



## TECHNOLOGICAL FORECASTING: “Ex” INSPECTION SYSTEM USING IMAGES AIDED BY AI IN OIL AND GAS INDUSTRY

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**Abstract** — This chapter addresses the growing role of artificial intelligence (AI) in supporting inspection of Ex equipment in the oil and gas industry. The study aims to identify technological trends and research gaps by conducting a bibliometric prospection in the Scopus database, focusing on works that combine AI, image-based inspection, and remote technologies in hazardous offshore environments. The search strategy retrieved 51 relevant publications published between 1989 and 2025, highlighting a sharp increase in research activity after 2014, particularly in countries with consolidated offshore operations such as the United States, the United Kingdom, and Norway. Challenges to conventional maintenance and inspection practices of electrical and mechanical Ex systems involve the fact that most methods and protocols employed are bureaucratic and labour intensive. The goal is to reduce inefficiencies and automate manual, repetitive tasks, encouraging workers to focus on more intelligent and critical work for the company. The main contribution of this work is to map the evolution and concentration of research efforts, offering insights for engineers, researchers, and decision-makers about the potential and limitations of AI-driven Ex inspection. The results reveal strong international collaboration networks, with leading contributions from academia and industry.

**Keywords** — Bibliometric Prospection, Ex Inspection, Machine learning, Remote Technology (RT).

### 1 INTRODUCTION

At industrial plants where flammable products are processed, e.g. plastics, varnishes, pharmaceuticals, oil refineries, etc., there are some locations where the possibility of an explosive atmosphere existing is identified. These locations are known as “classified areas”, and need to be recorded on the “area classification drawings”. These explosive mixtures occur mainly due to leaks from the process system. In the UK, a recent survey indicated that more than 200 gas and liquid releases occur offshore every year. Of this total, 6% were ignited, and most were liquid fires on hot surfaces. These releases are significant, involving typically more than 25 kg of gas. Onshore data is not so readily available, but estimates are around 1 000 fires per year in UK industry, with 14 fatalities averaged over 10 years. Rangel (2016) reported that Bureau of Safety and Environmental Enforcement data shows from 2006 to 2010 there were 640 fires and explosions on platforms belonging to various oil companies operating in the Gulf of Mexico, resulting in 2 deaths and 12 serious injuries.



Ex equipment is designed with such special characteristics according to IEC 60019-17 (2013), that are unlikely to ignite an explosive atmosphere. To assure safe operation of the industrial plant, it is necessary not only that all Ex equipment is correctly specified and installed, but also adequately maintained, according to the technical standards requirements. Safety at electric installations in hazardous areas depends on many actions from the design phase until the maintenance activities. In the UK survey, it was found that one plant was only four years old, but 35% of its faults were due to defective installation or maintenance activities. So a commitment from management is needed, together with sufficient resources for inspection and maintenance. A paper policy is no good without resources, staff, competence and commitment. The main problems found in Ex maintenance activities are: Lack of management commitment to maintenance; No inventory of equipment (which may have been subject to un-recorded modification, addition, or repair); Excessive corrosion, especially in salt-laden air.

The following actions are recommended by Rangel (2016) to perform an inspection plan in a facility. Obtain the area classification documentation; Train people to perform inspection; Gather data of all equipment inspected; Obtain the Conformity Certificates and check if any special conditions of use are being followed; Ensure that identified necessary repairs are carried out without delay. Area classification documentation is developed using the IEC 60079-10 standard. Considering its recommendations, all data taken into consideration to define the extent of the classified areas must be recorded and kept available to plant employees. Linking the hazardous area classification drawings to inspection procedures is a good practice. By imposing a grid system on drawings, it enables better identification of inventory, making it easier to inspect.

Rangel (2005) proposed adequate training and related experience in hazardous areas are needed to keep industrial plants safe and to guarantee the integrity of Ex equipment. Workers need to know not only what is to be done, but mainly how to do it safely, keeping the integrity of Ex equipment. Many related nonconformities were attributed to the low qualification of maintenance professionals. It is worth noting that good workmanship is the result of competent people working within good systems of work. The whole inspection system is useless unless it is carried out by adequately trained personnel.

