


TRENDS AND PATTERNS IN ARTIFICIAL INTELLIGENCE RESEARCH FOR OIL AND GAS INDUSTRY: A BIBLIOMETRIC REVIEW

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ARTICLE INFO	ABSTRACT
<p>Article history:</p> <p>Received 17 March 2023</p> <p>Accepted 16 June 2023</p>	<p>Purpose: This paper aims to outline a broad-spectrum perspective of the structure of research in artificial intelligence (AI), in the oil and gas industry (OGI) based on bibliometric and distance-based visualisation of similarities (VOS) analysis.</p>
<p>Keywords:</p> <p>Artificial Intelligence; Oil and Gas Industry; Bibliometric Analysis; VOS Network Analysis.</p>	<p>Theoretical framework: The OGI has been one of the major contributors to the world economy. With the increasing energy demand, it has become necessary for the industry to adopt the latest technologies to enhance efficiency, reduce costs, and improve safety. One such technology is AI, which has the potential to revolutionise OGI.</p> <p>Design/methodology/approach: The paper uses the data from Scopus online database as of April 2023. Based on “key-terms” search results, 251 valid documents were obtained for further analysis using VOS viewer software and Harzing’s Publish or Perish for citation metrics and analysis.</p>
	<p>Findings: The finding shows that the Journal of Petroleum Science and Engineering is the field's most relevant journal, with 14 (5.58) published Articles. The People's Republic of China is the most productive country regarding AI research in the OGI. El-Sebakhy's (2009) article is the most cited article, with 113 citations and an average of 8.07 citations per year.</p> <p>Research, Practical & Social implications: AI could transform OGI. Thus, adopting AI technologies can increase efficiency, reduce costs, and improve safety, also may increase productivity and economic benefits in AI research-intensive countries.</p> <p>Originality/value: This study provides a comprehensive analysis of the existing AI research in the OGI, utilising bibliometric data and graphical networks.</p> <p>Doi: https://doi.org/10.26668/businessreview/2023.v8i6.2090</p>

TENDÊNCIAS E PADRÕES EM PESQUISA DE INTELIGÊNCIA ARTIFICIAL PARA A INDÚSTRIA DE PETRÓLEO E GÁS: UMA REVISÃO BIBLIOMÉTRICA

RESUMO

Objetivo: Este artigo tem como objetivo delinear uma perspectiva de amplo espectro da estrutura de pesquisa em inteligência artificial (AI), na indústria de petróleo e gás (OGI), com base na análise bibliométrica e visualização baseada em distância de similaridades (VOS).

Enquadramento teórico: O OGI tem sido um dos principais contribuintes para a economia mundial. Com a crescente demanda de energia, tornou-se necessário que a indústria adote as tecnologias mais recentes para aumentar a eficiência, reduzir custos e melhorar a segurança. Uma dessas tecnologias é a AI, que tem o potencial de revolucionar a OGI.

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Design/metodologia/abordagem: o artigo usa os dados do banco de dados on-line Scopus em abril de 2023. Com base nos resultados da pesquisa de “termos-chave”, 251 documentos válidos foram obtidos para análise posterior usando o software VOS viewer e Harzing's Publish or Perish para métricas de citação e análise.

Resultados: Os resultados mostram que o Journal of Petroleum Science and Engineering é o periódico mais relevante da área, com 14 (5,58) artigos publicados. A República Popular da China é o país mais produtivo em relação à pesquisa de AI no OGI. O artigo de El-Sebakhy (2009) é o artigo mais citado, com 113 citações e uma média de 8,07 citações por ano.

Implicações de pesquisa, práticas e sociais: a AI pode transformar a OGI. Assim, a adoção de tecnologias de AI pode aumentar a eficiência, reduzir custos e melhorar a segurança, além de aumentar a produtividade e os benefícios econômicos em países de pesquisa intensiva em AI.

Originalidade/valor: Este estudo fornece uma análise abrangente da pesquisa de AI existente no OGI, utilizando dados bibliométricos e redes gráficas.

Palavras-chave: Inteligência Artificial, Indústria de Petróleo e Gás, Análise Bibliométrica, Análise de Rede VOS.

TENDENCIAS Y PATRONES EN LA INVESTIGACIÓN DE INTELIGENCIA ARTIFICIAL PARA LA INDUSTRIA DEL PETRÓLEO Y EL GAS: UNA REVISIÓN BIBLIOMÉTRICA

RESUMEN

Propósito: Este documento tiene como objetivo esbozar una perspectiva de amplio espectro de la estructura de la investigación en inteligencia artificial (AI) en la industria del petróleo y el gas (OGI) basada en el análisis bibliométrico y de visualización de similitudes (VOS) basada en la distancia.

Marco teórico: La OGI ha sido uno de los principales contribuyentes a la economía mundial. Con la creciente demanda de energía, se ha vuelto necesario que la industria adopte las últimas tecnologías para mejorar la eficiencia, reducir costos y mejorar la seguridad. Una de esas tecnologías es la AI, que tiene el potencial de revolucionar OGI.

Diseño/metodología/enfoque: el documento utiliza los datos de la base de datos en línea de Scopus a partir de abril de 2023. Con base en los resultados de la búsqueda de "términos clave", se obtuvieron 251 documentos válidos para un análisis más detallado utilizando el software de visualización VOS y Publish or Perish de Harzing para las métricas de citas. y análisis.

Hallazgos: El hallazgo muestra que el Journal of Petroleum Science and Engineering es la revista más relevante del campo, con 14 (5,58) artículos publicados. La República Popular China es el país más productivo en cuanto a investigación de AI en la OGI. El artículo de El-Sebakhy (2009) es el artículo más citado, con 113 citas y una media de 8,07 citas al año.

Investigación, implicaciones prácticas y sociales: la AI podría transformar OGI. Por lo tanto, la adopción de tecnologías de AI puede aumentar la eficiencia, reducir los costos y mejorar la seguridad, y también puede aumentar la productividad y los beneficios económicos en los países intensivos en investigación de AI.

