Recommendation of Counteractions for Prevention of Critical Events in Sub-Surface Drilling Environments

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ABSTRACT

Sub-Surface Drilling is the process of making boreholes into the Earth, which can reach depths of many kilometers. One of the major purposes of such boreholes is the exploration of oil or gas bearing formations with the goal to recover the content of such reservoirs. Problems in drilling operations pose serious risks for the crew and the environment and can cause significant financial losses. Critical events usually do not arise abruptly, but develop over time before they escalate. In this work, the authors present a system that integrates sensor data and machine learning algorithms into a decision support system (DSS), thus helping to avoid critical events by monitoring and recommending preventive measures. The authors describe how the DSS is implemented as a distributed system and how data-driven decision support processes are implemented and integrated into the system. The DSS detects drilling operations by recognizing temporal patterns in the sensor data and uses a combination of detected operational rig-states and sensor data to predict and recommend preventive measures for the stuck pipe problem. The sensor data, detection results and predictions are distributed to all stakeholders and displayed in appropriate user interfaces.

Keywords: Crisis Prevention, Critical Event Detection, Decision Support System, Drilling Support, Event Detection, On-Line Learning, Random Forest, Real-Time, Ream & Wash Operation, Stuck Pipe, System of Systems

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INTRODUCTION

Drilling a borehole is always guided by technical, economic and safety constraints. In the first instance safety plays a major role. Preventing crew, equipment and environment from injury, damage and pollution is a key focus. Equipment and instrumentation are inspected, tested and refurbished at regular intervals determined by a combination of risk assessment, local practices and legal requirements. Although this procedure provides a high degree of safety, the penetrated rock formations can always cause surprises that may lead to critical situations. Possible problems include influxes from high-pressure geological formations into the borehole, loss of circulation fluid into permeable zones or a drill pipe getting stuck in the borehole. These critical situations usually do not arise abruptly, but develop over time, and will escalate if they are not promptly detected and immediate counter measures are applied.

Figure 1 illustrates the general problem. The sketch shows the relationship between event uncertainty and hazard potential for an evolving crisis over time. Dotted lines indicate hazard potential levels in the case of early counteraction application. The hazard potential and probability for the actual occurrence of a crises increases with the delay in applying counter measures. Early indicators for a crisis are unclear and have a high uncertainty. Over time it becomes clearer whether we are dealing with an emerging crisis or not. But as the uncertainty about the state decreases, the hazard potential increases and makes the implementation of countermeasures more difficult and dangerous. Therefore it is crucial to detect critical events and decide on countermeasures as early as possible.

A decision support system (DSS) for these operations must involve the operational staff on the rig (drilling platform), on-site and remote analysts, and data-driven decision support processes that analyze available sensor data. In this paper we present such a decision support system for drilling operations using the example of stuck pipe problems. The approach presented in this work is part of a larger collaborative system for decision support developed within the European research project TRIDEC. This project focuses primarily on new approaches and technologies for intelligent geo-information management in complex and critical decision-making processes. The consortium consists of 10 European partners from 6 countries, will be finished after 3 years in late 2013 and has a
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