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Improved decision making with new efficient workflows for well placement optimization

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ABSTRACT

Determining optimum infill well placement has been one of most challenging events in overall field development strategy of any types of field. Because there could be a large number of possible candidates for new infill well locations, it is not practically feasible to evaluate all candidate locations, particularly at high-resolution geological models including millions of geological cells. Conventional static measure maps generally used in the industry has limited applicability as this does not address dynamic fluid flow and interference between existing wells. In contrast, direct application of stochastic search optimization methods such as genetic algorithms to large-scale field models may better account for dynamically changing reservoir conditions but can be complex to apply or computationally expensive.

We propose a novel method for infill well placement optimization designed as a two-stage optimization based on both dynamic flow diagnostic characteristics and genetic algorithm optimization methods. The main advantage of the proposed method over the conventional approach of using static reservoir property maps is its ability to integrate static reservoir properties with dynamic variables such as sweep efficiencies. By incorporating sweep efficiencies, new infill well potential map is generated to guide the optimization. The other benefits of this method are its maneuverability and capability to search in a narrower and tight space making the evolutionary algorithm an appropriate choice to identify rewarding locations which was not practically applicable due to the significant computational burden.

The proposed automated workflow is seamlessly integrated from building a simulation model to performing reservoir simulation and conducting the optimization process. The workflow is combined with novel engineering methods to identify best rewarding well location areas, and to identify strategies to maximize sweep efficiency through optimizing well placement and completion strategies resulting in substantial engineering time-savings. The power and utility of the proposed workflow are first demonstrated by a synthetic example and then applied to a full field model. Strategies to improve incremental oil recoveries were identified with a proposed novel, iterative and robust workflow.

1. Introduction

Placement of infill producers and injectors is an important aspect of the overall development strategy of any field and is a challenging task because the reservoir performance is generally affected by highly uncertain and nonlinearly correlated engineering and geologic variables. Determination of optimal well locations is particularly challenging for mature fields where new infill wells have to be drilled based on an improved understanding of the reservoir description and performance (Taware et al., 2012). Because of a large number of possible candidates for new infill well locations, it is not practically feasible to evaluate all candidate locations, particularly at high-resolution geological models. Therefore, a practical approach is necessary to optimize the infill well placement in an efficient way.

Prior researches related to well placement optimization are overall classified into two streams: reservoir quality maps and formal optimization methods. The reservoir quality map based approach uses the static grid properties (some dynamic factors such as remaining oil, pressure, productivity index etc.) to identify high-value regions which are targeted for infill well locations. The quality map which is a 2D representation of production potential in a reservoir has been proposed to guide well placement in publications (Cruz et al., 1999; Nakajima and Schiozer, 2003; Filho and de, 2005). Some quality map based approaches are based on static model properties only (Maschio et al., 2008), which might not necessary give the correct indication of good well location. Cottini-Loureiro and Araujo Fresky (2005) and

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Nomenclature

cl	closeness measured between two cells
d	physical distance between two cells
g	acceleration of gravity
p	pressure
q	flux between two cells
z	elevation of a given cell
φ	porosity
ρ	fluid density
S_o	oil saturation
T	Transmissibility between two cells
NZ	Number of layers
Φ	flow potential
Γ	connection path between two cells
α, *β*, *γ*	weights for different terms of constructing WPM map, where α+β+γ=1.0
DSDC	Dynamic Sweep/Drainage Capacity
SCHR	Static Hydrocarbon Richness
EWA	Existing Well Avoidance
WPM	Well Potential Measurement

Guimaraes et al. (2005) constructed the quality map by running the flow simulator varying the position of a single well multiple times. The quality map is measured by total cumulative production or NPV. It is a good quality map in the sense of capturing actually flow; but it is too computational prohibitive, especially for high resolution field models. Recent researches have proposed dynamic measure map based on technique such as streamline-based partition (Taware et al., 2012) or inter-well flow diagnostic (Shahvali et al., 2012; Lie et al., 2015). The streamline technique traces the trajectory of particle movement at given velocity field. When streamlines are mapped to cells, it is not easy to cover each cell if the number of traced streamlines is not sufficient. The inter-well flow diagnostic technique actually solves the equation for non-diffusive tracer using multiscale finite volume scheme. It is useful as a proxy in many situations but it is based on the single phase simple flow and is hard to consider complex completions, operations, the existence of aquifer etc.

