Chapter 21

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Harnessing Artificial Intelligence and Big Data for Innovation and Sustainability in the Oil and Gas Industry

Nazila Ragimova[1], Vugar Abdullayev[1], Bahar Asgarova[1], Mahbuba Shirinova[1], Vusala Abuzarova[1]

[1]Azerbaijan State Oil and İndustry University. Baku, Azerbaijan.

ABSTRACT

The oil and gas industry has a significant political and economic weight in a number of countries around the world. Therefore, the issue of improving management methods in this industry is considered relevant. For this purpose, the article provides a number of basic characteristics of the object. Then, the issues of using scientific innovations that are or can be applied in the management of the oil, petrochemical and gas industries, including the use of various areas of artificial intelligence, are considered. The use of a large amount of data in the management of this industry is inevitable. The article is devoted to the use of artificial intelligence and big data in the oil and gas industry.

Keywords: Oil and Gas Industry; Artificial Intelligence; Management; Big Data.

INTRODUCTION

First, let's briefly describe the main characteristics of the facility. As we know, oil, as well as the petrochemical and gas industries, have a significant political and economic weight in a number of oil and gas producing countries of the world. The oil and gas industry includes the extraction, storage, transportation, processing, sale and resolution of other issues of crude oil. Work in this area begins with geological exploration. After oil or gas is extracted, it is transported to a refinery. Here, after a series of "testing" procedures, the oil is separated into several products that are directly used as raw materials in industry after the first distillation. After this, re-distillation, hydrotreating and deep cleaning are carried out.[1,2,3] The result is the following: several types of fuels such as petroleum oils, diesel, automotive, jet, aviation, gas turbine, boiler fuel and so on. Natural gas extraction involves extracting gas from the earth's crust using wells, while processing includes the processes of cleaning, transporting, and preparing raw gas for use.

Petrochemical products include the following substances, which mainly belong to three classes: hydrocarbons, sulfur compounds and naphthenic acids.

The main raw materials for the production of petroleum products are hydrocarbons. The simplest of these products are methane, ethane, propane and butane. Ethane, propane and butane are paraffins and are subsequently converted into olefins by chemical processing. Aromatic hydrocarbons include benzene, toluene and xylene.

Methane processing produces methanol, ammonia and methyl chloride compounds. These are used, respectively, to produce antifreeze, ammonia fertilizers, and acids.

Ethylene or ethyl alcohol is extracted from hydrocarbons in large quantities, which is then

used to produce polymers, solvents and chemical fibers.

Other products are obtained as a result of complex chemical reactions. Their derivatives are mainly raw materials or intermediates for fuels, lubricants, and explosives.

In the modern oil industry, crude oil is not used in the form in which it is extracted from the well. This is the raw material that goes directly to the oil refinery.

Transportation is most often carried out by pipeline or tankers. Since oil has a very complex composition, which depends on the conditions of its formation, different types of oil are distinguished. In addition, any of the types is always divided into several fractions, depending on the density characteristics and boiling point.[4]

Fractionation allows you to determine the distillation methods and the amount of products that can be obtained from a particular type of crude oil.

All these processes are carried out in factories in laboratory conditions, which is a rather complicated process, despite the modern level of science and technology, the knowledge that a person has and can apply in practice.

Only then is rectification carried out - the separation of the raw material into gasoline, kerosene, paraffin, lubricating oils, ligroin, fuel oil, gas oil and other components.[5]

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Currently, scientists are investigating alternative sources of hydrocarbons, in particular, gas hydrate emissions in the seas. The main promising areas of chemical oil refining include: expanding the raw material base; maximum use of oil production waste; improving exploration and production technologies; using alternative raw material sources.

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The use of artificial intelligence in this type of enterprise allows the following to be achieved: optimization of production processes, management of equipment and devices, market management, risk management, production design, etc.

Currently, the application of Artificial Intelligence in the oil and gas industry is developing rapidly, as the concept of artificial intelligence is gradually integrated into various stages of the industry, such as smart drilling, smart production, smart pipeline, smart processing, etc. With artificial intelligence algorithms, developers have developed a series of practical application technologies in exploration and development. The use of ANN method in the exploration field has already achieved good results in reducing exploration risks and improving the success rate of exploration wells.[7] In the drilling field, new equipment such as automatic drilling rig and smart drill pipe have improved the drilling level and significantly reduced the cost.[8] In oil field development, optimization of the development plan based on historical oil field production data is the main application mode of Artificial Intelligence technology.[9,10,11]

In order to optimize production processes, the company is faced with the need to make many management decisions every day, which affects the economic efficiency of the company. Entrusting such decisions to artificial intelligence can significantly reduce the chance of error and improve quality.

