Knowledge management for decision-making by applying data mining to real-time drilling parameters

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1. Abstract

This paper presents the implementation of data mining to foster the exploitation of real-time drilling parameters. By relying on statistics and exhaustive analysis of drilling scenarios, data mining applied to real-time drilling data permits to anticipate drilling and borehole conditions, thus optimizing decision-making.

Data mining applied to real-time drilling data repositories allows to reduce time in decision-making during crucial drilling operations, drawing upon the analysis of non-trivial real-time drilling parameter values and by leveraging historical data from previous wells and structured technical knowledge of drilling specialists. This permits to establish a knowledge management strategy for drilling operations, based on knowledge repositories and inference routines methods, enabling the generation of a preemptive data model for each operative scenario during drilling operations.

By preserving drilling scenarios and technical knowledge, the knowledge management strategy supports future professionals in the oil and gas industry, thus reducing the impact of generational changes.

2. Context

2.1. Knowledge management in the oil industry

Knowledge management –an ensemble of best practices oriented to develop and apply the knowledge of an organization, whereas documented or related to expertise or personnel– has been successfully implemented in the oil and gas industry for almost 20 years [1]. Technology transfer, reducing the impact of turnover and preserving the expertise of specialists have been the main objectives of knowledge management. As a result, a corporate view of knowledge management has been widely accepted within the industry, and benefits have been reported [2, 3].

From an operative point of view, there are still several areas of opportunity to deploy knowledge management as a strategy to optimize the exploitation of data and the expertise of the specialists. Operations that involve high risks, complex technologies, vast volumes of data, and severe environments, such as drilling operations, may benefit greatly from the implementation of knowledge management to optimize decision-making.

2.2. Real-time drilling operations

Drilling operations around the world are facing challenges related to geological complexity, lack of specialists and increasing data volumes. As a matter of fact:

- Drilling costs have drastically increased, particularly in deep waters and in highly heterogeneous formations.
- The complexity and volume of data generated at the rig site has significantly increased.
- There are not enough specialists available to expediently monitor, assess and analyze the data generated at the rig site.
- Bringing the data to the specialists is less expensive than sending specialists to every rig.

Real-time operations have been proposed and successfully implemented to attend these challenges, by allowing drilling specialists to monitor, analyze and evaluate multiple drilling operations from a single location. Drilling data is collected, aggregated, transmitted, visualized and exploited in real-time by applying the right technology and procedures [4]. As a result, drilling staff located at the rig site benefit from preventive alerts and technical recommendations that allow optimizing the drilling process.

Real-time data is standardized to ensure interoperability, that is, to permit integration between data stores and engineering viewers and software in real-time, according to the oil industry standard for drilling data, WITSML. WITSML (Wellsite Information Transfer Standard Markup Language) is an open standard, available for all operators and contractors, and has been implemented worldwide [5].

WITSML provides the following benefits:

- Adoption of these standards by energy companies and support of these standards by service, supplier and software vendors will:
- Allowing oil & gas companies to leverage their investment in highly instrumented fields to enable new capabilities for automation and optimization that would otherwise be impossible or difficult to achieve.
- Reducing the cost of information exchange between software within an operating company and between operating companies, partners, contractors, and regulatory authorities.
- Reducing the cost of replacing or substituting software to benefit from improved functionality.

Real-time data is stored in a WITSML store. Data can then be retrieved for visualization, monitoring, and assessment purposes. Data can also be logically structured as a data warehouse for data mining purposes, yet this particular use is less frequent in the industry.

Nowadays, Real-Time Operation Centers (RTOCs) are commonly based on WITSML for monitoring and reporting a set of variables to help drilling engineers to improve field operations performance, and avoid undesirable incidents during daily activities.

