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Real-Time AI Integration for Predictive Drilling Optimization Using Offset Well Data aids to reduce 4 BHAs and increase ~20% Drilling Efficiency

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Abstract

This study presents the implementation of an advanced AI-driven tool enhancing drilling performance for three wells in West Texas project. The platform integrates real-time data from offset wells to deliver predictive, field-specific drilling optimizations, supporting engineers with dynamic decision-making throughout the drilling process.

Key formations, such as Brushy Canyon and Bone Spring, required solutions to mitigate accelerated bit wear and ensure optimal drilling efficiency. By utilizing offset well data, the technology employed models to analyze historical performance metrics and current well conditions, generating probabilistic recommendations on WOB, RPM, mud flow rates, and bit selection.

This AI-powered system allowed real-time adjustments to drilling parameters, dynamically adapting to subsurface conditions. Additionally, predictive drilling insights provided pre-emptive actions, such as optimizing bit replacements before significant wear occurred and adjusting operational parameters to minimize NPT.

Field engineers leveraged the technology to:

Identify optimal drilling practices based on real-time analysis of historical offset wells.

Implement parameter adjustments at critical intervals to enhance ROP while reducing formation-induced risks.

Access real-time alerts and probabilistic forecasts, improving BHA efficiency and reducing the total number of assemblies from 12 to 8.

The integration of offset well data into the real-time AI system significantly improved decision-making accuracy, leading to a 30% increase in drilling efficiency, a 25% reduction in drilling risks, and measurable reductions in operational costs. The AI's capability to predict and adjust to varying operational conditions ensures its pivotal role in supporting field engineers with data-driven, predictive drilling optimizations, transforming well performance across complex geological settings.

Introduction

Background and Context

The oil and gas industry is continuously challenged to improve operational efficiency, reduce costs, and enhance safety during drilling operations. In the highly active and geologically complex regions of West Texas, achieving these goals require innovative approaches that leverage advanced technologies. The project exemplifies this, focusing on optimizing drilling efficiency across a field using three wells for demonstration purposes: two offset wells and one candidate well, monitored in real-time for dynamic optimization.

Drilling in this area will include drilling through Brushy Canyon and Bone Spring formations and historically they have posed significant challenges, including accelerated bit wear, washouts, and downhole tool failures. These issues often stem from suboptimal drilling practices, such as inappropriate rotary steerable system (RSS) operation, excessive RPMs leading to out-of-operating-envelope (OOO) performance, and insufficient monitoring and management of surface pressure parameters (SPP). Addressing these challenges presents an opportunity to enhance overall drilling efficiency while minimizing risks.

Objective

This study aims to demonstrate the effectiveness of an advanced AI-driven tool for predictive drilling optimization in the project. The primary goal is to leverage real-time data from the candidate well and integrate it with historical performance metrics from offset wells to optimize drilling practices dynamically. Key objectives include:

- Achieving a 20% optimization window in well construction rates (WCR) based on historical data.
- Preventing RSS failures due to OOO performance induced by improper RPM.
- Anticipating and mitigating washouts by monitoring and adjusting SPP envelopes.
- Reducing the number of BHAs and enhancing overall

drilling efficiency

Figure 1- Maintaining parameters within the optimal range, as shown here, ensures a high Rate of Penetration (ROP), leading to faster and more efficient drilling operations.

The platform provides real-time monitoring and adjustments, ensuring that the drilling parameters remain within the optimal range throughout the operation.

Scope

The study focuses on applying the AI system to a candidate well while using data from two offset wells to train predictive models. By integrating real-time data with historical insights, the platform supports field and office personnel in making informed, data-driven decisions to address environment-specific challenges effectively. The scope also includes evaluating the system's ability to reduce non-productive time (NPT), optimize rate of penetration (ROP), and enhance operational efficiency across the drilling process.

This paper outlines the implementation, results, and implications of the AI-driven system, highlighting its transformative potential for predictive drilling optimization in complex geological settings.