Originalidad/valor: este estudio proporciona un análisis completo de la investigación de AI existente en OGI, utilizando datos bibliométricos y redes gráficas.

Palabras clave: Inteligencia Artificial, Industria de Petróleo y Gas, Análisis Bibliométrico, Análisis de Red VOS.

INTRODUCTION

The oil and gas industry (OGI) has long been a significant contributor to the global economy, with a complex and rapidly evolving landscape. In recent years, the advent of artificial intelligence (AI) has brought new opportunities and challenges to the industry, promising to revolutionise the way oil and gas companies operate. AI is a computational science that imitates the human mind for decision-making and problem-solving by combining computer science and robust datasets. Researchers have applied various AI algorithms to develop specific prediction-making systems based on input data (Yoshikawa *et al.*, 2020; Shrivastava, 2023;

Cheng *et al.*, 2023). AI technologies have the potential to unlock significant value by enabling advanced data analytics, predictive maintenance, process automation, and improved decision-making. Thus, the implementation of AI in the OGI has the potential to optimise production rates and reduce lifting costs (Gupta & Shah, 2022). This technology's applications encompass enhancing reservoir modelling and averting maintenance needs. This approach is utilised to identify the optimal configuration for scheduled maintenance to prevent failures and enhance maintenance efficiency. The detection of defects is a significant application of AI in the OGI, as it facilitates identifying patterns and preventing failures through the analysis of relevant readings (Sircar *et al.*, 2021). The integration of AI within the OGI is experiencing a swift expansion. It is being utilised in intelligent drilling, production, and refinery. Several practical technological applications are utilised in the processes of exploration and development. Significant achievements have been made in the exploration sector by mitigating exploration risks and enhancing the success rate of exploration wells. AI has facilitated the development of more precise techniques for designing fracture schemes and selecting optimal operating wells and target layers (Li *et al.*, 2021).

Despite the utilisation of AI in repository enhancement has been largely adopted as a means of streamlining progress based on historical oilfield production data. However, in the era of big data, it is imperative to thoroughly explore the immense potential value of large datasets in enhancing oilfield operations. Also, identifying concealed, previously unknown, and potentially valuable information is a pressing concern in artificial intelligence research for oilfield development (Li *et al.*, 2021). The increasing significance of AI in oilfield development can be attributed to the recent developments in big data and the continuous enhancement of various related algorithms. In conjunction with other relevant technological advancements such as cloud computing, the Internet of Things, and virtual reality, novel AI-based systems and innovations will continue to be introduced. These are expected to serve as an effective means of reducing costs and enhancing efficiency (Koroteev & Tekic, 2021).

Furthermore, although prior research has advocated for the widespread implementation of AI in the OGI, a consensus regarding the effectiveness of these technologies has yet to be established within the field. Bibliometric analysis is a method of quantitative evaluation used to assess the quality and development of literature associated with a specific topic. The analysis of important scientific data may provide a comprehensive comprehension whereby outcomes can offer recommendations on performance assessment, ascertain the influence of establishments, and articulate advancements in the domain (Kandoth & Shekhar, 2022;

Yazdani, Ansari, & Sami, 2022; Kassab *et al.*, 2023; Akhtar *et al.*, 2023). Add to that, the categorisation of bibliometric methods was divided into two distinct groups by (Donthu *et al.*, 2021; Gardazi, Hassan, & Bello, 2023). The subject matter pertains to a performance analysis that scrutinises the contributions of research constituents in a conventional manner of presenting information, including authors, institutions, countries, and journals. The second method referred to as "science mapping," centres on identifying connections among research components through the application of citation analysis, co-citation analysis, bibliographic coupling, co-word analysis, and co-authorship analysis.

Bibliometric research encompasses diverse disciplines and employs multiple methodologies to provide precise information. The authors Niu *et al.* (2016) conducted a study on the worldwide research on artificial intelligence from 1990 to 2014. The study employed two citation databases, namely the science and conference proceedings citation indexes, for data analysis. The findings encompass the location of authors, the AI-related topics, the nations and academic institutions that exhibit the highest volume of publications, the most productive keywords, and additional pertinent information. A bibliometric analysis was conducted to identify patterns in academic collaborations and the scientific output of AI to reveal global trends in AI research (Ferrari *et al.*, 2020; Shrivastava, 2023). According to Obileke *et al.* (2020), 84 countries were involved in researching bioenergy. The study revealed that the institutions in China and Denmark were the most productive in this field. The visual findings suggest that increased collaboration and information sharing among countries are necessary to facilitate further research in this domain.

The utilisation of AI in research about the OGI has recently experienced a significant surge, owing to the progress made in relevant fields and methodologies. Nevertheless, a comprehensive bibliometric analysis for this abundance of literature in this field is still lacking. This study conducted a bibliometric analysis of the utilisation of AI in OGI research, encompassing literature and publications from 1982 to 2023. A prolonged duration enables the meticulous examination of global information dissemination patterns and trends. The present study analyses the distinctive features of nations or regions in the field of AI technology as applied to the OGI, focusing on research trends and targeted predictions.

In light of the above discussion, this paper sought to science mapping of AI in the OGI. In order to empirically document the field's volume, intellectual structure, and directions for knowledge advancement, authors turned to bibliometric techniques. The use of bibliometrics, text mining, and data visualisation. The authors address the following research questions: *Q1*.

What is the growth state of publications over the years? Q2. What are the most productive publication source titles? Q3. Which are the most prolific countries in publication productivity? Q4. What are the most highly cited and influential articles? Q5. Who are the most cited and influential authors? Q6. What are the most frequently appearing keywords? Q7. What are AI's potential future research directions in the oil and gas industry?