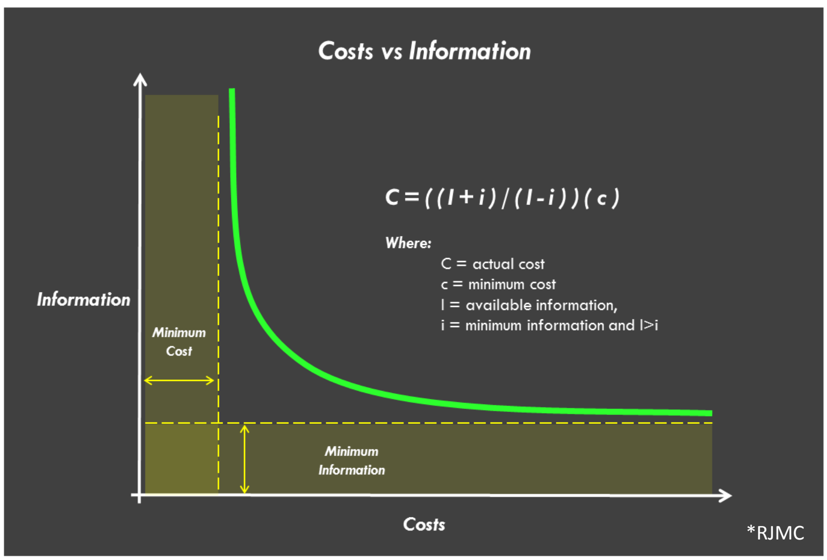
Basically, real-time services integrate drilling data and display it at an RTOC, where it is interpreted and used by a specialized engineering staff to monitor and alert of any undesirable operative event that, according to their knowledge, could cause or is causing and undesirable incident on the field. Nevertheless this applied knowledge is not been registered at the time, so it is not available for future decision-making situations.

3. Scope

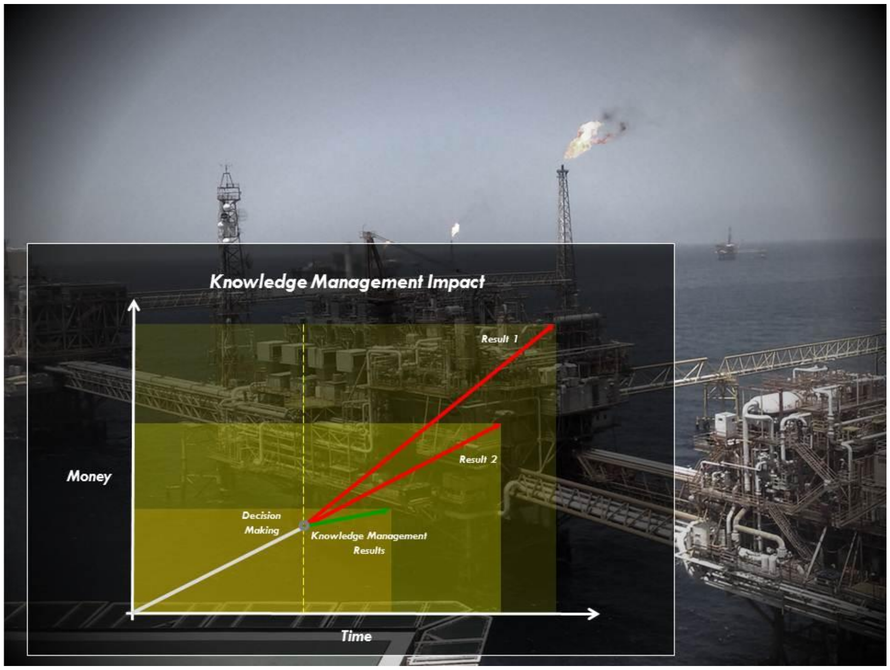
This paper presents a knowledge management strategy intended to optimize decision-making during drilling operations, by reducing nonproductive times (NPTs) and costs. Knowledge management applied to drilling operations may enable collection and structured storage of implicit knowledge from drilling specialists, thus preserving common and unusual solutions for future uses.

Considering that an action must be taken every time an undesirable event appears, and that the cost of this action is directly proportional to the elapsed time between the presentation of that event per se and the implementation of the correct action to minimize its impact, then reducing this time reduces as well the cost of the operation.

In field operations, most of the time consuming activities correspond to the decision-making process before taking the right action. This takes us to focus on the decision-making process in order to reduce the elapsed time from event to action, closing the gap between the RTOC staff and the valuable information needed to make the right decision.

