Neural Networks Facilitate Precise at - Bit Formation Detection Suitable for Deployment in Automated Drilling Systems

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Abstract

Objective

Drilling operations with rapid transitions between low and high unconfined compressive (UCS) stress formations create both invisible-lost-time and non-productive-time. Both of which are highly undesirable by operators and service providers in the current age of mandated capital efficiency. Stringers typically exhibit high-UCS carbonate formations and are embedded in softer rocks. Penetrating stringer intervals can therefore produce deflections along the well path, which need to be removed by time-consuming and expensive reaming operations to avoid failure of casing installation. Premature bit wear is an additional risk including the potential for lost cutters or dulling, resulting in lower rate-of-penetration and/or bit trips among other issues. Current formation evaluation measurements generally provide information behind the bit and therefore are only useful in retrospective validation. This approach has proven promising, but is limited to very high-contrast transitions, and the availability of drilling dynamics measurements from downhole. This paper presents an alternative, data-driven solution using a multi-layer supervised machine learning model to identify such formation changes.

Methods

Analysis is performed on commonly acquired surface, measurement-while-drilling (MWD) data and logging-while-drilling data (LWD) to identify correlations between such data and logged formation bulk density. As an example, commonly used MWD data comprise vibration measurements, which correlate strongly with the at-bit rock density. These types of correlation are used as the basis to train a convolutional neural network (CNN) Several different network architectures were explored and trained with varying feature subsets to arrive at the optimum combination in terms of accuracy of bulk density prediction.

Results

The CNN was trained and tested on drilling datasets acquired in offshore North Sea basins yielded promising results in terms of accuracy. It yielded a mean absolute error of 0.085 g/cm^3 across the training data set containing 90500 m of drilling data and performed on a similar level with test data. It was noted that the CNN captures the formation change at the correct depth accurately. Given the time criticality of formation change identification the almost immediate reaction of the CNN lends itself to being a powerful tool for formation change detection at-bit.

Novel Information

The vast majority of published work on leveraging machine learning with respect to formation evaluation concentrates on offline applications such as automatic well-log interpretation, offset analysis or evaluation of planned optimum drilling parameters. The presented work goes a step beyond and provides a concept for a real-time application for automated monitoring of the drilling process. The service can be deployed utilizing real-time data from the MWD data acquisition system.