

Artificial Intelligence in Oil and Gas Industry

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ABSTRACT

Artificial intelligence (AI), as the most important general-purpose technology of today, is rapidly entering industries, creating significant potential for innovations and growth. It is reshaping industries everywhere. It has revolutionized various sectors, including the oil and gas industry by applying advanced data analytics and machine learning to increase efficiency and effectiveness in hydrocarbon production. The oil and gas companies play a vital role in the economy. They are the latecomers to digitalization, but they are also getting more and more dependent on AI solutions. The benefits of AI for the oil and gas sector are unparalleled. This paper discusses in detail and demonstrate how AI is transforming the oil and gas sector.

KEYWORDS: oil & gas industry, petrochemical industry, artificial intelligence, robotics, machine learning

INTRODUCTION

The impact of AI on all spheres of human life is hard to miss. AI has penetrated medicine, education, industry, business, and finance. Machine learning, for example, is a type of AI in which the program analyzes and identifies patterns in the data and optimizes performance without being directed to do so. As a result, the machine learns and improves automatically.

“Data is the new oil” is the highly used phrase these days, and in the case of oil and gas industry, it is a perfect metaphor. Natural gas and oil companies would not be successful at finding oil and gas deposits without technology. Overall, the oil and gas sector (O&G) has long been putting a premium on tradition and caution rather than innovation. Now, all companies in the industry use the latest technology to improve their processes, increase productivity, and protect their market. Many companies are actively working with AI in the oil and gas industry, developing effective solutions. AI may very well be the investment priority for oil and gas companies wanting to see big advances. Through advanced data analysis and machine learning, AI has optimized

operations, improved efficiency and safety, enabling more autonomous and predictive drilling.

WHAT IS ARTIFICIAL INTELLIGENCE?

The term “artificial intelligence” (AI) is an umbrella term John McCarthy, a computer scientist, coined in 1955 and defined as “the science and engineering of intelligent machines.” It refers to the ability of a computer system to perform human tasks (such as thinking and learning) that usually can only be accomplished using human intelligence [1]. Typically, AI systems demonstrate at least some of the following human behaviors: planning, learning, reasoning, problem solving, knowledge representation, perception, speech recognition, decision-making, language translation, motion, manipulation, intelligence, and creativity.

The 10 U.S. Code § 2358 define artificial intelligence as [2]:

1. “Any artificial system that performs tasks under varying and unpredictable circumstances without significant human oversight, or that can learn from experience and improve performance when exposed to data sets.

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2. An artificial system developed in computer software, physical hardware, or other context that solves tasks requiring human-like perception, cognition, planning, learning, communication, or physical action.
3. An artificial system designed to think or act like a human, including cognitive architectures and neural networks.
4. A set of techniques, including machine learning, that is designed to approximate a cognitive task.
5. An artificial system designed to act rationally, including an intelligent software agent or embodied robot that achieves goals using perception, planning, reasoning, learning, communicating, decision making, and acting.”

AI provides tools creating intelligent machines which can behave like humans, think like humans, and make decisions like humans. The main goals of artificial intelligence are [3]:

1. Replicate human intelligence
2. Solve knowledge-intensive tasks
3. Make an intelligent connection of perception and action
4. Build a machine which can perform tasks that requires human intelligence
5. Create some system which can exhibit intelligent behavior, learn new things by itself, demonstrate, explain, and can advise to its user.

AI is not a single technology but a range of computational models and algorithms. The concept of AI is an umbrella term that encompasses many different technologies. AI is not a single technology but a collection of techniques that enables computer systems to perform tasks that would otherwise require human intelligence. The major disciplines in AI include [4]:

- Expert systems
- Fuzzy logic
- Neural networks
- Machine learning (ML)
- Deep learning
- Natural Language Processors (NLP)
- Robots

These computer-based tools or technologies have been used to achieve AI's goals. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. Figure 1 shows a typical expert system, while Figure 2 illustrates the AI tools. These tools are gaining momentum across every industry. Analytics can be considered a core AI capability. Figure 3 shows a

concept illustration for the use of modern artificial intelligence technologies for the production of oil and gas [5].

