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DIGITAL SHAKER SURVEILLANCE USING COMPUTER VISION TECHNOLOGY ON A DEEPWATER RIG

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ABSTRACT

This paper describes deploying and operating a computer vision system on a deepwater rig to measure drilled cuttings in real-time using a remotely monitored camera system.

The objective was to demonstrate that autonomous cuttings characterization could provide useful data to improve drilling performance. Two wells, one in the Mediterranean Sea and one in the Atlantic Ocean, were monitored consecutively over one year. The system used an optical sensor and image analysis software to quantify and qualify cuttings on the rig's shakers during drilling operations.

Data acquired at the shakers during different drilling activities showed strong correlation between cuttings load and perturbation in various drilling parameters, leading to improved hole cleaning and wellbore stability assessments. The study also highlighted safety benefits from reducing crew exposure to hazardous areas.

By autonomously characterizing drilled cuttings, the system aims to enhance drilling efficiency, optimize penetration rates, and prevent pack-off events. The successful application of image analysis to digital shaker surveillance represents a promising advancement in cuttings recovery rate measurement.

INTRODUCTION

ENI is committed to continuously improving the safety and efficiency of its operations. In this context, the company identified an innovative solution that allows monitoring drilled cuttings that exit the shale shakers during drilling operations.

During drilling, the presence of rock fragments in the wellbore is an inevitable consequence of the drill bit in action. Good drilling practices must therefore provide proper hole cleaning to avoid the excessive accumulation of cuttings in the wellbore and the significant associated risk of getting downhole equipment stuck. Finding the optimum combination of drilling parameters and mud characteristics to achieve this can be a major challenge.

The situation is made worse if rock fragments of larger dimensions (known as cavings) unexpectedly fall into the wellbore from the borehole wall. Such wellbore instability can be caused by insufficient circulating pressure (resulting in borehole collapse) or excessive circulating pressure (resulting in formation fracturing) while drilling.

Both the accumulation of cuttings and cavings have consequences when tripping the drill string or casing into or out of the well. Such difficulties range from excessive torque and drag to stuck pipe.

The actions that can be taken to solve each issue are quite different, so it is critically important to correctly identify the root cause of the problem. This is further complicated by non-pressure related causes, such as poor well geometry or the creation of 'key seats' in the borehole wall.

Possible causes of wellbore instability include:

Purely geomechanical reasons – shear failure of the borehole wall due to in situ stresses and rock resistance. Symmetrical portions of the borehole will collapse, giving it an ovalized cross-section. In such cases, the preferred solution is an increase in mud weight.

Overpressure in low permeability shales – tensile failure due to a poroelastic response of the rock to an imbalance between fluid pressure in the rock and mud pressure in wellbore. In this case, the entire circumference of the borehole will collapse. This can again be solved by increasing mud weight.

Preexisting planes of weakness or pre-fractured rock (e.g., a rubble zone) – cavings are mobilized by mud filtration into discontinuities in the rock, leading to an irregular hole cross-section. In this case, increasing the mud weight could worsen the filtration rate and mobilize even more rock. The best remedial approach is to minimize and control pressure fluctuations to prevent excessive mud infiltration.

The drilling team's ability to react quickly and appropriately to borehole conditions could be enhanced by deploying a system to continuously measure the quantity of cuttings being returned and to quickly detect cavings and alert the team to their presence.

The more quickly and reliably deviations in cuttings return rate or the presence of cavings can be reported, the more rapidly and effectively the drilling team can respond.

Optical sensors were considered because of their advantages over cuttings flow meters, which mechanically collect and weigh the cuttings on an intermittent basis. A camera is easier to install, provides continuous remote monitoring, reduces risk (e.g. of injury caused by moving mechanical parts), and can make several different measurements simultaneously.

ENI postulated that the ability to cross-reference visual data from the shakers with mudlogging data would provide its drilling team with a more comprehensive understanding of the operational situation, enhancing their ability to manage wellbore stability and ensure the effectiveness of hole cleaning operations.

