Using Real-Time Data for Automated Drilling Performance Analysis

By G. THONHAUSER*

Abstract

Drilling performance analysis from the operating company's view is part of the workflow for E&P drilling activity and stimulates organizational learning. The derived measurements help to improve safety, cost effectiveness and quality of ongoing and future operations.

Today, operating companies rely on performance analysis that is primarily based on daily activity breakdowns, which are defined through a large variety of activity coding schemes.

However, these activity reports are subjective human observations. This fact implies a number of limitations such as the level of detail that results from the time-consuming data entry process and the influence of individual barriers for learning.

To overcome these limitations, this paper investigates the use of process related data measured in real time for performance analysis while and after drilling.

It shows that it is possible to automatically derive activities and events from real-time data, just as it is possible to accomplish an understanding of various events, which result in non-optimal performance or trouble time through visual inspection of data plots.

Quality problems with existing real-time data (revealed during post analysis) are discussed, as well as their origin in the historically developed paradigm of a geology-driven, depth-based view of the drilling process.

The importance of a time-based view of the continuously ongoing drilling process is stressed, as well as the changing and challenging nature of the rig environment.

This setup requires new concepts for data handling, which are able to cope and scale with varying requirements.

An extensible and flexible infrastructure for measurement data handling is introduced that scales with the complexity of wells, fulfilling existing analysis and visualization requirements.

An example shows a comparison between automated rule based performance analysis and results obtained from traditional reporting.

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Introduction

The petroleum industry is challenged by a highly mobile work force and constantly changing organisations as part of its normal business processes. In addition, restructuring of the organisation, such as recent mergers and internal reorganisations, typically result in a smaller workforce.

As a result, people in the industry, forced by economic requirements, perform more and more work in an environment with steadily increasing complexity. This goes along with a high risk of permanent know-how loss for the organisation.

Typically, organisations try to handle this challenge by rigorous definitions of business processes leading to more or less strict guidelines people should follow.

This type of approach, in its purest sense, leads to manageable organisations, being quite efficient to handle reasonable static, explicit knowledge (knowledge that can be put on paper, formulated in sentences, stored in databases etc.), but is not designed to enable a flexible learning, and knowledge sharing environment and culture .

The challenge is to make tacit knowledge (held by humans that form the organisation) explicit. In other words, encourage people to share and to distribute knowledge.

The result is a requirement to change traditional ways of handling the information, which should be shared throughout the organisation, making it attractive for people to share their know-how, which often may be considered their personal competitive advantage.

An information technology system can only support an organisation and be a platform for people working together.

Analysing performance, in this context, is a sensitive area, especially if such analysis is supported by information technology not transparent to the people being analysed. It is of key importance that such a system is open to the people and people are involved in the complete analysis process and are stakeholders of such a concept.

This paper focuses on the drilling process and related information. The concepts presented here may be extended to other well related processes such as completion or intervention processes.

Traditional Drilling Information Management

In general, information about the drilling process is captured via reporting systems for a formal data exchange between rig and office. Those systems evolved from traditional paper reports into modern relational database systems but still reflect the structure of those reports to a large extent.

Most of the information stored is collected with a depth-based view, or on a daily basis (report date), which limits the possibility to link tools, measurements and activities.

It is important to note that these systems originally where designed to exchange information between rig and office to coordinate daily operations, not primarily to capture drilling know-how for the organisation.

Data collection

Drilling information may come from various sources at the rig. The main source of such information is the daily morning report, which includes a number of data sets:

– Activity Breakdown
– Drill String, Bottom Hole Assembly, and Bit Information
– Mud Information
– Geology Information
– Casing Information
– Etc.

In general, all reporting has in common that it is done on a reporting interval basis (daily) at a defined reporting time (e. g. midnight, or 06:00 hours).

The information collected at the rig is sent to the office, where it is typically stored in a relational database system. Information is shared via access to the relational database system and the possibility for the user to use various forms of reports (daily or summary reports).

Drilling activity breakdown

Basis for drilling performance analysis is the daily activity breakdown, which summarizes the drilling activities of the past reporting interval. In some cases, e. g. for rate of penetration analysis, this information is combined with depth based mud logging information.

