A Fundamental Approach to Oil and Gas Leaks Detection

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ABSTRACT
Leak detection is a very important step in the production and maintenance of oil and gas pipelines. It is needed to check tightness specifications and to ensure other installation specifications are fulfilled. In this paper some pipeline leak detection methodologies are studied to come up with a design structure that could ease pipeline leak detection and monitoring via Google earth. A common difficulty identified for most of these methods is the aspect of generating a leak alarm when the pipeline is under normal operation, such irregularities found in most methodologies reduce the confidence operators have in a system because in most cases a real leak may be overlooked. The design direction of this work is a proposed methodology for effective real time leak detection and monitoring of oil and gas pipelines.

CCS Concepts
• **Software system models → Model-driven software engineering**

Keywords
Pipeline, Leak Detection, Oil and Gas, Real Time Monitoring, Google Earth

1. INTRODUCTION
Pipelines face threats of leaks, damage, and breaks, which can be caused by aging equipment, lack of adequate maintenance, extreme weather, natural disasters (such as earthquakes), or even deliberate sabotage [10]. For underground pipelines, problems are difficult to detect, locate, and repair. Surface pipelines detection and repair can be easier, but remote locations increase the challenge. Leaks, damage, and breaks cause product loss and flow stoppage, resulting in environmental and financial damage. Financial damage can include fines for environmental incidents, failure to meet refinery contractual obligations, the need to purchase additional product to replace lost product, cleanup of spills, and damage to reputation. While this approach is still relatively new, hardware and software technology along with experience and knowledge have evolved so that there is now the understanding of how to reliably and cost-effectively assemble the pieces to create solutions that optimize operations and help to avoid or quickly identify and resolve problems. This ultimately helps to reduce costs, increase safety, and improve industry's overall performance. Some similar approaches are also developed for downstream operations, specifically in the area of pipeline leak detection [17]. Pipeline operators face similar challenges as upstream operators in terms of operational scale and remoteness and the need to quickly make sense of huge volumes of available data. For operators, vast networks of pipelines move oil and natural gas from producing sites to refineries and manufacturing plants and on to markets for distribution. These pipelines meander through densely populated urban areas and extend through boundless, remote regions, in some cases easily accessible from the surface, in other cases located underground. Existing technology for pipeline leak detection, such as sensors and network infrastructure, can gather necessary data and even provide some useful information about cause. However similar to early upstream solutions workers do not have the tools necessary to help make sense of all the data, to bring it all together in a comprehensive view so they can quickly identify, locate, and resolve problems. None of these models considered the effects of anticipatory anomalies, differential topologies, pipe dimensions or corrosion allowance on pipeline-leak frequency [21]. This paper therefore proposes an integrated designs using Google earth platform that can adequately monitor and detect pipeline leaks, it is a fundamental approach to oil and gas leaks detection that could lead to a conceptually real-time pipeline leak frequency model for oil and gas pipelines location monitoring and leak detection system [7]. The aim is essentially to present a design framework that will eventually lead to the development of a software based management system for oil and gas pipelines monitoring and leak detection, which will be applicable to fundamentally all carbon-steel pipelines exposed to serious corrosion attack, either internal or external and leakages and transporting fluids. It can be useful in evaluating the technical and capital alternatives in pipeline design, operation, and maintenance.

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2. ENVIRONMENT AND SCOPE
A network of pipelines is used to transport oil and gas from areas of crude oil production to oil consumers has recently broadened, especially in Nigeria. In Nigeria today, increases in fuel consumption has led to a comparative rise in the development of pipelines and its attendant risks such as leakages [2]. It became necessary, therefore to develop an information system that would help stakeholders make managerial decisions promptly, and to provide environmental monitoring of pipeline construction and maintenance areas and to ensure a quick and effective response to emergency [9]. This design approach is a distributed leak detection system that is responsible for coordinating the communication between geo-stationary space satellite, the oil and gas physical pipeline network images, Google Earth station and the internet cloud [8]. Information in the design leads to the tasks of developing a software interface that will be able to communicate with the monitoring models via to provide trending,