OIL AND GAS INDUSTRY

The oil and gas industry is complex and diverse, as typically shown in Figure 4 [6]. The industry deal with lots of data coming from manufacturing processes. It divides into upstream, midstream, and downstream, as shown in Figure 5 [7]. The upstream summarizes the subsurface (mining) part of the industry, including exploration, field development, and production of the crude oil/gas. The upstream segment is the most capital-intensive part of oil and gas and the segment of enormous uncertainties to tackle. It covers crude oil and natural gas production. It includes searching for potential underground or underwater crude oil and natural gas fields, drilling exploratory wells, and subsequently drilling and operating the wells used to lift the crude oil or raw natural gas to the surface. Companies from the sector deal with enormous uncertainties handled manually and relied on expert knowledge, not the actual data.

Midstream stands for storage and transportation of oil and gas. In midstream business, AI can support proper planning and execution, optimal route selection, etc. In contrast, it helps refiners plan optimal blending, forecasting the demand, estimating prices, and improvising customer relationships in the downstream business.

Downstream is for refinery and distribution, i.e., production of fuels, lubricants, plastics, and other products. Figure 6 shows a downstream operation [8]. By embracing AI, downstream firms achieve refinery and distribution cost reduction and reach regulatory compliance faster in several ways. Beyond crude oil and natural gas, downstream oil and gas companies benefit from AI-driven predictions of consumer demand for various products. The application of AI in downstream oil and gas companies involves real-time monitoring systems that optimize refineries. Those systems monitor operations and collect data during distillation, catalytic cracking, and hydrogenation. They also screen data from energy meters and equipment sensors. Downstream operations can be optimized to minimize costs and maximize spreads. AI predictive maintenance reduces AI downstream processes and optimizes maintenance planning.

ARTIFICIAL INTELLIGENCE IN OIL AND GAS

The oil and gas industry is highly competitive, and companies are always looking for ways to increase efficiency and reduce costs. Like every industry today, the O&G sector is trying to figure out how to adopt and deploy artificial intelligence and its tools.

These forms of AI are used in the oil and gas industry [8]:

- *Machine learning*: Machine learning (ML) is a specific area that has seen significant deployment in oil and gas in recent decades. It analyzes data for pattern recognition to predict outcomes. ML is often used in reservoir exploration, drilling, or fault detection. Machine learning for oil and gas reduces the risk of drill-bit failures and optimizes extraction rates.
- *Deep learning*: As a more advanced form of ML, deep learning utilizes complex neural networks for tasks like precise seismic analysis to process data and identify more complex details within it.
- *Generative AI*: This is a sub-category of artificial intelligence (AI) that aims to help the user create an image, video, or song using different instructions called user “prompts.” It learns from existing datasets, gen AI creates, for example, new data samples, emergency instructions, or smart summaries. Using gen AI, oil and gas companies and logistics providers automate mission-critical supply chain processes. Generative AI in oil and gas adds resilience to planning so all stakeholders make the supply chain run like clockwork. In the oil and gas industry, Generative AI is a groundbreaking tool that can transform how oil and gas experts tackle tasks, interpret data, and convey intricate concepts.
- *Natural Language Processing (NLP) and Computer Vision*: Interpret human language and visual data for tasks like report generation and quality control.
- *Edge AI*: Processes data locally on IoT devices without relying on cloud storage or Internet connectivity.
- *Intelligent Robots*: Robots designed with AI capabilities for hydrocarbon exploration and production, to improve productivity and cost-effectiveness while reducing worker risk.
- *Virtual Assistants*: Online chat platform that helps customers navigate product databases and processes general inquiries using natural language.

Figure 7 shows AI use cases in oil and gas sector [9].