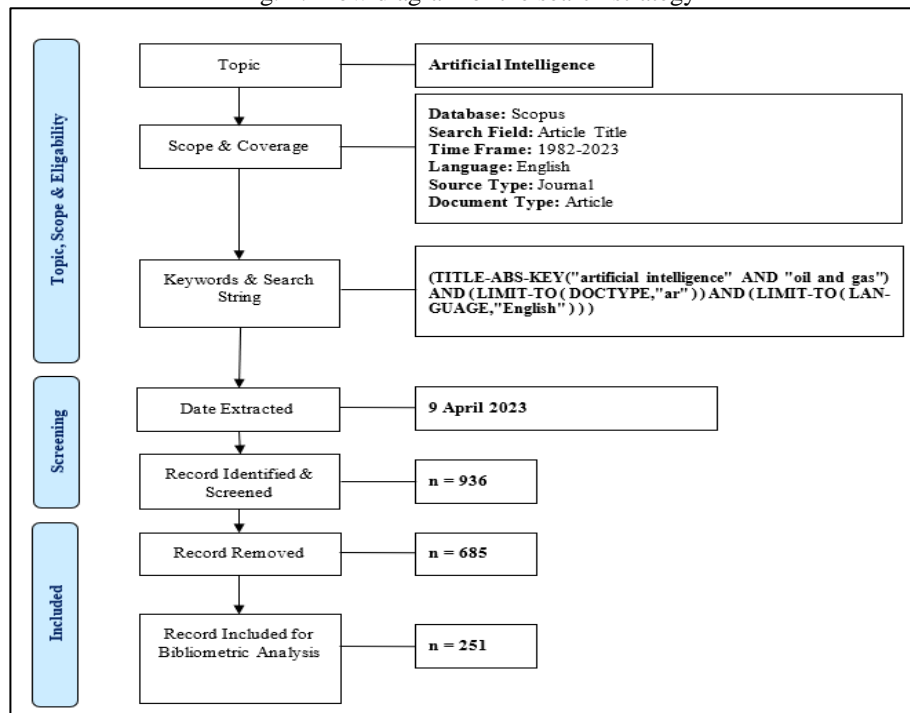
The remainder of this paper is organised as follows: First, it presents the theoretical background concerning AI in the OGI. Then, describe the research method used in this article. Next, the data extracted from the Scopus database is presented in the analysis and results discussion section. And finally, the conclusion section addresses the study's overall findings as well as the research limitations and future research directions.

METHODOLOGY

The research sample selection was conducted based on information obtained from the Scopus database. The exported dataset included comprehensive bibliographic records encompassing citation and bibliographical data, funding particulars, abstracts, keywords, and other relevant information. The main criterion for conducting bibliographic research was limited to scholarly articles published from 1982 to 2023. Several scientific papers have focused on the competitive nature of the Scopus bibliographic platform in comparison to other specialised databases (Harzing & Alakangas, 2016; Yazdani *et al.*, 2022). As highlighted in these studies, the most significant advantage of Scopus is its more comprehensive time coverage of recorded units (Mongeon & Paul-Hus, 2016). Scopus is a comprehensive database that combines an extensive collection of abstracts and citations from academic literature across diverse disciplines to the relevant topic. The present study employed the keywords "Artificial Intelligence" and "Oil and Gas" to search for relevant research articles. The inquiry produced a comprehensive collection of 936 scholarly articles published from 1982 to 2023. These articles were subsequently subjected to inclusion and exclusion criteria to refine the selection further. The study's criteria for inclusion were as follows: (1) the article had to be published in a peer-reviewed journal, (2) the article had to be written in English, (3) the article had to be pertinent to AI and the oil and gas industry, and (4) the article had to comprise original research or analysis. Also, the study employed exclusion criteria to ensure the quality and relevance of the selected articles. These criteria included eliminating duplicate articles, non-oil and gas industry-related articles, articles that did not centre on AI or related technologies, and articles that were not published in a peer-reviewed journal.

Furthermore, this study concentrated on the titles of the articles since they indicate the related topic derived from the research subject and the study's purpose. Furthermore, Kassab *et al.* (2022) explained in their study that the title of an article is the first thing a reader sees; therefore, it is essential to grab their attention with relevant information. Fig. 1 shows the search strategy. Based on the query, the results of the given criterion amounted to 251 scientific papers, of which bibliographic data was retrieved on 9 April 2023. Next, the data were analysed using "Microsoft Excel" to calculate the frequencies of the published materials and to design the relevant chart and graph; "VOSviewer" software to construct and visualise the bibliometric networks; and "Harzing's Publish and Perish" software to calculate the citations metrics and some of the other frequencies. Those tools benefit by investigating the keywords co-occurrence and reference co-citation, authors, and sources.

Fig. 1: Flow diagram of the search strategy



Source: Zakria et al. (2021)

Moreover, considering the advantages of conducting a literature review as highlighted by Mallingu and Zeman (2020), the subsequent stage of the results and findings endeavours to ascertain and scrutinise the most frequently referenced five articles of AI within the OGI. The utilisation of this approach facilitated the researcher in constructing a methodical synopsis, exposing deficiencies, accentuating observations and patterns, and illuminating prospects for future research. Following the methodology established by Demir *et al.* (2017), our literature

review was delimited to studies that specifically examined the implementation of AI within the OGI. The outcomes of this particular stage are exhibited in the second phase of the analysis and findings.

RESULTS AND DISCUSSION

The analysis has been divided into two distinct phases. The first phase is dedicated to examining research trends, encompassing the growth of publication documents, productive publication titles, and country collaboration and productivity of extracted scholarly works. The second phase pertains to research quality and encompasses citation analysis, authorship, and keyword analysis. The majority of the results are presented in the form of frequency, percentage, and visualisation. In addition, a comprehensive analysis of the five highest-cited articles on AI in the OGI was conducted, focusing on citation metrics and analysis. The findings were presented and thoroughly discussed.

