Remotely Piloted Unmanned Underwater Vehicle Design and Control for Pipeline Maintenance

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Abstract- In this paper we have described the design and implementation of a remotely operated vehicle (ROV) for maintenance of petroleum pipelines. The petroleum sensor embedded in to the underwater vehicle is used to detect the concentration of petroleum dissolved in water at desired location. The vehicle is designed to move along the nearby surface of the pipeline and continuously sense any leakages present. The real time video is transmitted to the ground station via a Radio Frequency (RF) channel along with the location of the leakage, if any. The location of the vehicle is monitored using Global Positioning System (GPS) and an Inertial Measurement Unit (IMU).

I. Introduction

The objective of our research is to build an unmanned underwater vehicle to inspect petroleum pipelines placed under the sea. We have specifically focused on leakage of petroleum from the pipelines so we are using array of sensor to perform the task. The oil spill from pipelines at the sea bed can affect the entire aquatic ecosystem and cause the death of aquatic animals and plant life. The contamination of water due to such oils can be cleaned up to an extent but the effect will continue to remain at the microscopic level for several years. This can cause a lot of mutations in growth of the living organisms for several generations. So the impact of an oil spill is clearly very devastating on a large scale. This makes the maintenance and upkeep of the pipelines all the more significant. We were thus motivated to develop a remotely operated vehicle which will move along the pipeline and detect any leakages by simply using the sensor embedded into the system. In many of the existing pipelines sensors are placed at regular intervals along the pipeline to collect data and reticulate it to the surface. Now this requires constant monitoring of the network and will give an idea of the current pipeline condition. However, the leakage may happen at any point along the pipeline length. This requires a more efficient monitoring of the entire pipeline. The performance and life span of the sensor may get affected by continuous exposure to the sea water. The ROV will be useful in this regard to monitor the whole pipeline and detect leakage at any arbitrary point.

II. Overview

The overall block diagram is shown in Figure1.The ROV consists of the following sensors: petroleum sensor, ultrasonic sensor and accelerometer. Also a GPS and IMU are used to monitor the vehicle location. The vehicle is submerged until the depth of the pipeline and then the petroleum sensor is activated. The readings from the ultrasonic sensor as well as the camera feed are used to maintain the vehicle in close proximity to the pipeline. Whenever a leakage is detected by the petroleum sensor the current location of the vehicle is transmitted to the ground station. Initially the depth of the pipeline is obtained from the user.

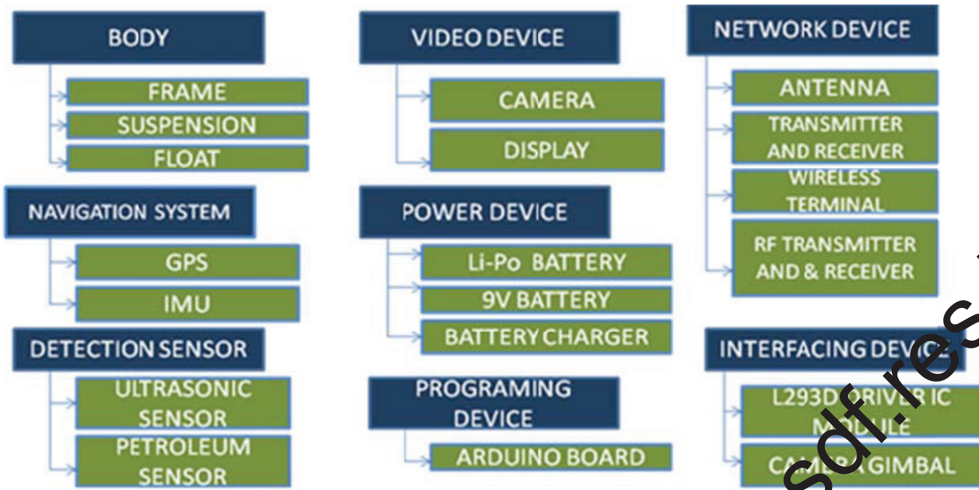

Figure 1Core Devices of ROV System

III. Vehicle Design

The basic design of the ROV as given in Figure 2 was modelled in CATIA software to test the buoyancy of the vehicle. The given frame design functions as the water compartment of the vehicle. Holes are drilled on all corners to allow the water to flow out. Two floats are attached to the frame to maintain the vehicle above the water. Three geared motors mounted with 3 blade boat propellers are used to control the vehicle dynamics and direction. To submerge the vehicle in water the geared motors are switched on. The depth to which the vehicle sinks depends upon the speed at which the motors are running. One motor is placed in the upward direction in the front of the vehicle. This front motor provides the maximum thrust. The other two motors are placed on either side. They are used to control the vehicle direction. The load is attached to the bottom of the vehicle. This is an airtight container consisting of the electronic components.

