Oil spill detection & control: The way forward

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Abstract - An oil spill can be defined as the discharge crude oil into the environment due to human activity. The environment can be terrestrial or marine. This is considered as a form of pollution. Pollution due to either accidents or deliberate oily discharges from ships represents a serious threat to the marine environment.

In most of the cases the oil spills occur in the marine environment. Oil spills in the marine environment is a critical issue as it could lead to various catastrophes to the marine environment, which in turn affect the biological lives of both aquatic organisms and also to the human beings apart from these it has a severe influence on the economy and ecological environment of a country. Also, some research teams term oil spills as a devastating environmental hazard. Therefore, there is serious need to address this type of hazard and carry out effective prevention measurements. The paper discusses a noble three-dimensional approach for preventing the oil spills. The paper focuses on some of conventional methods used for the detection with their limitation, the modern proposed idea, and future scope for enhancing the efficiency for effective oil spill detection. Various case studies and implementing the proposed idea ascertains the effectiveness in the detection and monitoring the oil spills.

Keywords- oil spill detection, radars, UAV, remote monitoring, unmanned surface vehicle, smart buoys, Bragg scattering

1.INTRODUCTION

The oil spill pollution is a serious environmental issue which leads to the wastage of natural resources and causes serious contamination among the aquatic organisms, also it has a long-term effect on the lives of human if the polluted region is not cleaned. The reason for such kind of pollution may be the emerging production and transport of oil which carries the risk of many types of on sea accidents that can cause oil spills. This can be the result of either damage to the vessel or during the transportation and drilling operation or due to meteorological condition over the offshore units. Apart from the mentioned reasons another potential cause can be sabotage or intentional damage of oil installations. For the past many years several satellites, surveillance ships, and other technologies were used for the detection, but these techniques gave uncertain results and in accurate information about the oil spill. Furthermore, the weather conditions over the polluted area always prevented the accurate detection and carrying out the countermeasures. As a result, it is necessary to develop an adaptive approach that address the above uncertainties in detection and monitoring the oil spills. The problem of oil spill pollution has drawn the interest of many organisations and have contributed for the detection and remote monitoring.

But, a few of them have focused on a combined approach in dealing the problem. For example the most commonly used techniques was the utilization of the SAR (Synthetic Aperture Radar) but apart from detecting the oil slicks the radar image also detects the exact look alike of the oil slicks which can be algae layer or just a temporary boat trail. Hence it is difficult to discriminate between the real image and the look alike. Dedicated oil spill surveillance agencies also failed to address this misclassification. When an oil spill is detected it is necessary to recover the spilt oil for this the surface operation is carried out by sending boats which have skimmers fixed in them. But it possesses hazard for the humans operating on the boat, also the skimmers have a little impact on affected area. A less known fact is that oil spill also occurs due to the explosion of the underground submarine pipeline. But it is tedious to detect the underground explosion using satellite and other existing conventional surveillance system.

Thus, to address the above issues an UAV system with dedicated electronic suite is proposed for the effective monitoring and detection of oil spill pollution in the aerial technique. For the surface operation an unmanned vessel is proposed which is capable of gathering the information about the intensity of the oil spill pollution. This may be deployed for the post detection activity. And lastly a smart floating buoy is suggested for detecting any oil spill due to the underground pipeline explosion.

2.BACKGROUND AND CASE STUDIES

In the recent past too, we have seen serious cases of the oil spills. Such incidents are the Mumbai oil spill, Bohai oil spill Gulf of Mexico oil spill etc. Taking the Mumbai oil spill as the case study reports revealed that lack of modern technology hindered recovery Efforts which led to a huge loss to the marine ecosystem. It took nearly 3 months to clean the contaminated region and the efforts were hampered with the weather conditions over the Arabian Sea. Another case is the Bohai oil spill where the leakage of the crude oil occurred from three oil installation. This included an underwater submarine pipeline. Thus the proposed concept is based on the outline of the above cases.

3. CONVENTIONAL METHODS AND THEIR LIMITATIONS

For the detection of the oil spill pollution organizations have depended upon the Synthetic Aperture Radar imagery. Many case studies related to oil spill detection and mapping of oil spills have been done by the SAR imaging techniques. The images of SAR are collected and later analysed for further work. The images collected by the SAR contains dark region.