The information about the activities captured at the rig is non-structured text information, which is classified using activity classification schemes. These coding systems allow classifying each operation in one or more levels of codes. Codes define the type of activity, productive, or non-productive operations and sometimes the cause of problems. There are a number of limitations:

- The information content of those reports is limited as an activity is typically only commented with a small number of words.
- Typically only operations with duration of more than 15 minutes are reported (sometimes even 30 minutes).
- Non-consistent use to classification codes, even within the same drilling organisation, leads to inconsistent results.

Using this type of information as basis for performance analysis shows the importance for well defined activity description and coding principles and rigorous quality standards.

Data may, or may not be quality controlled and edited before the information is stored in the database. Only a small number of systems used in the industry are based on a defined set of quality assurance guidelines.

Process Oriented Drilling Information Management

Automation technology allows documenting and describing industrial processes with a steadily increasing amount of data. The data collected at a high cost is generally not extensively used for interpretation and decision support.

Ideally, the information generated by the rig data acquisition systems should be the basis for the decision making process of the operating personnel.

The system presented in this paper utilises such information in combination with existing reporting information.

Data management concept

The majority of the processed data is real-time data, with additional information about the environment (machinery etc.) and reports, which reflect the human interpretation of the data observing the behaviour of the environment.

Specific focus is put on data quality. Automatic analysis requires the highest possible data quality, as the analysis result depends on the input. Typical data problems are related to measurement problems e. g. measured borehole depth showing inconsistent values.

The quality of the data depends on the way it was collected. The decision making influence of a particular set of data depends on the quality.

The amount of data stored is reduced as much as possible by the extraction of a maximum of information characteristic for the particular application.

The possibility to exchange and to compare data must be assured. Therefore standards are used. The XML (”Extensible Mark-up Language”) is used as format to exchange data. This way data, as well as structure, can be transported in one medium. For the management of drilling data WITSML™ as a data exchange standard is supported.

System abstraction

In order to account for the different system aspects the following abstract model is proposed :

- Environment Information
  - Surface
  - Subsurface
- Human Observations
- Measurement Data.

The proposed model fully captures current reporting information with a change towards a time-based, process oriented view.

Environment

In the context of the environment all relevant information pertinent to the rig and the subsurface construction, related resources, and configurations, is captured. The environment may be a very complex model and collection of real world objects .

One of the most important aspects that have to be considered is the time reference. Changes of the environment over time have to be persisted, so that the environment can be reconstructed at any later point in time. This allows the integration with human observations and measurements.

Human observations

The traditional reporting paradigm is shifted to a concept of human observations that are generated during the course of the project.

Reports composed by humans (from observation) are associated with three problems:

- Observation is naturally subjective
- Inaccuracy (often as function of the observation time)
- Inexact time references (specifically true for drilling activities).

Nevertheless, observations are of great use in data mining and analysis. Often problem patterns can only be identified clearly by using human observations.

Building on observations, is the concept of reporting by exception. Other than traditional reporting, the target of observations is to define deviations from an expected (or planned) behaviour. Exception reports can be well structured and detailed, resulting in a higher quality of reporting, with lesser time effort for entry.

Measurement data

Measurement data is process or environment related data, which is usually represented by a stream of data over time (i.e. continuos measurements at a specific sample rate).

While the representation of measurement data is fairly simple compared to environment or observations data, the data might be meaningless without additional information about the environment.

The presented concept includes a highly flexible way to integrate multiple streaming data sources (nodes) through an interconnected network infrastructure.

Integration of data in space and time

There are many different sources of data and information. The data providers and users of the data are distributed in space and time.

This represents one of the most challenging actual problems for data management and integration. Requirements include access to present and past information on- and off-site at the same time.

Depending on available network infrastructure mirroring or client-server architectures are currently used options, which are both problematic due to bandwidth availability and cost.

A possible solution is the use of mobile agent technology, which overcomes network latency and results in reduced network load and allows a robust and fault-tolerant operation on heterogenous systems.