BENEFITS

AI in the oil and gas industry brings numerous benefits, including enhanced efficiency, cost reduction, and improved safety. Artificial intelligence technology is being put to use in certain highly specific applications. By processing and analyzing the

big data, AI algorithms are now aiding us in solving complex problems. When utilized together, AI and big data solutions have an almost limitless range of potential applications and can optimize a wide variety of operations within the energy sector to deliver improved efficiency, reliability, and sustainability. AI helps oil and gas companies assess the value of specific reservoirs, customize drilling, and completion plans according to the geology of the area, and assess risks of each individual well. Other benefits of AI in O&G section include the following [10].

- *Safety*: The most prevalent problem in coal mining is safety. The oil and gas industry needs to increase the need to improve safety and reduce environmental impact. The risk of injury in oil and gas plants and mines is extremely high. Failure to comply with safety rules and protocols can lead to irreversible damage to health and even death. The industry is inherently risky, and accidents can have severe consequences for both workers and the environment. AI technology can help companies improve safety by identifying potential hazards and implementing measures to mitigate them. No one has cause to worry that machine learning technology will soon replace manual labor entirely. Instead, it will make skilled workers more efficient, spare them unnecessary tasks and, most importantly, improve workplace safety.
- *Automation*: By automating routine tasks and optimizing complex operations, AI enables companies to streamline their processes and reduce operational costs. Employees’ routine tasks are being automated by AI technology, which will have the impact of freeing up time for employees to contribute more that is directly relevant to their field of expertise. AI has contributed to the development of autonomous drilling systems, which can automatically analyze and adjust drilling parameters in real time to increase efficiency and safety.
- *Monitoring*: AI computer vision solutions can monitor the workplace. They can alert management even about the smallest of regulatory deviations. The only purpose is to keep workers safe from serious harm.
- *Predictive Intelligence*: With the proliferation of sensors and other data-gathering technologies, companies have access to more data than ever before. Companies are heavily investing in AI-powered solutions that can analyze data from sensors and other sources to improve efficiency and minimize downtime. AI technology can help

companies make sense of this data and extract insights that can inform decision-making and drive operational improvements. Predictive intelligence allows engineers to convert cross-sourced historical and real-time data into actionable insights for drilling preparation.

- *Predictive Maintenance:* AI-powered predictive maintenance models have revolutionized operations in the oil and gas industry. It enables the implementation of condition-based maintenance methods for critical infrastructure. Using machine learning techniques, AI can predict failures and perform predictive maintenance on key equipment and machinery. This helps reduce operating costs and minimize unplanned downtime.
- *Operations Optimization:* AI can analyze vast amounts of operational data, such as pressure, temperature, and flow measurements, to identify hidden patterns and trends. This allows companies to streamline their operations and improve production efficiency.
- *Image and Video Analysis:* AI enables automated analysis of images and videos captured in the oil field, making it easier to detect anomalies, leaks, and damage, thereby improving risk management and safety.
- *Optimizing Hydrocarbon Recovery:* AI can improve reserve estimation accuracy and help optimize production strategies, leading to greater hydrocarbon recovery and more efficient exploitation of reservoirs.
- *Emissions Reduction:* By improving efficiency in energy production and consumption, AI can help reduce greenhouse gas emissions associated with the oil and gas industry.
- *Risk management:* AI can analyze real-time and historical data to assess risk and assist in strategic decision making to protect infrastructure and assets in risky situations.
- *Cost Reduction:* The oil industry faces formidable challenges to reduce costs, including volatile oil prices, escalating operational expenses, and the need for substantial investments in new technologies. Work in upstream oil and gas industries was once considered highly labor-intensive, but AI has helped change this perspective. Companies are now maximizing production while minimizing costs, all thanks to AI-powered process automation and predictive maintenance.
- *Greater Decision-Making:* In mining, fast and accurate decision-making is crucial. AI is the bridge between decision-makers and accurate data trends. Operators can use AI to make better exploration and production decisions, and optimize acquisition strategies with better forecasts of lease transaction prices. Critical decisions can now be made much faster and more accurately.
- *Innovation and Improvement:* AI technologies, including machine learning and predictive analytics, are revolutionizing traditional practices in oil and gas. By automating data analysis and operational processes, AI enables companies to innovate in areas such as exploration, drilling, and production.
- *Better Customer Experience:* The oil industry faces significant challenges in delivering exceptional customer experiences. AI enhances customer interactions by improving service delivery and responsiveness. Oil companies can utilize AI to predict customer needs and streamline supply chain operations, ensuring timely delivery of products.
- *Competitive Advantage:* The adoption of AI provides a significant competitive edge by enabling companies to operate more efficiently and make data-driven decisions. AI helps in optimizing resource allocation, predicting market trends, and enhancing operational agility, which is crucial for staying ahead in a highly competitive market.
- *Environmental Protection:* AI plays a crucial role in promoting sustainability within the oil and gas sector by optimizing processes to reduce emissions and improve energy efficiency, AI helps companies adhere to environmental regulations. Many oil and gas companies are actively seeking to reduce their carbon footprint and make their operations greener, and AI comes to the forefront in these endeavors.