The oil spills are mainly characterized by their dark level with respect to the background emission. Studies have found that the dark regions obtained resemble like the oil slick but originally are algae or boat trails. It is a tedious task to differentiate the oil slicks with the algae or other biological slicks. Sometimes boatmen purposely spread big fishing nets which resemble like an oil slick. This misclassification has led to confusion among various agencies. Though some algorithms have been developed to avoid this misinterpretation, but these are not accurate, and the information obtained from them is not reliable. These SAR sensing techniques is based on the backscatter of the signal transmitted therefore these signals depend upon the wind and sea condition. Another study revealed that the SAR imager do not provide the thickness of the oil slick. Laser Fluro sensors are another devices which are used for the detection of oil spill but these have the drawbacks such as heavy size, heavy weight, it has high operational cost when taken airborne etc. In conclusion, most of the current detection methods addressing the oil spill and are strongly affected by the lighting, temperature, and weather conditions, in addition these are associated with high cost.

Generally, when the oil spill is detected a team is sent for the recovery and observation of the contaminated area. But sometimes the area can be hazardous for the human. Commonly used systems for remote oil sensing include optical sensors, laser Fluro sensors, microwave sensor and acoustic sensors. However, due to the lack of accuracy of prior information, the exact knowledge of oil spill region may be inaccurate and uncertain. Furthermore, dynamically changing ocean currents can cause the polluted zone to vary in shape therefore this technique is not advisable.

For effective oil recovery, the selection of the target area is important the correct identification of the most affected area and the least affected area should be taken into consideration currently there is hardly any technology that caters to this need. Also a team of skilled workers must be employed for the target selection which sometimes may be erroneous.

With the growing demands of oil supply the oil industries have extensively relied upon the submarine pipelines for oil production and transportation. However, there exit the dangers caused by oil spill, because submarine pipelines are prone to damage for some reason. Accordingly, there lacks a technology that can observe the behavior and can supply accurate information in time for oil spill pollution and recover. At present, the modelling for forecasting oil spill behaviors and occurrence is usually based on sea surface or offshore zones However, the model for submarine oil spill is relatively lacking.

Lastly as cited above about the security and safety of the oil installation and the offshore units currently a very few measures are taken to address this issue. Though there are security personnel available in these units but there is no early warning system existing which gives in advance information about unwanted intrusions.

Therefore, it is necessary to design a concept that overcomes the above limitations which includes the latest

technology with a vision to maximise the efficiency of the oil spill detection and recovery method.

(i) Detection using Unmanned Aerial Vehicle.

An unmanned aerial vehicle (UAV) is an aircraft without a human pilot on board. UAVs are a component of an unmanned aircraft system; which include a UAV, a ground-based controller, and a p2p communication system. The UAV proposed here is portable which can be launched from a boat or helicopter or from an oil installation itself. The main purpose of the UAV is to gather accurate information about the oil spill pollution. The architecture of the UAV is comprised by an electronic suite which contains an array of sensors. This suite consists of microwave radar, thermal IR sensor, communicational and navigational functionalities and lastly the on-board sensors coupled with the UAV to perform image detection and auxiliary functionalities. The UAV is connected to the ground control unit which constantly monitors the activities of the UAV. The electronic suite components are discussed briefly below.

(ii)Thermal IR Camera

The general emergency response whenever an oil spill pollution occurs in order to acquire the information about the oil spill affected areas and the thickness of the oil slicks the techniques of satellite imagery, aviation and remote sensing are applied to the whole process. Various imaging methods are employed in order to obtain the accurate and reliable data however, it is difficult to achieve in the airborne environment. For example, observer angle and spatial resolution etc. are commonly affected the monitoring results in satellite data. In this case the thermal infrared camera has the advantage that it can deployed airborne for the field detection and verification. The underlying theory of the thermal IR camera is based upon the electromagnetic wave emission. Each particle from of the emitted the wave possess internal temperature, on this fact the thermal IR camera operates on the basis of this statement the thermal infrared camera is implemented effectively in this accident because oil has a lower emissivity than water in the polluted region thereby having lower temperature. So if any oil slicks is present then it can be easily detected by analysing the difference in the temperature between oil slick and sea water. The thermal infrared remote sensing can work during daytime and night, so it is a potential device for operational effectiveness.

Considering the property of heat flux of oil slicks, it is higher than seawater, and it interprets that the oil slicks appear different from the background. The characteristic of the heat flux and is independent of the known interference factor like foam, algae, biological coverings boat wakes etc. Through this characteristic, we could distinguish oil spills from other similar phenomenon in an infrared image of target water which may resemble like an oil spill. The thickness of the spill is determined by observing the grey value of the processed image. That is more the gray value more is the thickness of the oil slick.