Distributed Decision Support

The presented concept of distributed decision support goes beyond sharing data in a distributed network infrastructure. The steadily increasing amount of data has to be filtered for information content before being provided to the user.

It is considered key to extract important information customized for the particular interest and view of each single user. A number of methods are used to extract information from data.

The presented system is not an expert system in the classical view. It follows a heuristic approach using a combination of different algorithms, which allow giving decision support based on knowledge collected and stored.

The methods allow to describe the behaviour of the system and to add new know-how to the knowledge pool.

There is no focus on a single particular method. The system is a hybrid of analytical and non-deterministic methods. A number of different methodologies was tested and evaluated to reach the defined target (e. g. fuzzy logic, production rule systems, Bayesian networks, etc.).

Automated Operations Recognition

One application of the presented platform – integrating environment, observation, and measurement data – is the automatic operations recognition of drilling operations. The key targets of such an approach are:

- Reliable performance analysis independent of activity classification systems and the problems associated to assuring classification quality.

– Time and cost savings. Companies estimate about 1 to 4 hours of time spent by one person for reporting per day, per well. An automated operation reporting saves time and allows the drilling personnel to focus on the drilling process.

Typically 15 to 25% of drilling time is lost time due to some kind of trouble encountered during the drilling process. In addition, an estimated 15 to 25% of drilling time may be considered hidden lost time. This includes all the time reported which was not considered as lost time.

In order to eliminate lost time the first step is to clearly recognise and define any potential lost time. Traditional operations' reporting does not provide the necessary detail to fulfil this task, nor the required accuracy.

Reporting example

As a simple example the following traditional drilling report entry should be examined:

00:00 to 04:00	Run in hole
04:00 to 06:00	Circulating bottoms up
06:00 to 10:00	Drilling from 1200 to 1400 meters
10:00 to 15:00	Pull out of hole.

Running in hole period

The information given does not allow deriving more information than calculating an average tripping speed of 5 m/min. This estimate is only possible assuming that the hole tripping interval was covered in those 4 hours.

The information does not give information about the time to build the bottom hole assembly, possible problems with single connections and a realistic tripping speed, e. g. to evaluate surge and swap problems.

A considerable amount of additional information has to be collected (or assumed) to lead to a more detailed realistic result.

Circulating period

Evaluating the circulation period is essentially limited to duration. It is not possible to see how many pumps were operating, which flow rate was used and what the corresponding pump pressure was.

Rate of penetration analysis

Using the given information as basis for a rate of penetration analysis would use would result in a gross drilling time with a rate of penetration of 50 m/h.

Assuming using triple stands for connection (about 27 m of pipe prepared in the mast) the real scenario could look like this:

The driller will have to make approximately 7 connections. If we now know that the driller reamed and washed before the connection for 15 min. and circulated for 10 min. after the connection (which was not reported) the net rate of penetration calculates as roughly 184 m/h for the drilled interval.

If such non-reported reaming and washing times are considered bit performance evaluations may be potentially totally misleading. Even combining this information with depth-based rate of penetration data, does not lead to information about possible problems with hole instability leading to additional reaming etc.

Pulling out of hole

For the pulling out of hole operations similar limitations as for running in hole have to be considered.

Drilling data requirements

Drilling data requirements only include already existing data, which is typically measured at a 1 to 0.2 Hertz frequency on most of the rigs.

Our example analysis requires a set of 7 to 10 channels of standard measurements to perform a very comprehensive analysis of the drilling operations discussed in the example.

For this type of analysis frequency of 1 Hertz is recommended with 0.2 Hertz being a limit where the recognition accuracy for certain operations starts decreasing significantly.

Abstraction of the drilling process

The primary step to recognise drilling operations is to create an abstraction of the process. This definition requires drilling engineering expert know-how and can be considered an adequate step to capture procedural drilling knowledge from experts.

The second step is to link these activities with one or more measurement data streams, which allow recognising state changes of the system.

The third step is to abstract the data sources in a way so that they can be used as an input for a rule based system. The abstraction allows using measurement data as context for a rule based system to find system state changes.

