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Two-phase flow simulation using parallel computers with distributed memory

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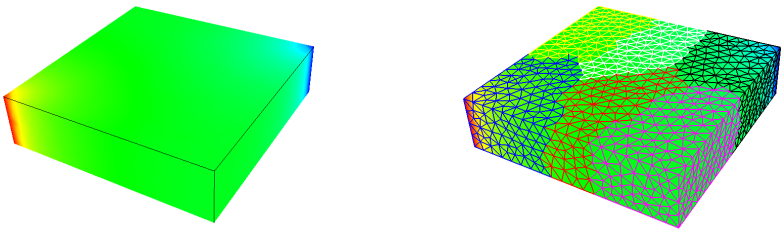
ABSTRACT

The two-phase flow of oil and water in petroleum reservoirs can be modelled by a set of coupled nonlinear partial differential equations that cannot be solved using analytical techniques. In order to properly predict the flow behaviour numerical methods are required to approximate the exact solution at discrete points in the reservoir. In the present paper, a vertex centered edge-based finite volume method (EBFV) with median dual control volumes built over a primal tetrahedral mesh is used to discretize fluid flow equations through porous media. A computer program has been developed using C++ to perform the simulations in serial and parallel computers.

Due to its easy implementation, the IMPES (IMplicit Pressure Explicit Saturation) method is applied producing an elliptic type pressure equation and a hyperbolic type saturation equation. The elliptic equation is solved implicitly by a variation of Crumpton's two step approach, then velocities are directly computed from the pressure field and, finally, the saturation equation is solved explicitly through a higher order MUSCL (Monotone Upwind Scheme for Conservation Laws) method. Heterogeneous and anisotropic (full absolute permeability tensor) media are easily handled in a sub-domain by sub-domain approach. For each physical sub-domain (material properties, e.g. permeability, are associated to sub-domains), a list of edges and nodes and their associated geometrical coefficients are stored in order to make the gradient recovered independent for each sub-domain in order to avoid physical inconsistencies that would occur along control surfaces adjacent to material discontinuities.

The parallel simulator presented here was implemented and tested in a cluster of PC's with distributed memory to predict fluid flow behaviour in petroleum reservoirs, for problems where the discretized domain does not fit into the memory of a single computational node. For this situation, a coarse mesh is initially distributed among all processors required for a simulation. Then, the distributed mesh is refined to the required level of accuracy.

At the current stage, the simulator is capable to solve the elliptic equation on parallel computers as shown in figure 1, for a simple model application considering a homogeneous and isotropic media. The mathematical and numerical developments of IMPES formulation has already been done and tested for 2D meshes in serial computers using MATLAB. The implementation for 3D meshes with parallel computers is on the way and performance results will be available soon.



(a) **(b)**

Figure 1 – Elliptic equation simulating a ¼ fivespot flow in a reservoir in serial (a) and in parallel computers (b).

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