diagnostic data, and detailed schematics on the oil fields pipeline; a system capable of detecting leaks in pipelines using Google Earth Platform. The system will include software based geo-referenced geological landscape and topographical maps and data, obtained through Google Earth Remote Satellite Imaging (GERSI). High resolution images, obtained from GERSI, can be used to compile large-scale environmental maps that serve as a base for monitoring compilations and would permit users to trace spatial and temporal landscape variations in pipeline damage impacted area and will give an instantaneous overview of problematic areas. The system can identify potential and actual damage or leak-related incidents, including those caused by accidental or malicious human intervention. This data is a crucial component of the system [11]. The Google Earth tool will have direct connection to the earth geostationary satellite in space from where life and real time images can be sourced. The solution will also use other data sources in addition to the main data source, including pipeline operations data and historic data. The solution will create its own knowledge base, a data store for the results of trend analysis, pattern recognition, event detection, and other data analysis. This federated data approach which merges together multiple disparate data sources into a virtual database is necessary for the fast detection and response required for this solution, enabling operators to build and run various workflows that leverage software based tools for advanced data analysis [5].

3. RELATED WORK

This section presents a review of leak detection methods with the aim of providing the major themes in this line of research. Jun Zhang [6] in the work on designing a cost effective and reliable pipeline leak detection system discussed the ATMOS PIPE statistical pipeline leak detection system, incorporating advanced pattern recognition functions. It is a cost effective real time leak detection system with a very low false alarm rate. Discussions on this methodology supported the design direction of the present proposed design for effective leak detection and monitoring of oil and gas pipelines. Leak detection is a very important step in the production of reservoirs. It is needed to check tightness specifications and to ensure other installation specifications are fulfilled. In the light of this assertion, N. Hilleret [7] described a method emphasizing on techniques used for particle accelerators; in it, the most widely used leak detector will be presented with its different types in the context of the accelerator operation.

3.1 Leak Detection Methodologies

Due to so much damage caused by oil and gas pipeline leaks to the environment, many more strict constitutional rules are introduced in oil and gas producing countries to minimize the effects of such damages [4]. To this end many of such countries and industry players are seeking for very reliable and cost effective methods for detecting leaks to enable them correct and ease the level of damages caused to the environment and mankind. In this paper some pipeline leak detection methodologies are studied to come up with a design structure that could ease pipeline leak detection and monitoring via Google earth [3]. These include hardware and software based methods having the capabilities for leak sensitivity, location estimate capability, operational change, availability, false alarm rate, maintenance requirement and cost. A common difficulty identified for most of these methods is the aspect of generating a leak alarm when the pipeline is under normal operation, such irregularities found in most methodologies reduce the confidence operators have in a system because in most cases a real leak may be overlooked. A few leak detection methodologies are as follows: Halogen leak detector method, ATMOS PIPE, The spark coil technique, and Pressure change method. Halogen leak detector method as exemplified in figure 1 is based on the increased emission positive potassium and sodium ions because of the sudden presence of the halide composition [6]. The detection process follows the amount of current flowing through the ions, i.e. the higher the current the more the leak size; it is therefore more suited for use in rough, medium and high vacuum pipelines.

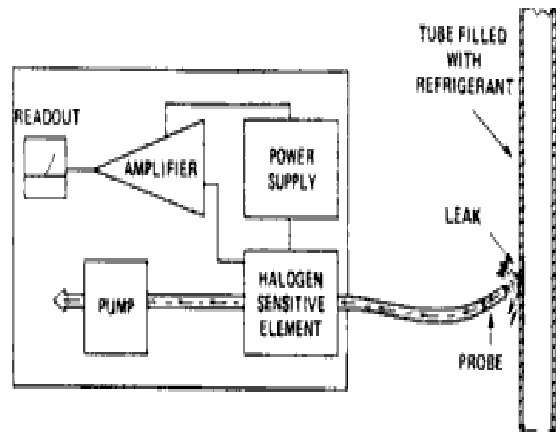

Figure 1: Halogen Leak Detector (Source: Andrej Pregelj et al, 1997)