Examples for drilling activities, which were defined for automated analysis, are:

– Bottom Hole Assembly (BHA) Runs
– Tripping
– Making Connection
– Ream and Wash
– Circulating
– Drilling in Rotating or Sliding Mode.

Rule processing

The automated operation recognition is based on rules. For each operation to recognize a rule set has to be defined. Each rule set consists of one or more rules.

A rule consists of a condition part and a conclusion part (if *condition* then *conclusion*). If one of the required condition information is not available (e. g. the corresponding measurement channel is not available), the whole rule set is ignored.

In the initialization phase of the system, it is tested which rules are available and which context variables are required. Then the available data channels are determined.

From this a list of all data channels to monitor and all possible context variables are generated. In case of missing channels alternative rule sets are used, in some cases with a loss of information.

As an example the pump strokes of each pump may be used to determine whether mud is circulated. In addition this will allow monitoring each single pump.

For the case, where only the mud flow rate is available as data channel, the system is still able to determine whether the rig is circulating, but the rules monitoring the pump will not be applied.

As a general rule, the system will preferably work with raw data channels, which reflect direct measurements and try to avoid derived or calculated channels with sometimes unknown data quality.

The system is designed to process in online and offline mode with the following definitions:

– Online processing means evaluating the operation recognition for every new value of the online data from data acquisition.
– Post processing means analysing historical data by reading large data sets to memory and then processing per data point.

Rule output

The output of the rules is any state change of a context variable with different options for persistence (non-persistent, text file, or data base). Typically, the information is stored in the system's data store along with human observation data.

With this rule system output a large variety of operations analysis can be performed.

As an analysis example a bottom hole assembly run can be exactly defined and split into making up BHA time, tripping time per single stand, each single connection, drilling time etc. A bit used for a certain BHA run can be related to the formations it drilled and exact information about net and gross rate of penetration can be determined.

Figs. 1 to 4 show examples for a graphical output of drilling operations analysis.

Figure 1 shows the results of reaming and washing operations around making two connections before and after drilling a stand.

Figure 2 shows the interpretation of reaming and washing operations as shown in but considering generating hole operations (net drilling time).

Figure 3 shows reaming and washing action while tripping out of hole. A number of connections are shown together with indicating periods increasing, keeping, and lowering the mud flow rate.

Figure 4 shows three trips during a hole section. In addition four short trips were recognized for that period.

Combining the results of the various results of the rule sets allows a large variety of drilling analysis steps. The formulation of a number of well documented analysis procedures for this new type of information generated is currently in progress.

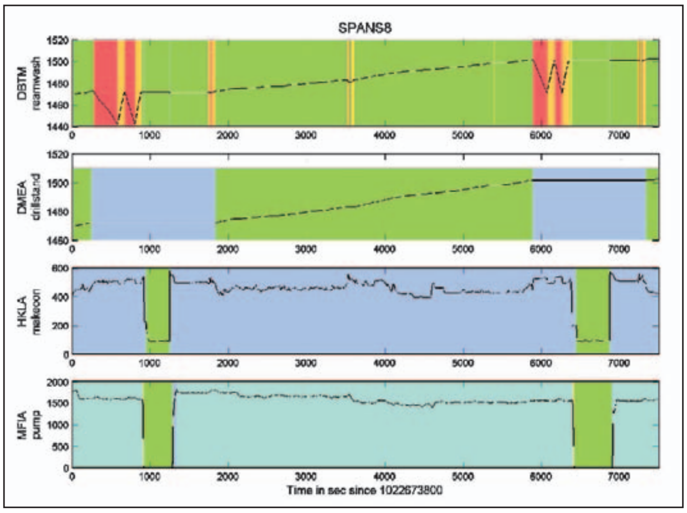

Fig. 1 Operations Analysis: Ream and Wash – Drilling – Making Connection – Pumping