According to Bulgarelli (2005), vital information includes area classification drawings, records of installed equipment, apparatus type, gas group, T class and category. The location of records of previous inspections should be recorded. Maintenance requires more detailed knowledge than when the equipment is first installed. Problems of routine inspections can be reduced considerably if the documentation of each system is accurate and includes the points to be checked. Periodic inspections on installations in hazardous locations are very important for the plant and people safety, and require highly qualified personnel. Challenges to conventional maintenance and inspection practices of electrical and mechanical Ex systems involve the fact that most methods and protocols employed are bureaucratic and labour intensive.

Koola (2025) observed that operation and maintenance (O&M) costs, resulting from standardized inspection and maintenance practices, have been quite considerable for government and industry. O&M cost accounts for a large proportion of lifecycle costs in critical systems; for instance, the O&M expenditure in the offshore platform amounts to 20% - 30% of total costs.

Today, there are a variety of robotic and autonomous systems (RAS) being developed and deployed in various industries, including aerospace, manufacturing, energy, transport, agriculture, healthcare, etc. Macaulay (2022) proposed RAS systems are widely used to support monitoring, maintenance and inspection of mechanical systems and civil infrastructure. These technologies are provided with artificial intelligence (AI), sometimes referred to as machine learning (ML), to enable and complete complex tasks, as well as process vast amounts of data. This revolution has provided an interest and demand for the use of RAS technologies to support the monitoring, inspection and maintenance of offshore wind farms, gas and utility pipelines, power lines, bridges, railways, high rise buildings, vessels, storage tanks, underwater infrastructure, etc., in order to mitigate the current health and safety risks that human operators currently experience while inspecting or monitoring such infrastructure within the energy, transport, aerospace and manufacturing sectors. There is a drive in both industry and government for the development and availability of RAS technologies



that can be deployed to provide data on the condition of assets and help technicians undertake actions deemed necessary, based on the information provided by RAS. This information can be signals provided by hardware instruments, or images taken by cameras from damaged, shadowed, rough, or rusty surfaces.

Here in Brazil some softwares for Ex inspections that are used in Oil and Gas facilities, these softwares works like a digital check list with compliance by IEC 60019-17 for inspections and maintenance activities, with photos registers and approval process for signature of Ex inspectors and Ex Engineers. The output of these programs are Inspection reports and databases for Ex equipment inventory. With these technologies we have improved our quality of inspections, time for reports and response time, to planning the maintenance in those installations with nonconformities.

The most expensive square meters in the world are in the Offshore facilities, like an FPSO (Floating, Production, Storage and Operating platform), and this is a big problem with POB (people on boarding) during the operation and maintenance of these installations. Because of this, and for faster response about Ex inspections and maintenance to guarantee the process safety and mitigation of the explosion risk, the use of smart tools and softwares are necessary with AI integrated for help the operator/maintenance technician during the inspection and diagnosis of lacks on installation and nonconformities according to the technical standards.

Technological forecasting for these smart tools and software, with the development of Ex Inspection programs aided by AI, is our goal to see a revolutionary method for Inspection, using a RBI (Risk based in inspection) to attenuate the risks and improve process safety in oil and gas installations.

