PS Machine Learning Algorithms for Predicting Liquid Loading in Gas Wells

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Abstract

Liquid loading is a term used to describe the situation where the gas produced from a well is unable to carry the liquid that is also produced along with it (Khetib et al., 2022). As a result, the liquid starts to accumulate in the wellbore. This accumulation of liquid can cause a decrease in gas production and in severe cases, it may even lead to a complete stoppage of production (Khetib et al., 2022) . The phenomenon of liquid loading in gas wells occurs when the critical gas velocity is less than a certain value, leading to a decrease in gas flow rate and ultimately a decrease in production (Merzoug et al., 2022). To simulate this phenomenon and study it in detail, we conducted experiments in a multiphase flow loop. We aimed to compare the results of the experiment with machine learning algorithms to predict the loading and unloading of the well. The purpose of this experiment was to examine the start of liquid accumulation in a gas well using a 2.4 meter vertical rigid pipe system with a 0.0508 meter (2 inch) internal diameter (Khetib.Y, 2022). The study analyzed the flow of gas and liquid in a vertical direction to gain insight into how liquid builds up in a vertical tube as gas flow decreases. We varied the gas and liquid flow rates to simulate different conditions and recorded the pressure and flow rate data (Khetib.Y, 2022). We used this data to train machine learning algorithms such as Support Vector Machines (SVMs), Random Forests, XGBoost, and Neural Networks, to predict whether the well is loaded or unloaded. We then compared the predictions of the machine learning algorithms with the experimental data.

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Objectives

The purposes of this study are to develop a reliable predictive model using machine learning algorithms for accurately determining liquid loading in gas wells, contributing to more efficient operations and enhanced safety measures.

To investigate and compare the predictive performance of different machine learning algorithms, including (but not limited to) decision trees, random forest and support vector machines for the given problem. To design a system that can utilize readily available operational data from gas wells, reducing the need for additional instrumentation or expensive data gathering processes.

Fig 1. Photo of the experimental facility (Khetib. Y, 2022)

Fig 2. Illustration of the slug flow regime in a vertical tube

Methods

The data was collected from 9 distinct experiments with varying conditions, through a data acquisition system with more than 10000 rows and 3 different input variables, representing at every combination different condition for the liquid loading. Pressure in the tubing, Water flow rate and Gas flow rate.

The data was cleaned by deleting the extra data generated from the difference of time between the physical phenomenon occurring in the multiphase flow loop and the flow meter registration. No problem was found with the missing data, simply because it wasn't any. A correlation analysis of the independent and dependent variables resulted in the following correlation matrix. The variable of interest for the prediction, the critical gas velocity, is highly correlated with water flow rate, gas flow rate and pressure inside the tubing, with correlation being calculated using Pearson's correlation coefficient. This is a good indication that our predictive variables are very indicative of our predicted variable, which is a good sign that machine learning models will have high predictability power.