As we have noted, work in the oil industry begins with geological exploration, and then with the extraction of crude oil. Here, using artificial intelligence, attempts should be made to solve the problems of developing “smart wells”, optimizing the geological exploration and production process.

Machine learning[6] algorithms are used to determine the exact location of individual devices and equipment used in the oil and gas industry and to monitor them. Sensors help detect malfunctions and accidents.

Artificial intelligence is also used to optimize oil and gas extraction processes. The analysis of information used in the process opens up wide opportunities for reducing costs and using green technologies. To achieve this, seismic and geological information received from sensors and various monitoring systems is processed, and the volume of oil or gas produced over a certain period of time is automatically determined. This also plays an important role in forecasting in this area.

For example, neural networks help LUKOIL stabilize production in mature fields.[2] Artificial

intelligence algorithms allow for maximum use of reservoir potential and infrastructure capabilities by optimizing equipment performance.

As mentioned, the modern concept of artificial intelligence in the oil and gas industry is mainly associated with machine and deep learning algorithms. This allows them to apply the knowledge gained from training to large data sets. Unlike a control system with manually coded instructions to perform specific tasks, artificial intelligence provides the control system with the opportunity to independently learn to recognize new situations, make predictions and suggest the most optimal solutions to problems. Of course, artificial intelligence cannot solve these problems without the necessary devices and equipment. Of course, devices and equipment do not require small costs.

Computer vision, a specialized area of artificial intelligence, can be used to radically improve the management of these operations. From vast networks of pipelines snaking beneath the ground to towering drilling rigs extracting oil from miles beneath the earth, computer vision offers a new perspective on the industry. Figure 1 depicts the segments of the oil and gas industry.[1]

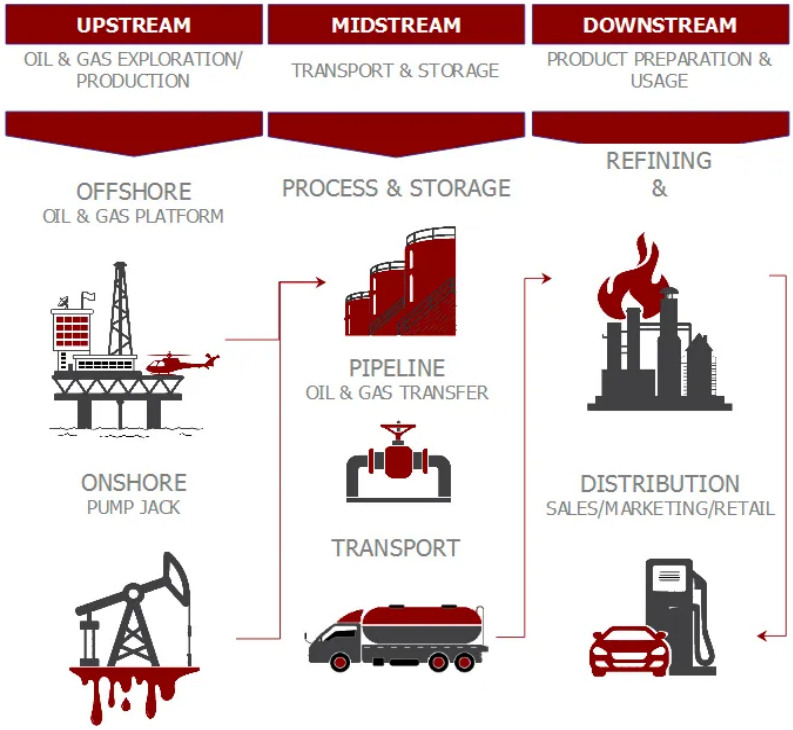


Figure 1. Segments of the oil and gas industry

The oil and gas industry can be divided into three main segments: exploration and production (extraction), transportation and storage, and refining and marketing. The first segment of oil and gas is exploration and production. Geologists and engineers search for oil and gas deposits, then drill them out from under the ground and extract them. Then comes the transportation and storage segment. This segment transports natural gas, mainly through pipelines, and crude oil, mainly through pipelines, tankers, and trucks, to refineries or storage tanks. Finally, refining and

marketing companies convert crude oil and natural gas into useful products such as gasoline, diesel fuel, jet fuel, and various petrochemicals.

Computer vision can be applied to every segment of the oil and gas industry. Almost anywhere a camera can monitor an operation, computer vision can intervene and improve efficiency. Various computer vision tasks such as object detection, image segmentation, and object tracking can be used to extract valuable information from visual data.

Let's look at a few examples of how computer vision can be applied to every segment of the oil and gas industry.

During the drilling process, computer vision can be used to analyze video footage from a camera-equipped well. By identifying the characteristics of the rock formations encountered, AI can help optimize the location and trajectory of the wellbore to maximize production from each oil well.

