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A geometry-based adaptive unstructured grid generation algorithm for complex geological media

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ABSTRACT

In this paper a novel unstructured grid generation algorithm is presented that considers the effect of geological features and well locations in grid resolution. The proposed grid generation algorithm presents a strategy for definition and construction of an initial grid based on the geological model, geometry adaptation of geological features, and grid resolution control. The algorithm is applied to seismotectonic map of the Masjed-i-Soleiman reservoir. Comparison of grid results with the "Triangle" program shows a more suitable permeability contrast. Immiscible two-phase flow solutions are presented for a fractured porous media test case using different grid resolutions. Adapted grid on the fracture geometry gave identical results with that of a fine grid. The adapted grid employed 88.2% less CPU time when compared to the solutions obtained by the fine grid.

1. Introduction

Accurate flow solution in fractured reservoirs requires a proper grid in subsurface porous media domains. To obtain a proper grid in subsurface porous media, geological features (fractures and faults), heterogeneity, and well locations must be considered. Effect of these parameters should be reflected in grid resolution. An optimum grid resolution can improve prediction of flow transport by increasing solution stability, convergence, and accuracy. In this paper a novel unstructured grid generation algorithm is presented that considers the effect of geological features, and well locations in grid resolution. In addition to grid resolution control based on geological features, the proposed grid generation algorithm presents other novelties that include a strategy for definition and construction of an initial grid based on geological models, geometry adaptation of geological features, and grid quality enrichment.

Many researchers employ various grid generation procedures and techniques to tackle the space discretization of reservoir media since efficient simulation of reservoir flow can directly affect transport and production management. To ensure this efficiency, reservoir domains are represented as a continuum porous media with explicit geological features and are considered as complex geometry (Voelker, 2004).

Flow domains with complex geometry can be discretized more efficiently using unstructured grid techniques. Delaunay-based triangulation (Bowyer, 1981; Chew, 1989; Rebay, 1993; Sloan and Houlsby, 1984; Watson, 1981) and advancing-front technology (Gumbert et al., 1989; Lo, 1985; Lohner and Parikh, 1988; Peraire et al., 1987; Pirzadeh, 1992) are two classical methods that are extensively used to generate unstructured grid in reservoir domains. Other researchers have developed or employed grid tools for special applications based on the two classical unstructured methods (Aziz, 1993; Blocher et al., 2010; Evazi and Mahani, 2010; Holm et al., 2006; Karpinski et al., 2009; Merland et al., 2011; Monteagudo and Firoozabadi, 2004; Naji and Kazemi, 1996; Prévost et al., 2005; Rasaei and Sahimi, 2008, 2009; Sahimi et al., 2010, Pellerin et al., 2014). Use of classical unstructured methods for complex reservoir media may impose restriction or constraints with these methods (Xing et al., 2009). Field and boundary cells are generated in two different steps which can result in high computational costs for large scale problems (Mavriplis, 2000). Another restriction is associated with merging boundaries (Karimi-fard, 2013).

Many Delaunay-based triangulation programs have been employed for discrete fracture media. Triangle (Shewchuk, 1996), DistMesh (Persson and Strang, 2004), TetGen (Si, 2006), Gmsh (Geuzaine and Remacle, 2009), GRUMMP (Ollivier-Gooch, 2010), and G23FM (Mustapha, 2011) are examples of Delaunay-based grid generation programs. All of these programs start with a very well defined initial grid that requires additional preprocessing.

The proposed grid generation algorithm is motivated to eliminate constrains imposed by Advancing-front and Delaunay-based triangulations. A novel algorithm for generation of unstructured grids applicable to geological reservoirs is presented. The grid refinement procedure is based on point insertion and cell

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subdivision techniques. The main advantages of applying this algorithm to geological media as opposed to the above mentioned classical programs are based on fundamental procedures by which unstructured grids are produced.

In this paper, a coarse representation of the flow domain is introduced as an initial grid. This coarse initial grid can simply be constructed by connecting a few straight lines. The initial grid is then adapted to the actual geometrical model within the grid refinement procedure. Field (matrix) and boundary (fault or fracture) cells are refined simultaneously as the initial grid is adapted to a predefined geometry. This enables a more efficient use of grid quality techniques to enrich the overall grid near geological features. To demonstrate these novelties, first, the proposed grid generation algorithm is described using a realistic fractured geological media. Second, the adaptation of a coarse initial grid to a final geological model is demonstrated on seismotectonic map of the Masjed-i-Soleiman reservoir (Safari et al., 2010). Third, strategies for grid resolution control based on geological data are presented. Both grid refinement procedure and statistical results of this test case are compared to those obtained from the "Triangle" program. Finally, immiscible two phase flow solutions are obtained on a sample fractured porous media domain. The effect of grid quality and resolution are then highlighted on solution accuracy.

2. Unstructured grid generation algorithm

To describe the current unstructured grid generation algorithm, an attempt is made to generate unstructured grid in a realistic geological media. Complex arrangement of large-scale fractured faults within seismotectonic map of the Masjed-i-Soleiman area, shown in Fig. 1, has been selected for this reason.

Scalable geometries of the main faults within the Masjed-i-Soleiman area map are extracted and are shown in Fig. 2.

