NEW FORMS OF MODEL REDUCTION IN RESERVOIR SIMULATION
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1 BACKGROUND

- There is a need to obtain reservoir models of lower complexity that can yield approximated output results as the fine scale models.
- The central idea of the R2CM Chair is to develop, test, and apply new methods of model validation (or invalidation) together with integrated dynamic reservoir monitoring and control, amenable to fast simulation, parameter estimation, uncertainty quantification, and production optimization.
- Model reduction by proper orthogonal decomposition (POD) has been applied somewhat successfully in reservoir simulation and optimization.
- Here, we introduce the idea of model reduction using Bilinear approximations and HOSVD. Both have been developed to overcome to main issues in POD: dependency on training inputs and loss of geological structure.

MODE REDUCTION IDEA

- The model reduction idea is to find an equivalent dynamical system of lower complexity (i.e., number of states – pressures, saturations) to be computed at every time step.
- The main tool is called POD, whereby one saves and manipulates the reservoir’s states snapshots based on a set of training input parameters.
- The reduced-order model is obtained by state projection, often by means of singular value decompositions (SVD).

3 METHODOLOGY / THEORETICAL FORMULATIONS

**Bilinear Approximations**

- One can re-write a non-linear dynamical system in the bilinear form.
- The tool used here is the Carleman bilinearization and the "Kronecker product".
- By augmenting the state-space, one can recast the system in the bilinear form and perform state projection using linear methods.

**HOSVD**

- In the regular SVD approach, one needs to vectorize the snapshot matrix.
- HOSVD is based on saving the snapshots as images ("as-is-it")
- HOSVD is based on multi-linear algebra

4 RESULTS

**Bilinear Approximations**

- Proof of concept → tested in a small gas reservoir (nonlinear).
- Comparisons of taking the linearized model versus the bilinear model.
- Comparisons by taking the reduced bilinear and the reduced linearized → compared RMSE.
- The reduced model is independent of the training inputs and, thus, is input-output invariant.
- Bilinear model → outperforms the linearized reduced model.

**HOSVD**

- Tested on SPE10. Comparisons: SVD X HOSVD → permeability reconstruction was used using parameterization and the Ensemble Kalman Filter (EnKF).
- HOSVD can potentially preserve geological properties.

EnKF Integration Steps using HOSVD

Output Results

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