

# Gas Leakage Detection in Pipeline by SVM classifier with Automatic Eddy Current based Defect Recognition Method

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## Abstract

It's well-known that industrial safety is now a top concern. Nowadays, accidents caused by flammable gases occur frequently in our everyday lives. Gas cylinders, which are used for household purposes, wide range of businesses, and vehicles are often reported to be on the verge of exploding. Explosions have left a large number of individuals seriously wounded or could also be lethal in certain cases. This project's goal is to use a HOG features for SVM classifier which is used to identify pipeline gas leaks and keep tabs on them. In addition, the system utilises an image processing technique to identify pipeline fractures. Early detection and identification of pipeline flaws is a predominant aspect of this study. According to the suggested design, the robot capture the image down the pipe, looking for any signs of gas leakage by the Eddy Current method. This type of recognition has proved superior to other traditional methods. The methods with efficiency parameters and the results were compared and are tabulated in the results section. In the future, the data in the course of detection could be sent through GSM to a mobile application.

**Keywords:** Leak detection, mobile robot, eddy current effect, support vector machines, HOG features, pipeline leakage

## 1. Introduction

Generally, gas, oil, and water are the main economic drivers in most nations. Oil and gas pipelines deliver natural resources from remote locations across the world. Pipelines serve as the primary means of transport from the producers to the consumers [1-3]. Maintaining these pipelines is extremely expensive and finding the precise location of a leak in a pipe may be a dreadful toil for human. Robots utilize altitude and latitude ideas to identify these places, and then transmit that data to the user or operator, who may then use it to pinpoint the precise position. A subsequent accident may be avoided since the switch will be turned off by the user. These are necessary for a stable political environment, long-term economic growth, and personal safety [4]. Figure 1 shows the gas pipelines.

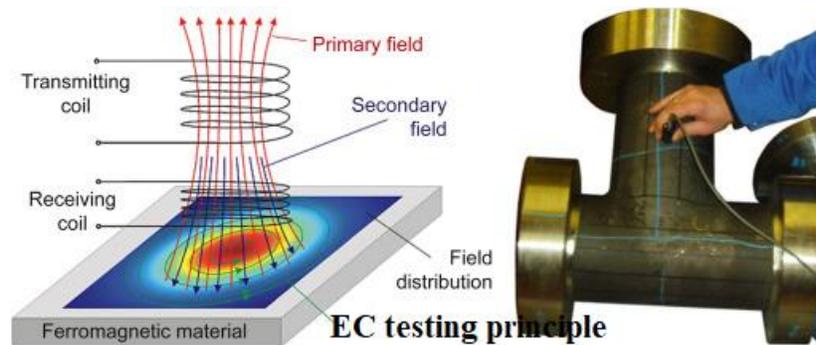


**Figure 1.** Gas Pipeline

Transporting a variety of fluids through pipes is possible because pipelines can handle liquids with a wide range of properties. Transported fluids must be contained within the pipeline at all times and should not come in contact with the outside world. However, no matter what

material is used to construct the pipe, it will degrade with time, becoming more prone to fractures and severe corrosion [5-8].

Pipeline fractures and corrosion have resulted in many incidents involving fluid spills. These mishaps have devastating effects on the environment, wildlife, and people. Therefore, preventing such fluid leaks is critical to avert catastrophe. Regular pipeline inspections are a great method to stay guarded. The results of the inspection are evaluated and utilized to assess the pipeline's condition. The pipeline's state is used to predict the location and the quantity of fluid leak from the pipe, as well as the maintenance activities that need to be performed on the pipeline. Accidental leaks are kept to a minimum since the pipe condition can be checked. In nuclear power plants, oil and gas terminals, refineries, industrial sites, cased pipeline crossings, and distribution pipes of all kinds, the pipe inspection is a critical task connected with emerging assessments for surface and underground piping. Intelligent pigs are the inspection systems that are intended to search for a particular kind of defect using a single technology using a single inspection instrument [9-11].



**Figure 2.** Eddy Current Experimental Principle

Electromagnetic induction is used in Eddy Current testing to find faults in conductive materials. A current-carrying excitation coil is positioned close to the component under test.