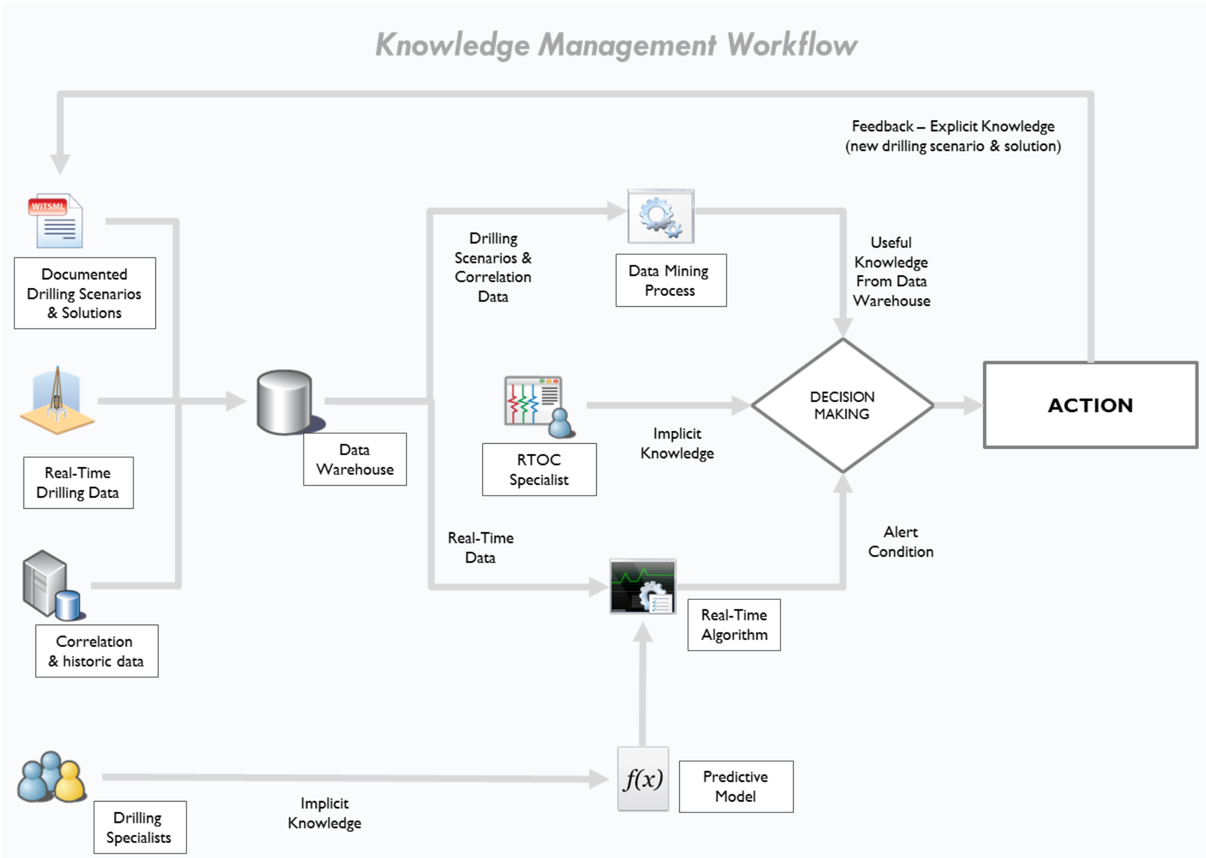


People are the main factor in the decision-making process. Data mining is only the method. Implicit knowledge is the base. When field data is combined with implicit knowledge from specialists, under a knowledge management strategy, results are obtained in less time, thus reducing operative costs associated to NPTs.



4. Knowledge management for decision-making during drilling operations

The challenge to implement knowledge management in the drilling process is defining the workflow allowing for the connection of technical data with the expertise of the specialists. Given the nature of decision-making during drilling operations, an interactive knowledge



management workflow is thus required, involving explicit knowledge analysis, implicit knowledge use, and data mining to extract useful knowledge from available data and information:

The main components of the workflow are:

- Data warehouse that feeds the workflow. Data warehouse stores both real-time and correlation data, as well as documented drilling scenarios and solutions.
- Real-time algorithm derived from the predictive model, determined beforehand by drilling specialists, to identify alert conditions from the real-time data.
- Data mining process to identify repetitive patterns observed in previous drilling scenarios, thus providing useful knowledge to optimize decision-making.
- Decision-making process, allowing interaction of implicit knowledge from drilling specialists with the real-time and data mining results.

- Actions resulting from the decision-making process and implemented at the rig site to reduce NPTs.
- Documentation of the new drilling scenario and its related action and its aggregation to the data warehouse, to drilling scenarios available increase, allowing for a more precise definition of patterns by the data mining process.

These components are described as follows:

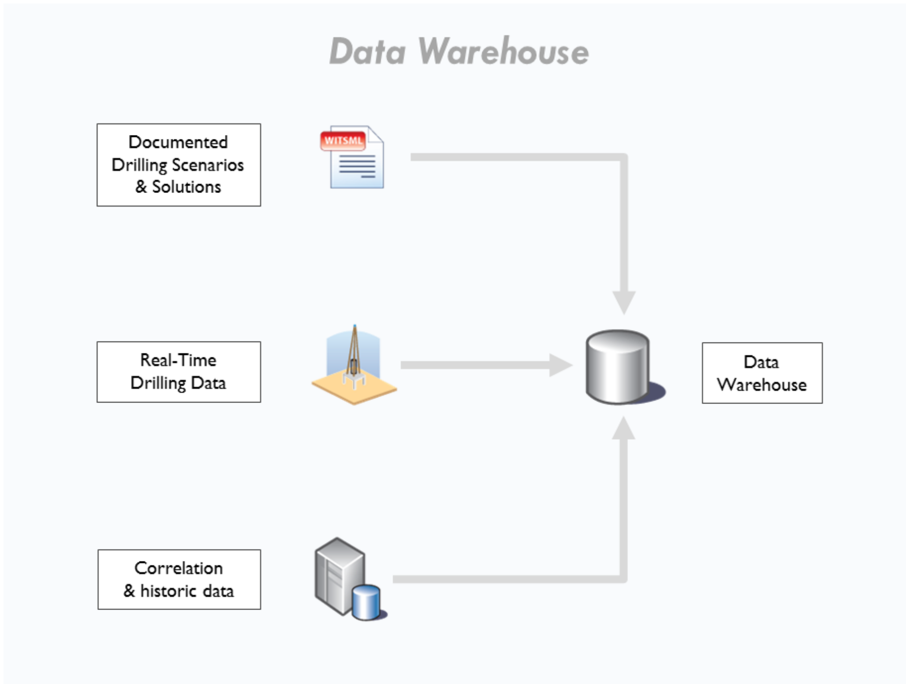
4.1. Data warehouse

This is the main data repository where all the defined variables are stored. The data warehouse is fed by:

- Real-time data collected at the rig site. Data collected is classified as follows:
    - *Surface parameters*, such as torque, hook load, bit depth, RPM, and rate of penetration.
    - *Downhole tool (LWD/MWD/PWD) parameters*, such as gamma ray, resistivity, inclination, azimuth, and bottom pressure.
    - *Mudlogging data*, such as lithology, chromatography, and descriptions.
- Correlation and historic data from previous wells. This includes wireline logging data.
- Documented previous drilling scenarios and applied solutions.

Real-time data, documented operative events, operative conditions and information, and data from correlation wells, are being represented as a WITSML data warehouse. Real-time data and previously stored correlation data is pulled from the WITSML store; information regarding operative conditions for each drilling scenario and operative events are represented as WITSML data to be aggregated into the data warehouse. Intrinsic knowledge, such as alert conditions during trips or drilling operations, are documented as drilling scenarios and thus converted to information to be aggregated to the data warehouse as well. Intrinsic and explicit knowledge is therefore integrated into a single, logical data warehouse.

The data warehouse, as described above, is integrated of real-time and correlation data, information concerning the operative conditions, and information from implicit knowledge:



Data and information composing the data warehouse are structured by variables. Main variables are:

- Well name, location, field, formation target, year of drilling.
- Operative conditions: rig name and capacities, crew, mud type.
- Real-time data, from all data families, such as surface parameters (mud flow rate, torque, block position, hook load, stand-pipe pressure, rotary etc.), downhole parameters (resistivity, trajectory etc.), and mudlogging data (lithology).
- Correlation well name, location, field, formation target, year of drilling.
- Drilling scenarios or alert conditions, such as losses, gains, drag etc., as wells as operative ranges defined for normal operations, as well as solutions implemented for each scenario.

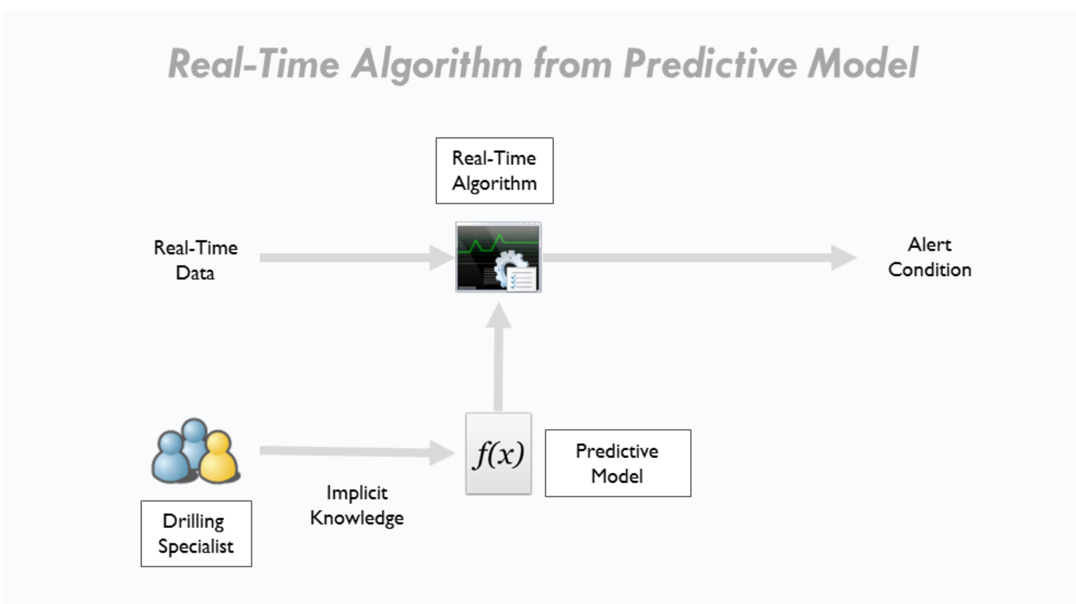
It is important to mention that the aforementioned list of variables is not exhaustive, and may include as many variables as needed to precise the output of the data mining process and thus the resulting pattern describing the conditioning elements of each alert condition.

