Term Project:

Deep Neural Networks for Reservoir Production Forecasting

Introduction

In petroleum engineering, reservoir simulation is a fundamental tool used to predict the behavior of hydrocarbon reservoirs over time. Reservoir simulation involves creating mathematical models that represent the physical properties and processes occurring within underground rock formations containing oil, gas, and water. These simulations help engineers understand how fluids flow through porous rock, how production rates change over time, and how different operational strategies might affect recovery efficiency.

Traditional reservoir simulation requires solving complex partial differential equations that describe fluid flow through porous media, considering factors such as rock properties (porosity and permeability), fluid properties (viscosity, density, compressibility), and initial conditions (pressure, temperature, fluid saturations). The process typically begins with building a geological model of the reservoir, populating it with rock and fluid properties, defining initial conditions, and then running numerical simulations to predict future performance.

However, running detailed reservoir simulations can be computationally expensive and time-consuming, especially when multiple scenarios need to be evaluated or when real-time decision-making is required. This is where proxy modeling becomes invaluable. A proxy model is a simplified mathematical representation that can approximate the behavior of a complex system with significantly reduced computational cost. In reservoir engineering, proxy models can quickly estimate production forecasts, enabling rapid screening of different development scenarios and optimization of field operations.

In this final project, you will develop a deep learning approach to create a proxy model for reservoir production forecasting. By leveraging the power of deep neural networks and image processing techniques, you will create a model that can accurately predict oil production rates and cumulative production based on reservoir property maps, potentially providing near-instantaneous forecasts that would otherwise require hours or days of computational time using traditional simulation methods.

Project Description

Data Preparation:

You will receive a comprehensive dataset containing 1,050 reservoir model samples, each representing a unique reservoir realization. Each sample consists of:

- Permeability and porosity maps (64×64 grids) provided in TIFF format, representing the heterogeneous spatial distribution of these key reservoir properties

- An Excel file containing the corresponding production data including oil rates and cumulative production for six specific time periods, as well as initial water saturation (Sw) values.

The model inputs for each sample are:

- Permeability map (64×64 spatial distribution)
- Porosity map (64×64 spatial distribution)
- Initial water saturation (Sw)

The target variables you need to predict are:

- Oil production rates on the first day of months 1, 3, 5, 7, 9, and 11 of a production year
- Cumulative oil production on the first day of months 1, 3, 5, 7, 9, and 11 of a production year

Data Preprocessing:

Extract and process the reservoir property maps from the TIFF files, converting them to suitable formats for deep learning model input. Preprocess the images by applying appropriate techniques such as normalization, data cleaning, or data augmentation to enhance model performance. Handle the tabular data from the Excel file containing initial water saturation values and production targets. Split the dataset into training, validation, and testing.

Model Evaluation and Optimization:

Evaluate the performance of your trained model on the test set using appropriate regression metrics and plots for each target variable. Analyze the model's performance across different time periods and identify any temporal patterns in prediction accuracy.

Iterate and refine your model until you achieve satisfactory performance that demonstrates practical utility as a reservoir proxy model.

Documentation and Presentation:

Document your project thoroughly, including:

- Detailed description of data preprocessing steps and rationale
- Model architecture design decisions and alternatives considered
- Training methodology, hyperparameter selection, and optimization process
- Comprehensive evaluation metrics and performance analysis
- Discussion of model limitations and potential improvements

- Challenges encountered and how they were addressed

Prepare a presentation and comprehensive report to showcase your work, emphasizing both the technical implementation and the practical value of your proxy model for reservoir engineering applications.

Learning Objectives

This project will challenge you to apply your knowledge of deep learning, image processing, and petroleum engineering principles in an integrated manner. By completing this project, you will:

- Gain hands-on experience with proxy modeling techniques
- Learn to handle multi-modal input data (images and scalar values) in neural network architectures
- Understand the practical challenges and considerations in developing machine learning solutions for engineering applications
- Demonstrate your ability to leverage cutting-edge techniques to solve real-world problems in engineering

The successful completion of this project will showcase your capability to bridge the gap between advanced machine learning techniques and practical engineering applications.