Through many millimeters of coating, automatic Eddy Current testing may be utilized to identify the tiniest holes in the pipelining more efficiently. This setup has been shown in the figure 2.

Currently, wireless technologies are widely utilized in a wide range of fields and applications, including pipeline monitoring. Leakage detection systems use a wide range of techniques. Some new technologies make it possible for remote systems to locate leaks or to detect leaks and provide the operator with a report about them. In this article, a Raspberry Pi-based wireless gas leakage monitoring system with web-based GSM monitoring is presented.

## **2. Organization of the Research**

In the next sections, you will find: Section 3 that summarizes previous researches on gas leakage detection systems conducted in a variety of industries. A discussion of the suggested technique for identifying leaks in the pipeline is included in Section 4. Section 5 contains a discussion of the findings in relation to the parameters that have been calculated. Section 6 ends the study effort by outlining the potential tasks for the future.

## **3. Preliminaries**

The design and execution of a cost-effective gas leak detection system were presented by A. Mahalingam et al. The system keeps an eye on the gas level and detects it continuously. This method can only be used in certain locations where leaks are discovered or occur naturally. This system isn't useful after that [12].

Detecting gas pipeline leaks was the area of study for Zhao Yang et al. A SCADA system communicates with the pipeline to collect data [13]. When an MQ6 gas sensor detects LPG gas, a signal is sent to a microcontroller, as suggested by Aashish Srivasthava et al. The flaw in this design is that the microcontroller in use is inefficient with regard to managing memory [14].

An aerial GPR method was used by Bradford et al. to identify an oil spill in and beneath snow. Under snow oil reduces the impedance contrast with core ice, leading to abnormal low-amplitude radar reflections, according to this research. This study's findings show that a 2 cm thick oil layer trapped between sea ice and snow may be identified with a 51% decrease in reflected force utilizing a one gigahertz instrument. Even with a low signal-to-noise ratio, the authors claim that their method outperforms others [15].

Impulse ground-penetrating radar was used by Zoubir et al. to identify landmines using a Kalman filter [16]. Ng,W et al suggested to add a particle filter that enhances this research. GPR systems have been plagued by false alerts due to false cluster suppression landmine detecting algorithms that use correlation methods. The system helps detect, check, and manage LPG leakage. It's suggested that the MQ6 gas sensor, which primarily detects LPG, is used as is a buzzer warning system [17].

When a gas leak is detected, a sensor shuts off the regulator knob, stopping further leakage. This method was suggested by Manswi Sharma. The cloud is used by a wifi module to send the user a SMS or e-mail [18].

An SMS-based gas leak warning system was suggested by Anandhakrishna et al. Gas sensors are used in kitchens to detect gas leaks. The problem of gas wastage is also checked with the aid of an infrared sensor. If the sensor doesn't identify a vessel over the burner for an extended length of time, an alert will sound [19].

F. Aimen et al developed an image-processing-based method for detecting SF6 gas leaks. Infrared imaging detection of SF6 gas leaks is simple due to the differing infrared absorption characteristics of SF6 gas and air. However, this method can only detect one gas at a time [20].

## Research Gap

This research work summarizes a detection mechanism for a wide range of pipeline gas leak detection techniques. This section contains a research gap based on the different pipeline leak detection techniques that have been evaluated. It's also critical to pinpoint the source of the leak and estimate the leakage rate early so that spills may be contained and maintained before they cause significant environmental harm.

Recent static type gas detection techniques have many drawbacks. Large industries such as chemicals or any petroleum businesses, benefit from the use of mobile robots for gas leakage with location detection. Due to this reason, the gas leakage detector design is used to detect the effects of prevention measures in any chemical or petroleum industry. A gas leak in the oil and gas sector poses a serious threat to the safety of both employees and the operations of the company. A gas leak's hazards might be minimized if it was detected and reported expeditiously.

## 4. Methodologies

The following technique is included in our suggested approach in order for the robot to identify the hole in the pipeline in an effective way, as shown below.