(iii)Microwave imagery

Here the microwave imagery is used due to the unique all-weather penetration capability of microwaves. The microwaves can penetrate through clouds and provide data during day as well as at night. Hence the microwave remote sensing will provide the opportunity to detect the extent of oil spills over the sea surface and measure the thickness of oil over the sea surface. For this purpose, we use Special Sensor Microwave Imager (SSM/I) satellite. The evaluation of the oil spill is done by taking the images at various frequencies ranging from 5 GHz to 76 GHz and analysing the brightness temperature of each image. A brief comparison Brightness Temperature is carried out. It is seen that the brightness temperature of the region of the oil spill is greater than the unpolluted region. And the thickness is determined by observing the density of the oil film i.e. more the brightness temperature more is the density of the oil slick.

(iv) Ultra-wide high-resolution camera

An ultra-wide high-resolution camera is included in the electronic suite so as to capture the real time images and videos. These images and videos provide real time footage of the accident area. Also it can be distributed among the ground staff to deploy the required countermeasures.

(v)Night vision camera

The night vision camera is another audio visual equipment which can be used for night operations. The night vision camera will provide the real time footage during night time thereby enabling flawless operation during night time.

(vi) Sensors and indicators

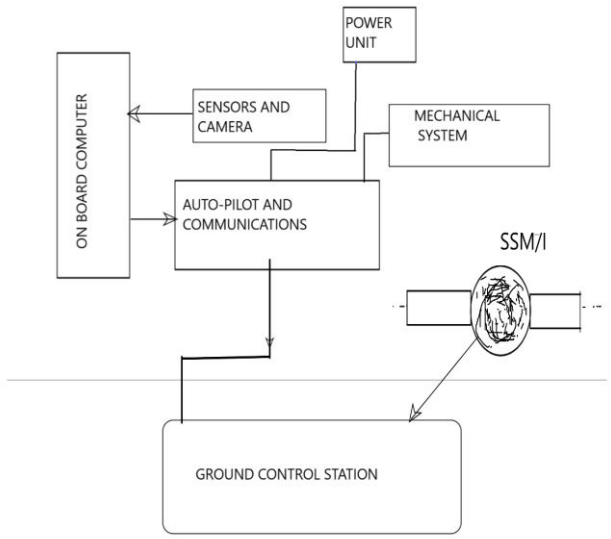
Various sensors like wind sensor, pressure sensor, temperature sensor are used for further information gathering. Aids like accelerometer, gyroscope, altimeter, tachometer, barometer etc. are used for accurate flight positioning and calibration.

The UAV platform is composed by a computer along with the communication equipment. This computer is responsible for the UAV navigation capabilities. DGPS sensor is interfaced with this computer that provides accurate positions to the autopilot system and subsequently to the ground control staff. The flight data is recorded in the in-flight memory.

The captured images are outputted to the portable computer along with the GPS. The GPS module has continuous update system that constantly sends different commands to the listener, with information about its position and satellite location. It requires a 5-V supply. And communication is through the RX/TX ports. With the geotags, these images reported the to the command centre. Also, the command centre monitors the oil spill remotely through the UAV communications equipment.

After the flight, the collected data is sent to the further processing and calibration, and combined with satellite, and other monitoring results.

Lastly the GIS is applied for the mapping of area of oil spills. According to the graphs, the staffs will be equipped with the accurate information be able to decide the clean-up region precisely and quickly.



(vii) Unmanned surface vehicle.

The concept of using the unmanned surface vehicle is proposed here as to increases the efficiency in the oil spill detection and recovery process. Current methods rely upon coordination between multiple independent parties, which introduces time delay and reduces efficiency of the process. In this regard unmanned surface vessel could help in the process of detecting the oil spill and collecting samples from the polluted area. The USV also prevents the staff from going into hazardous areas for the preliminary investigation.

Some examples of USV include the popular, ROAV that was designed for river applications. The vehicle can carry up to 50-kg payload and has a well-structured control system that supports customization, thus the vehicle can be custom-built according to mission requirements. The primary objective of the developed USV are: (1) to navigate to the location of oil spill remotely, (2) to gather information of contaminated water, (3) and send confirmation wirelessly to an onshore base station.

To satisfy these requirements, the suggested structure of the USV is light weight, good speed, and ability to operate under various sea conditions.

For the design part vehicle requires Guidance, Navigation and Control (GNC) systems which forms together a position and orientation feedback control system. It includes the, path planning path computer and collision avoidance system essential for the unmanned vehicle. We consider the combination of Proportional-Integral-Derivative (PID) control, and intelligent control for the manoeuvrability of the vessel.

For the power unit of the USV we consider using combination of wave enengy and solar energy also a rechargeable Li-ion battery unit. The communication with the vehicle is achieved via satellite, cellular network, or Wi-Fi, and commands are sent to the USV via web-based interface directly from the command centre.