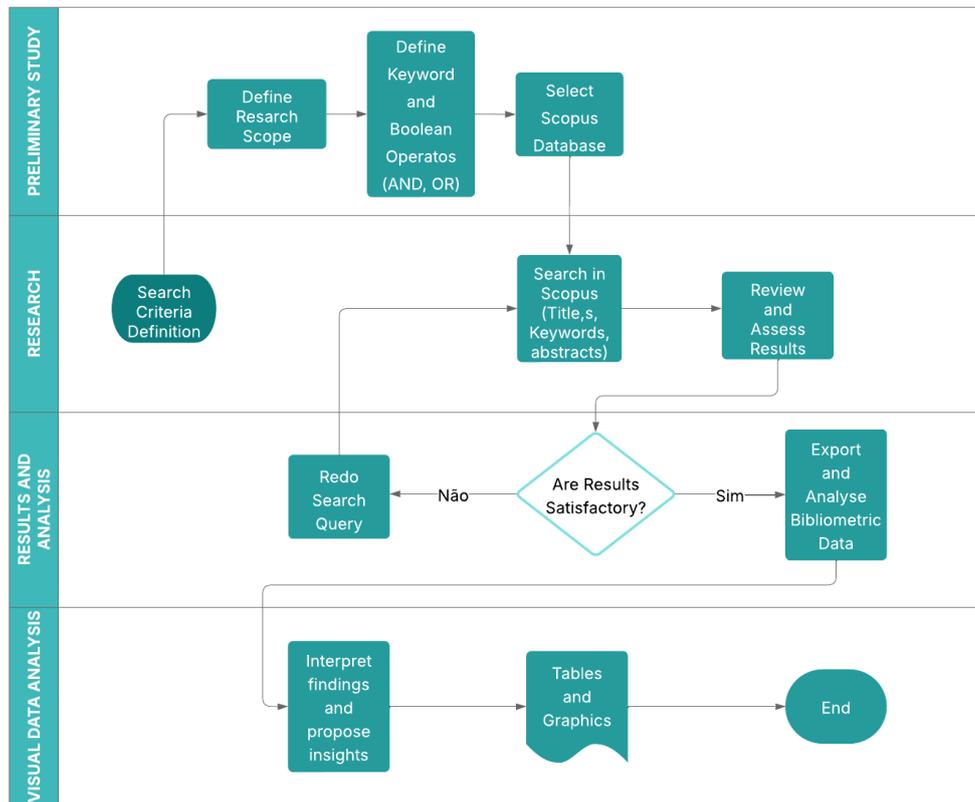
This technology included a qualitative assessment of potential economic benefits of Remote Technology (RT). RTs can provide significant financial benefits through operational cost savings, time savings, reduction of risk to personnel, and early failure detection. The goal is to reduce inefficiencies and automate mundane, repetitive tasks, encouraging human focus on more intelligent and critical work for the organization. Providers of drone-based blade inspections and maintenance report operational cost savings of between 35% and 80% compared to manual when conducting blade inspection, cleaning, and lightning protection system testing. Cost savings of up to 50% in blade defect marking and categorization are reported.

This article explores these technological trends by conducting a bibliometric prospection of publications indexed in the Scopus database. The analysis focuses on the intersection of AI, image-based inspection, and remote technologies applied to Ex environments in the oil and gas industry. By mapping the evolution of research output, identifying leading countries, institutions, and collaboration networks, the study provides insights into the current state of the art and highlights research opportunities to advance safety and efficiency in hazardous environments.

## 2 METHOD OF PROSPECTION

Regarding its objectives, this research is classified as descriptive, with a quantitative approach. The bibliographic search procedure adopted the following flowchart:

Bibliometric Prospecting Process using Scopus and Boolean Operators



Source: Author (2025).

The bibliometric recovery search criteria were defined to cover any type of technology that was associated with remote technology for inspections in oil and gas and offshore facilities. This choice was made to explore the developments that have been made for the sector and their degree of maturity, without initially restricting it to a specific technological route. Performed web-based searches for literature, publications, news articles, and marketing materials relevant to RT. The mapping of the state of the art was carried out in the online database Scopus, to discover the most reliable, relevant, and up-to-date research in one place only. To analyze the annual evolution of research, we searched for documents from the period of 1989 to 2025. The grouping into families and the graphs presented in this work with statistics of the results were automatically generated by the standard tools of the database. The firsts searches return 9,476 articles using the keyword ( "Image\*" AND "inspection" AND "industr\*"), but after that was refining the search to 348 articles, adding the AI keyword, and then, improving and optimizing the search to 51 articles, in offshore installations.

Based on preliminary research, keywords and Boolean operators were defined for searching the Scopus database. The keywords used were: ( "AI" AND "inspection" AND "offshore" ); ( "Remote technology" AND "RBI" ), combined with the Boolean operators AND and OR.