The main applications of AI in the oil and gas industry include the following:[4]

- In oil exploration, AI algorithms analyze seismic data to predict the presence of oil and gas with high accuracy.
- For example, Shell uses AI to interpret geological data and accelerate the discovery of new resources by 30 %.
- In production optimization, AI predicts equipment wear and prevents accidents. "Digital twins" of oil fields simulate different production scenarios and select the optimal one.
- In logistics and oil refining, AI plans transport routes taking into account weather and demand. Neural networks in oil refineries monitor fuel quality and reduce failure rates.
- In ecology and safety, AI monitors emissions and helps companies comply with ESG standards. Drones with AI analytics quickly detect pipeline leaks.

ESG (Environmental, Social, Governance) standards[5] are a set of criteria covering environmental, social and governance aspects to assess the sustainability and responsibility of companies. These standards help measure a company's impact on the environment, its treatment of its employees and society, and the transparency of its corporate governance practices.

Drones equipped with cameras and computer vision can be used to autonomously scan miles of pipelines, detecting leaks, cracks and corrosion in pipelines in incredible detail. This can replace risky manual inspections and reduce the costs associated with downtime for repairs.

Oil refineries and petrochemical plants are complex systems with multiple processes that require monitoring. Computer vision can analyze video feeds from cameras in these facilities to identify inefficiencies or potential equipment failures. It also provides for the reception, pre-processing, and transmission of information from transmitters and other devices.

For example, Ultralytics YOLOv8[3] supports multiple computer vision tasks and can be used to create innovative solutions in the oil and gas industry.

YOLOv8 is a computer vision model architecture developed by Ultralytics. You can deploy YOLOv8 models on a wide range of devices, including NVIDIA Jetson, NVIDIA GPUs, and macOS

systems, using the open-source Python package Roboflow Inference to run your vision models.

Another example is vapor detection and segmentation using Ultralytics YOLOv8 (figure 2).

YOLOv8 supports the task of sample segmentation in computer vision.

Storage Tank Detection with YOLOv8-OBB (Oriented Bounding Box) - Tanks are used in the oil and gas industry to store crude oil, petroleum products, and other materials. The integrity and proper maintenance of these tanks are essential to prevent leaks, contamination, and other safety hazards.

The YOLOv8-OBB (Oriented Bounding Box) model is specifically designed to detect and localize objects with arbitrary orientations. It is ideal for identifying storage tanks from the air. Once a tank is detected, further processing can be performed to segment the tanks from the background and even identify specific features such as rust spots or structural deformations. Automated detection processes can better support the safety and efficiency of storage operations.

Big data analytics helps in regulating the major oil and gas operations such as exploration, drilling, production and supply in three sectors – upstream, midstream and downstream. Among all the business segments, upstream segment is the most dominant segment due to the increasing use of big data analytics for unconventional shale gas discovery. Moreover, volatile oil prices are increasing the uncertainty in the oil and gas business. Thus, organizations are adopting a data-driven approach to minimize their risks. Next, downstream is expected to be the second-largest segment due to the increasing use of product analytical solutions that help refineries standardize the chemical composition of finished products.[12]

As in other industries, the oil and gas industry must consider six key criteria or six "V" characteristics of Big Data.

1. Volume: at least 150 GB of data should be collected per day.
2. Velocity: the enterprise should be provided with the required increased computing power (virtual or physical) to work with data arrays in real time.
3. Variety: the incoming information has different formats or levels of structure. For example, social media content can be very different even on the same page.
4. Veracity: the data sources can be trusted and the results of their processing are reliable enough to make decisions.
5. Variability: the flow of data is variable, it can even be affected by the time of day or weather conditions. For example, during rush hour, more data comes from taxi drivers.
6. Value: data can have different meanings for the company. For example, transactions with large buyers are considered more important than transactions with small buyers.

Big data software for the oil and gas industry collects and analyzes data from multiple sources, both in real-time and in batch mode, i.e., on a specific calculation schedule (e.g., every 12 hours, every 24 hours, every week). The real-time component allows for response to events (e.g., shutting down equipment during an oil spill, adjusting drilling fluid pressure), while the batch layer is responsible for comprehensive historical analytics (e.g., drilling patterns).[13]