Some of these benefits or advantages are summarized in Figure 8 [11].

CHALLENGES

While some oil and gas companies, like BP, Shell, Saudi Aramco, and Gazprom Neft are jump-starting their AI initiatives by investing aggressively in startups and R&D, several challenges are preventing them to massively and rapidly implement AI in the exploration and production of oil and gas. AI initiatives will not fail because of bad algorithms, but rather because of lack of vision, late or even no changes in the organization's operational and business

model, due to lack of high-resolution data and poor collaboration. Other challenges of AI in O&G section include the following [7]:

- *Experts:* The success of artificial intelligence critically depends on human intelligence. To actively use AI in processes and products, companies must grow in-house teams composed of data and AI specialists. This means that oil and gas companies will become (partially) data-driven companies and, that AI specialists will become irreplaceable in supporting almost all innovation efforts in oil and gas companies in the future.
- *Shortage of Talents:* Finding and retaining AI talent is a challenging task. There is a significant shortage of AI talent on the job market, and with more and more companies getting into AI and forming their own AI groups, prospects are not good for the next decade. This is especially true for oil and gas companies. Hundreds of thousands of Baby Boomers heading into retirement at the same time when fewer and fewer young people have chosen to major in areas like petroleum engineering, geology, and other key areas of expertise relevant to the industry.
- *Partnership:* Next to working more with data and data scientists, petroleum engineers will have to learn how to work with AI assistants – products similar to Alexa and Siri, but focused on industry applications. In these new partnerships, the challenge will be to combine best from the two sides. AI is expected to be dominantly used by humans to augment their decision-making abilities rather than replace them.
- *Quality Data:* AI tools need the good quality data of a suitable volume to be trained and then to work properly in the operational mode. Access to big and quality data is a crucial enabler and barrier for AI applications' successful development. Oil and gas fields generate large amounts of raw data. Still, it is not a guaranty for success as there are known issues with the quality and accuracy of field data and overall lack of large volumes of labeled data in the oil and gas industry. To enhance the value of data oil and gas companies possess or can access, they will have to redesign and adjust their organizational structures and processes.
- *Collaboration:* Artificial intelligence is born in open and collaborative environment as a consequence of academia being a leading force in AI research for decades, almost without any business influences. This created culture of free sharing. Oil and gas companies are not famous for their joint industry projects, especially between competitors and especially not in strategic domains such as AI. They have to embrace open collaboration as a standard to succeed in the era of AI once they join the race. The need to acquire the latest AI technology and talent are additional reasons for oil and gas companies to adopt open collaboration.
- *Cybersecurity:* The integration of AI systems increases vulnerability to cyber threats, as interconnected systems can expose sensitive operational data. The rise in the number of physical and cyberattacks and its security spending have necessitated the need for artificial intelligence tools to encrypt the working system into their enterprise's security. Video cameras as sensors help in monitoring the security threats in the utilities all day.
- *Cultural Resistance:* The oil and gas industry is traditionally conservative, leading to resistance among employees and stakeholders towards adopting AI technologies. This cultural inertia can hinder innovation and the effective implementation of AI solutions. Employees may be reluctant to embrace new technologies, fearing job displacement or unfamiliarity with AI-driven processes. Customer preferences and expectations may also resist changes to established practices.
- *Regulatory Compliance:* Navigating the complex regulatory landscape is a major challenge for AI deployment in the oil and gas sector. Companies must ensure compliance with various regulations concerning data privacy, environmental standards, and safety protocols. With the global energy demand escalating, companies in the oil and gas field face growing demands to boost operational efficiency, cut expenses, and adhere to safety and environmental regulations.