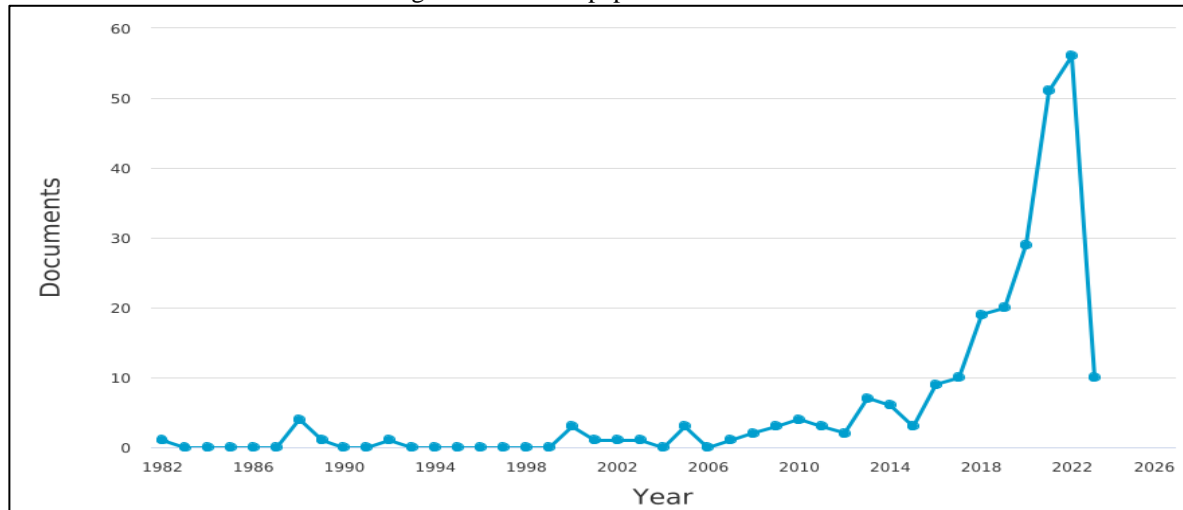
Research Trends

The study analyses the research trends by evaluating the growth of publications by years, productive publication titles, country collaboration, and evaluation of and productivity of extracted scholarly works.

Growth of Publication

The first publication covered in the Scopus database, which fulfils inclusion criteria by containing key terms in the article title, dates back to October 1982. Called "*Some comments on the application of pattern recognition to oil and gas exploration*," this paper has been published in the journal "*Geoexploration*," continued as "*Journal of Applied Geophysics*" written by Bois (1982). Fig. 2 provides an overview of recent advancements in the study of AI in the OGI. As a result, the results evaluate 251 articles in the Scopus database. Even though AI conversations have happened since the 1980s, the recent decade has seen a rise in focus on AI in the OGI. As 56 Articles were published in 2022, 51 were published in 2021, 29 were published in 2020, 20 were published in 2019, and 19 were published in 2018. The total number of observed publications shows that the interest in AI in the OGI topic has been attracting considerable research attention in recent years.

Fig. 2: Number of papers in 1982-2023



Source: Scopus Analytics.

Productive Publication Titles

Furthermore, among the most widely read academic journals, the *Journal Of Petroleum Science And Engineering* (5.58 %), *Energies* (3.98 %), *Journal Of Natural Gas Science And Engineering* (3.19 %), and *Leading Edge* (1.99 %) are the most prolific periodicals in terms of article output as shown in Table 1.

Table 1: Most active source title

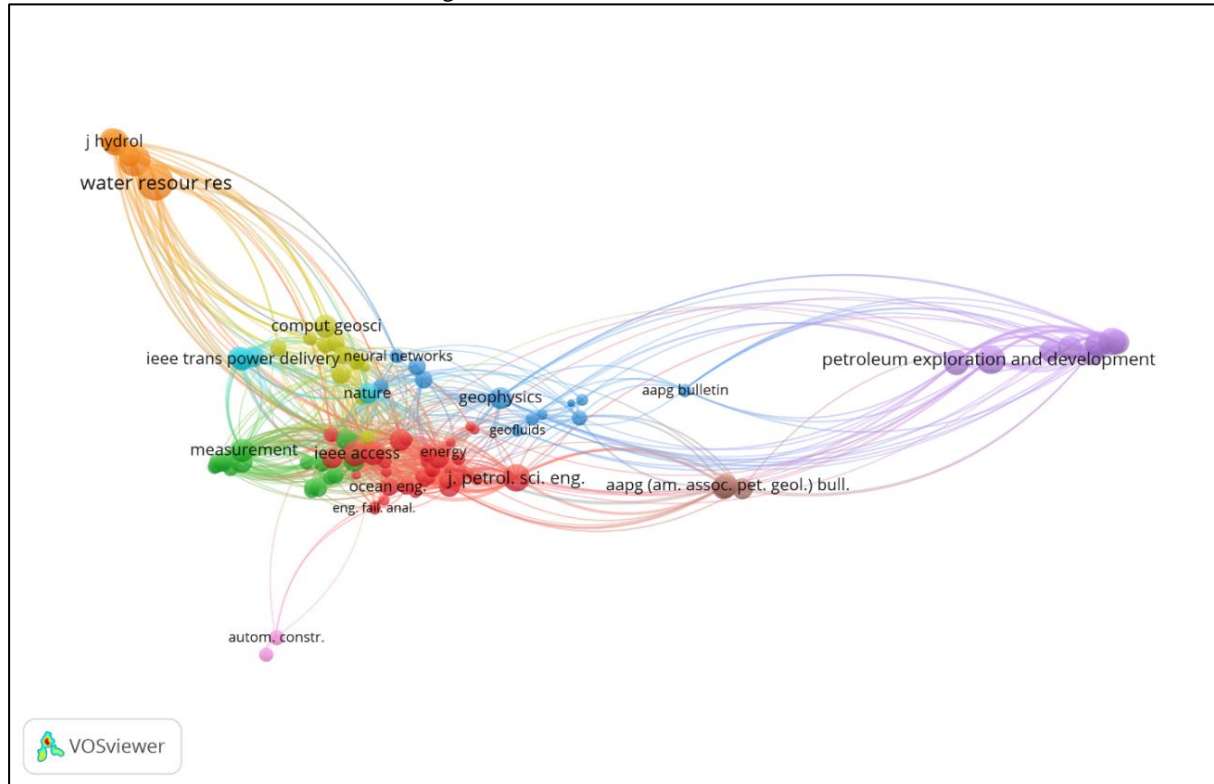
Source titles	Record count	%
Journal Of Petroleum Science And Engineering	14	5.58%
Energies	10	3.98%
Journal Of Natural Gas Science And Engineering	8	3.19%
Leading Edge	5	1.99%
Petroleum Exploration And Development	5	1.99%
World Oil	5	1.99%
Expert Systems With Applications	4	1.59%
Frontiers In Earth Science	4	1.59%
IEEE Access	4	1.59%
Journal Of Petroleum Exploration And Production Technology	4	1.59%