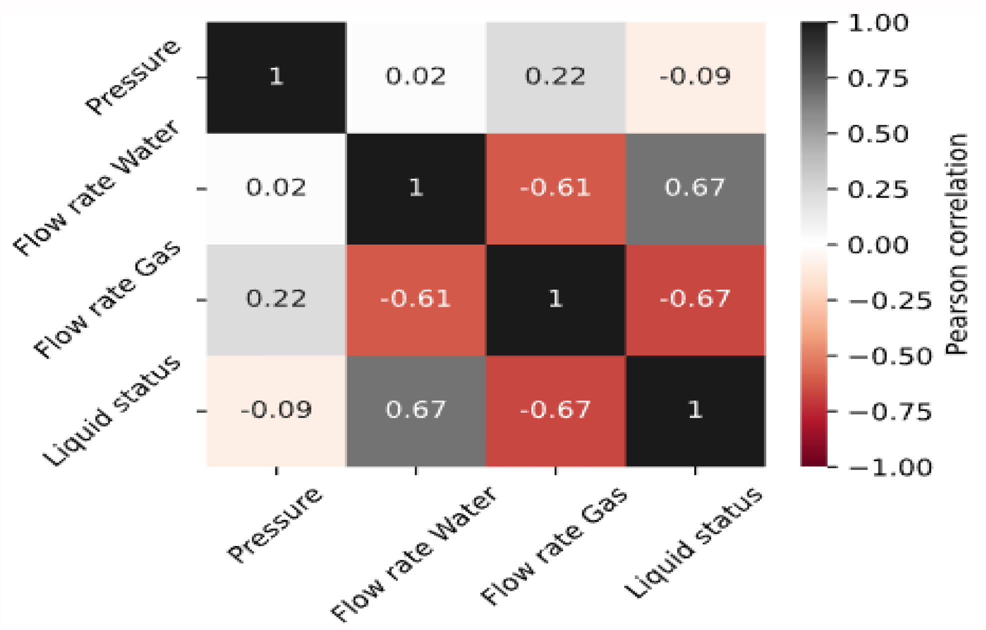

Fig 3. Correlation matrix for the different variables in the dataset

Results

After the implementation of few machine learning models, we decided to reveal the most appealing with high accuracy. Which are the "Random Forest", "Gradient Boosting", "AdaBoost", "Logistic Regression" and "SVC".

Post the fitting to the training set which consisted of 80% training, the models were then evaluated on the last 20% of data which was set aside for testing purposes. Random forest regressor had the highest R-2 score among all others, which yields near perfect predictions. On the other hand, other models had less accurate predictions, but don't go below 80%.

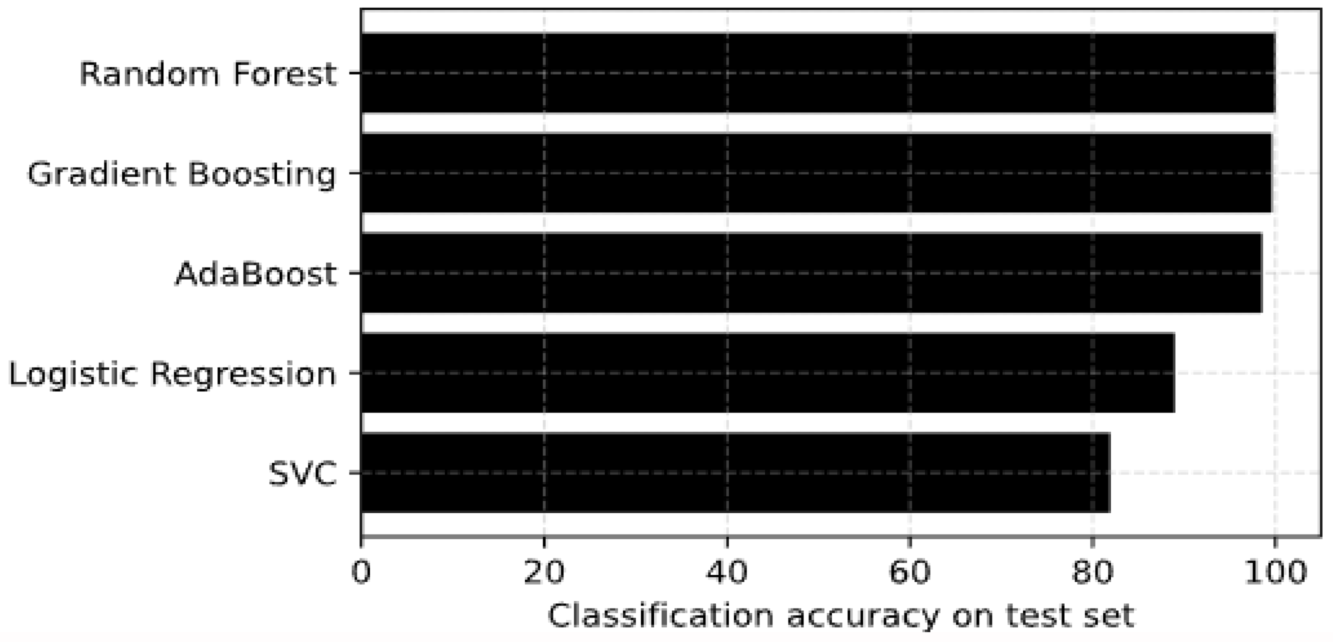

Fig 4. R-2 score of the different regression models on test set

Conclusion

From our experiments, the Random Forest Regressor emerged as the most accurate algorithm, It is also noteworthy that the algorithm with the lowest accuracy, the Support Vector Classifier (SVC), still achieved an accuracy rate of 81%. This underscores that machine learning models, even those that are not the top-performing in this context, can provide valuable insights and reasonably accurate predictions, reinforcing the potential of machine learning in this field. We believe that these predictive tools can be further developed and integrated into practical applications, contributing to more efficient and safer operations in the gas production industry.

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