

Artificial Intelligence - Data Capture and Back-Office Measurement Applications

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INTRODUCTION

The Oil and Gas industry is incorporating Artificial Intelligence (AI) technologies to improve their operational efficiency, reduce costs, and enhance safety.

Artificial Intelligence

Artificial Intelligence (AI) can be categorized in various ways, depending on the criteria used for classification. Here are some common types of AI:

- **Based on capabilities:**
 - *Narrow AI (Weak AI):* AI systems designed for specific tasks, such as virtual assistants, recommendation systems, or image recognition software.
 - *General AI (Strong AI):* AI systems that possess human-like intelligence and can perform a wide range of tasks, such as problem-solving, learning, and understanding natural language. General AI has not yet been achieved.
- **Based on learning methods:**
 - *Supervised Learning:* AI models learn from labeled data by mapping input-output pairs. Examples include regression and classification algorithms.
 - *Unsupervised Learning:* AI models learn from unlabeled data by identifying patterns and structures within it. Examples include clustering and dimensionality reduction algorithms.
 - *Reinforcement Learning:* AI models learn from interacting with an environment and receiving feedback in the form of rewards or penalties. Examples include Q-learning and Deep Q-Networks (DQNs).
- **Based on architectures:**
 - *Symbolic AI (GOF AI - Good Old-Fashioned AI):* AI systems based on symbolic reasoning and manipulation, such as expert systems, rule-based systems, and logic programming.
 - *Connectionist AI:* AI systems based on neural networks that mimic the structure and function of the human brain. Examples include feedforward neural networks, recurrent neural networks (RNNs), and convolutional neural networks (CNNs).
 - *Evolutionary AI:* AI systems based on genetic algorithms, genetic programming, and other evolutionary computation techniques that simulate natural selection and evolution.
 - *Hybrid AI:* AI systems that combine different approaches, such as integrating symbolic AI with neural networks or incorporating evolutionary algorithms into connectionist AI.
- **Based on application areas:**
 - *Natural Language Processing (NLP):* AI techniques used to understand, generate, and analyze human language, including text and speech.
 - *Computer Vision:* AI techniques used to analyze and interpret images, videos, and other visual data.
 - *Robotics:* AI techniques used to create intelligent, autonomous robots that can navigate and interact with their environments.
 - *Expert Systems:* AI techniques used to create systems that can make decisions or provide recommendations based on expert knowledge. e. *Game AI:* AI techniques used to create intelligent agents and opponents in video games and simulations.

These are just a few ways AI can be classified, and many AI systems can fall into multiple categories.

Measurement Data Capture and Back-Office Measurement

Measurement data capture and back-office measurement are essential processes in the oil and gas industry that involve the collection, analysis, and management of data related to the production, transportation, and sale of hydrocarbon products. These processes ensure the accurate quantification of oil and gas volumes, which is crucial for operational efficiency, financial management, and regulatory compliance.

- **Measurement data capture** refers to the process of collecting, recording, and transmitting data from various points in the oil and gas value chain. This data is typically acquired from sensors, meters, and other devices installed at production sites, pipelines, and storage facilities. The data collected includes flow rates, pressure, temperature, and other parameters critical to the operation and monitoring of oil and gas assets.

Key aspects of measurement data capture include:

- *Metering and instrumentation*: Accurate metering devices and instrumentation are essential for collecting reliable data. These can include flow meters, pressure transmitters, temperature sensors, and gas analyzers, among others.
 - *Data acquisition systems*: These systems collect and store data from the field devices, often in real-time. They may be centralized or distributed, depending on the scale and complexity of the operations.
 - *Data communication and transmission*: Information from data acquisition systems is transmitted to remote locations for further processing, analysis, and decision-making. Data communication can occur through various means, such as satellite, wireless, or wired networks.
- **Back-office measurement** refers to the set of processes that involve the management, analysis, validation, and reporting of the measurement data collected from the field. This typically occurs at a central location where data from multiple sources is consolidated, processed, and used for various purposes, such as billing, allocation, loss detection, and regulatory reporting.

Key aspects of back-office measurement include:

- *Data validation and reconciliation*: Data quality is of utmost importance in the oil and gas industry. Back-office measurement includes checking the collected data for errors, inconsistencies, and potential discrepancies, and reconciling any differences to ensure accuracy.
- *Allocation and reporting*: The validated data is used to allocate volumes of hydrocarbon products to various stakeholders, such as producers, transporters, and customers. This process involves dividing the measured quantities among the parties involved, based on ownership, contracts, or regulatory requirements. Accurate allocation and reporting are crucial for financial management and compliance with regulations.
- *Trend analysis and forecasting*: Back-office measurement also involves analyzing historical data to identify trends, patterns, and anomalies, which can inform decision-making and support forecasting for production, transportation, and sales.