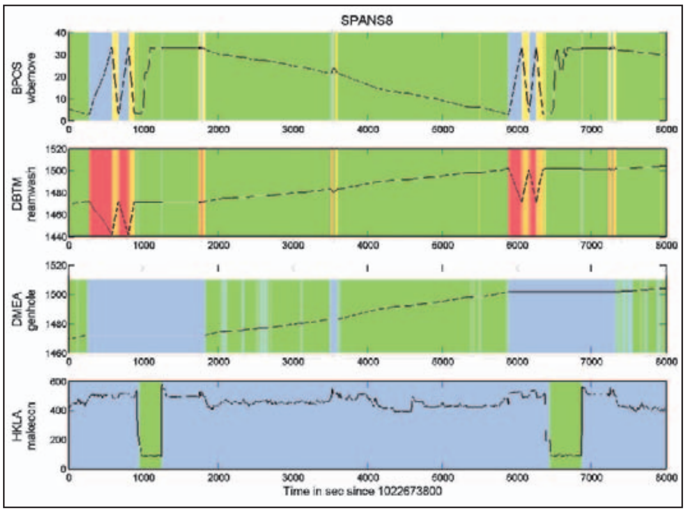

Fig. 2 Operations Analysis: Tripping – Ream and Wash – Drilling – Make Connection

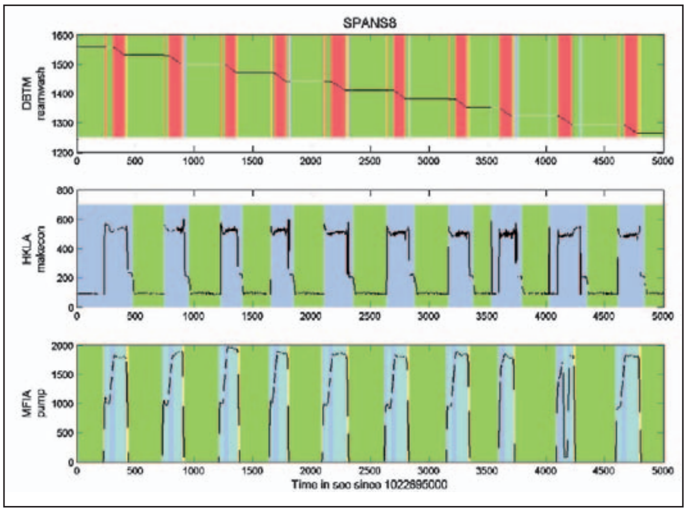

Fig. 3 Operations Analysis: Ream and Wash – Making Connection – Pump

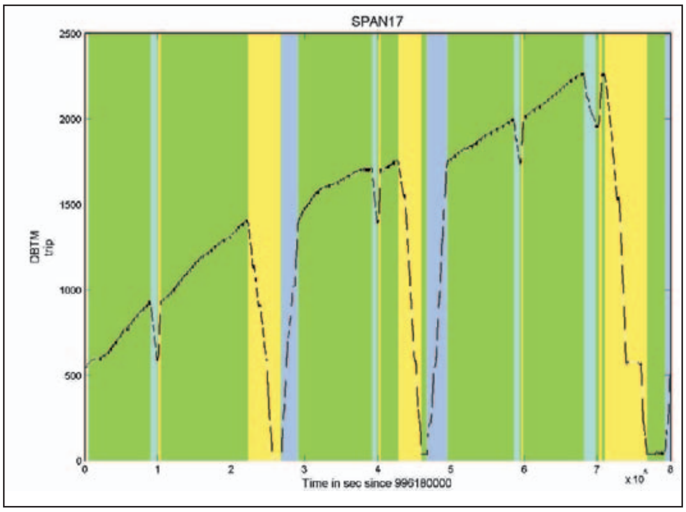

Fig. 4 Operations Analysis: Tripping

Conclusions

A concept for a framework and strategy to capture drilling information is presented. In addition a way to utilise existing drilling data in a novel way is presented.

It is shown that current drilling reporting practises have to be revised in order to utilize information from modern automation systems.

A time-based – process – driven view of the system is recommended to maximise the utilisation of time based measurement data.

Existing reporting data can and has to be integrated in such an approach as human observations.

Automated operations analysis can be combined with the concept of reporting by exception.

High-resolution operations analysis can be performed with existing data.

There is a very high potential for automated process optimisation and early problem recognition.

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