APPROACH

ENI met DrillDocs and learned about its proprietary CleanSight technology during a bootcamp in San Francisco. The system uses computer vision algorithms and machine learning to interpret images captured by cameras focused on the shale shakers. This enables real-time monitoring of cuttings frequency, size, and shape, from which cuttings volume can be calculated. When integrated with drilling parameters from the rig's data system and mudlogging information, this provides key insights about wellbore stability and hole cleaning efficiency.

ENI recognized the potential of CleanSight and launched a pilot project to evaluate its application on a deepwater rig. This first-of-its-kind test was conducted in 2023-2024 on a 7th generation drillship during the drilling of subsea wells offshore Egypt and the Ivory Coast.

Installation

The CleanSight system was installed on the Saipem Santorini while it was in the Gulf of Mexico prior to rig move. This involved several key components and processes—illustrated in Figure 1—to ensure the setup was robust, functional, and compliant with safety standards:

1. **Cameras**: Two Axis XFQ-1656-DD explosion-proof cameras were installed to monitor shakers #3 and #4. These cameras are hazard-rated for use in challenging offshore environments and equipped with advanced features like high-resolution imaging, light compensation, and deep learning analytics for real-time monitoring of cuttings.
2. **Camera Alignment and Configuration**: The cameras were positioned and aligned to provide accurate fields of view for monitoring shaker operations. Once the shakers were operational, further remote tuning was applied to optimize parameters such as exposure time and motion blur.
3. **Mounting Hardware**: The cameras were attached to custom mount bars using U-bolts, which were secured with Loctite to avoid loosening in the high-vibration environment. The mounts were designed to provide optimal fields of view of the shaker decks.
4. **Cabling and Network**: Five network cables were installed—three from the Local Equipment Room (LER) to the server rack, and two from the cameras to the server rack via penetration blocks. The cameras and server were connected to the rig's network infrastructure, enabling remote monitoring and data transmission. Firewall settings were configured to allow remote access via TampNet internet service.
5. **CleanSight Server Rack**: The server rack was planned to be installed in an AC room but there was insufficient space, so it was installed in the Toolpusher's Cabin Data Room (TCDR), which lacked functional air conditioning. However, the server did not experience any heat-related downtime.
6. **Touchscreen Monitor**: A touchscreen monitor was mounted in the company's man office.

