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RESEARCH

Leakage detection in pipeline systems using machine learning

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Abstract
The reliability of pipeline systems as a criterion is of enormous significance in sustainable pipeline operation and the protection of the environment. In their basic form, conventional leak detection techniques are often slow and not sensitive enough to suit many purposes, particularly in the early detection and control of leaks in large distributed systems. In this paper, we examine the application of machine learning—One-Class Support Vector Machine (SVM)—to the existing pipeline leak detection systems. Using both COMSOL Multiphysics for simulation and MATLAB for data analysis, this work proves that machine learning is applicable to improve leakage assessment. Using detailed simulations under various operational conditions, the k coefficients of the One-Class SVM model pinpoint pressure, temperature, and velocity abnormalities that suggest leakage. The results also clearly indicate the model's effectiveness in accurately identifying leak locations in addition to simply identifying their presence, making it a significant improvement over current approaches by increasing response speed while decreasing possible losses and threats to the environment.

Keywords Pipeline leak detection · Machine learning · One-class support vector machine (SVM) · Leakage assessment · COMSOL multiphysics simulation · MATLAB data analysis

Introduction

Pipeline leakage detection plays a critical role in ensuring safe functionality and performance, particularly in fluid transport infrastructure, while also minimizing environmental repercussions. Conventional detection methods, including pressure gauges, flow measurements, and visual inspections, often fall short in sensitivity and timeliness, making them insufficient to prevent significant losses or damages (Momeni & Piratla, 2021). These limitations are particularly evident in large and complex pipeline networks where effective and rapid leak detection is crucial.

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In contrast, Artificial Neural Networks (ANNs) and machine learning algorithms have gained prominence in civil engineering for providing efficient solutions in structural optimization and predictive modeling (Kaveh, 2024; Kaveh & Rahami, 2006). Gradient-based neural networks have proven effective in enhancing computational accuracy and optimizing complex structural designs (Iranmanesh & Kaveh, 1999). Further advancements in machine learning regression models have enabled accurate predictions of ultimate buckling loads in variable-stiffness composite cylinders, ensuring safer and more reliable structural assessments (Kaveh et al., 2021). Additionally, the integration of metaheuristic algorithms with ANNs has significantly enhanced predictive accuracy, as demonstrated in Fiber Reinforced Polymer (FRP) strength estimation (Kaveh & Khavaninzadeh, 2023).

Machine learning technologies are now increasingly applied to pipeline leak detection, offering more sophisticated learning methods, faster response times, and real-time monitoring capabilities. Advanced algorithms analyze large datasets to identify patterns and distinguish between normal operations and potential leak indicators. One-class Support Vector Machines (SVMs) have emerged as a particularly effective method for enhancing pipeline leak detection,

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