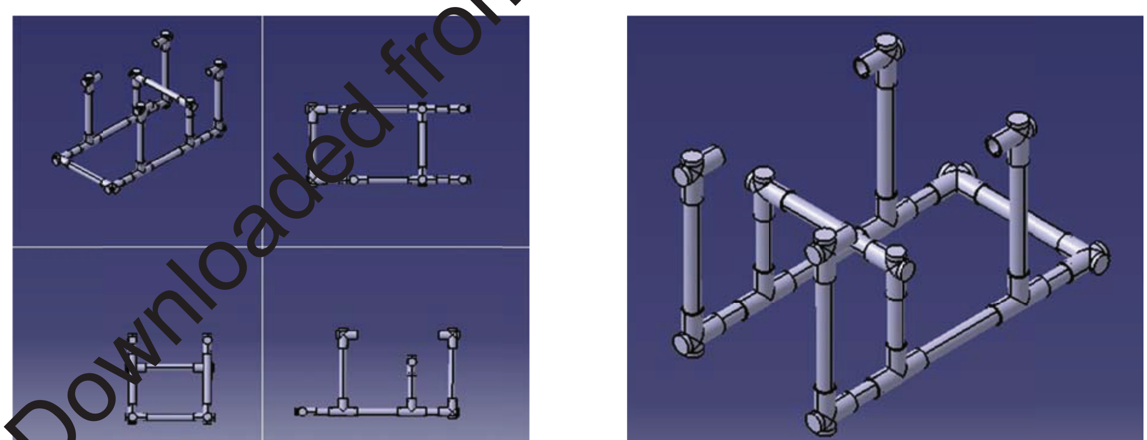

Figure 2 Vehicle Frame (a) all views (b) isometric views

IV. Vehicle Control and Automation

An Atmega-328 16-bit processor is programmed and used as an embedded controller for all the sensors and the actuators. Ultrasonic sensor helps to maintain the proximity between pipeline and vehicle using distance measurement algorithm. The calibrated output of ultrasonic sensor is shown in Figure 3. An ultrasound signal is sent and reflections from the obstacle are received. The time delay between transmission and reception is used to calculate the distance of the obstacle. The processor is programmed to specify the time period of the signal to be transmitted. Any obstacle in the path is avoided by using the sensor reading to change the direction of rotation of the motors. The procedure for obstacle avoidance is shown in Figure 4.

```
Setup()
{
      pinMode( trigPin, OUTPUT)
      pinMode(echoPin, OUTPUT)
}
Loop()
{
trigPin(LOW, 2)
trigPin(HIGH, 10)
trigPin(LOW)
duration = pulseIn(echoPin)
distanceInCm = (340 * duration) / 20000
}
```

Figure 3 Ultrasonic Sensor Calibration

```
Setup()
{
      pinMode( trigPin, OUTPUT)
      pinMode(echoPin, OUTPUT)
}
Loop()
{
trigPin(LOW, 2)
trigPin(HIGH, 10)
trigPin(LOW)
duration = pulseIn(echoPin)
distanceInCm = (340 * duration) / 20000
if (distanceInCm = = 10)
obstacle detected
}
```

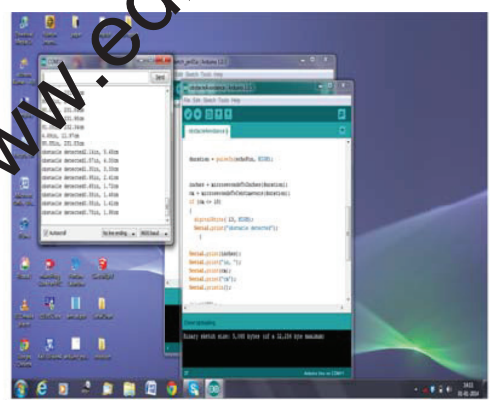

Figure 4 Obstacle Avoidance Procedure

The IMU reading is used to obtain the depth and the distance travelled by the vehicle. The GPS and IMU are interfaced to processor board. The IMU consists of an accelerometer, program shown in figure5, with 3 degrees of freedom and it gives the instantaneous value of acceleration along each axis. This is integrated twice to find the distance travelled. The distance value is cumulatively added to find the total distance travelled. When GPS signal is not available then the distance travelled by the vehicle on X axis can be added to the last known co-ordinate to find the current position. The distance travelled in the Y axis is the depth gives the current depth to which the vehicle is submerged.

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```
Setup()
{ }
Loop()
{
   analogRead(xaxis)
   analogRead(yaxis)
   analogRead(zaxis)
}
```

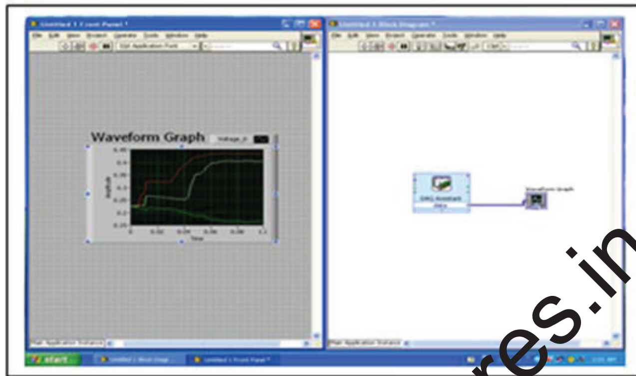

Figure 3 Accelerometer Offset Calculation

The petroleum sensor is given power supply only after the vehicle reaches the pipeline depth. This is done by obtaining the depth reading from the accelerometer and comparing it to the actual pipeline depth. When the petroleum sensor detects leakage, the microcontroller transmits the current location of the vehicle back to the ground station.

The movement of the vehicle is achieved using three geared motors attached to the vehicle frame. The geared motors are interfaced to the microcontroller using a L293D motor driver IC. This IC consists of two H-Bridge circuits which can control the direction of motor rotation. The signal for motor movement is given from the ground station via the wireless channel.

A wireless camera is mounted on the vehicle. This is used to transmit the real time video to the ground station over a 2.45GHz RF channel. The video can be used for obstacle avoidance as well as viewing the pipeline condition. Based on the image of the pipeline, the dimensions of the leakage can be found. This can be used to determine the method of repair. Noise reduction filters are used to remove any blur.

The circuit consisting of the programming board, sensors and actuators are all placed in airtight containers. Then water proofing of the containers is done finally.

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