4.2. Algorithm derived from the predictive model

Before implementing the knowledge management workflow, it is necessary to define a predictive model for identification of undesirable alert conditions, such as partial losses, drags, gains etc. The model is defined as a set of operative conditions, parameters and value ranges that lead to an operative undesirable scenario. For example, if the value of the stand-pipe pressure and output flow parameters diminishes, and the flow rate varies with time, a partial loss of drill fluid occurs at the rig site.

All alert conditions are thus defined as of this manner, in order to have a set of alert conditions described by the behavior of drilling parameters. This set of alert conditions constitutes the predictive model.

Once the predictive model is defined, it is represented as a real-time algorithm that identifies the existence of any predefined alert condition scenario by interacting with real-time data flowing from the data warehouse. Input of the real-time algorithm is real-time data plus the data corresponding to the last eight hours. This allows the algorithm to identify not only variations on values with regards to a value range, but also to determine patterns indexed in time in each of the involved parameters. If an alert condition is identified by applying the algorithm to the real-time data flow, an operative alert is generated. This alert triggers a decision-making process in order to decide whether or not to take an action, and what action to



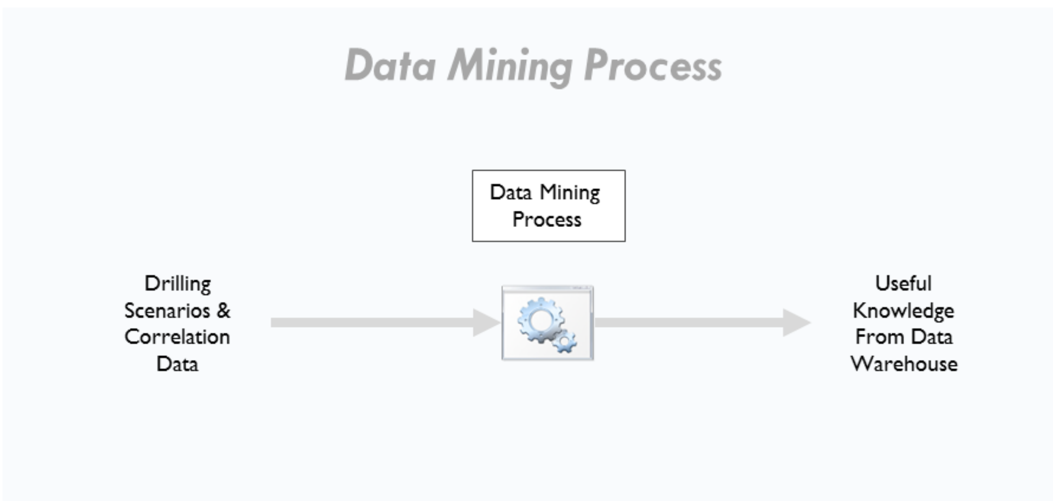
take –if needed.