### 4.1 Driving Mechanism

The movement mechanism within a pipe may be classified into three types according to our research. Using fluid pressure in a pipeline, the first design obtains the propulsive motion. This is a more energy-efficient option since it uses a pre-programmed mechanism. However, the robot's design must consider the integration of fluid pipelines.

In the second case, a flexible rod is used to change the propulsion of a snake-like robot. When used in a narrow pipe, this mechanism works well. The robot may be split into tiny coaches

that move independently to execute this process. Due to sub-coaches' improved attachment capabilities, the carrying capacity tends to rise. While this may be true, the engine coach must use more power to pull the tail because of the increased tractive effort required to do so.

The final design is often used as a driving mechanism inside the body. Using kinematic modelling, the robot's current location is determined and then allocated. The robot can comprehend its path ahead of time and utilise an angular speed sensor to monitor speed and time to compute the distance travelled thus far by the robot. A different approach is to use dynamic modelling, in which the locomotion must take the interference of flow into account before moving forward [21].

## **4.2 Direction-Finding Mechanism**

Differential drive, synchro drive, and articulated drive are suitable steering methods according to a good robot motion standard. Outside of the pipeline, the robot's degree of freedom may be accessed using specialised computing to adjust to common paths. In general, pipelines are made up of a straight line, an elbow (L form), branching (T shape, Y shape), and a vertical pipe [22].

The differential drive links the robot's movements to tank motions. Modulating the speed of the robot's side wheels determines the way it should rotate. Since the wheels spin in the opposite direction, this system requires knowledge of pipe geometry and may have its roots in a sliding issue. Synchro drive, on the other hand, enables each wheel to steer independently so that the car may have more flexibility. However, it may require more power since each wheel is connected to a separate motor.

## **4.3 Regulator Mechanism**

Our suggested work's control method has been divided into three categories as follows:

1. Tethered cable,
2. Wireless communication
3. Automatic drive.

The robot uses the tethered connection as a flexible power source when using a tethered wire. By the use of this design, the robot is guaranteed to accomplish the task within an acceptable timeframe. The robot has the ability to convert between automated and manual modes since it is linked via cable. The automated navigation burden is simplified by the mode-changing choices. However, this cable may be seen as a track line for pipeline operations, which can be used for a rescue mission in an emergency. However, the cable that's included has some unavoidable disadvantages such as the system's performance is largely dependent on the cable's length [23-27].

There are a lot of moving parts in an automatic drive, and this is the most difficult solution. As a consequence, adding additional high-precision sensors may hasten the depletion of available power. Despite the drawbacks, the independence from manual labour and the ability to operate in the completely automated mode under constrained circumstances makes this the preferred choice.

#### **4.4 Automatic Eddy Current Recognition Mechanism**

This research work implements to identify the Eddy Current (EC) method. Another non-destructive technique derived from the EC concept is EC or Eddy-Current. EC distorts magnetic induction and electromagnetic induction. Flaw identification on the conductive material surface is often accomplished using the EC method. As a result of the device inspection signal interacting with a pipe composed of conductive material, such as metal, an electrical current is generated. Using a coil system, the predetermined current is produced and controlled in various ways. Due to mutual inductance, an alternate magnetic field is generated, which alters the flow of EC on the

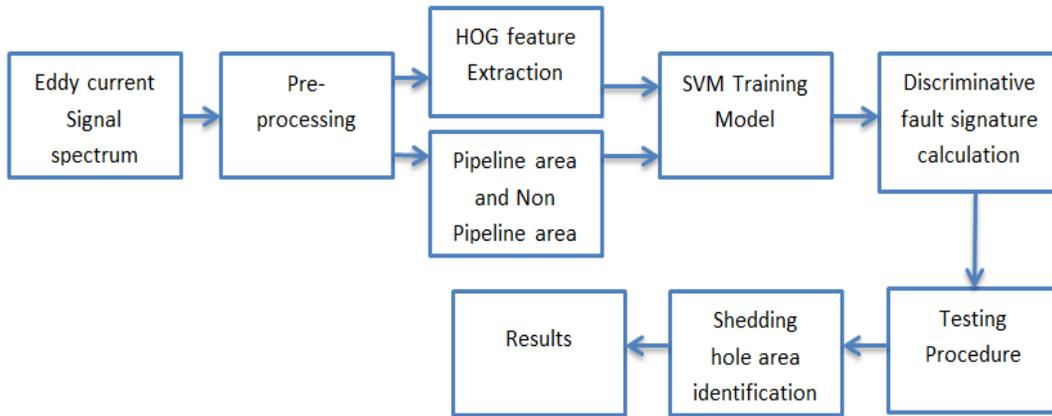
adjacent pipe wall's surface later. As a result, the magnetic field created by the current in the pipe wall is opposite to the magnetic field that induced it [28-30].