Some of these challenges are summarized in Figure 8 [11].

CONCLUSION

AI is an exciting and diverse scientific field. If deployed ethically and properly, it has the potential to positively impact every field of endeavor. The integration of artificial intelligence into the oil and gas industry represents a pivotal shift towards addressing the complex challenges of today's energy landscape. The O&G industry has been increasingly adopting AI technology in recent years, and this trend is expected to continue. It recognizes the power and impact that artificial intelligence can have on the industry's performance. The Oil and Gas Authority (OGA) is deploying AI in many ways, which will

assist them in discovering new oil & gas projections and enhance production from existing infrastructures. More information on artificial intelligence in O&G industry is available from the books in [12-18] and the following related journals:

- Energy and AI
- The AI Journal

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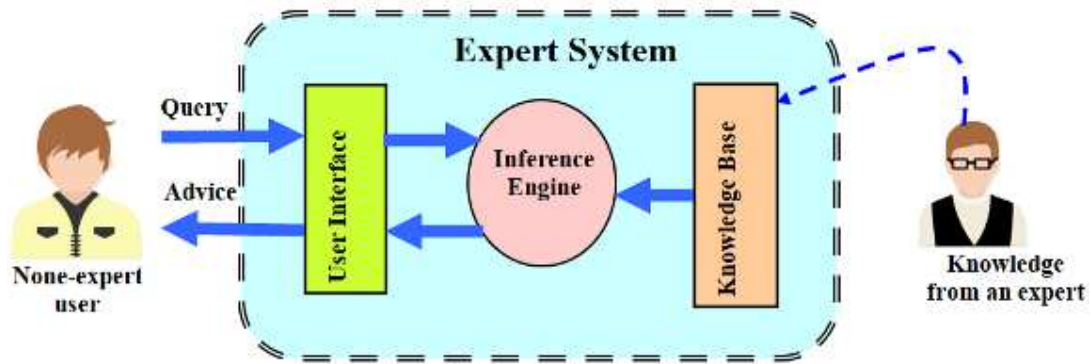


Figure 1 A typical expert system.

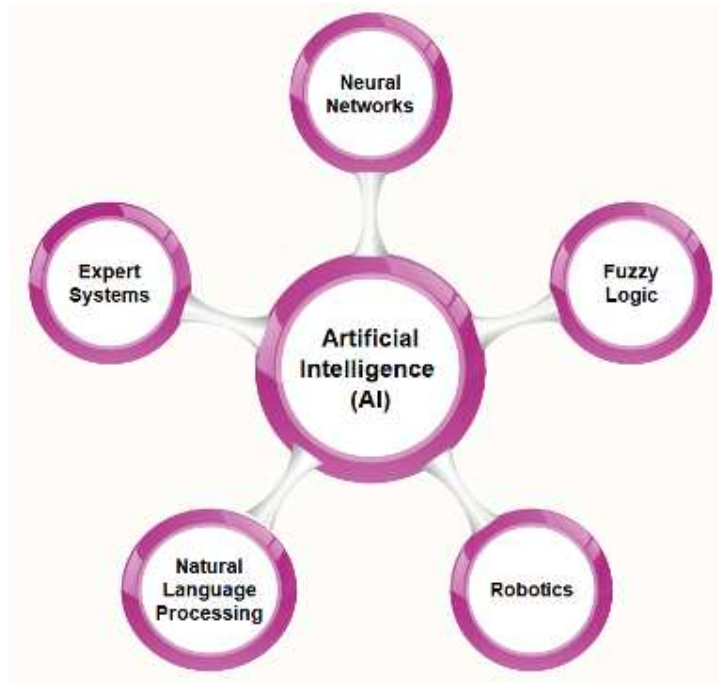


Figure 2 AI tools.