The hardware design is designed as:-

1. Navigation system: this includes the sensors like the Global Positioning System (GPS) and DGPS, gyroscope, accelerometer.

2. Detection System: This includes the camera for the analysis. The camera operates under a specific algorithm for the detection of oil spill.

3. Monitoring camera: There are two cameras fixed in the USV. One of them being a night vision camera. These are helpful in carrying out operations in both day and night conditions.

4. Communication system: this subsystem is responsible for providing communication channel between the operator and the vehicle. It is used to guide the vehicle or establish Wi-Fi connection with the on-board computer and feed desired GPS location for autonomous operation.

5. Vehicle design is responsible for the motion of USV. It includes the vehicle structure and propellers that provide thrust, as well as their driver connections.

6. Power system: consists of batteries that provide power to all subsystems such as the propellers, communication systems navigation system etc.

7. Sensors: The USV is equipped with a wide array of sensors these include, temperature sensor are used for further information gathering. Aids like accelerometer, yaw sensor, tachometer, barometer etc are used for accurate positioning and calibration. Voltage follower peak detector along with sample and hold circuit are fixed.

Working of the USV lies on the designed algorithm. The algorithm is framed taking into consideration of the following features

1. Adjusts to the shape of oil spill thus avoiding unnecessary exploration in oil free area
2. Attains an accurate information regarding the intensity of the oil spill, resulting in minimization of time and an increase in cleaning efficiency
3. Provides complete coverage of the oil spill regardless of its shape
4. Dynamically builds up the environmental map when the exact spill location is unknown

The conventional methods include optical sensor, Fluro sensors etc. but these have the limitations that they do not give instantaneous information, and due to the varying ocean wind current, these vary in shape and size.

The algorithm mentioned above can be derived from the concept of probability.

The affected area is surveyed and the area is processed in discrete time signals. Thus, divided into discrete samples. It is known that the oil and water have their energy. The detection of the affected region is done by observing the energy potential of each of the particles. The energy of the oil is more than the surrounding water hence the vehicle adapts to this energy level with the peak detector circuit and the sample hold circuit and acquires next target. If detected sample has less energy than the reference sample that sample is ignored, and the vessel moves to the next target. Using the concept of probability, the vehicle determines the more denser area and less denser area and collects the data. This data is processed using GIS and a suitable mapping is obtained. This map contains the precise information regarding the shape, size and intensity of the oil spill. Thus, the ground staff can be directed for the efficient recovery with the help
of this map.

Smart Floating buoys for detection of oil spill due to underwater pipeline.

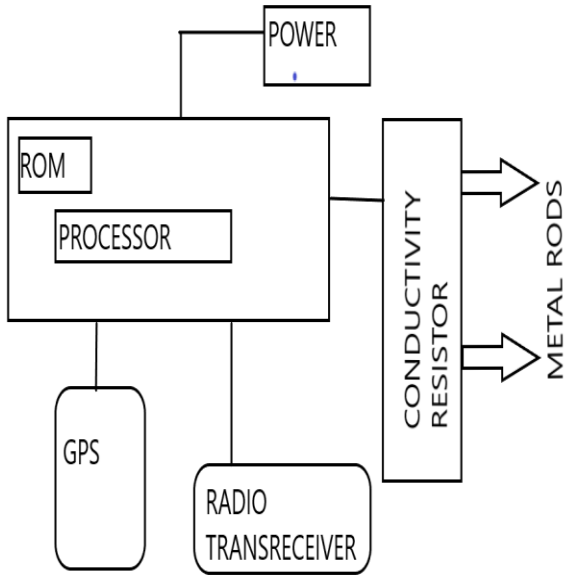
The buoys are the floating devices over the sea surface. Here an idea of smart buoy is introduced which detects oil spill due to underwater pipeline explosion.The smart buoys suggested here is essentially a wireless sensor network.
The detection of the underwater oil spill is carried out by measuring the electrical conductivity of the oil and water. The smart buoy is characterised by moderate weight and robust build quality so as to sustain harsh environmental conditions. It is recommended that the buoy should be movable freely for a small area. So it can detect a considerable area if spill movement is influenced by any ocean current or wind.

System design

The smart buoy consists of the following components

1. GPS Module- used to locate the precise position of the buoy.

2. Radio trans receiver-used for transmitting information about the oil spill
3. Arduino – a microcontroller (having RISC architecture) used for the on-board control unit, it processes the measurements collected by the conductivity sensor.
4. Conductivity sensor- measures the conductivity level of the substances in aqueous solution.
5. Power supply unit- the power to the processor is given by the solar cells and by an auxiliary piezoelectric sensor.