4.3. Data mining process

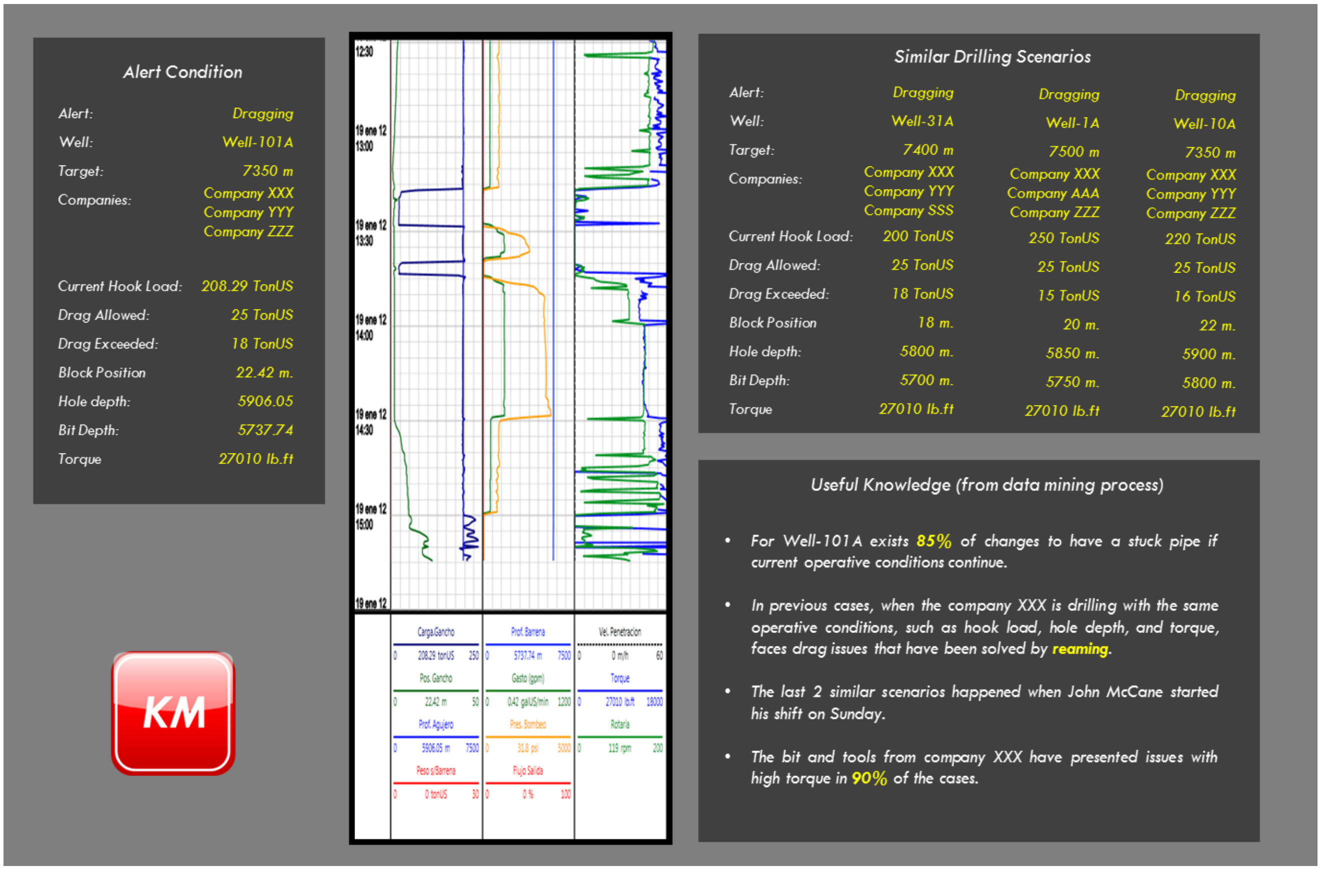
Data mining has been applied to oil and gas data warehouses to elucidate patterns and non-explicit knowledge that is embedded in explicit data.

The output information of the described real-time algorithm –an alert condition– also triggers a simple query for the data warehouse, based upon the variables listed in 4.1. The query pulls data from the data warehouse corresponding to similar scenarios to the one that triggered the alert condition.

This discriminated set of data feeds a data mining process, which analyzes all variables, ranges and drilling scenarios and selects the conditions that have a higher statistically weighing on a particular drilling scenario, given the current operative conditions. Conditions are then presented to a drilling specialist at the RTOC, along with the alert condition and the query