Source: Scopus analytics

A map of journal co-citation analysis was then computed and displayed (Fig. 3). Each journal's co-citations are represented on the co-citation map as a bubble or node. The journals are clustered together in close proximity because of the high rate at which they are cited by one another (Kassab *et al.*, 2023). This suggests a chain of overlaps in the subject matter of various articles. The map also includes a series of lines, each representing a co-citation link between two publications in different journals. Each node is assigned a colour that represents the frequency with which articles from the same journal are cited by one another. This suggests some degree of content similarity between publications of the same colour. In our sample of

5615 sources, 111 met the threshold of 10 sources citations. The analysis showed 107 items within 9 clusters of co-cited journals, as shown in Fig. 3.

Fig. 3: Co-citations of cited sources



Source: Created by the authors based on the VOSviewer analysis.

Country Collaboration and Productivity

According to an examination of the works indexed in Scopus, most of the articles were written by researchers in the following countries (China, Saudi Arabia, United States, Iran, United Kingdom, Canada, etc.) (see Table 2 and Fig. 4).

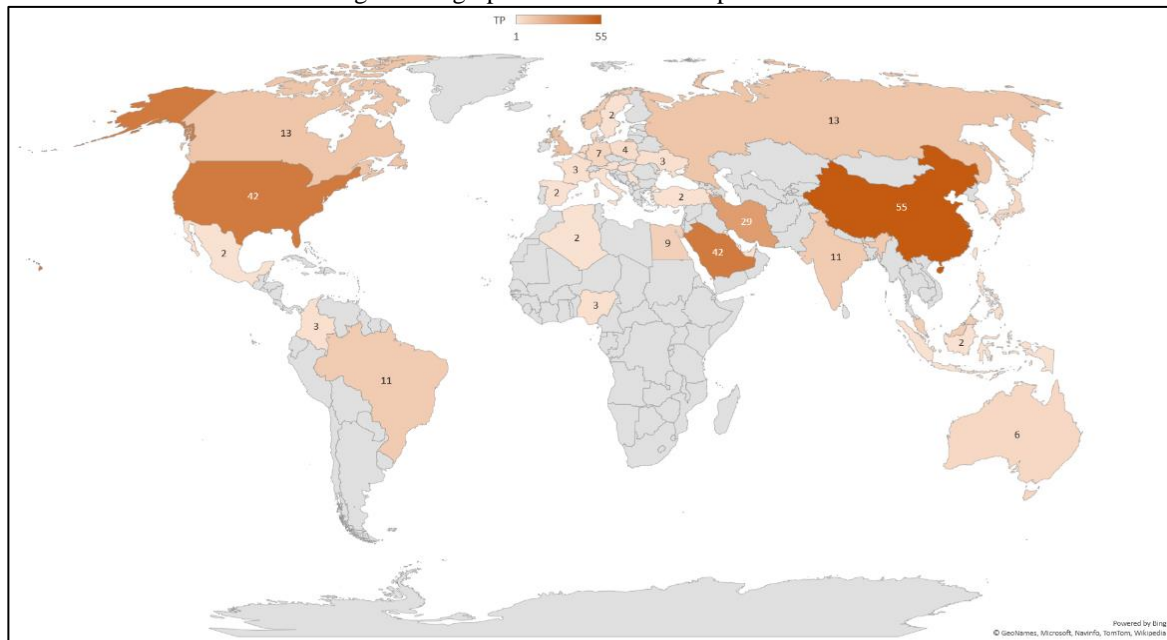
Table 2. Top 10 countries contributed to the publications

Country	Record count	%
China	55	21.91%
Saudi Arabia	42	16.73%
United States	42	16.73%
Iran	29	11.55%
United Kingdom	15	5.98%
Canada	13	5.18%
Russian Federation	13	5.18%
Brazil	11	4.38%
India	11	4.38%
Malaysia	10	3.98%

Source: Scopus analytics

Table 2 highlights the significance of international collaboration in AI research to enhance productivity and facilitate knowledge sharing. The observation that a limited number of nations are responsible for the majority of AI research within the OGI underscores the potential advantages of cross-border cooperation. Collaboration among researchers from diverse nations can facilitate the exchange of distinctive viewpoints and knowledge while consolidating their resources and proficiency to tackle mutual obstacles and create more resilient AI resolutions. Furthermore, enhanced collaboration has the potential to enhance the productivity and efficacy of artificial intelligence research while also fostering the creation of more innovative and consequential technologies.

Fig. 4: Geographical distribution of publication*



*Note: TP: Total publication by country

Source: Created by the authors.

Fig. 4 displays the diverse geographical distribution of publications originating from (China, Saudi Arabia, the United States, Iran, the United Kingdom, Canada, the Russian Federation, Brazil, India, Malaysia, etc.) indicating that research on AI in the OGI is being carried out across various regions globally. China, Saudi Arabia, and the United States have emerged as prominent leaders in AI research, as evidenced by the substantial volume of publications produced by researchers in these nations. Iran and the United Kingdom have made noteworthy contributions to the field of AI research, with a particular emphasis on its practical applications within the OGI. Canada, Brazil, and Russia are significant contributors to data analysis, machine learning, and reservoir modelling. India and Malaysia have made noteworthy

contributions to the field of study, particularly in data analytics, reservoir characterisation, and predictive maintenance. In general, it can be inferred that the geographic dispersion of publications indicates a worldwide endeavour in AI research for the OGI. This is evidenced by the participation of researchers from diverse regions who contribute their specific knowledge and viewpoints to the domain.