### 3 RESULTS

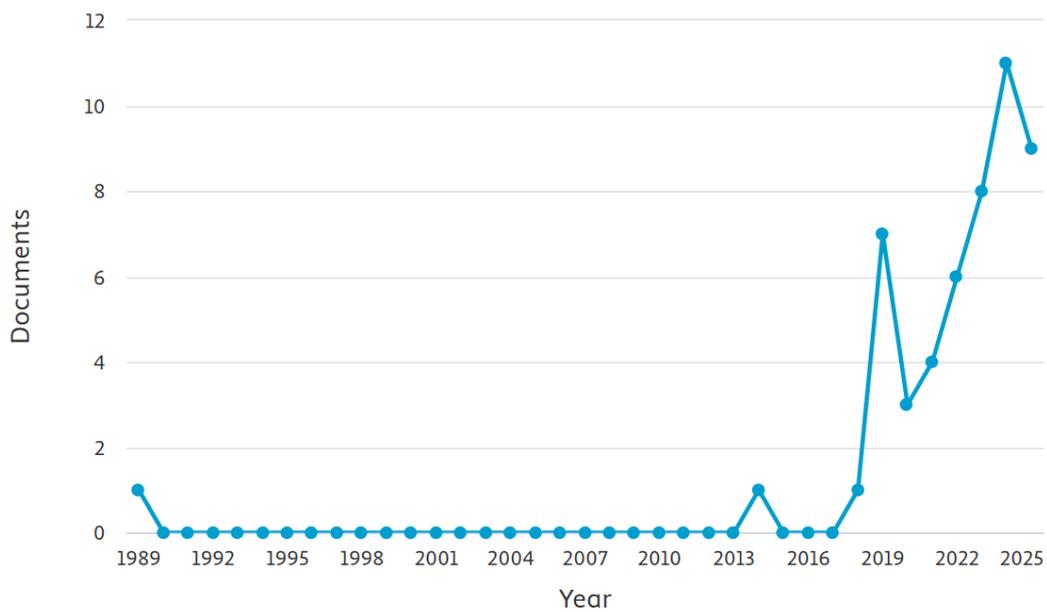
In total, 51 documents were identified, the first document published in 1989, the first inspection research using computer technology to predict the useful life of oil and gas equipment was already underway.



In 2014, the first article using artificial intelligence appeared, analyzing pipeline failures on the topside of a platform. From then on, there was exponential growth over a five-year period, with seven papers published in 2019. In 2020, there was a brief decline in the production of these papers, likely due to the global COVID-19 pandemic, which also impacted technology research for the oil and gas industry.

Graphic 1 - Documents by year, from Scopus analyzes - Remote Technologies w/ AI

### Documents by year

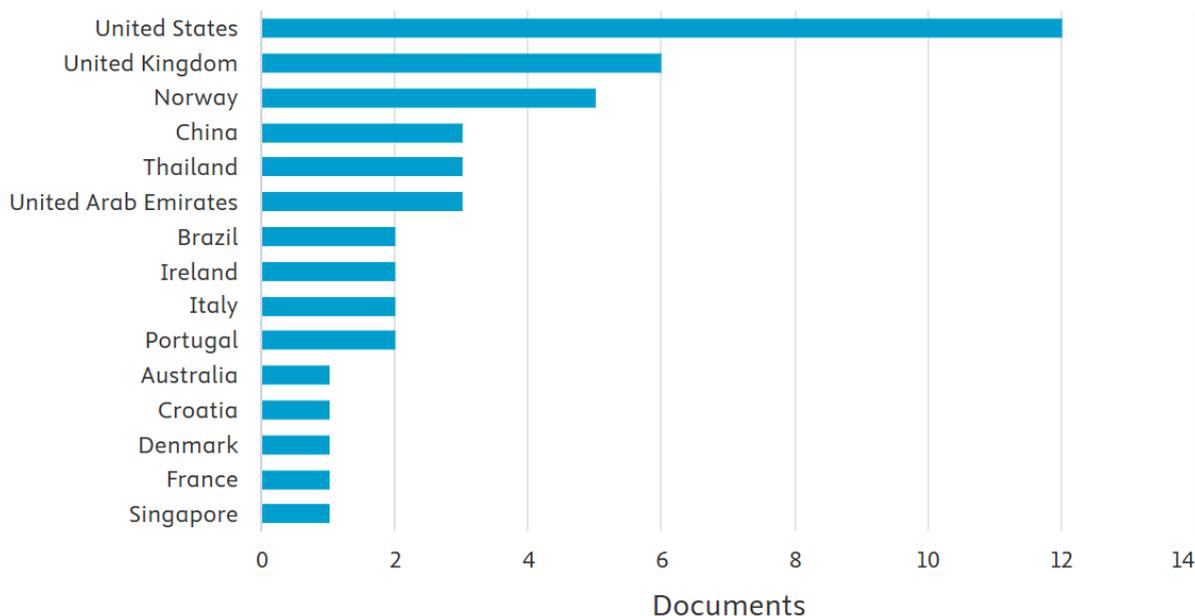


Source: Author (2025).

Graphic 2 - Documents by country issuer - Research about remote technology

## Documents by country or territory

Compare the document counts for up to 15 countries/territories.



Source: Author (2025).