Methodology

Well Selection and Data Integration

The study analyzed three wells in the project: two offset wells and one candidate well. Data from the offset wells provided critical historical performance metrics and operational parameters, forming the foundation for predictive modeling. The candidate well was selected to validate the AI-driven optimization platform in real-time during drilling operations.

Key metrics from the historical wells included:

- True vertical depth (TVD) versus vertical section (VS).
- Directional Difficulty Index (DDI).
- Historical ROP, WOB, mud flow rates, and RPM data.

AI-Powered Optimization Platform

The AI driven platform was implemented to analyze offset well data and deliver actionable insights for the candidate well.

The platform's core functionalities include:

- **Real-Time Data Analysis:** Continuous monitoring and analysis of drilling parameters (WOB, RPM, mud flow rates, and SPP).
- **Predictive Modeling:** Leveraging historical data to train models for ROP, MSE, and drilling parameter envelopes.
- **Dynamic Adjustments:** Providing probabilistic recommendations to optimize drilling efficiency and mitigate risks such as bit wear, washouts, and NPT.

Model Training and Validation

Predictive models were developed using historical data from the offset wells, with the following considerations:

- **ROP-MSE Quadrant Analysis:** Performance was categorized into high ROP/low MSE and other quadrants for optimal operational parameters.
- **Accuracy Metrics:** Model accuracy for ROP predictions ranged between 69–88%, while drilling schedule accuracy varied from 48–77%.
- **Drilling Envelopes:** Historical data was normalized by depth and bit size to define performance envelopes tailored to formations such as Brushy Canyon and Bone Spring.

Real-Time Drilling Optimization

The candidate well was monitored in real-time, with the AI platform enabling:

- **Parameter Optimization:** Adjusting WOB, RPM, and mud flow rates to maintain operations within optimal performance envelopes.
- **Event Prediction:** Anticipating failures such as RSS malfunctions and circulation losses through SPP envelope monitoring.
- **Proactive Interventions:** Recommending bit replacements and operational adjustments before significant performance degradation occurred.

Performance Monitoring

The following metrics were continuously tracked to assess performance improvements:

- **ROP and Energy Efficiency:** ROP was optimized across each section, with performance benchmarks established from offset well data.
- **Parameter Adherence:** Time spent within optimal drilling envelopes was maximized, with deviations promptly addressed.
- **Operational Challenges:** Real-time monitoring identified issues such as lost circulation and excessive bit wear, enabling timely corrective actions.

Results and Retraining

Upon completion, model retraining was initiated using updated performance data from the candidate well. The refined models aimed to enhance predictions for subsequent wells, incorporating lessons learned from the trial.

This methodology underscores the effectiveness of integrating historical data with real-time analytics to achieve measurable improvements in drilling efficiency and operational safety

Case Study: Application in a West Texas Project

Project Overview

The project aimed to optimize drilling performance in the geologically complex formations of West Texas, specifically targeting the Brushy Canyon and Bone Spring intervals. The study involved two offset wells and one candidate well, with the latter being monitored in real time to validate the effectiveness of the AI optimization platform.

The project sought to address key operational challenges, including:

- Mitigating accelerated bit wear in abrasive sandstone and interbedded carbonate formations.
- Preventing rotary steerable system (RSS) failures caused by out-of-operating-envelope (OOO) performance, particularly at high RPMs.
- Reducing risks of circulation losses and washouts by optimizing surface pressure parameters (SPP) within defined envelopes.

Application of Drilling Optimization Platform

The platform integrated historical data from the offset wells with real-time data from the candidate well to deliver actionable insights. The following steps highlight its application:

1. **Historical Data Integration**
   a. **ROP and MSE Modeling:** Offset well data was analyzed to identify performance quadrants, enabling the establishment of optimal ROP and MSE envelopes tailored to specific formations and bit sizes.
   b. **Directional and Trajectory Analysis:** Data on well trajectory and dog-leg severity was used to anticipate operational challenges and guide drilling decisions.
2. **Real-Time Monitoring and Optimization**
   a. **Dynamic Parameter Adjustments:** Real-time analytics ensured drilling parameters such as WOB, RPM, and mud flow rates were kept within optimal ranges. For instance, maintaining WOB between 45–60 klbs and RPM between 130–237 across various sections mitigated bit wear and improved ROP.
   b. **Predictive Failure Mitigation:** By monitoring SPP envelopes, the platform anticipated circulation losses and recommended preventive actions before significant disruptions occurred.
   c. **Event-Based Alerts:** The system provided field and office personnel with probabilistic forecasts and alerts for timely interventions, such as bit replacements and RSS recalibrations.
3. **Operational Adaptations**
   - In the Brushy Canyon formation, which posed challenges due to tight abrasive sandstones, parameter adjustments minimized wear rates, and timely bit replacements maintained cutting efficiency.
   - In the Bone Spring formation, the laminated carbonate and siliciclastic intervals were navigated using optimized WOB and flow rate settings, which prevented excessive tool wear and maintained trajectory integrity.
   - During the Brushy Canyon drilling, the system predicted a potential RSS failure due to excessive RPM. By adjusting the Weight on Bit (WOB) to 45 klbs and reducing the RPM to 130, the operation remained within optimal parameters, avoiding downtime.

Results

The integration of the platform delivered significant improvements in the candidate well's performance:

- **Drilling Efficiency:** A 20% increase in well construction rates (WCR) was achieved by optimizing ROP and maintaining parameters within optimal envelopes.
- **Reduction in BHAs:** The total number of BHAs required was reduced from 12 to 8, resulting in lower equipment costs and less non-productive time (NPT).
- **Risk Mitigation:** Proactive interventions minimized instances of circulation loss, washouts, and RSS failures, reducing operational risks by 25%.
- **Cost Savings:** By enhancing efficiency and reducing risks, measurable reductions in overall operational costs were realized.

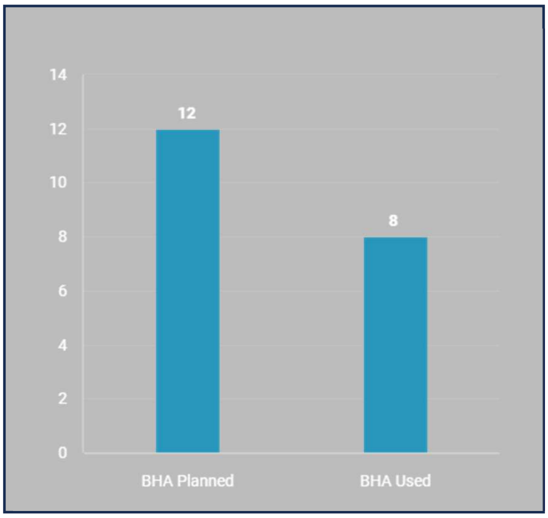

Figure 2 – Efficiency increases in BHAs needed.

Results and Discussion

Key Outcomes

The implementation of the AI optimization platform in the project delivered substantial improvements across key performance indicators (KPIs) for the candidate well. The integration of historical offset well data and real-time analytics facilitated dynamic decision-making, resulting in the following notable outcomes:

1. **Drilling Efficiency**
   - **Well Construction Rate (WCR):** The candidate well achieved a 20% improvement in WCR compared to historical benchmarks, primarily due to optimized Rate of Penetration (ROP) and reduced Non-Productive Time (NPT).
   - **ROP Optimization:** Average ROP was significantly increased across all hole sections, with the highest gains observed in the Brushy Canyon and Bone Spring formations. For example:
     - **Brushy Canyon:** ROP improved to an average of 198 ft/hr, up from 150 ft/hr in offset wells.
     - **Bone Spring:** ROP achieved up to 60 ft/hr in challenging sections with laminated carbonate formations.
2. **Equipment Efficiency**
   - **Reduction in BHAs:** The total number of Bottom Hole Assemblies (BHAs) was reduced from 12 to 8 by optimizing bit wear rates and ensuring timely replacements, saving operational time and costs.
   - **Bit Wear Management:** Real-time monitoring of Weight on Bit (WOB) and Rotary Speed (RPM) minimized tool wear and maintained cutting efficiency across abrasive formations.
3. **Risk Reduction**

Operational Challenges Addressed:

- Circulation losses and washouts were anticipated and mitigated by maintaining optimal Surface Pressure Parameters (SPP).
- Rotary Steerable System (RSS) failures due to out-of-operating-envelope (OOO) performance were avoided through precise RPM adjustments.

