Pimpri Chinchwad College of Engineering

Sector No. 26, Pradhikaran, Nigdi, Pune 411044
An Autonomous Institute Approved By AICTE and Affiliated To SPPU, Pune

DEPARTMENT OF INFORMATION TECHNOLOGY

Fundamentals of Digital Image Processing FA2 Report

of

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on

DIP for Detecting Gas Leaks using Infrared Camera images

Submitted By:

Pranav Ravindra Harad [123B1F028]

Guided By:

Dr. Harsha A. Bhute

1. Problem Statement

Gas leaks are potentially the most dangerous threat anyone will ever face. Gas leaks can cause disasters, financial loss, and long-term deterioration to ecosystems. Commercial-off-the-shelf (COTS) detection methods, like chemo sensors and portable detectors, have limited detection range and resolution. Infrared (IR) imaging is the only method able, non-interference, to fully inspect for gas leaks. The benefits of IR imaging include being able to inspect using zoom lenses. However, the impact of using IR imaging include low contrast images; noise (especially in congested area) and bias from environmental factors. A hybrid-type Digital Image Processing (DIP) based system, which will accurately detection, enhance and locate gas leaks in real-time is going to be at least a better gas leak detection method as time progresses.

2. Motivation

1. Industrial Safety: Gas leaks at refineries, chemical facilities, and pipelines usually end up with explosions and loss of life - e.g., as we learned from the 2014 GAIL pipeline disaster in India.

2. Environmental Protection: Methane leaks alone contribute to roughly 30% of global warming currently and therefore significantly contribute to climate change.

3. Economic Effects: The energy sector incurs billions in losses each year from leaks that go undetected or delayed detection; an infallible monitoring system would keep the losses to a matter of minutes.

4. Public Health: Long-term exposure to the emitted gas (for example: methane, carbon monoxide, and ammonia) are detrimental to public health and can result in respiratory disease, neuro damage, and even long-term risk of cancer in the surrounding population. Early detection is for worker safety and safety in the communities surrounding the operated facilities.

3. Objectives

i. Use classical digital image processing (Gaussian, bilateral, adaptive histogram) to improve the contrast of gas plume.

ii. To apply YOLO for accurate detection of gas leaks.

iii. To improve the accuracy of detection using optimized Digital Image Processing (DIP) preprocessing.

4. Introduction

Imagine walking next to a gas plant or gas pipeline everything seems alright however a silent invisible leak of gas could be happening all around you. Methane leaks are typically odourless and colourless but have caused some of the worst catastrophes in history like the 1984 Bhopal Gas Tragedy killing thousands in that area. Except for accidents, methane leaks are causing a climate crisis and global warmings.

In recent years, the need to develop advanced gas leak detection systems has grown substantially. According to the United Nations Environment Programme, cutting methane leaks is one of the fastest and most affordable ways to decrease the rates of climate change and can delay the global 0.3°C rise in temperature by the year 2040. Compounding the urgency of the issue, companies are under more regulatory and public scrutiny to green and secure their activities. This makes the combination of an infrared camera and Digital Image Processing not just a practical imperative, but also an ethical and environmental one.

Typical detectors do not cover large areas spatially or temporally (an image sequence cannot be viewed in real time). While infrared imaging tends to be an exception since it can sense an invisible plume, the true infrared information receives no commercial consideration because the unfiltered, unprocessed data is grainy and is unclear. Digital Image Processing (DIP) improves the infrared data to usable forms of information such as through advanced filtering and contrast enhancement, motion detection and AI-based segmentation methods. This paper describes state-of-the-art developments, and presents a hybrid DIP-based, sufficiently accurate approach to real-time deployable gas leakage detection.

5. Related Work

Sr. No.	Study Name	Features	Methodology	Research Gaps Present
[1]	An Infrared Image Enhancement Algorithm for Gas Leak Detection (2021)	Enhanced impetus to detect faint gas plumes beyond what was feasible with a traditional video	Applying Gaussian filtering with adaptive histogram methods	Video's moving aspects posed challenges
[2]	An Image Enhancement Method for Gas Leak Detection (2023)	Improved clarity of gas images with low contrast	Use of denoising, contrast stretching, and sharpening the gas image	Non-scalar and difficult to facilitate real-time or live monitoring
[3]	Improved Narrow-Band Leakage Gas Image Detection (2025)	Very high accuracy separating leak regions	Combination of bilateral filtering with a U-net deep learning model	Requires a lot of computing power and large datasets to train
[4]	Smoke Detection Algorithm based on Adaptive LOG (2011)	Able to detect movement in thermal video	Comparing frames with adaptive LoG filtering	Designed for smoke, not gas leaks, and outdated in design
[5]	GLRNet: Temporal Difference Gas Leak Recognition (2022)	Reliable in changeable and dynamic environments	Focused on gas leaks by comparing still vs. changed frames	Difficult to set up; needs annotated video datasets
[6]	Real-Time SWIR Image–Based Leak Detection (2019)	Able to detect and locate leaks in real time	Used SWIR infrared cameras, GPS, and IMU sensors	Expensive and highly sensitive to weather conditions

6. Methodology

The goal of this study is to combine Digital Image Processing (DIP) techniques and the YOLO. model to reliably detect gas leaks in still infrared (IR) images, looking specifically at image enhancement simultaneously with gas leak detection in this application.

Process:

Data Acquisition: Images of gas leaks were collected from the Roboflow "Gas-Leak" data set with 163 images at a size of 640x640 pixels, where the images contain gas leaks in the form of dark plumes, in this case using the industrial scenario and the example used did have a bounding box.

Preprocessing: The images were enhanced using DIP techniques and to enhance the images, 1) bounds to grayscale, 2) reduced noise using Gaussian filter, 3) enhanced edges using bilateral filter, and 4) enhanced image contrast in the areas of lowest visibility using the Contrast Limited Adaptive Histogram Equalization (CLAHE).

Detection: YOLOv8 will be finetuned on the Ultralytics platform on Colab using a GPU to detection gas plume using the preprocessed images annotated with bounding boxes (as an example used has a yellow bounding box).

Validation: Detection will be measured by using the mean Average Precision (mAP) measure for validation of gas leaks detection.

7. Conclusion

Applying Digital Image Processing (DIP) functions to the YOLO model improves gas leak detection to be a safer, economically viable, and less environmentally harmful approach in the industrial context. The following step is to prepare data, implement the algorithm, and develop a validation of the UAVs in providing ground truth gas leak detection from simulated data. This could improve monitoring efficiency and possibly provide a framework for better leak detection in practice. Future improvements could be realized with additional optimization with DIP systems and/or larger datasets to further assess the appropriateness with accuracy and industrial practice.

8. References

[1] Nie, X. et al. "An Infrared Image Enhancement Algorithm for Gas Leak Detection Based on Gaussian Filtering and Adaptive Histogram Segmentation." IEEE RCAR.

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