In summary, measurement data capture and back-office measurement are vital processes in the oil and gas industry that ensure the accurate quantification and management of hydrocarbon volumes, supporting efficient operations, financial management, and regulatory compliance.

AI Applications for Measurement Data Capture and Back-Office Measurement

Artificial intelligence (AI) is increasingly being used in the oil and gas industry to improve measurement accuracy, reduce costs, and increase operational efficiency. Here are some ways AI is being used in oil and gas measurement:



Figure 1. AI-generated Image: Technician Viewing Virtual Pipeline

- **Predictive Maintenance:** AI can be used to analyze data from sensors and other measurement devices to predict when equipment will require maintenance, reducing downtime and maintenance costs.

A real-world example of AI being used to predict sensor failure in natural gas measurement can be found in the operations of gas distribution companies, such as Pacific Gas and Electric (PG&E). PG&E, in collaboration with AI solution providers, has developed a predictive maintenance system to monitor and detect potential sensor failures in their gas distribution networks.

The AI-driven predictive maintenance system works as follows:

- *Data Collection:* PG&E collects data from various sensors installed throughout the natural gas distribution network. These sensors monitor factors like pressure, temperature, and gas flow rates. Historical data on previous sensor failures and maintenance records are also considered.
- *Data Preprocessing:* The raw data is cleaned, normalized, and structured, ensuring that it is suitable for analysis by the AI algorithms.
- *Feature Engineering:* Key features are extracted from the data, such as trends, anomalies, and patterns that may indicate potential sensor failure or malfunction.
- *Machine Learning Model:* A machine learning model, such as a neural network or decision tree, is trained on the preprocessed data and the extracted features. The model learns to identify patterns and relationships between the sensor data and the likelihood of sensor failure.
- *Prediction:* The trained model analyzes the real-time sensor data and provides predictions on the probability of sensor failure or malfunction. If the model predicts a high likelihood of sensor failure, the system alerts the operators and maintenance personnel.
- *Maintenance Scheduling:* Based on the AI-driven predictions, maintenance teams can proactively schedule sensor replacement or repair, minimizing the impact of sensor failure on the gas distribution network.

By implementing this AI-driven predictive maintenance system, PG&E can effectively monitor the health of the sensors in their natural gas distribution network. This helps them to prevent issues related to sensor failure, such as gas leaks, pressure imbalances, and service disruptions, while also reducing maintenance costs and improving overall network efficiency.

- **Real-time Monitoring:** Similar to predictive maintenance, AI can be used to monitor oil and gas pipelines and other equipment in real-time to identify potential problems before they become serious and cause damage or loss of production.

A real-world example of AI being used to monitor gas pipelines and facilities using measurement sensors can be found in Enbridge, a leading North American energy infrastructure company. Enbridge partnered with an AI solutions provider to develop a system that leverages machine learning algorithms and sensor data to monitor and maintain the integrity of their extensive natural gas pipeline network.

The AI-driven monitoring system involves the following steps:

- *Data Collection:* Enbridge collects data from a wide array of sensors installed throughout their natural gas pipeline network and facilities. These sensors measure factors such as pressure, temperature, flow rates, and acoustic data (to detect leaks). Additional data sources like satellite imagery, weather data, and geographic information are also considered.

- *Data Preprocessing*: The raw data from the sensors and other sources are cleaned, normalized, and structured to ensure that it is suitable for analysis by the AI algorithms.
- *Feature Engineering*: Relevant features are extracted from the data, such as trends, anomalies, and patterns that may indicate potential issues like leaks, corrosion, or equipment malfunction.
- *Machine Learning Model*: A machine learning model, such as a neural network or decision tree, is trained on the preprocessed data and the extracted features. The model learns to identify patterns and relationships between the sensor data and potential pipeline or facility issues.
- *Anomaly Detection*: The trained model continuously analyzes the real-time sensor data and detects any anomalies or deviations from normal patterns. Anomalies could indicate potential problems, such as gas leaks, pipeline corrosion, or equipment failure.
- *Alert System*: If the AI-driven monitoring system identifies an anomaly, it alerts the operators and maintenance personnel to investigate and address the issue. This allows Enbridge to take proactive measures to mitigate risks and prevent incidents.
- *Continuous Improvement*: The AI model is continuously updated with new data, allowing it to adapt and improve its predictions and anomaly detection capabilities over time.