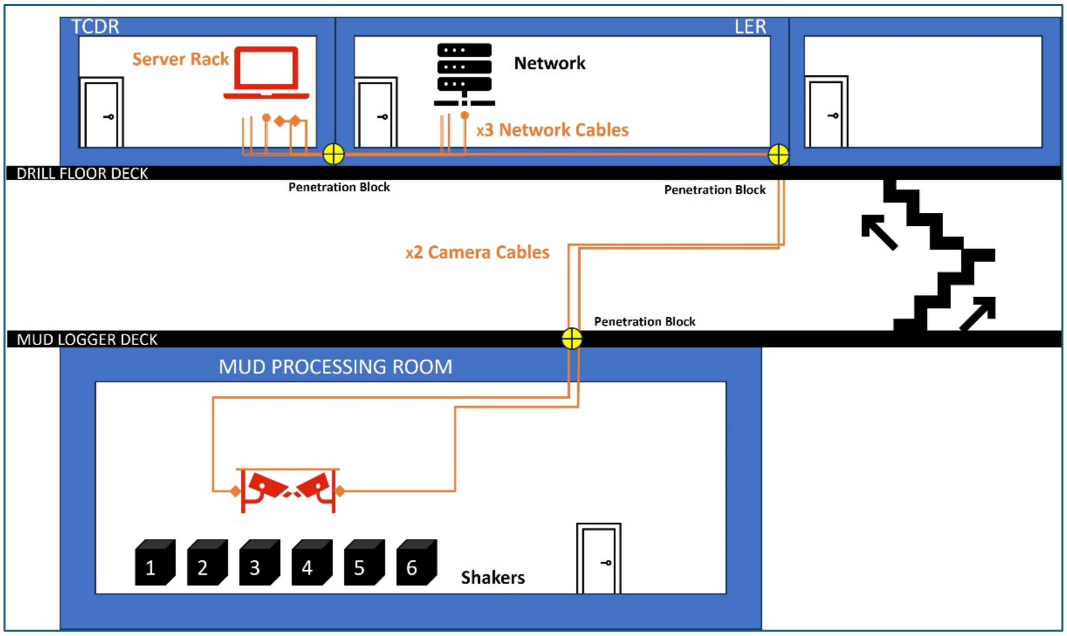

Figure 1: Cartoon of the CleanSight Installation on the Saipem Santorini Rig

Operation

The shakers were monitored during the drilling of approximately 10,000 meters, across hole sizes ranging from 8½-inches to 17½-inches, as well as five shoetrack drill-outs and the pumping of over 80 sweeps.

Changes in cutting load were measured qualitatively and quantitatively using computer vision techniques.

The following activities were monitored:

Well #1:

- Drilling 17½-inch section (enlarged to 22 inches), ~500 meters
- Running 18-inch liner
- Drilling 16½-inch section (enlarged to 18½ inches), ~1,200 meters
- Running 16-inch liner
- Drilling 14¾-inch section (enlarged to 16 inches), ~1,200 meters
- Running 13⅝-inch casing
- Drilling 12¼-inch section (enlarged to 13½ inches), ~900 meters
- Running 11¾-inch liner
- Drilling 10⅝-inch section (enlarged to 12¼ inches), ~900 meters
- Running 9⅝-inch liner
- Drilling 8½-inch section, ~350 meters

Final measured depth was 6,750-meters, with final inclination <10°.

Well $^{\#}$2:

- Drilling 17½-inch section, ~700 meters
- Running 13$^{3}/_{8}$-inch casing
- Drilling 12¼-inch section, ~600 meters
- Running 9$^{5}/_{8}$-inch liner
- Drilling 8½-inch section, ~1,300 meters

Final measured depth was 4,700-meters, with final inclination <10°.

Analysis

Image analysis was performed onsite using edge computing on board each camera and a central processing and storage rack housed in the rig's electronics room.

The image processing workflow, illustrated in Figure 2, below, involved:

- ***Pre-processing*** to optimize the image and isolate cuttings from the background (see example in Figure 3)
- ***Feature extraction*** to identify cuttings boundaries and calculate the number and size distribution of cuttings
- ***Labeling and classification*** to separate cuttings from other unidentified objects, which might be cavings or other debris