Research Quality

The evaluation of an article's "quality" or "impact" is determined by the frequency of its citation by other authors. The measure of a publication's or an author's impact can be determined through "citation analysis", which involves monitoring the frequency with which they are cited in subsequent publications.

Citation Analysis

As of 9 April 2023, the retrieved documents' citation metrics are summarised in Table 3, which displays the total citations for all papers retrieved and the average citations per year. According to the data, 251 retrieved articles have been cited 3574 times over 41 years (1982-2023), with an annual citation rate of 87.17.

Table 3: Citations metrics

Metrics	Data
Publication years	1982-2023
Citation years	41
Papers	251
Citations	3574
Citations/year	87.17
Citations/paper	14.24
Citations/author	1281.95
Papers/author	3.79
h-index	33
g-index	49

Source: Publish or Perish Software

The significance of this citation analysis lies in its ability to present a comprehensive summary of the citation metrics pertaining to the documents that have been retrieved. Table 3 contains crucial data necessary for assessing the significance and influence of the retrieved articles within the research community. A quantitative measure of the impact of articles over time can be achieved through the citation count and average citations per year. Researchers can utilise this data to ascertain the articles with the highest citation rates, monitor trends in the

specific field, and identify potential research gaps. Table 4 presents the top 5 articles with the highest number of citations.

Table 4: Top 5 highly cited articles

No.	Authors	Title	Year	Cites	Cites per Year	Source
1	El-Sebakhy	Forecasting PVT properties of crude oil systems based on support vector machines modeling scheme	2009	113	8.07	Journal of Petroleum Science and Engineering
2	Mohaghegh	Recent developments in application of artificial intelligence in petroleum engineering	2005	97	5.39	JPT, Journal of Petroleum Technology
3	Anifowose and Abdulraheem	Fuzzy logic-driven and SVM-driven hybrid computational intelligence models applied to oil and gas reservoir characterisation	2011	92	7.67	Journal of Natural Gas Science and Engineering
4	Helmy, Fatai, and Faisal	Hybrid computational models for the characterisation of oil and gas reservoirs	2010	84	6.46	Expert Systems with Applications
5	Nguyen, Trestian, To, and Tatipamula	Digital Twin for 5G and beyond	2021	78	39	IEEE Communications Magazine

Source: Prepared by the authors (2023)

First, one can see that the article entitled “*Forecasting PVT properties of crude oil systems based on support vector machines modeling scheme*” by El-Sebakhy (2009) produced the most influential document with the highest number of citations (113 citations or an average of 8.07 citations per year). The findings demonstrate the significance of PVT properties in reservoir engineering computations and the need for accurate prediction of these properties. The article highlights the limitations of neural network modelling schemes and proposes support vector machines as a new intelligence framework to predict PVT properties with higher accuracy and reliability. The study's comparative analysis reveals that support vector machines outperformed most published correlations, indicating their potential for solving other oil and gas industry problems. Therefore, this study emphasises the importance of advanced computational intelligence techniques in the petroleum industry to optimise reservoir performance and enhance oil recovery.

Next, the article entitled “*Recent developments in application of artificial intelligence in petroleum engineering*” by Mohaghegh (2005) produced the second most influential document with the number of citations (97 citations or an average of 5.39 citations per year). This article highlights the increasing need for powerful and intelligent tools in the OGI to support operations such as asset evaluation, seismic data interpretation, drilling, and reservoir management. With the rise of smart wells, intelligent fields, and real-time analysis of large amounts of data, there is a growing interest in using AI in the industry. The article discusses

the recent and advanced uses of intelligent systems, including neural networks, genetic optimisation, and fuzzy logic, in the industry and their potential role in the future.

Then, the article entitled “*Fuzzy logic-driven and SVM-driven hybrid computational intelligence models applied to oil and gas reservoir characterisation*” by Anifowose and Abdulraheem (2011) produced the third most influential document with the number of citations (92 citations or an average of 7.67 citations per year). The importance of this article lies in the fact that it highlights the use of hybrid models as computational intelligence tools in the prediction of important oil and gas reservoir properties such as porosity and permeability. The combination of three existing AI techniques - functional networks, type-2 fuzzy logic systems, and support vector machines - has increased the accuracy and confidence in predicting these properties. The sentence also notes the limitations of individual techniques and the need for hybrid models to overcome these limitations. The results of this work have shown that the hybrid models outperform the individual techniques and are more robust. The successful application of these hybrid models can lead to more efficient exploration, resource evaluation, and management, resulting in increased crude oil and hydrocarbons production to meet the growing world demand.

After that, Then, the article entitled “*Hybrid computational models for the characterisation of oil and gas reservoirs*” by Helmy, Fatai, and Faisal (2010) produced the fourth most influential document with a number of citations (84 citations or an average of 6.46 citations per year). The paper highlights the advantages of utilising hybrid models for reservoir characterisation in the OGI, which incorporate several computational intelligence techniques. The authors use a hybrid model incorporating fuzzy logic, support vector machines, and functional networks to forecast the two crucial properties of petroleum reservoirs, porosity and permeability. The study demonstrates that in terms of correlation coefficients and execution times, the hybrid model beats individual procedures and a combination of two independent components. According to scientists, the hybrid model offers a more reliable prediction while taking up less time during training and testing. The study emphasises the need to employ hybrid models to improve outcomes in this industry and underlines the potential of data mining and AI in optimising oil and gas exploration and management.