The race for innovative inspection solutions based on RBI is a major focus in the oil and gas industry, particularly in the offshore environment. Therefore, countries with the most activity in these environments and restrictive legal and technical frameworks to ensure process safety at these facilities stand out.

In this case, the USA, the United Kingdom, and Norway are the main countries with researchers focused on this field, due to their expertise and tradition in offshore activities.

As mentioned previously, oil and gas companies are the main funders and promoters of this research and the application of remote inspection innovation in their facilities.

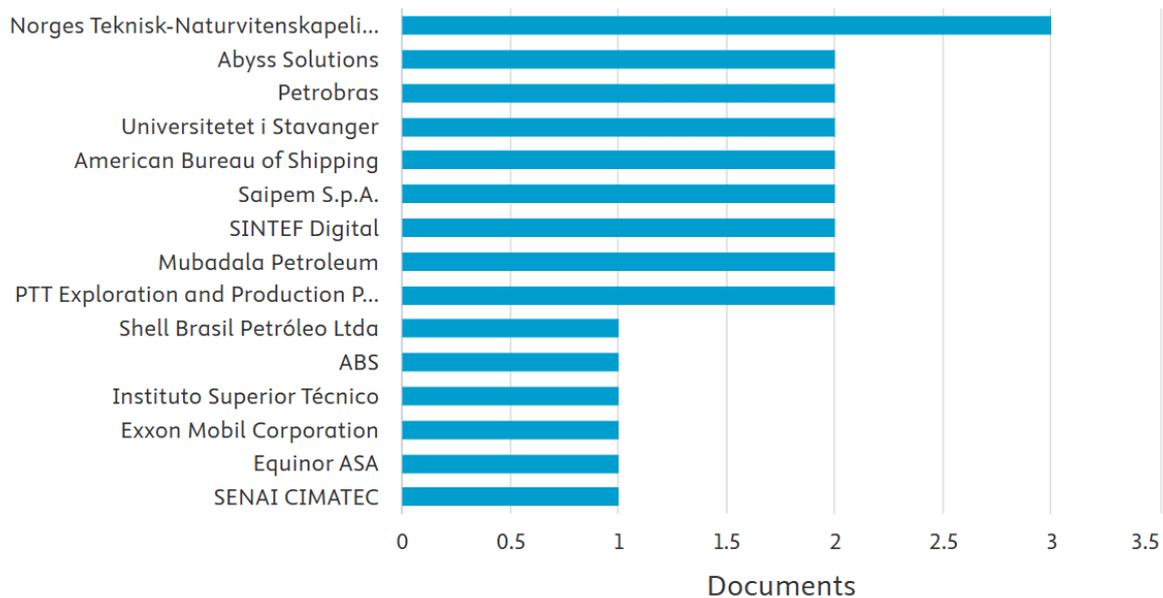
Walker (2024), says the new SAP Ex/ATEX solution has eliminated manual tasks leading to optimized technician efficiency and maximized tool time. The single solution approach has automated several critical process steps minimizing the risk of human error. "Single source of truth" and comprehensive reporting suite provided full insights into the entire inspection process empowering maintenance managers, reliability engineers, and regulators/auditors to take timely and accurate decisions. Single point data entry and image/video capture capabilities ensured timely and accurate information for key personnel such as gatekeepers, enabling informed decision making. These improvements are foreseen to have collectively contributed towards ensuring regulatory compliance and improved health & safety of staff. This innovation provides 55,6 % reduction in process steps, 206 crew-days saved per annum from a team and 100% reduction in Ex equipment updates.

Here in Brazil, Petrobras, Shell, and Senai CIMATEC are among the institutions and companies developing research in these areas for application in their units and plants.

Graphic 3 - Documents by affiliation - Remote Technology with AI using Images

## Documents by affiliation

Compare the document counts for up to 15 affiliations.



Source: Author (2025).