By implementing this AI-driven monitoring system, Enbridge can maintain the safety and integrity of their natural gas pipeline network and facilities more effectively. This helps them prevent incidents like gas leaks, pipeline ruptures, and equipment malfunctions, leading to reduced maintenance costs, minimized environmental impact, and improved overall operational efficiency.

- **Image and Video Processing**: AI can be used to analyze images and video data from cameras and drones to detect leaks, damage, and other issues that may affect production. Analyzed images of circular charts can be converted to temperature, pressure, and volumetric data using Computer Vision.

A real-world example of Computer Vision being used with natural gas meter charts to create volumetric data can be seen in the operations of energy producers such as Vermilion Energy (Vermilion). Vermilion contracts with an AI software and service provider to use an app that allows field personnel to easily capture images of circular charts and send the images to cloud-based servers where images are converted into digital volumetric data.

The chart conversion system involves the following steps:

- *Image Capture*: Field personnel use the smartphone app to take high-resolution images of the circular charts from their natural gas meters. These charts typically display gas measurement data over a specific period (e.g., daily or monthly).
- *Image Preprocessing*: Images are submitted to cloud servers where they are preprocessed to enhance their quality and remove any noise, distortion, or artifacts. Techniques such as resizing, rotation, contrast adjustment, and edge detection are used to improve the image's clarity and readability.
- *Feature Extraction*: Computer vision algorithms extract relevant features from the preprocessed images, such as the chart's scale, the position of the pen or pointer, and the metered data represented by the circular chart's trace.

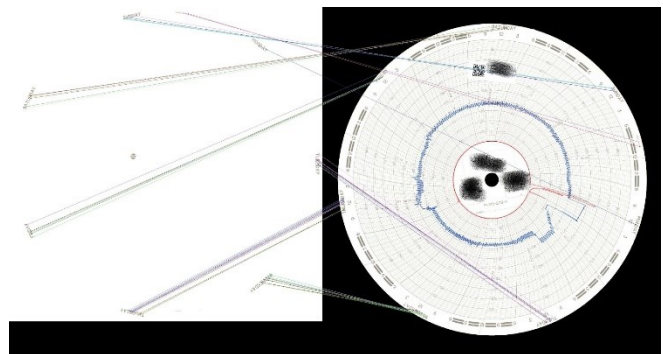
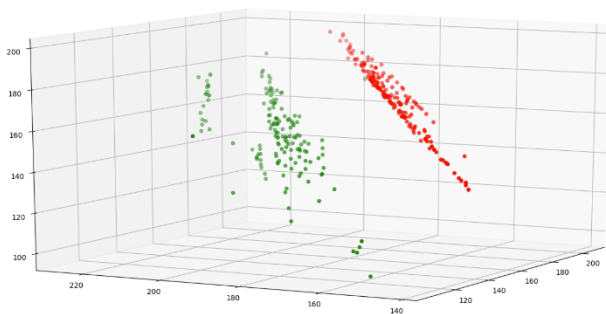


Figure 2. Computer Vision Chart Image Feature Extraction

- *Data Conversion:* The extracted features are processed to calculate the volumetric gas measurement data. This involves converting the circular chart's trace into a time series of gas measurement values, which can then be used to determine the total volume of gas measured during the specified period.

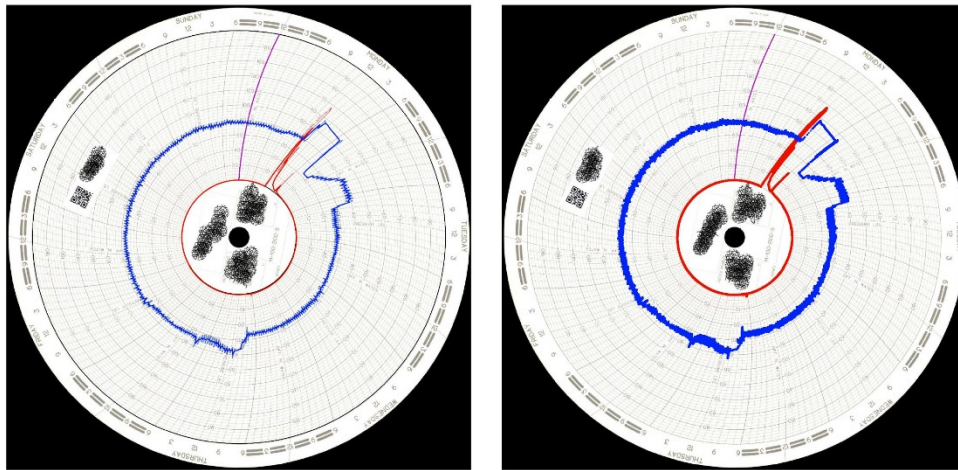


Figure 3. Computer Vision Chart Image Process Variable Tracing

- *Data Validation:* Users can then review and validate the calculated volumetric data before submission. This ensures the accuracy and reliability of the data.
- *Data Submission:* Once validated, the converted volumetric data are reported to production accounting via automated and manual methods.