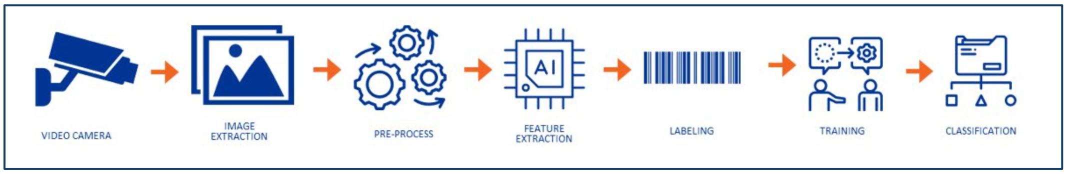

Figure 2: Image Capture and Analysis Workflow

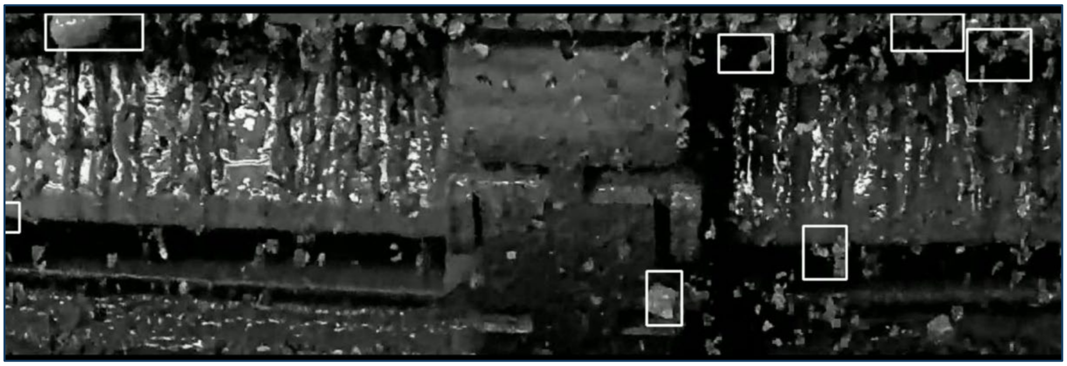

Figure 3: Example of Image Detection in Action

Estimated shaker load data was delivered to the offshore drilling team via displays in the company man's office (or wellsite geologist's room) and at the driller's console. Configurable alerts were sent via email to relevant personnel, and the project was also remotely monitored via a multi-platform open-source analytics and interactive visualization web application.

RESULTS

The result of the pilot was positive, achieving significant improvements in the team's ability to monitor and optimize operational parameters in real time, helping to reduce operational risks, such as stuck pipe, and increasing overall drilling efficiency, including hole cleaning operations.

The image analysis model detected operational events at both shakers, including indicators of well control issues, the presence of cavings, the occurrence of cuttings influxes, and the impact of pumped sweeps.

These events were correlated with drilling parameters to confirm their relevance and relationship to hole cleaning and wellbore stability, further validating results reported by DrillDocs (2022)[1], TUDRP (2023)[2], Exxon (2024)[3], and AkerBP (2025)[4].

The cuttings load data demonstrated credible correlation to drill pipe connections, pumping sweeps, changing penetration rate, and changes in inclination.

Safety benefits were also recognized as a result of reducing the frequency of crew entries into the hazardous shaker area and improved PPE compliance.

Example 1: Anomalous Cuttings Volume Detection

A temporary flow rate reduction was experienced at 02:30 due to an issue with the rigs pumps. This was followed at 04:00 by a large increase in cuttings on the active shaker (marked '1' in Figure 4), consistent with the 90-minute lag time between bit depth and the shakers.

The digital shaker surveillance system flagged the anomaly as an unexpected upward trend in shaker load and issued an alert to the drilling team. No further action was required after the event was correlated to the flow rate reduction, which had already been remediated.

Figure 4: Shaker Load Increase Related to Flow Rate Reduction

Example 2: Cuttings Return Rate vs. Inclination

As hole angle increases, cuttings tend to form beds along the low side of the hole, leading to an accumulation of cuttings in the wellbore.

Figure 5, which compares the cuttings volume being observed at the shakers with other drilling parameters—including flow rate and rate of penetration—provides a clear indication of this trend.

Comparing this information to predicted hole cleaning behavior helps the drilling team to optimize drilling parameters (flow rate, rate of penetration) and alerts them to any excessive cuttings accumulation that might lead to pack-off issues when tripping out of hole or running casing.

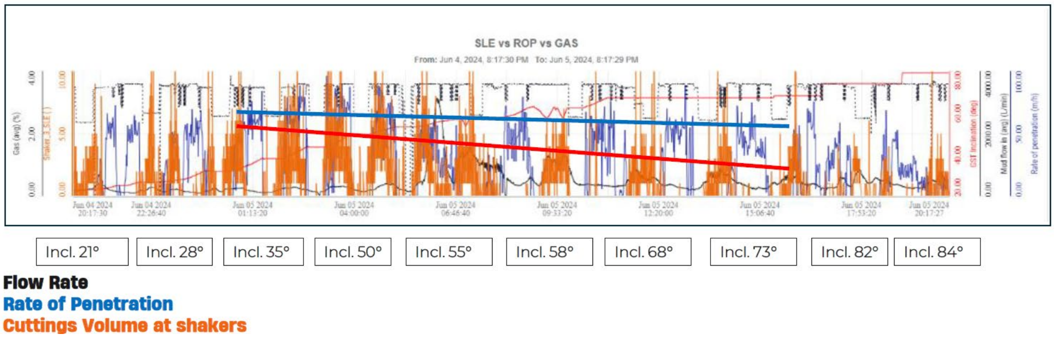

Figure 5: Change in Cuttings Return Rate vs. Well Trajectory

Example 3: Circulation Time Optimization

After stopping drilling due to an MWD event at 01:40 (marked 'A' in Figure 6), a sweep was pumped and the hole circulated clean for almost 3 hours (until 04h25, marked 'B').