ATMOS PIPE is a statistical pipeline leak detection system, incorporating advanced pattern recognition functions. It has been developed at Shell applying advanced statistical techniques to flow and pressure measurements of a pipeline [18]. Variations generated by operational changes are registered and a leak alarm is generated only when a unique pattern of changes in flow and pressure exists [12]. This statistical method does not use mathematical models to calculate flow or pressure in a pipeline but it detects changes in the relationship between flow and pressure using measurement data available. As the system monitors a pipeline continuously it learns about continual changes in the line and flow/pressure instruments. The spark coil technique uses a high voltage and sparkling point to create the electromagnetic radiation which causes the generation of glow in non-metal glass and plastic elements [16]. Drawing the leak antenna along the tested element the defect spot is very clearly marked and the inner pressure can be estimated by a skilled personnel. Pressure change method as illustrated in figure 2 uses pressure gauges which are ordinary used to monitor the system performance. Suspected leak sites can be sprayed with a solvent while watching the gauge for a pressure rise that occurs when the solvent enters the leak.

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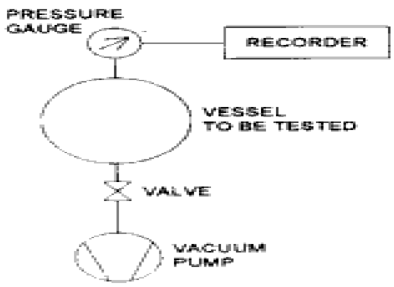

Figure 2: Pressure Method (Source: Andrej Pregelj et al, 1997)

4. DESIGN OF THE SOFTWARE BASED DETECTION AND MONITORING SYSTEM

Some factors taken into consideration in this design approach are the fact that uniform industry standards for leak detection and monitoring do not exist, especially in relation to non-computational pipeline monitoring approaches to leak detection. Metrics to capture sensitivity and reliability should be normalized to provide more relevant information for pipeline operators. Integrating all these issues into a common design will achieve communication between the various integrating elements [19]. Channeling the resultant software based communication through Google Earth tool can process the signals and project same for effective detection and monitoring, readability, and interpretation purposes. A model is generated that can receive and send spatial data from the pipeline network via Google Earth to monitor and detect uncomplimentary activities within the pipeline infrastructure. Google Earth tool pick up geographic information system (GIS) spatial data, amplify and transmit them into the internet cloud from where it can be channeled to software based monitoring client. Earth Geo-stationary satellite intercepts area images and signal, routes to routing devices in Google Earth stations for upward real time relay on the internet cloud.

Conditioned spatial data is processed by server and projected to the network monitoring software which is projected for display. This represents bulk of computing activity considering the variables, such as: Spatial data variables, Pressure drop leading to independent development of dynamic model, Activity change along pipelines, and Data variation between normal spatial data and spatial data with changed activity. The design is made up of elements that can handle the spatial data and the on-site data by integrating both to generate values to be feed into the software based system. From the schematic view of the real time Google Earth GIS capture system presented in figure 3 it can be seen that the Geo-stationary space satellite takes photograph of the areas covered on the Earth [20]. The images captured are transmitted to the earth satellite and into the Google Earth Station from where it is retransmitted into the internet cloud to be accessed by client machines which processes the data.

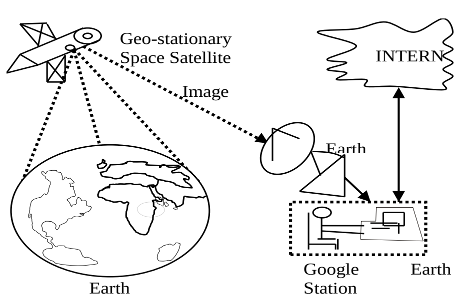

Figure 3 Google Earth Live GIS Capture Schematic System

Once the Google Earth GIS is loaded in the internet cloud it can be accessed by the dictation and monitoring client on the base site. Figure 4 illustrates the flow of the GIS images required for pipeline monitoring from the internet cloud to the internet service providers (ISP) server [14]. The detection and monitoring system makes request on the Google Earth through the server and the Google Earth responds by sending in the requested GIS images.