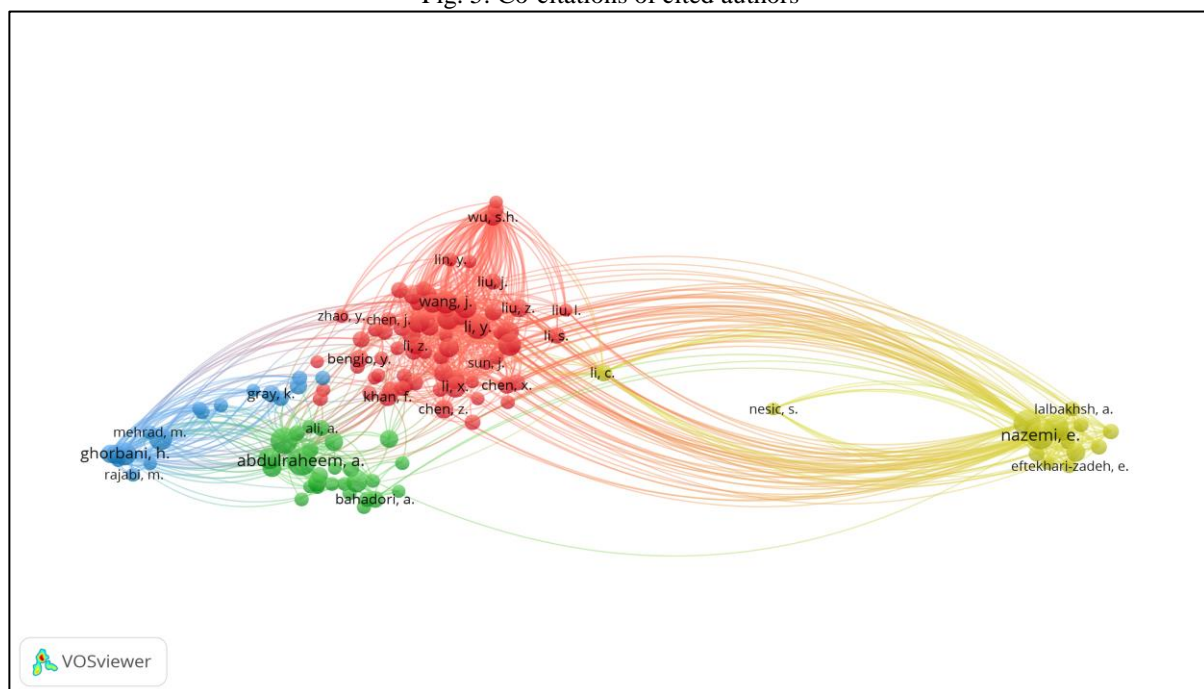
And finally, Then, the article entitled “*Digital Twin for 5G and beyond*” by Nguyen, Trestian, To, and Tatipamula (2021) produced the fifth most influential document with the number of citations (78 citations or an average of 39 citations per year). The research underscores the obstacles encountered by scholars in realising the complete potential of 5G

networks, notwithstanding their initial deployment in numerous nations. The successful implementation of AI in supporting the digital transformation of various industries, including the OGI, has been observed. The concept of a digital replica has been utilised in various sectors, albeit its application in the context of 5G/6G networks is still in its nascent stage. The research indicates that digital twins possess the potential to serve as a robust instrument in the creation and implementation of intricate 5G ecosystems. Digital twins have been identified as a viable solution for enhancing operations, monitoring equipment performance, and predicting maintenance needs in the OGI. This approach has the potential to enhance efficiency and reduce costs. The research highlights the prospective benefits of integrating AI and digital twin technology to enhance the efficiency of oil and gas operations and optimise the utilisation of 5G networks.

Authorship Analysis

The most significant research communities are concentrated by analysing the relationships between the most frequently cited authors. Only 132 of the 18155 authors had at least 15 citations from other works. In addition, four distinct groups of academics were found, as shown in Fig. 5.

Fig. 5: Co-citations of cited authors



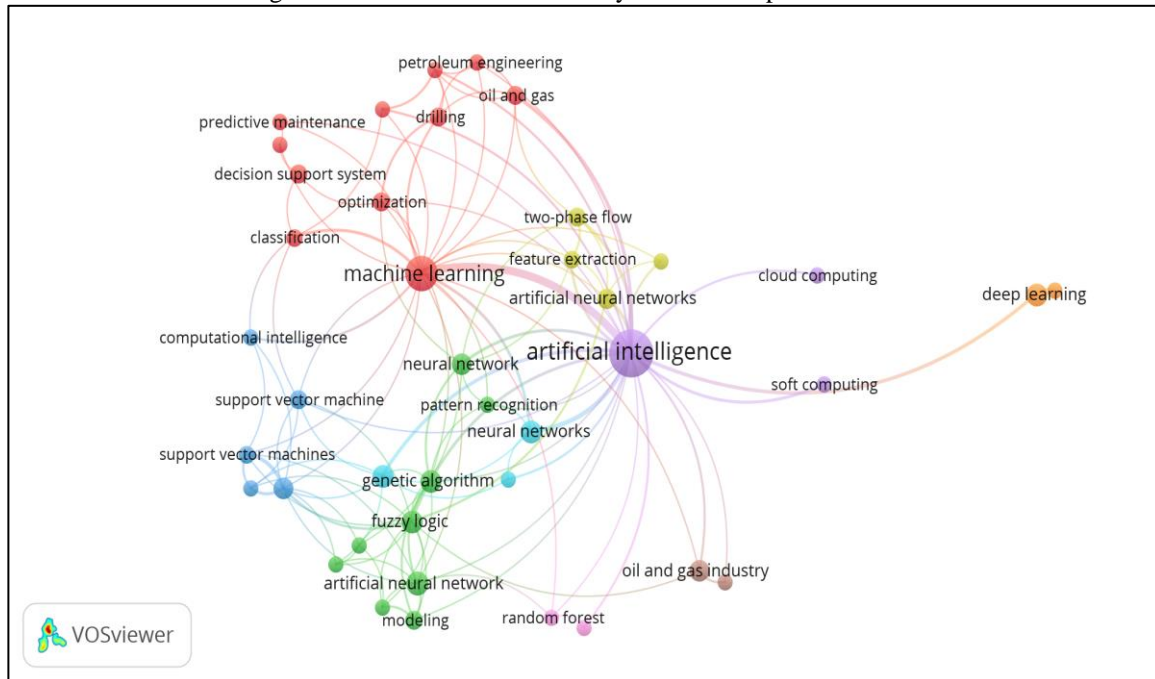
Source: Created by the authors based on the VOSviewer analysis.