Block diagram of in board electronics of the smart buoy.

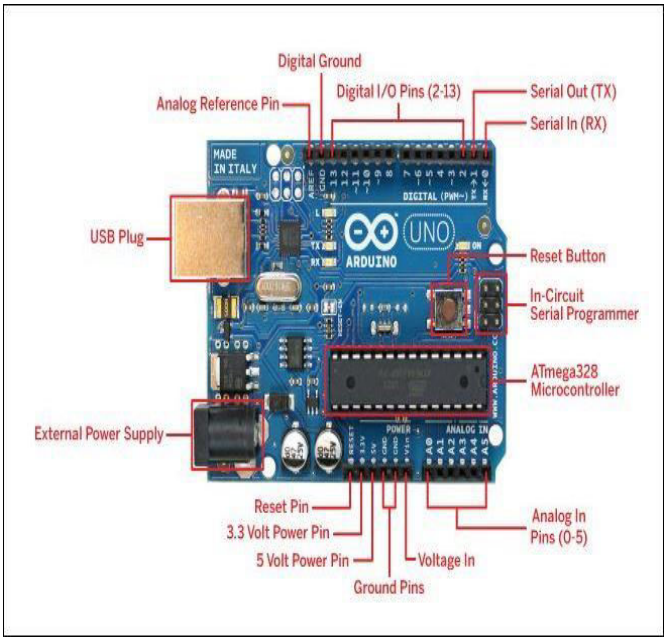


Fig shows the Arduino board.

Whenever any underground oil pipeline leakage occurs the oil will rise up due to the buoyancy. The spilt oil will gradually rise up and after a certain time it will start floating at the surface. The spilt oil forms the jet current or trajectory with low operating pressure, and subsequently the oil spilled is dispersed by water current .This buoyancy characteristics is considered while designing the smart buoys.

The conductivity sensor is a passive sensor based on concept of the difference in electric conductivity properties of a substance in different aqueous solutions. The sea water possesses high electric conductivity as compared to oil which has low electric conductivity. This is due to the fact that the sea water has lot of dissolved salts in it. Apart from this the current passing through sea water is high, as compared to the oil. The measurement is carried out by connecting two metal rods to each of the projection of the sensor and dipped into the sea water. Current is passed to each of these metal rods thus by measuring the intensity of the current through rod the presence of oil can be detected. The measured current is passed to a resistor so as to convert it to voltage. The Arduino board acquires the data from the sensor. The GPS module updates the command centre about its position along with satellite location. There is also a facility for the clock synchronisation which is helpful for real time measurements. The radio trans receiver transmits the data signals to command centre therefore establishing a wireless communication link between the two. Once the oil spill is detected the ground staff team can carry out the required countermeasures.
For detection the smart buoys are placed just above the underground pipeline. Like this many buoys can be placed over submarine pipeline network for any oil spill detection.

4. CONCLUDING REMARKS AND THE WAY FORWARD

In this paper a three-dimensional method for monitoring and detection of the oil spill was discussed. The UAV system for the aerial monitoring and detection using TIR camera and microwave imagery was proved useful when applied to the case studies of various oil spill. The purpose of developing this concept was to detect the oil spills at sea with

accuracy and cost effectiveness. The USV used for the surface operation cam generate accurate result about the affected region along with mapping of the contaminated area. The concept of the smart floating buoy was introduced which can detect oil spill due to submarine pipeline explosion. This paper also analysed the conventional methods and stated their limitations.

Though the concepts introduced here overcame the limitations, but a lot can be done to increase the efficiency in the detection and recovery of the oil spill pollution. Concept of artificial intelligence and neural networks can be applied in detection. Since the current detection of the oil spill is dependent upon the wind speed, wind speed less than 2m/s gives erroneous results and data regarding the oil spill. In this regard more advanced satellite and radar detection capabilities can be introduced for oil detection in quiet sea.

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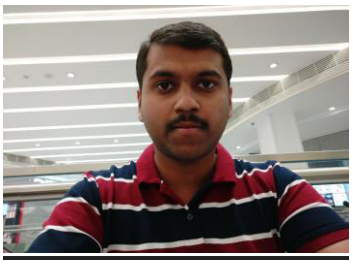
ABOUT THE AUTHOR



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He has presented several papers in various forums at college/university level. Besides that, the author is a creative writer in English language & literature. Also, he has participated & completed various projects pertaining to the field of electronics. He is a recipient of Indian Prime Minister's Scholarship for meritorious studies at Engineering Degree level.