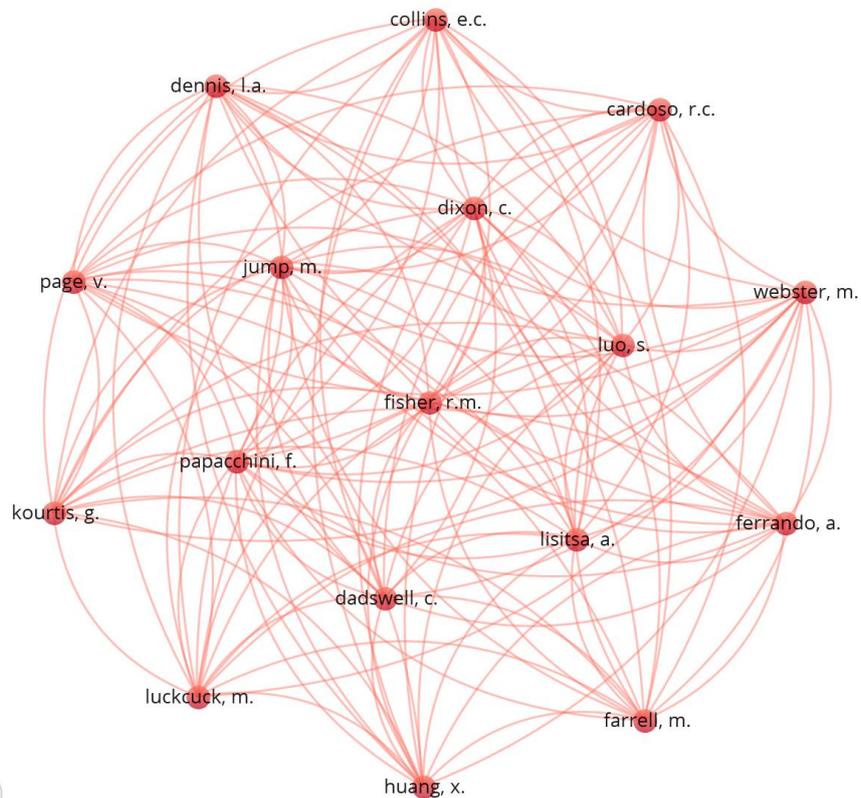
Figure 2 below presents the network visualization generated in VOSviewer from bibliometric data retrieved in Scopus using the keywords AI, inspection, offshore, remote technology, and RBI. The analysis was conducted using the co-authorship approach, where each node represents an author and each link indicates the existence of at least one co-authored publication within the dataset.

The visualization reveals a highly interconnected network, suggesting a strong level of collaboration among the identified researchers. The node size reflects the number of publications or the total link strength of each author, indicating their relative influence within the network. Authors such as Jump M., Fisher R.M., and Huang X. appear as central figures, demonstrating high connectivity and acting as potential hubs in the research community.

The thickness of the connecting lines indicates the strength of the co-authorship relationship; thicker lines denote a greater number of shared publications. The dense web of connections, with minimal isolated nodes, suggests that research in AI-driven offshore inspection and RBI technologies is being developed through collaborative, multi-author efforts, often crossing institutional or geographical boundaries.

This network mapping enables the identification of key contributors and collaborative clusters in the field, providing valuable insights for researchers seeking to establish partnerships, benchmark expertise, or identify leading institutions in AI-based offshore inspection technologies.

Figura 2 - Network Visualization by VOSViewer



Source: Author (2025).

#### 4 CONCLUSION

The landscape of remote technologies is changing rapidly, with significant innovation occurring in two specific areas: miniaturization of sensors and increasing application of data science principles to the processing of remote technology data. DNV has identified data mining and machine learning as key developments within the field of data science that will increase the effectiveness and utility of remote technologies.

There is strong evidence that deploying remote technology for offshore operations and maintenance will not only increase safety by reducing the need for technicians to work offshore but will also reduce costs, potentially significantly. For example, savings of 35% in operational costs and 50% in marking/categorizing defects have been reported for rotor blade inspections using drones and inspection softwares aided by AI.

Despite these advances, the practical application of AI-driven inspection tools in the oil and gas industry remains limited. Most studies are exploratory, focusing on proof-of-concept approaches rather than large-scale industrial deployment. This highlights a clear gap between academic research and operational practice, particularly in regions such as Brazil, where digital solutions for Ex inspections exist but are not yet fully integrated with AI for predictive analysis and real-time decision support.

The contribution of this work lies in mapping the evolution and concentration of research efforts in



this domain, offering a reference point for engineers, researchers, and industry professionals. By identifying trends, gaps, and collaborative networks, the study provides strategic insights for future developments.

Looking ahead, further research is needed to:

- integrate AI-based tools into existing standards and inspection protocols,
- expand real-world validation of image-based inspection systems,
- and strengthen the digitalization of maintenance practices in hazardous environments.

If successfully implemented, these advances may significantly enhance process safety, reduce operational costs, and minimize risks to personnel in the oil and gas industry.

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