However, the shaker load distribution (red and white heat map) and shaker load estimate (line graph below the heat map) both show negligible cuttings return rate after ~03:40 (marked 'C'). No unidentified flowing objects (UFO), which would have indicated the presence of cavings, were detected (marked 'D').

This suggests that the circulating time could have been reduced by 30 minutes or more (marked 'E'), which represents a considerable cost saving at the fully loaded spread rate.

Figure 6: Cuttings Return Rate Monitoring While Circulating

DISCUSSION

Images gathered and interpreted during the pilot test validated the company's hypothesis that cross-referencing visual data from the shakers with mudlogging data would provide its drilling team with a more comprehensive understanding of the operational situation. Their ability to manage wellbore stability and ensure the effectiveness of hole cleaning operations was measurably enhanced.

During the pilot test, additional system capabilities were explored, further enhancing its value beyond the original concept. This included monitoring wellbore clean-out efficiency, detecting potential caving events, and identifying foreign objects in the cuttings stream—including cavings, pieces of rubber, and cement debris—and monitoring mechanical performance to avoid uneven wear-and-tear on shaker components.

These functionalities further expanded the system's impact on real-time decision making, and further improved operational safety and efficiency throughout the drilling process.

Cuttings transport modeling and hole-cleaning practices have long suffered from a lack of real-time cuttings recovery rate data with which to calibrate and adjust the underlying assumptions and models. This has led to inefficient drilling practices, including suboptimal rates of penetration, excessive hole cleaning time before trips, and stuck pipe incidents requiring time-consuming and costly remediation.

The derivation of cuttings recovery rate data from real-time video represents a novel approach to closing this gap. However, new ways of working must be developed to connect this new information to the modeling process in real-time so that operational gains can be fully realized.

The effectiveness of the system tested during the pilot was limited by several factors, including:

Proximity to the shaker – the quality and resolution of the video image, which is the ultimate driver of measurement efficacy, is impacted by how close the camera can be mounted to the shaker. This will be improved in the future when shaker rooms are designed with cameras in mind.

Number of cameras installed – only two of the rig's six shakers were monitored, with data being extrapolated based on the distribution of flow between shakers at the header box. This is inherently less accurate than monitoring each of the shakers independently and cannot account for any preferential flow of cuttings or cavings to one shaker over another.

Novel image analysis models – the image analysis and object classification models being used are still very new. Continuous improvement in this area will improve system accuracy and efficacy over time.

Nevertheless, applying an image analysis model to autonomously characterize drilled cuttings' size, shape, and volume will clearly help optimize overall penetration rates, improve hole-cleaning practices, reduce lengthy circulation times, and help avoid pack-off events.

The experimental work and field examples discussed in this paper demonstrate the progress that has been made towards successfully applying novel image analysis and modeling capabilities to digital shaker surveillance and using them to measure drilled cuttings recovery rate in real time.

CONCLUSIONS

Computer vision techniques have been successfully applied to shale shaker surveillance to provide useful information about cuttings return rate and the presence of cavings or other foreign objects indicative of critical downhole situations.

Data acquired from digital shaker surveillance correlates strongly with drilling operations, providing confidence in its applicability for real-time operational decision making.

The pilot project demonstrated the system's ability to deliver instantaneous and cumulative measurements and trends in cuttings frequency, size distribution, and volume.

The integration of digital shaker surveillance data with other drilling parameters and mudlogging data leads to improved decision making about wellbore stability and hole cleaning. This leads to immediate time and cost savings through reduced circulating times and avoided or quickly mitigated stuck pipe incidents. Annual cost savings of $10 million per year are projected if the technology is deployed as a standard operating practice across the company's rig fleet.

Further developments in camera deployment, image capture, image analysis, and object classification will lead to continuous improvement in the accuracy and efficacy of data generated using this approach.

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