The cluster in red includes 132 items and is led by Li, Y. (86 citations and 4411 total link strength), Wang, J. (69 citations and 4336 total link strength), and Wang, Y. (66 citations and 3139 total link strength). The cluster in red, led by Li, Wang, and Wang, is the largest and may represent a highly productive research group that has been cited frequently in the field. This cluster's research may strongly influence the direction of research in the field and may serve as a significant resource for future work. The cluster in green includes 27 items and is led by Abdulraheem, A. (129 citations and 3074 total link strength), Elkatatny, S. (109 citations and 3012 total link strength) and Mahmoud, M. (62 citations and 1742 total link strength). The cluster in green, led by Abdulraheem, Elkatatny, and Mahmoud, is a smaller cluster but may represent a highly specialised research group focused on a particular subfield. This cluster's research may be highly innovative and influential, but its impact may be limited to a smaller group of researchers working in that specific area. The blue cluster includes 17 items and is led by Ghorbani, H. (76 citations and 4984 total link strength) and Wood, D.A. (69 citations and 4116 total link strength). The blue cluster, led by Ghorbani and Wood, may represent a collaborative research group focused on a particular theme or approach. This cluster's research may be highly interdisciplinary and have significant implications for other research areas. Finally, the cluster in yellow colour includes 16 items and is led by Nazemi, E. (116 citations and 10474 total link strength). In addition, this cluster comprises Roshani, S. (114 citations and 11798 total link strength) and Roshani, G.H. (86 citations and 8106 total link strength). The yellow cluster, led by Nazemi and Roshani, is the smallest but may represent a highly influential group of researchers with a broad impact across the field. This cluster's research may be highly innovative and may have significant implications for the direction of research in the field as a whole. Overall, this authorship analysis can provide a valuable snapshot of the current state of research in the field, highlighting prominent researchers and potential areas for collaboration and future research.

Keyword Analysis

Keyword analysis is an important tool in scientific research as it helps to identify trends and patterns in a body of literature. In this particular analysis, the identification of the five main clusters summarises the most common topics discussed in the scientific literature related to the field of study. Fig. 6 displays the keyword groups identified by the VOSviewer software, highlighted in different colours.

Fig. 6: Co-occurrence of author keywords in the publications.



Source: Created by the authors based on the VOSviewer analysis.

Of the total of 807 keywords, 43 had at least three occurrences each. Eleven distinct groups emerged from the data. The five main clusters serve as a summary of the most common topics discussed in the scientific literature. The largest set, consisting of 11 items, can be found in the red cluster that is being driven by the phrase “*machine learning*.” This suggests that machine learning is a highly researched and popular topic in the field. Understanding the different approaches and techniques related to machine learning can help researchers to develop better models and algorithms for their own research. The keyword “*artificial neural network*” serves as the umbrella term for the green cluster, which contains a total of 9 individual items. The keyword “*artificial neural network*” is important because neural networks are fundamental to machine learning. Researchers who are interested in building and optimising neural networks will find this cluster to be of particular interest. The keyword “*functional networks*” serves as the overarching for the 5 items that make up the blue cluster. The keyword “*functional networks*,” is important because functional networks are a type of neural network that is designed to model complex systems. Researchers interested in functional networks can use this cluster to identify studies that explore this topic in greater depth. The keyword “*artificial intelligence*” consists of 3 items that make up the violet cluster. The keyword “*artificial intelligence*,” is important because it highlights the broader field of artificial intelligence, which encompasses many different techniques and approaches beyond machine learning. Researchers who are interested in exploring the broader field of AI can use this cluster to identify studies

that explore different approaches. Lastly, the keyword “*deep learning*” consists of 2 items that comprise the orange cluster. Deep learning is a subset of machine learning that is designed to learn from large amounts of data. Understanding the different techniques and approaches related to deep learning can help researchers develop more accurate and efficient models for their research.

In a nutshell, the keyword analysis offers valuable insights into the significant concepts and technologies pertinent to AI research in the oil and gas sector. This data has the potential to inform future research endeavours and enable industry stakeholders to remain current with the most recent advancements in the domain.

CONCLUSION

The bibliometric analysis on the utilisation of artificial intelligence in the oil and gas sector demonstrates a significant degree of enthusiasm and financial commitment towards this technology. Ultimately, these findings suggest a growing trend towards adopting AI in this industry. The utilisation of data analytics and machine learning is crucial in extracting valuable insights that aid in making informed decisions, optimising asset management, and enhancing production efficiency. Moreover, the identification of authors and institutions with significant influence has the potential to facilitate collaboration and the exchange of knowledge among researchers and industry stakeholders. The identification of emerging technologies and applications of AI within a given sector has the potential to foster innovation and disruption, thereby providing organisations with a competitive advantage in a rapidly evolving industry.

Bibliometric analysis is subject to certain limitations, primarily stemming from its reliance on articles published exclusively in the Scopus database. Additionally, the temporal scope of the analysis is limited to the period between 1982 and 2023. Furthermore, the analysis focuses solely on the volume and regularity of publications without taking into account the influence or calibre of individual articles. The scope of the analysis is restricted to articles published in the English language, which may result in the exclusion of pertinent research published in alternative languages. The utilisation of citation counts as a surrogate for impact has been observed; however, it is plausible that significant publications may have been disregarded.

Conversely, the study's bibliometric analysis offers a foundation for future research on implementing artificial intelligence in the oil and gas industry. To further elaborate on the research, the study proposes an extension of the analytical scope to include additional databases

and literature sources. Additionally, it recommends investigating diverse research domains and practical applications of AI within the industry. The research additionally proposes an examination of the challenges and opportunities pertaining to the integration of AI, encompassing ethical and societal implications. Notwithstanding the constraints of the analysis, the research constitutes a preliminary stride towards an additional investigation of the subject matter of AI in the OGI and amplifies our comprehension of its capacity to transform the sector.

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