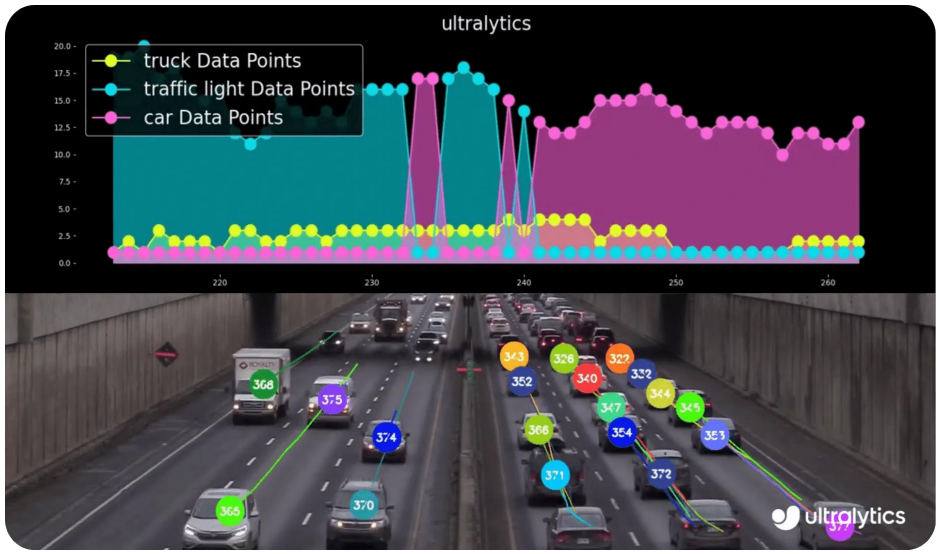
Applications of Big Data in the oil and gas industry fall into various categories:[14]

- Exploration management: here, mainly geophysical, seismic and geochemical data sets are used.

- Reservoir engineering: here, data sets such as pressure, temperature and fluid composition are used.
- Drilling management: here, data sets for monitoring and analyzing velocity, pressure and temperature are used.
- Production management: here, sensor and automation data sets are used. In short, the analysis of all the general data is used to manage the various sub-areas, and finally the overall management level is organized.

In general, the potential applications of Big Data in the oil and gas industry are as follows: Exploration Seismic data analysis, Microseismic data exploration, 1D, 2D and 3D geological mapping, Closed Reservoir Management, asset modeling, Reservoir modeling, Enhanced oil recovery, Automated production decline analysis, Engineering Production sharing techniques, forecasting, Well casing damage prediction, Remote smart oilfield management, Pipeline monitoring and repair, Transportation Energy efficiency improvement, Downstream Oil Asset management, Well productivity management, Health and Safety, Safety forecasting, Trade and Market volatility analysis, Sales Crude oil price forecasting, etc.[15]

High efficiency is also achieved when YOLOv8 is used for vehicle tracking and monitoring at oil and gas facilities.



Source: [16]

Figure 2. Vapor detection and segmentation using Ultralytics YOLOv8

Artificial intelligence, particularly computer vision and models like YOLOv8, is transforming operations in the oil and gas industry. Computer vision can improve intelligence and maintenance through use cases such as steam detection and vehicle tracking.

Now let's explain the rules for working with Big Data.

Before starting to create a database, it is necessary to determine which technologies will be used to collect, store, process and analyze data.

Collection: it all starts with the collection of information, identification of its sources and

integration of the necessary processing technologies. It is also important that data cleaning specialists who set up filters for further analysis participate in the process.

Storage: since even a few computers are not enough for large volumes of information, companies resort to the services of cloud providers and use distributed computing power. At the same time, new technologies (Data Vault, Data Lake, Data Mart) should be used for storage:

Processing: MapReduce technology is more often used for processing large volumes of data.

Analysis: at this stage, it is necessary to get the most useful and valuable from the entire data warehouse. A number of analytics are used in the process. Analysts help to find hidden patterns and develop solutions to improve the product.

CONCLUSIONS

In the modern world, the most important factor for the collection, storage, processing and analysis of data for decision-making in the oil and gas industry is considered to be the most important. Here, the correct and efficient use of new information technologies is an important requirement. Also, by analyzing big data, ways to collect, process, store, transmit information about the management object in the oil and gas industry and the ability to use this information are obtained.

YOLOv8-OBB, which is specially designed to detect and localize objects of arbitrary orientation, should be used.

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Conceptualization: Nazila Ragimova, Vugar Abdullayev, Bahar Asgarova, Mahbuba Shirinova, Vusala Abuzarova.

Data curation: Nazila Ragimova, Vugar Abdullayev, Bahar Asgarova, Mahbuba Shirinova, Vusala Abuzarova.

Formal analysis: Nazila Ragimova, Vugar Abdullayev, Bahar Asgarova, Mahbuba Shirinova, Vusala Abuzarova.

Drafting - original draft: Nazila Ragimova, Vugar Abdullayev, Bahar Asgarova, Mahbuba Shirinova, Vusala Abuzarova.

Writing - proofreading and editing: Nazila Ragimova, Vugar Abdullayev, Bahar Asgarova, Mahbuba Shirinova, Vusala Abuzarova.