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Stanford ERE

Deep-Learning Based Surrogate model for Subsurface Flow Problem

https://youtu.be/QGk5YkZ0jGw

INTRODUCTION

In this project, we introduced a surrogate model aiming to replace the time-consuming and expensive reservoir simulator. This CNN-LSTM based model can accurately predict production rate utilizing input well location and geophysical characteristics of reservoirs, thus can be a perfect alternative to address the optimization problem of well location.

APPROACH

The model architecture is a Recurrent Residual U-Net. The architecture includes a encoding net consisting of Convolutional and Residual Blocks, which transform permeability field and well location to useful features for the subsequent parts, a ConvLSTM for time series evolution, and a decoding net to eventually output the pressure/saturation maps for each time step.

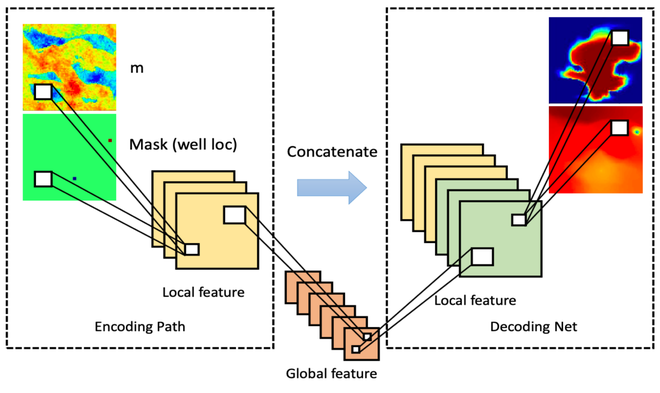

Fig.1. The architecture of U-Net

Since the well location matrix is sparse, we introduce some 3*3 mask mini-matrices around well locations to make our model more aware of the well locations.

LOST FUNCTION

To train the model, we defined lost function as shown,

$$\ell = \arg\min_{\theta} \frac{1}{n_t}\sum_{t=1}^{n_t} ||\hat{y}^t - y^t||_p^p + \lambda \frac{1}{n_t}\frac{1}{n_w}\sum_{t=1}^{n_t}\sum_{w=1}^{n_w} ||\hat{y}_w^t - y_w^t||_p^p.$$

where λ is weight for well state, n_t is number of step and n_w is the number of wells, $\hat{y}$ and y are pressure/saturation of test and simulation results, while p represents the norm we use.

LEARNING CURVE (RELATIVE ERROR)

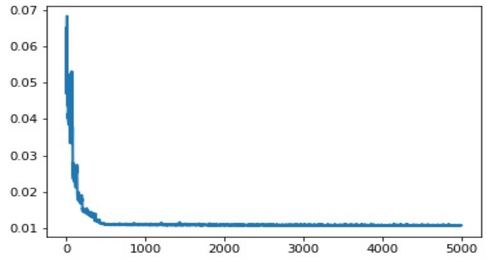

Fig.2. Learning curve

RESULTS

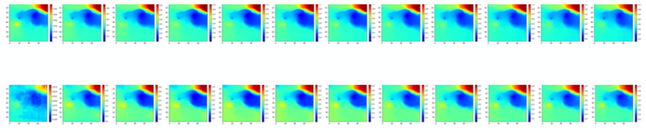

Fig.3. pressure of test samples

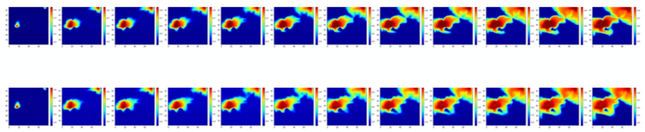

Fig.4. saturation of test samples

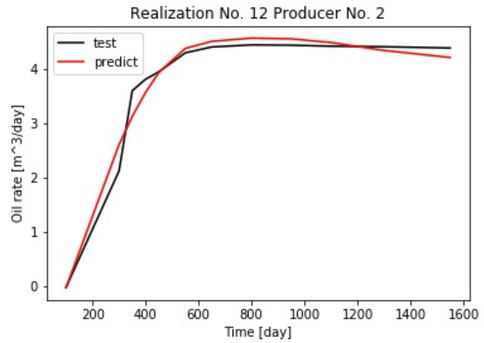

Fig.5. oil rate

CONCLUSIONS & FUTURE WORK

The surrogate model could generate close pressure and saturation maps to the simulation results. Next step, we will add more weight to the blocks around the well in the loss term to improve results. In the future, we may implement the surrogate model in well location optimization to maximize the oil production.

REFERENCES

[1] Tang, M., Liu, Y., Durlofsky, L. J. (2019). A deep-learning-based surrogate model for data assimilation in dynamic subsurface flow problems.

[2] Zhou, Y.(2012) Parallel general-purpose reservoir simulation with coupled reservoir models and multisegment wells. Doctoral dissertation, Stanford University