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# Tensor-based reduced order adjoints for water flooding optimization

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## 1 Introduction

Large-scale models for oil reservoirs are at the core of current methods for reservoir management. These model-based techniques aim to counteract the effects of subsurface uncertainty on production, by applying a systematic approach consisting of the use of state and parameter estimation, prediction and economic optimization. Reservoir models are simulated numerically, and the evaluation of any stage of the management scheme is a computationally expensive task, hence there is a potential to use reduced-order modeling for accelerating these procedures. In this work, we focus on reducing the computational complexity of economic optimization by using a tensor-oriented approach for reduced-order modeling.

## 2 Production optimization

The purpose of model-based production optimization is to determine a production strategy that maximize profits based on large-scale numerical models for the multi-phase flow through porous media. Traditionally, the financial measure used to describe performance along the life cycle of the reservoir is the Net Present Value (NPV), which, in a simplified form, is a measure of the net earnings of oil production minus the costs associated with water injection and production. The problem of maximizing NPV can be formulated as a dynamical optimization problem constrained by the models for multiphase flow. From an optimal control perspective, the adjoint system of equations can be derived from the conditions of optimality, and it can be used for the computation of a search direction to a local optimum [1]. A step evaluation of the optimization procedure is computationally expensive, as it requires one set of flow and adjoint simulations. The use of reduced-order models may therefore reduce the computational burden of performing water flooding optimization.

## 3 Tensor-based empirical projection spaces

Proper Orthogonal Decomposition (POD)-based techniques generate projection spaces from simulations data, and can be used for reducing the computational complexity of reservoir models [2]. In reservoir engineering, classical POD has not succeeded due to its inability to capture correlations from highly nonlinear dynamics, and the resulting reduced order models turned out to be either unstable or inaccurate. In

this work, we exploit the spatial-temporal correlations from simulations by computing the projection spaces using tensor decompositions as presented in [3]. Snapshots of the oil saturation are stacked in multidimensional arrays and novel techniques for tensor decompositions are used to find tensor based empirical projection spaces [4].

## 4 Reduced order adjoints

Classical Galerkin projection of the flow and adjoint models onto tensor-based projection spaces is performed to obtain reduced-order models. Gradient-based optimal production strategies for water flooding are determined by using POD reduced-order models, as introduced by [5], and tensor-based reduced order models, as proposed in [3]. For the application case, the tensor strategy shows a better financial performance compared to the POD strategy and it is close to the optimal strategy for the full order model.

## 5 Acknowledgements

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