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Rate of penetration (ROP) forecast based on artificial neural network with online learning

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ABSTRACT

The prediction of the rate of penetration is important since it allows for drilling optimization and operational planning. Drilling costs alone can constitute from 42% to 95% of the overall project cost of an Engineered or Enhanced Geothermal Systems (EGS), especially for deep wells. The present work considers an optimized training and prediction model for ROP prediction based on artificial neural network using an online learning methodology that updates the learned values as new data becomes available. The drilling data comes from an EGS well located in Pohang, South Korea, and drilled up to 4.2 km. The model is able to handle the cumulative nature of the drilling data in real time and forecast ahead values for the same well, and for other wells located in a region with similar characteristics. The neural network learning process was set into stages, and only the subsequent 25 points were predicted. Most sections returned acceptable errors, while others are affected by the variability on the in situ values. The results corresponding to each interval will serve for further adjustments of the model.

1. INTRODUCTION

Artificial neural networks have been applied to a wide variety of field research areas that include computer vision, speech recognition, and petroleum engineering (Bilgesu et al. 1997). Regarding oil industry, ANN have been used for ROP prediction (Gidh et al. 2012). Its ability to consider many input parameters into a model makes it advantageous (Monazami et al. 2012). It has been shown that this technique is dependent on the size and quality of the input variables, and in general the results improved as the model is feed with more training cases.

The model is trained with a selected group of input parameters that are provided during the ANN learning phase. Two types of learning modes are available within the

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software, On-line and off-line training, and they distinguish from each other basically on the training cases are managed after training (Shin 2001). In on-line training, the provided input parameters are discarded after being processed, however the weights are updated.

Owing to the accumulative manner the drilling data is generated in the field, this work explores the applicability of an ANN with an on-line training algorithm for ROP prediction especially in subsequent drilling sections within the same well.

2. METHODOLOGY

The data is from an enhanced geothermal project located in the city of Pohang, South Korea. The drilling parameters were recorded during the construction of the first well (PX-1). The total number of data points is 3770, covering the depth section from 0.3 to 4.2 km. The drilling parameters list includes: drilled depth, pore pressure gradient, equivalent circulating mud density at the hole bottom, weight of bit, bit diameter, rotary speed, fractional tooth height worn away, flow rate, parameter u, bit nozzle diameter, weight of bit per inch of bit diameter, threshold bit weight and ROP. Due to their variability, only the ROP values were filtered using an FFT filter with a window size of 10 points as a way to enhance ANN pattern recognition.

All the aforementioned drilling parameters were used to feed the model during training. The division of the data into 10 sets allowed for 9 training stages with increasing number of points. Furthermore, during prediction only the first 8 parameters were provided and the algorithm was asked to return the ROP predicted values for a specific depth. The "Generalized Data Analyzer and Predictor" software was used to implement the on-line ANN algorithm.

3. RESULTS

A total of nine prediction were carried out. However, only the subsequent 25 ROP points were considered for this study. Therefore their corresponding mean error and correlation coefficients are presented in Table 1.

Table 1. Mean error rates and correlation coefficients of each predicted ROP group.

Training stage	Predicted stage	Number of points	Mean Error (%)	Correlation coefficient
1	2	25	3.7	0
1-2	3	25	28.8	-0.58
1-3	4	25	21.9	-0.57
1-4	5	25	10.6	-0.21
1-5	6	25	37.2	-0.14
1-6	7	25	35.5	0
1-7	8	25	13.5	0
1-8	9	25	11.1	0
1-9	10	25	43.5	-0.90

On the other hand, Fig. 1 shows the forecasted ROP values after the 4th training stage. The extrapolated range was fixed to evaluate the response with increasing data values after each training stage was completed. The predictions returned more static values with low variability which differ at some degree with the measured cases. The accuracy of the forecasted points was observed to be dependent on the sudden changes of the ahead sections.

Therefore, although the forecasted values did not vary considerably within each predicted group, the overall error and correlation coefficient was altered by the subsequent changes of the measured data. This can be improved at some point, by selecting a more appropriated error ranges in the algorithm during the leaning phase.

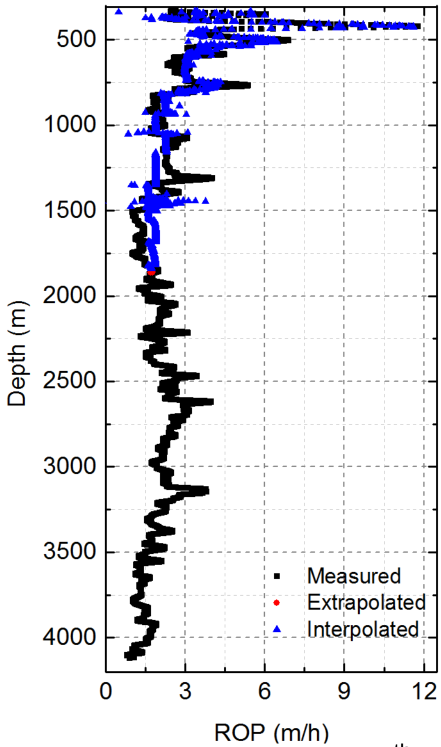

Fig. 1 Predicted ROP values after the 4th training stage.

3. CONCLUSIONS

An on-line artificial neural network approach was used to forecast the rate of penetration during drilling. The technique is capable of following the accumulative nature of the drilling data, especially when it is restricted to the forecast within the same well. A prediction length of 25 subsequent points after each training stage yield error percent values that vary as the accumulative training stages increased.

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