The quality map is a 2D representation of reservoir response and can be limited to measure and indicate a possible location of single infill wells. In practice, we usually encounter multiple wells infill placement optimization problems, where quality map only is not adequate. A formal optimization algorithm is necessary for searching the optimum infill well locations as well as optimizing drilling sequences. Handels et al. (2007) have proposed adjoint-based, one of gradient based algorithm, for infill placement optimization. However, due to the discretizing nature of well locations, stochastic search approach is more widely applied to this problem, such as Genetic Algorithm (Montes et al., 2001), hybrid Genetic Algorithm (Badru and Kabir, 2003; Salam et al., 2015), ensemble-based optimization (Chen et al., 2009; Forouzanfar et al., 2016) and covariance matrix adaptation evolution strategy (Awotunde and Sibaweihi, 2014). Formal optimization methods for well placement, although promising and necessary in certain complex problems, have not been used in field applications because of their current limitations. Global optimization methods such as genetic algorithms require a large number of simulation runs which become impractical at application to large scale geological models. The gradient-based method also requires many numbers of iterations to converge or find solutions if the starting point is far away from the optimum locations. To utilize the benefit of the formal optimization in an efficient manner, a good starting point that can be obtained from the quality map should be essential.

In this paper, we propose an efficient infill well placement optimization method where we focus on improving practical applicability to field scale optimization. This paper is organized into two sections. In the first section, we present the proposed workflow, explaining the details of each component and illustrating them with results from application to a sector model. Then, this proposed workflow is applied to a full field model, where the locations for both producers and injectors are optimized. Through the application, the proposed workflow proves to be practical and efficient approach to field scale infill well optimization.

2. Infill well placement optimization workflow

We propose a structured approach to optimize well locations by designing it as a two-stage optimization. Other engineers can easily apply this workflow to their infill well placement management project or adapt this workflow to their own available software. In the first stage of optimization, we utilize a Well Potential Measurement (WPM) map, our proposed quality map, to identify 'sweet spots' for infill drilling. The WPM map incorporates three parts information: dynamic sweep/drainage capacity, static hydrocarbon richness, and existing well location avoidance. The created WPM map works as a proxy to help sample producers/injectors candidate pool using optimization technique such as tournament selection. Then, stochastic search approach, such as Genetic Algorithm (GA), is applied to search optimal well location combinations and sequence of drillings at stage-two. After stage-two optimization process, the most optimum well locations are decided and with that reliable reservoir oil recovery forecast is conducted. A brief outline of our proposed optimization workflow is shown in Fig. 1 and details come as follows.

- ***Compute dynamic flow capacity properties using flow-based/distance-based regions partitioning.***

The inclusion of dynamic flow capacity estimated at well locations into the quality map is essential in order to make the map-based approach efficient. Also, it is important to consider that the generation of dynamic factors should not be computationally inefficient. To have such regards considered, we adopt two practical partitioning techniques: flow-based partitioning and distance-based partitioning. The flow-based region partition includes all cells whose mobile fluids would eventually flow into the cells that are connected to the well, assuming the current pressure field. For the distance-based region partition, the cells are assigned to the closest wells, where the closeness is measured by the sum of inverse transmissibility over the connection path. Once

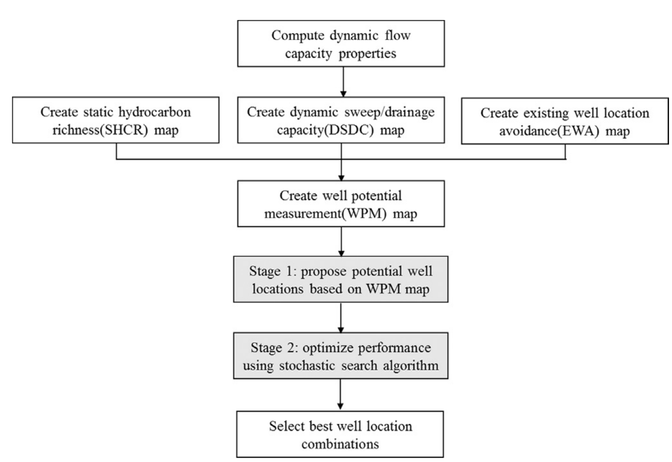

Fig. 1. : Proposed workflow for well placement optimization.