Corrosion or metal loss produces inhomogeneity in the material, which changed the flow of ECs due to mutual inductance. These signals have a phase and amplitude change between input and output, which may be traced to the pipe fault being investigated. When an amplitude measurement occurs in a limited frequency range, it cannot be further examined. Solving this problem requires looking at a pulsed signal over the whole spectrum. The small space is expanded into a large depth range, making analysis possible.

#### **4.5 Defect detection robot**

Defect identification based on histograms of oriented characteristics is the foundation of the suggested method. Many studies discuss the benefits of analyzing flaws using a camera. The fault was verified using an SVM classifier on the histogram of oriented gradient (HOG) characteristics in the research of halfway [31]. This area of interest was extracted from the pictures using a low-cost segmentation method. The research avoids color intensity analysis to overcome the instability induced by background noise and non-uniform lighting circumstances.

The research, on the other hand, looked at the most serious flaws found and made no mention of the minor ones. Defects of various orientations and shapes harm performance since only HOG characteristics were utilized in this investigation. A standard automated gas leakage detection system typically supports this technique. Furthermore, this suggested work supports these processes and includes HOG feature extraction for the SVM classifier, resulting in increased efficiency. Figure 3 depicts a block diagram of this kind [32, 33].



**Figure 3.** Proposed Framework for SVM Classifier

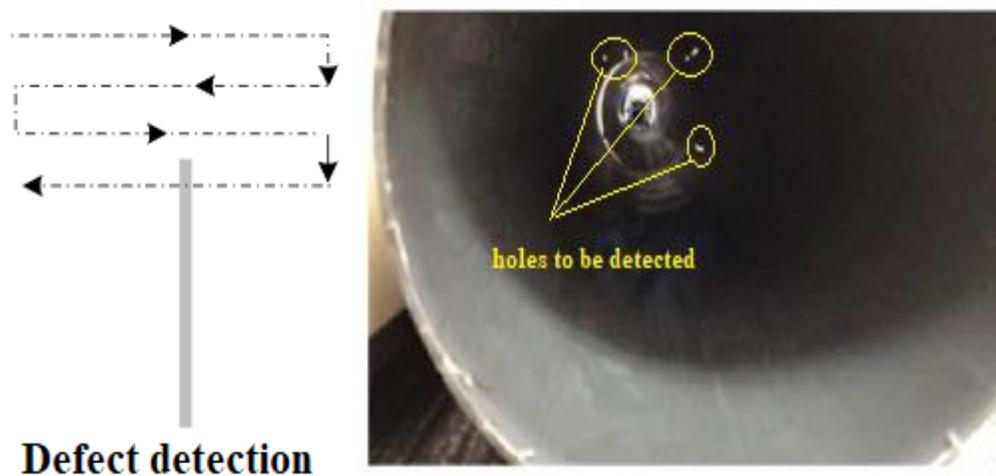
## 5. Results Discussion

Ten inspection missions were performed as part of the tests and a successful mission was defined as one that included exploration and escape. The robot speed was kept constant and enforced with a very modest value in all trips to enhance the scanning dataset. A manual hole was created in the pipe line with various measurements which has shown in figure 4.



**Figure 4.** Holes on the Pipeline by Manual

Figure 4 depicts several manually made holes that need to be identified in order to be classified. It is also possible to scan for defects using the hole-based defect detection method, as shown in figure 5. The system configuration was successful in detecting the hole with greater precision across a large number of experimental testing sessions since the fault locations were equally distributed across each pipe. The split result from the train and validation set follows the same distribution as stated in the aforementioned approach.