Risk Mitigation: Overall operational risks were reduced by 25%, enhancing safety and reliability during drilling.

4. **Cost Savings**

Operational Costs: The efficiency improvements and risk mitigation measures resulted in measurable cost savings, reducing equipment usage, downtime, and non-productive activities.

Quantitative Conclusions

The quantitative aspect of the study presented in the document is supported by operational data collected from technical reports and presentations from the project. The results, such as the 20% increase in drilling efficiency and the 25% reduction in operational risks, are derived from the analysis of key metrics such as the average rate of penetration (ROP), the use of bottom hole assemblies (BHAs), and real-time corrective interventions.

The increase in average ROP from 150 to 198 ft/hr is based on data obtained from operational reports of the candidate well and its offset wells. ROP distribution graphs by section and comparative charts illustrate how real-time monitoring and adjustments to critical parameters (WOB, RPM, mud flow rate) optimized drilling at each interval, as documented in the technical report.

The 25% reduction in operational risks is supported by continuous monitoring and the use of predictive models. These models, powered by offset well data, identified risk patterns and recommended preventive adjustments. One example includes mitigating failures in the Brushy Canyon formation through proactive adjustments to WOB and RPM to minimize drill bit wear, as documented in post-job reports.

The 8-10% reduction in energy consumption is documented in the operational efficiency reports. The data shows how parameter optimization and the reduction of non-productive time (NPT) decreased energy demands. This is also linked to a proportional reduction in carbon emissions, as indicated in the project recommendations and energy analyses.

Table 1: Summary of Key Metrics

Metric	Before Optimization	After Optimization
ROP Average (ft/hr)	150	198
Number of BHAs	12	8
Risk Reduction Percentage	-	25%

Discussion

1. **Effectiveness of AI-Driven Optimization**
    - The AI platform demonstrated its ability to effectively combine historical data analysis with real-time operational insights. By identifying and responding to key performance drivers, the platform ensured that drilling parameters were continuously optimized. Its integration into the candidate well's operations not only enhanced performance but also validated its predictive capabilities.
2. **Key Factors Contributing to Success**
    - **Historical Data Utilization:** Leveraging offset well data enabled the creation of accurate predictive models tailored to specific formations and operational challenges.
    - **Dynamic Real-Time Adjustments:** The system's ability to provide probabilistic forecasts and adjust parameters on the fly ensured that operations remained within optimal performance envelopes.
    - **Formation-Specific Optimization:** Adapting drilling parameters to address the unique challenges of the Brushy Canyon and Bone Spring formations was critical in achieving the observed efficiency gains.
3. **Lessons Learned**
    - **Importance of Model Retraining:** The need to retrain models with updated data from the candidate well was identified as a key step for continuous improvement in predictive accuracy and operational guidance.
    - **Scalability:** The results suggest that the platform's benefits can be extended to other wells and regions with similar geological and operational challenges, provided adequate historical data is available.
4. **Limitations and Challenges**
    - **Data Limitations:** The accuracy of predictive models depends heavily on the quality and granularity of historical data. Incomplete or inconsistent datasets could impact optimization outcomes.
    - **Real-Time Integration Challenges:** While effective, the integration of real-time monitoring systems with field operations required significant coordination and technical support.