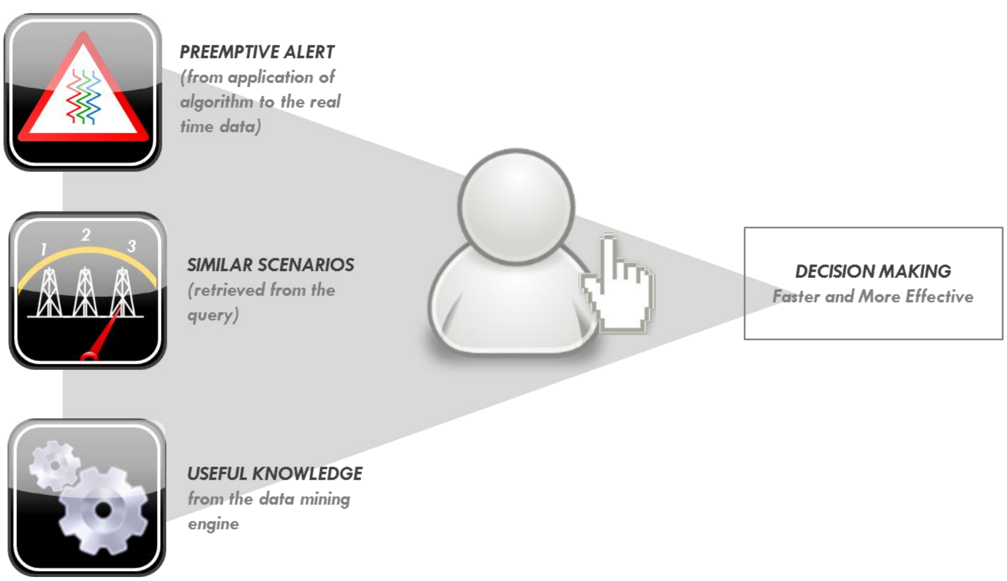


results, providing the specialist with more data to make a more accurate and faster decision.



4.4. Decision-making process

As mentioned above, the decision-making process involves, as well as the implicit knowledge of the RTOC staff and the preemptive alert generated from the real-time algorithm, the useful knowledge generated from the data mining process, thus leveraging and sharping the aim of



the entire process.

Traditionally, decision-making at RTOCs take into account only real-time data from current operations. Under this scheme, for the decision-making to be effective, an ideal 24-hour monitoring of every single drilling operation is mandatory. Besides the dependency on the ability of the specialist to identify in a timely manner an alert condition, usually there is not available information on previous similar scenarios and the solutions that were implemented to solve them.

The knowledge management workflow described in this paper proposes an innovative approach to the decision-making process, by implementing automated alert generation from a real-time algorithm plus the displaying of conditioning elements detected by a data mining process in previous similar –and not so similar– drilling scenarios. This approach allows drilling specialists at RTOCs to timely identify alert conditions in current drilling operations and propose an action, i.e., a solution, based not only on his implicit knowledge, but on actual conditioning elements not necessarily evident from previous similar drilling scenarios. As of this manner, decision-making based on a knowledge management workflow is not only more accurate, but faster, and reduces error margins normally existent at conventional decision-making processes, where all decision-making relies on implicit knowledge.

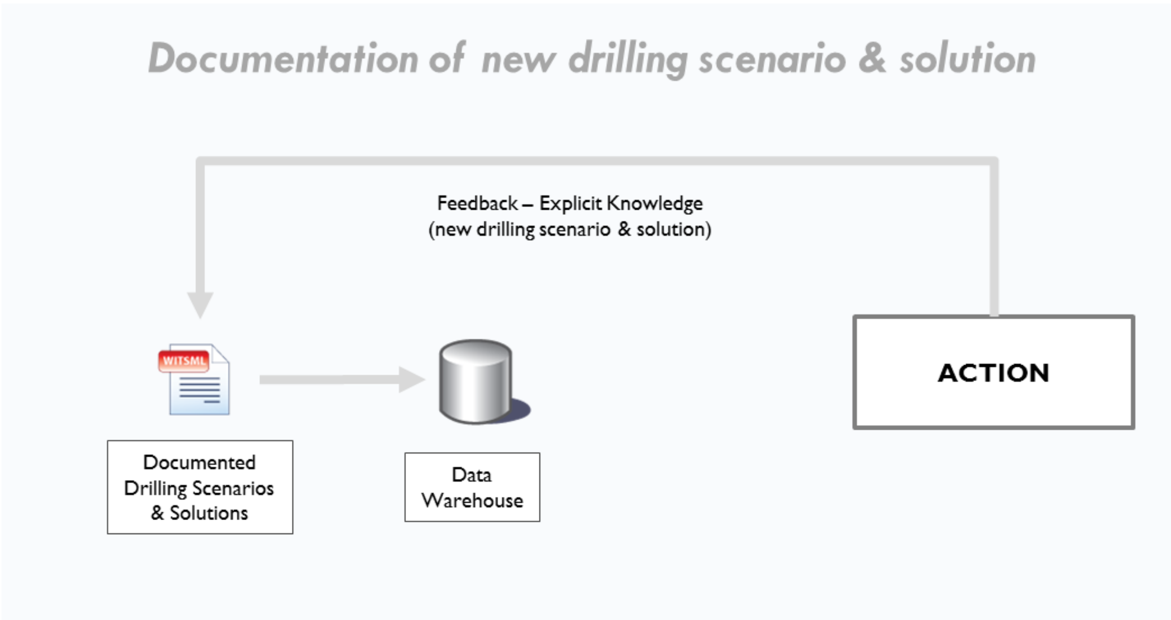
4.5. Actions

The decision made by the RTOC staff is communicated to field staff at the rig site, in order to diminish the elapsed-time between the event that triggered the alert and the solution of that event. Actions taken by the field personnel are correspondingly registered back in the data warehouse, in order to keep track of the complete cycle and store not only drilling scenarios, but factual and feasible solutions as well.