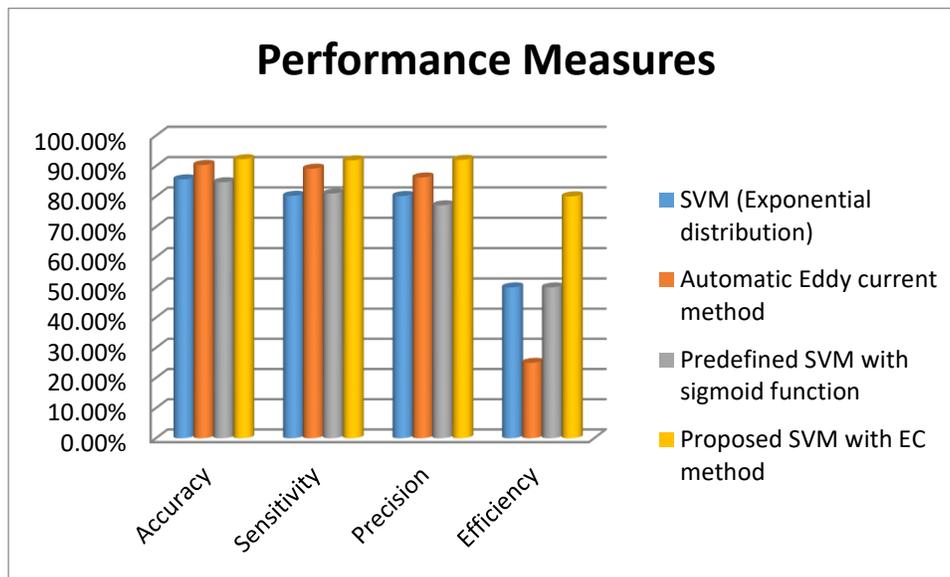


**Figure 5.** Experimental Setup of Eddy Current Method Detection

It's also possible to use a cross-validation approach. However, if a tiny piece of scanning data is separated in the middle, it may result in information discontinuity and discrepancy. The learning pattern may be distorted if the signal at the starting chunk is removed and then the new chunk is connected successfully. This is especially true for data signals like ultrasound. According to the evaluation measure, SVM's polynomial performance identified the fault exactly. The performance measures are computed and tabulated in table 1.

**Table 1.** Computed Performance Measures

S.No	Model metrics	Accuracy	Sensitivity	Precision	Efficiency
1	SVM (Exponential distribution)	85.61%	80.17%	80.12%	Moderate
2	Automatic Eddy current method	90.34%	89.12%	86.23%	Low
3	Predefined SVM with sigmoid function	84.66%	80.92%	77.06%	Moderate
4	Proposed SVM with EC method	92.24%	91.87%	92.04%	High



**Figure 6.** Overall Performance Measures

The detection result shown on the 2D pipe-cutting surface agrees with the visualised data from the 3D construction pipe signal. A good outcome is impossible due to the constraints of a

lab-scale environment despite the great precision. This last step should include the testing of system's performance with various sizes, structures, and faults. This graph (figure 6) has shown the proposed method's overall performance measures.

It is found that, SVM would deplete its resources if it uses kernel techniques. Another factor to think about is the trade-off between performance and control capacity when performing a very complicated operation. Also, the kernel features are limited with exhaustive for SVM. Moreover, a complex function is used to compute the ability of control.

## 6. Conclusion

As a result, using a conventional mechanism such as driving, direction-finding, regulator, and automated Eddy Current identification, this suggested framework has improved the efficiency of the present system. In addition, we've compiled a list of our suggested algorithm's calculated performance characteristics. It is found that there is still potential for development and expansion of the suggested system in all areas, from the robotics design to the detection strategy. Field test trials in various forms, diameters, and materials are needed to validate the efficacy of the detection method since this study solely analyses it in a lab-scale setting. To broaden the scope of the analysis, other data types that make use of various aspects of pipe status, such as pictures, should be included. Because the data includes useful geometric information, there are many opportunities to improve speed by creating a schema that makes use of multiple kernels.

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