By using the chart capture app, companies can efficiently and accurately convert circular chart images into usable volumetric data. This streamlines the billing process, reduces manual reading errors, and empowers companies to better understand and manage their gas measurement systems. Additionally, the digital transformation of gas meter data helps companies optimize distribution and resource management.

- **Machine Learning:** AI can be used to train machines to recognize patterns in data, which can help to identify trends and anomalies in oil and gas measurements. This can help to ensure data quality.

Random Forest and Decision Trees are popular machine learning algorithms that can be employed to replace incorrect or missing natural gas measured volumetric data. Here are examples of how these techniques can be applied:

- *Decision Trees:* Decision Trees are a type of algorithm that can be used for both regression and classification tasks. In the context of natural gas volumetric data, a Decision Tree Regressor can be used to predict missing or incorrect data points. To accomplish this, historical data containing correct volumetric measurements, as well as relevant features (e.g., time, temperature, pressure, and flow rate), can be used to train the model. Once trained, the model can be applied to the dataset with missing or incorrect values to generate predictions and replace the problematic data points.
- *Random Forest:* Random Forest is an ensemble learning method that builds multiple Decision Trees and combines their predictions to produce a more accurate and robust result. For replacing incorrect or missing natural gas meter volumetric data, a Random Forest Regressor can be employed. The algorithm works by training multiple Decision Trees on random subsets of the available data and features, reducing the risk of overfitting. The final prediction is generated by averaging the predictions of all the individual trees. This approach is typically more accurate than using a single Decision Tree, as it accounts for the variability and potential biases in the training data.

To illustrate the application of these techniques, consider a natural gas distribution company that records volumetric data from meters installed at various customer locations. They have noticed that some of the recorded data is either missing or likely incorrect. Using historical data, the company can train a Decision Tree or Random Forest Regressor

with features like time, temperature, pressure, and flow rate. Once the model is trained, it can be applied to the dataset to predict and replace missing or incorrect volumetric data, ensuring a complete and accurate dataset for further analysis and billing purposes.

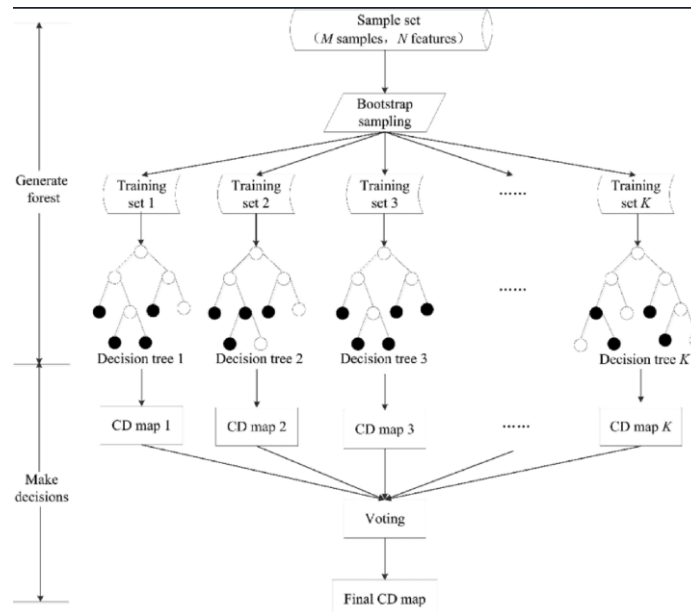


Figure 4: Flow Chart of Random Forest Classifier.

- **Virtual Assistant:** AI systems such as ChatGPT are designed for specific tasks, such as virtual assistants, recommendation systems, or image recognition software.

ChatGPT, as a language model based on the GPT-4 architecture, exists within the broader AI classification system as an example of artificial narrow intelligence (ANI) or weak AI. ANI systems are specialized to perform specific tasks or solve particular problems, and ChatGPT is designed to understand and generate human-like text based on the input it receives.

