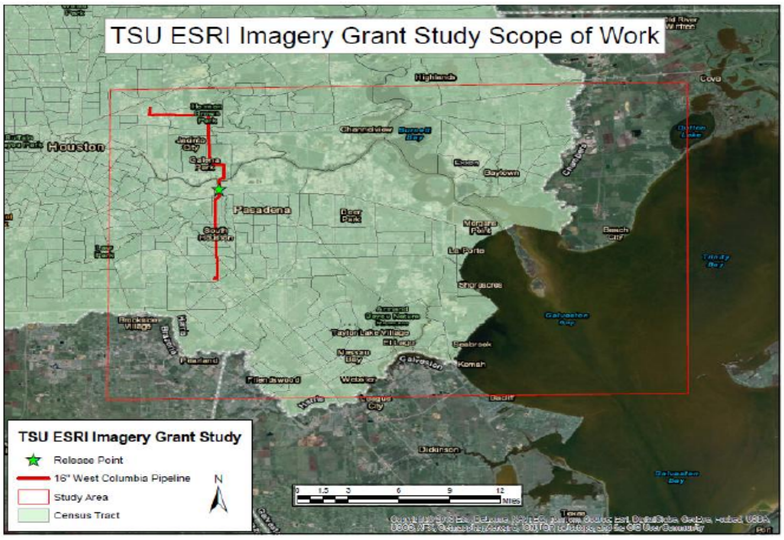

Figure 5. Target pipeline and release point location

Figure 6. Landsat8 natural color image

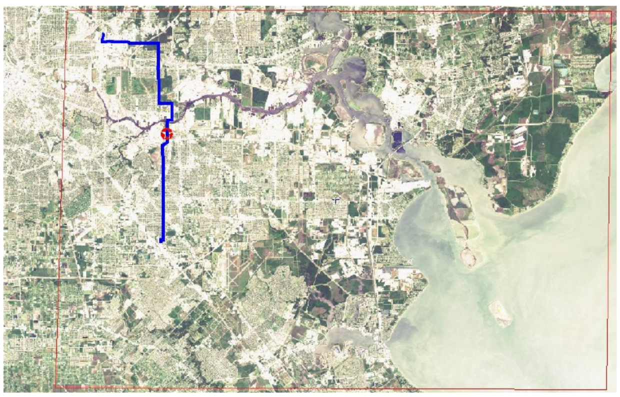

Figure 7. The study area on the Landsat8 natural color image

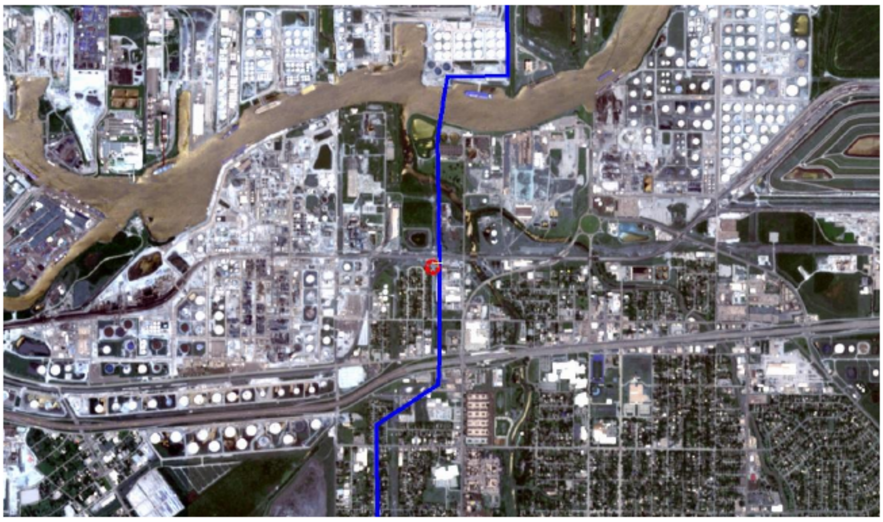

Figure 8. The site of oil leakage on Rapid Eye image sat a 1:1 resolution

The Mosaic function of the package was also employed to create a mosaic of the images coveringmost part of the Houston Metropolitan region.

VI. CONCLUSION

In order to solve the problem of long delay time and low data precision, a remote system for oil spill detection based on ZigBee and GIS is designed in this paper. The paper confirms the effectiveness of SAR imagery in third party activities monitoring. According to a pipeline failure investigation report, root cause of the leak was due to a cracked girth weld. The SAR images take right before the incident highlight several spots surrounding the incident site close to the pipeline. It is possible that some vehicles or equipment were utilized in some construction work on the site, which may change the pressure and trigger the oil leakage from the pipeline on the site later. The demonstration of pipeline route detection in the case study also gives us confidence on the use SAR and Rapid Eye imagery to improve the current pipeline routes in the national mapping system. This paper analytically summarizes the results obtained from surveying spectral characteristics of spill oil film at sea. M along use of AVHRR and TM data, the image of oil spill in several marine accidents has been processed and identified, and the place and area of oil spill in obtaining images are the same as investigation in the scene of accidents.

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