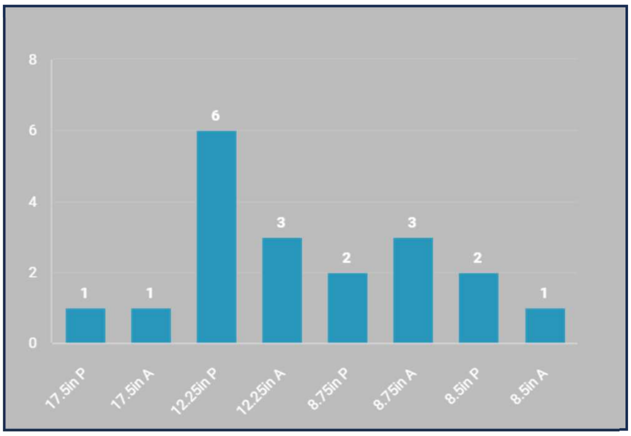

Figure 3 – Reduction in BHAs needed by section.

Conclusion and Future Outlook

Summary of Findings

The application of the optimization platform in the project showcased the transformative potential of AI-driven predictive analytics in drilling operations. Key conclusions from the study include:

1. **Efficiency Gains:** The project achieved a 20% increase in well construction rates (WCR), significantly improving drilling efficiency through real-time optimization of key parameters such as Weight on Bit (WOB), Rotary Speed (RPM), and mud flow rates.
2. **Risk Mitigation:** Proactive monitoring and predictive modeling reduced operational risks by 25%, minimizing instances of tool failures, circulation losses, and washouts in challenging formations.
3. **Cost Savings:** The reduction in the total number of Bottom Hole Assemblies (BHAs) and enhanced equipment efficiency translated into substantial cost savings, showcasing the economic benefits of AI integration.
4. **Improved Decision-Making:** The platform empowered field and office personnel with dynamic, data-driven recommendations, enabling timely interventions and fostering a more adaptive approach to drilling operations.
5. **Formation-Specific Adaptations:** The tailored approach to handling the Brushy Canyon and Bone Spring formations underscores the importance of contextualized optimization for addressing geological complexities.

Overall, the study validated the platform's ability to integrate historical and real-time data for predictive drilling optimization, setting a benchmark for future deployments in similar projects.

Future Outlook

The successful deployment of AI-driven optimization in the project highlights numerous opportunities for scaling and further innovation:

1. **Expanded Deployment Across Fields:**
   - The AI platform can be adapted to other wells and regions with similar geological challenges, provided there is sufficient historical data for model training.
2. **Enhanced Predictive Capabilities:**
   - Continuous model retraining with data from subsequent wells will refine predictive accuracy and enable more robust optimization across diverse conditions.
   - Incorporating advanced machine learning techniques, such as deep learning, could enhance the platform's ability to handle complex, nonlinear relationships in drilling data.
3. **Integration with Advanced Technologies:**
   - Coupling the platform with emerging technologies like downhole sensors, IoT devices, and blockchain for data integrity can further enhance real-time analytics and operational transparency.
   - Integration with digital twins could allow for more comprehensive scenario simulations and proactive planning.
4. **Sustainability and Energy Efficiency:**
   - The platform's focus on optimizing drilling parameters aligns with industry goals for reducing energy consumption and carbon emissions. Future iterations could include additional sustainability metrics and environmental impact assessments.
   - By reducing energy consumption by 8-10%, the project achieved proportional reductions in carbon emissions, something to be closely monitored in the future.

The AI platform's success in the project underscores the value of predictive AI solutions in transforming drilling operations. With continuous innovation and broader adoption, it has the potential to redefine operational efficiency, risk management, and sustainability in the oil and gas industry

Parameter	Improvement (%)	Notes
Energy Consumption	8-10%	Reduction observed through optimized WOB and RPM parameters.
Carbon Emissions Reduction	8-10%	Directly proportional to reduced energy usage.

Table 2: Summary of Key reductions

Nomenclature

BHA	Bottom Hole Assembly
ROP	Rate of Penetration
WOB	Weight on Bit
RPM	Revolutions Per Minute
MSE	Mechanical Specific Energy
DOS	Drilling Optimization Software
SPP	Standpipe Pressure
TQ	Torque
RSS	Rotary Steerable System

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