ChatGPT is built upon the transformer architecture, which is a type of deep learning model that excels at handling sequential data like text. Specifically, it falls under the category of natural language processing (NLP) models, which focus on tasks involving understanding, interpreting, and generating human language. NLP models like ChatGPT can be used for various applications, such as machine translation, text summarization, question-answering, and conversational AI.

It's important to note that ChatGPT doesn't possess artificial general intelligence (AGI) or strong AI, which would imply the ability to understand and perform any intellectual task that a human being can do. Current AI models, including ChatGPT, are still limited to specific domains and tasks.

Examples of ChatGPT uses:

- As a Reference:
 - *Prompt to ChatGPT:* Provide the gross heating value for methane as: Fuel as Ideal gas (Btu/ft³) per GPA-2145 2016.
 - *ChatGPT Response:* The gross heating value (GHV) for methane, as an ideal gas, can be found using the GPA-2145-16 standard (published by the Gas Processors Association in 2016). The standard specifies the heating values for various natural gas components, including methane, in Btu/ft³. According to the GPA-2145-16 standard, the gross heating value for methane is approximately 1,010 Btu/ft³ (British thermal units per cubic foot). This value represents the amount of heat energy released when a given volume of methane is burned completely. Keep in mind that actual heating values may vary slightly due to the presence of impurities or differences in measurement conditions.
- As a Code Generator: Example - VBA for Excel

- *Prompt to ChatGPT:* Create a way for Excel to generate a random number between 1 and 100 every time I click on a cell in the sheet.
- *ChatGPT Response:* To create a way for Excel to generate a random number between 1 and 100 every time you click on a cell in the sheet, you can use VBA's Worksheet_SelectionChange event. Open Excel and press Alt+F11 to open the VBA editor. In the Project Explorer window, double-click on the worksheet where you want this functionality. Typically, it's named "Sheet1" (or "Sheet2", "Sheet3", etc.) under "Microsoft Excel Objects". In the code window for the sheet, paste the following VBA code:

```
Private Sub Worksheet_SelectionChange(ByVal Target As Range)
    Application.EnableEvents = False
    Target.Value = Int((100 - 1 + 1) * Rnd + 1)
    Application.EnableEvents = True
End Sub
```

Press Ctrl+S to save the workbook.

Close the VBA editor by pressing Alt+Q.

Now, when you click on any cell in the sheet, it will generate a random number between 1 and 100.

- To Run Equations of State: Example: Hydrate Formation –
Note: A deep dive into AI (Artificial Neural Network) for predicting hydrates can be found at: <https://www.sciencedirect.com/science/article/pii/S0920410515301686>.
- *Prompt to ChatGPT:* What is the likelihood of hydrate formation given the natural gas composition saturated with water and measured at 40 deg F: Mol% of CO2 4.021 Mol% of Nitrogen 1.342 Mol% of Methane 64.816 Mol% of Ethane 10.474 Mol% of Propane 8.777 Mol% of iButane 1.395 Mol% of nButane 3.861 Mol% of iPentane 1.275 Mol% of nPentane 1.362 Mol% of Hexane 2.668 Mol% of H2S 0.008.
ChatGPT Response: Without the pressure, we will need to determine the pressure at which hydrate formation is likely to occur for the given temperature (40°F) and gas composition. Using the Hammerschmidt equation in reverse, we can solve for the pressure:

$$P = (A * T_f - C) / B$$

Given the operating temperature of 40°F, let's calculate the hydrate formation pressure:

$$P = (238 * 40 - 28.2) / 0.029$$

$$P \approx 327.6 \text{ psi}$$

The Hammerschmidt equation suggests that hydrate formation is likely to occur at a pressure of around 327.6 psi for the given temperature of 40°F and the provided gas composition. However, keep in mind that this is a rough estimate and may not be completely accurate. For a more accurate assessment, consult an expert or use specialized software.

Note: The same gas composition entered in the Colorado School of Mines CSMHyd software application, produced a pressure value of 132.575 psia. While ChatGPT did produce a value, its use of the Hammerschmidt equation was probably not the best choice.

CONCLUSION

Artificial Intelligence will revolutionize data capture and back-office measurement applications, streamlining operations and enhancing decision-making processes across all disciplines. With the power to analyze vast amounts of data quickly and accurately, AI-driven solutions not only improve efficiency but also enable organizations to identify patterns, trends, and opportunities that were previously elusive. Furthermore, these advanced technologies will prove to be invaluable in automating repetitive tasks, reducing human error, and freeing up valuable time and resources for more strategic initiatives. As AI continues to evolve and mature, we can expect an even greater impact on the way businesses operate, manage data, and ultimately leverage information to stay ahead in an increasingly competitive global landscape.