Figure 3 Concept illustration for the use of AI for production [5].



Figure 4 The complexity of the oil and gas industry [6].

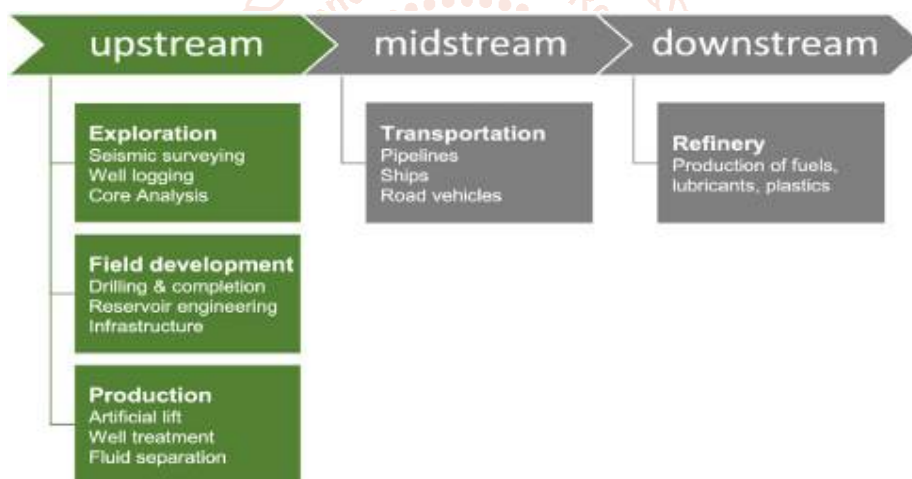


Figure 5 The oil and gas industry divides into upstream, midstream, and downstream [7].

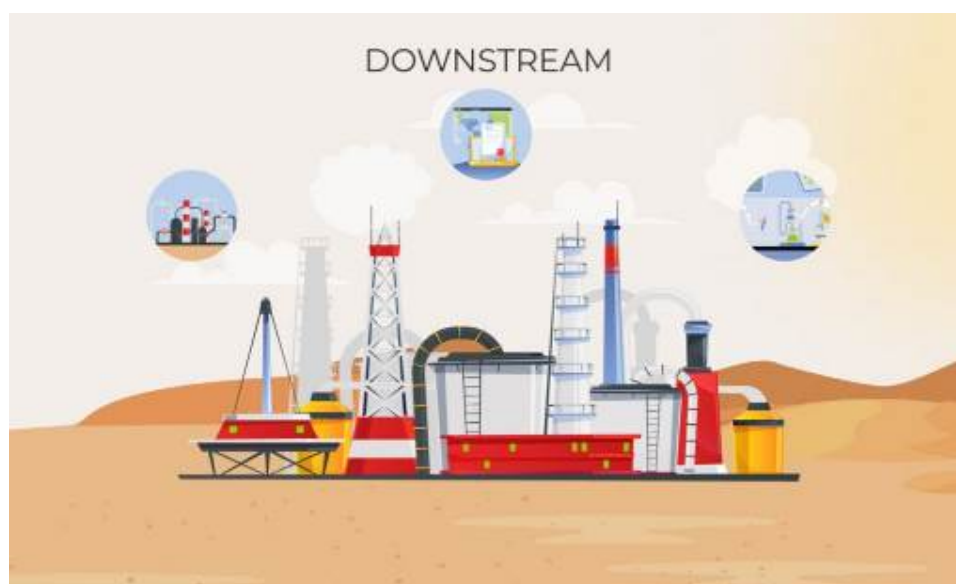


Figure 6 A downstream operation [8].

Artificial Intelligence Use Cases in Oil and Gas



Figure 7 AI use cases in oil and gas sector [9].



Figure 8 Some of the advantages AI in O&G operations [11].



Figure 9 Some of the challenges of AI in O&G industry[11]