Actions are integrated by the new, documented drilling scenario and their correspondent solution, and are stored back at the data warehouse under a documented drilling scenario form.

4.6. Documentation of the new drilling scenario & solution

Registration of results is the key for the model to be useful in real-time operations. It is clear that, when first implemented, the time elapsed between undesirable event and the solving action may be similar to the time that would be elapsed if a conventional, empirical model is implemented. Nevertheless, as the model is used and the data warehouse is fed with more scenarios, decisions and actions –i.e., as explicit knowledge is stored at the warehouse, the output will be more precise and will provide the required knowledge and information to make a



faster decision.

The resulting action, to be implemented by the field staff at the rig site to reduce the impact of an undesirable event, is aggregated to the data warehouse as an ensemble of variables, values and ranges. This allows converting the implicit knowledge of the drilling specialist –represented in actions, decisions, recommendations– into explicit knowledge, ensuring its preservation with two purposes:

1. Document, in a structured form, the actions, solutions and recommendations generated by the drilling specialists for future uses.
2. Increase the reliability of the data mining output, by increasing the number of drilling scenarios composing the data warehouse.

5. Benefits from the knowledge management strategy

By implementing a model involving real-time and correlation data, implicit knowledge, and patterns from previous drilling scenarios, the following benefits are obtained:

- Minimized the duration of elapsed time between an undesirable event at the rig site and the decision on the solving action, thus reducing NPTs and associated costs.

- Implicit knowledge becomes explicit, recordable knowledge, so specialists benefit from documented lessons learned and better operative practices in a selective manner, as only knowledge relevant to the current alert condition is used.
- The data warehouse contains a growing knowledge base that minimizes loss of the most valuable asset of the organization –implicit knowledge.
- Optimized learning curve for new personnel on field operations.

6. Next steps

Future actions required to achieve the implementation of this model are:

- Define predictive models for all possible drilling scenarios.
- Building the algorithm for each drilling scenario.
- Test different data-mining engines and configurations.
- Define of data structure to be used to document implicit knowledge, such as a decision made by the RTOC staff, in order to store it as explicit knowledge in the data warehouse.
- Include geological and engineering scenarios in the data warehouse, such as projected geological column vs real geological column, and depth vs time information, to identify and generate geological and engineering alerts.

7. Conclusions

The knowledge management strategy proposed in this paper is intended to reduce the time between an undesirable drilling scenario –or alert condition– and its solution. This is achieved by optimizing decision-making through the provision of all relevant data and knowledge to a particular, current drilling scenario.

By preserving drilling scenarios and technical knowledge at a single data warehouse, the knowledge management strategy supports the decision-making process of future professionals in the oil and gas industry, thus reducing the impact of generational changes.

As of today, the knowledge management strategy is implemented as a workflow that reacts to a set of conditions leading to an alert. It is nevertheless feasible to upgrade the workflow to not only exploit useful knowledge and store every drilling scenario for future uses, but to prevent drilling scenarios *from happening*. The knowledge management strategy may thus evolve to become a proactive model, allowing for prediction of alert conditions.

8. References

[1] P. Leavitt, "Applying Knowledge Management to Oil and Gas Industry Challenges", American Productivity and Quality Center, October 2002.

[2] S. Poruban, J. Clark, "Managing Data & Knowledge: Oil, gas industry makes advances in managing data, knowledge", Oil & Gas Journal, vol. 99, issue 50, December 2001.

[3] R. P. Peebler, "Competing in the new era of knowledge-based petroleum companies", Proc. Indonesian Petroleum Association Annual Convention, pp. 157-165, October 1996.

[4] C. Pérez-Téllez, R. Rodríguez-Rosas, I. Ramírez, R. Bermúdez, C. Palavicini, "Applying a Real-Time Engineering Methodology to Drill Ahead of Potential Undesirable Events", Proc. Offshore Technology Conference (OTC), May 2012.

[5] WITSML Standards. Energistics. Retrieved January 10, 2012, from http://www.energistics.org/witsml-standard.