The unstructured grid generation algorithm begins with an initial grid which is a coarse representation of porous media. The initial grid is divided into two different scales of dimension. The first dimensional scale represents porous media matrix. The matrix consists of a grid with triangular cells. The second dimensional scale is associated with cells that are representing geological features. These cells are designed by $(N-1)$-dimensions (a line in two-dimensional grids), where N denotes the dimension of porous media matrix. Initial unstructured grid for the Fig. 2 geometrical model is illustrated in Fig. 3. It can be seen that the geometry of fractured fault cells are constructed with 15 simple straight lines. These lines are designated as common edges shared by adjacent triangular matrix cells. It is noted that map scales are also shown around the initial grid for ease of location comparison.

This initial unstructured grid contains 24 vertices, 15 fracture cells and 40 triangular matrix cells. To refine the initial grid of Fig. 3, two special forms of connectivity matrices are proposed to

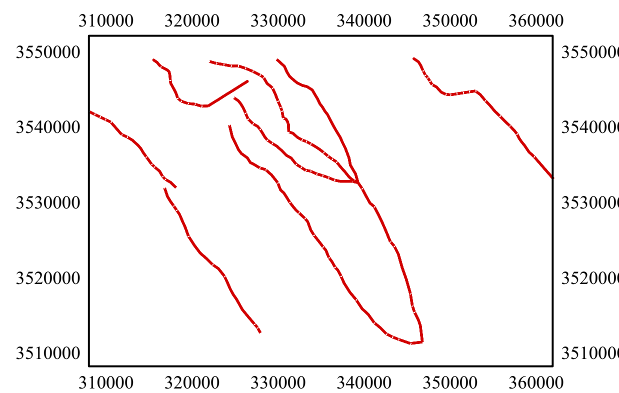

Fig. 2. The geometrical model of main faults from the Masjed-i-Soleiman area map.

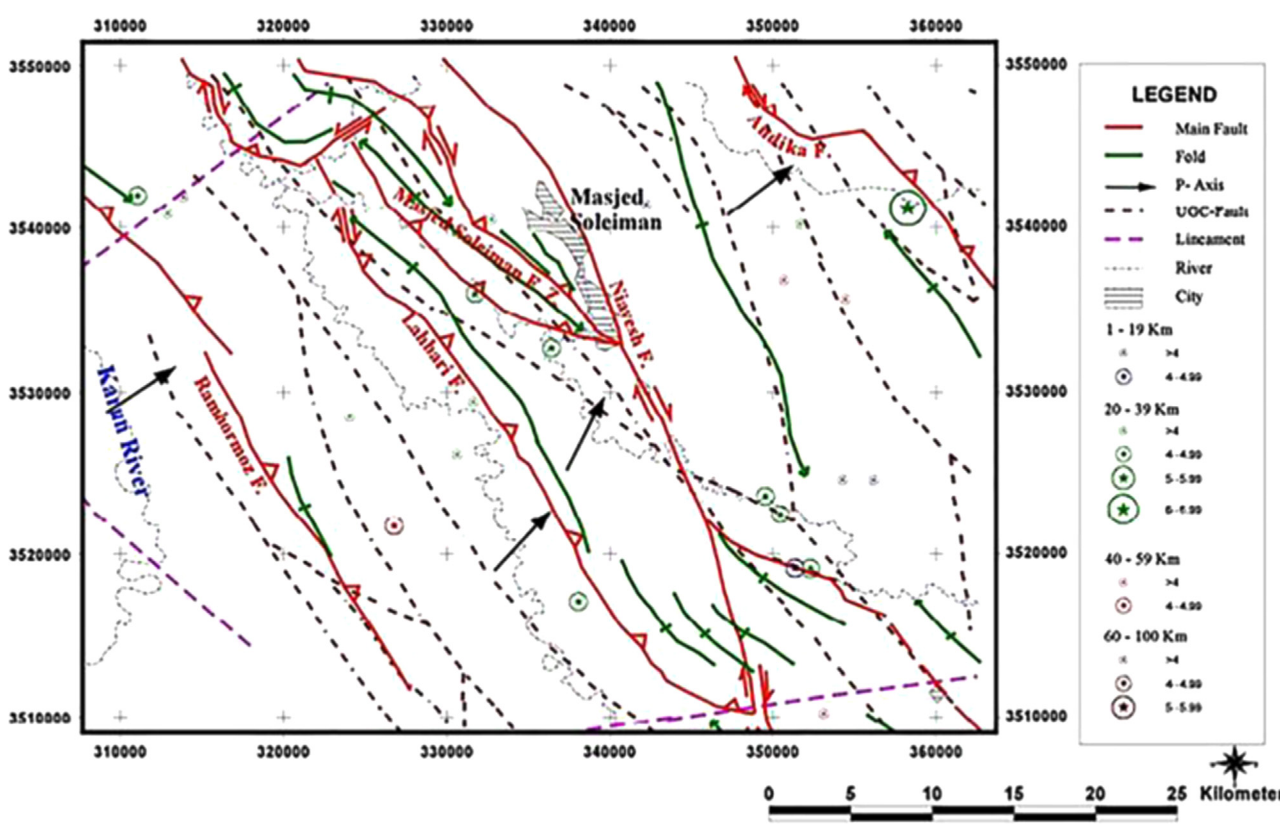

Fig. 1. Seismotectonic map of the Masjed-i-Soleiman area (Safari et al., 2010).