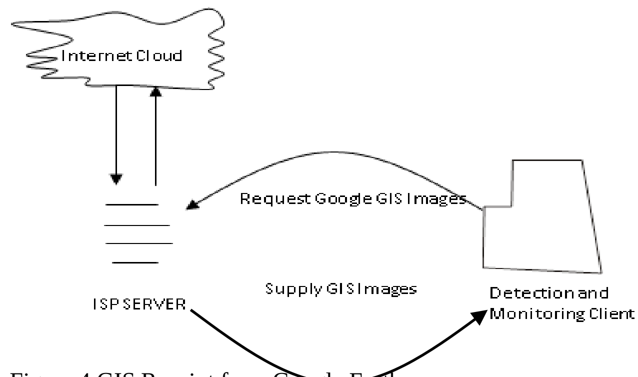

Figure 4 GIS Receipt from Google Earth

The supplied images are basically dependent on the location details given to Google Earth on latitude and longitude along the basement of the pipeline [15]. It can equally be a simple zoom of the areas where malicious tamper may be suspected or may have occurred so that activities at such areas will be easy to monitor and any attempt at tampering with the pipeline facilities will be easily detected. In figure 5 the system design shows Google Earth as the entry point of the system since we do not intend to control what happens at the Google Earth Station point of data capture. The Nigerian National Petroleum Company for example, NNPC-Joint venture data received from the oil companies is equally feed into the system [1]. The detection and monitoring system (DMS) integration engine infuses the data collected from the oil companies into the Google Earth system and the integration engine in turn sends the outcome of the integration to the Software based DMS.

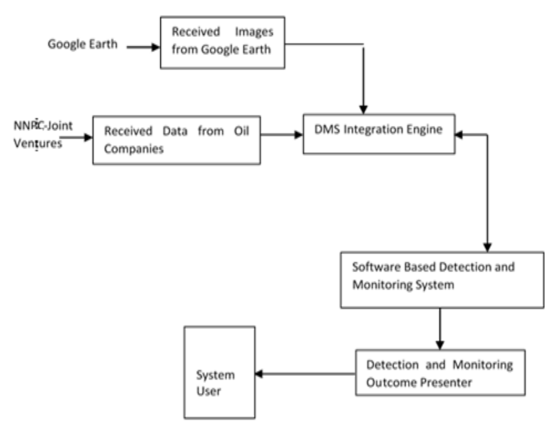

Figure 5: Detection and Monitoring Client System Design Structure

The software based detection and monitoring system processes the integrated information and sends the outcome to the detection and monitoring outcome presenter part of the system. The presenter finally sends the fine tuned outcome to the system user [13]. Using the Google Earth tool and data from our geographic information system manager (GISM) that has been sent in for analysis and processing. The Server will be configured to receive and respond to alerts and tailored dashboards for a high-level view of all pipeline operations.

5. CONCLUSION AND FUTURE WORK

Most operators of oil and gas pipelines demands the installation of automated leak detection and monitoring systems for cost effective and reliable maintenance of the systems. It is therefore necessary, depending on the operational complexities to design a leak detection and monitoring system that could meet the industry needs. To this end some pipeline leak detection methodologies are studied to come up with a design structure that could ease pipeline leak detection and monitoring via Google earth. A common difficulty identified for most of these methods is the generation of false leak alarms resulting into loss of confidence on such methods by the industry players. The design proposed in this paper is for effective real time monitoring and detection via Google earth platform. In the future, the software based rule processing engine is being developed for processing of the spatial data feed into it through the Google earth tools refinements.

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