Datapages/Search and Discovery Article #90224 GeoConvention © 2014, FOCUS - Adapt, Refine, Sustain Calgary, Alberta, Canada, May 12-16, 2014

Customized Integrated Unconventional Modeling; The Way You Want

Amir Shamsa, Yasin Hajizadeh, Sergei Fillin, Jean-Paul Dessap, Mehdi Majdi Yazdi, Schlumberger Information Solutions, Calgary, Alberta

Summary

There have been considerable advances in numerical engines and gridding algorithms in the simulation of unconventional resources in recent years. However, there is potentially a huge delay in implementing these innovative solutions in commercial simulators and modeling platforms. We present a novel framework to integrate customized advanced numerical simulation tools with geophysical and geological (G&G) modeling workflows. The framework enables the industry peers build advanced simulation tools and communicate with the G&G software effortlessly. The workflow can also be used in academia to make student familiar with the fundamentals of conventional and unconventional modeling or be applied in large-scale research projects. We demonstrate this novel communication mechanism using a customized seismic simulation code integrated with a geological modeling package. It is concluded that the framework provides an ocean of opportunities for companies seeking an advanced integrated earth modeling platform that can provide accurate field performance predictions.

Introduction

Recent advances in reservoir simulation algorithms have pushed the boundaries in conventional and unconventional modeling. With new shale and heavy oil projects being planned, universities and oil companies try to establish novel integrated modeling frameworks that can address the challenges of these developments. Few of these advances include new thermal simulation algorithms (Lie et al. 2013), multiple porosity models for shale reservoir simulation (Yan et al. 2013), dual continuum and discrete fracture simulation (Moinfar et al. 2013), AMG and multicore solvers (Mishev et al. 2011) (Pravilnikov et al. 2013) and geomechanical considerations (Cokar et al. 2013). However, the time gap between research and commercial implementation can be large and thus there is a need for a reliable communication mechanism that can be used to easily integrate simulators with current G&G software.

We have developed an innovative framework, called KITSUNE (KIT for Simulation UNder Evolution) which facilitates the flow of data between custom simulation engines and Petrel environment. The inputs of the plugin can be as complex as needed and visualizations of the outputs, 3D grids or functions are performed within Petrel. The simulator engine is developed by scientists in high level languages (C#, Fortran, etc.) and is supplied to the plugin as a dynamic-link library (DLL) file. It allows the use of a wide selection of Petrel tools to quickly and efficiently create simulation models, run sensitivity cases and analyze results. This plugin can be used to integrate Petrel with any custom simulator that follows the predefined class architecture. Nwosa (2013) developed a 2D water-oil code to simulate a 5-spot injection scheme and used KITSUNE to connect the numerical engine to Petrel. In the next section, we introduce another application of this plugin to simulate seismic wave propagation in a reservoir.

Example

To demonstrate the workflow, we developed a custom simulator that simulates the propagation of a pressure disturbance in a reservoir. The pressure propagation is heuristically dominated by hyperbolic partial-differential equation to illustrate the flexibility of this tool:

$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial y^2} + \frac{\partial^2 p}{\partial z^2} = \frac{1}{v^2} \frac{\partial^2 p}{\partial t^2} \tag{1}$$

This equation can be numerically estimated by the central-difference quotient operating on both sides. The explicit scheme leads to:

$$\begin{aligned} p_{i,j,k}^{n+1} = {} & \lambda_x^2\, p_{i-1,j,k}^{n} + \lambda_y^2\, p_{i,j-1,k}^{n} + \lambda_z^2\, p_{i,j,k-1}^{n} - 2(\lambda_x^2 + \lambda_x^2 + \lambda_x^2 - 1) p_{i,j,k}^{n} + \lambda_x^2\, p_{i+1,j,k}^{n} + \lambda_y^2\, p_{i,j+1,k}^{n} \\ & + \lambda_z^2\, p_{i,j,k+1}^{n} - p_{i,j,k}^{n-1} \end{aligned}$$

where $\lambda_x = \frac{v\Delta t}{\Delta x}$, $\lambda_x = \frac{v\Delta t}{\Delta y}$ and $\lambda_z = \frac{v\Delta t}{\Delta x}$. Upon solving this partial differential equation forward in time, we will end up with the pressure (or stress) propagation as if it is a travelling wave. In other words, the initial pressure disturbance is acting as our source (for example dynamite or airgun). Recording the disturbance at any grid point through the reservoir grid is like having a receiver at that point. In equation 1, *v* is compressional velocity of each grid point which is a function of density, bulk and shear modulus:

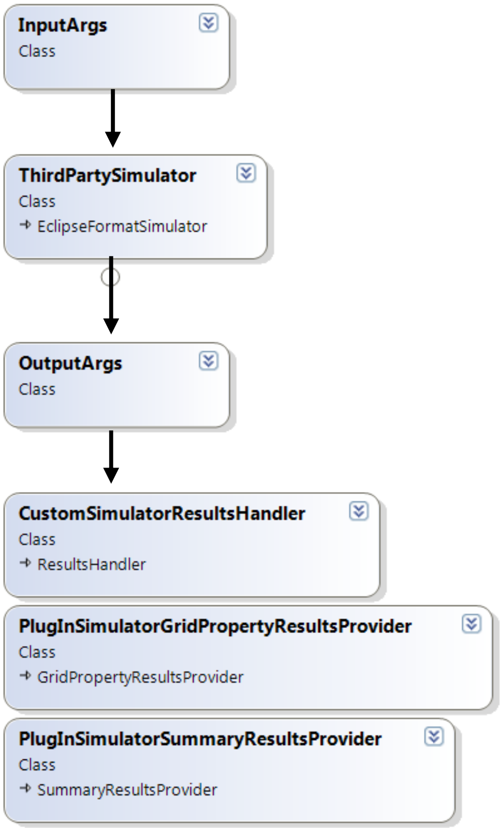
$$v_p = \sqrt{\frac{K + \frac{4}{3}\,\mu}{\rho}} \tag{3}$$

The bulk and shear modulus for the saturated rock can be calculated from the Gassmann equation (Gassmann, 1951). In order to apply the Gassmann equation, we need to have porosity and saturation values as well as the fluid (oil, gas, water) and rock properties which are accessible through *define simulation case* input parameters. Upon clicking the *export simulation case*, this information would be passed to the custom wave simulator.

Figure 1 shows the general structure of the code and how various parts of a reservoir simulator should be defined using the provided classes. Figures 2 & 3 illustrate how the pressure disturbance is propagating through the 3D grid. Figure 3 shows the time slice (top row) and cross section (bottom row) that pass through the source point. It should be reminded that the simulations are performed using the custom seismic simulator and the visualization of results is handled by Petrel. Figure 4 shows the pressure disturbance that can be thought as the stress recorded at two grids. The red curve is the grid which contains source point and, the green line is the stress response of a grid on the surface away from the source point. They can be considered the receiver records at those grids.

Conclusions

We have developed a novel generic workflow to integrate non-commercial reservoir simulation engines with geophysical and geological (G&G) modeling software. This communication protocol is installed as a plugin in the G&G software and allows the engineers and scientists to focus on improving the workflow efficiency rather than spending their time in parsing inputs and results between various platforms. This seamless integration brings endless possibilities in conventional and unconventional resources studies. Geoscientist will be able to use the latest advances in reservoir simulation directly in their G&G applications and benefit from the vast arrays of interpretation, sensitivity studies, optimization and visualization tools available in these software. This will directly translate to accurate reservoir performance predictions and improved financial performance of companies.



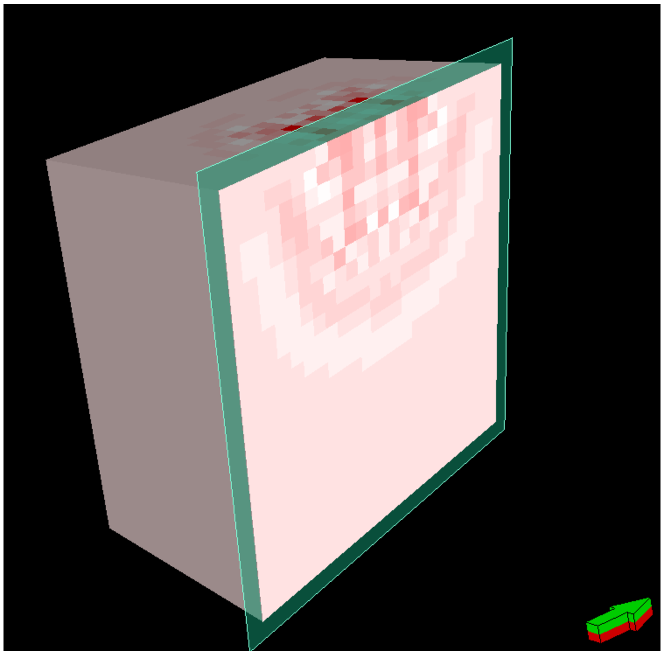


Figure 1: General structure of the code

Figure 2: 3-D model

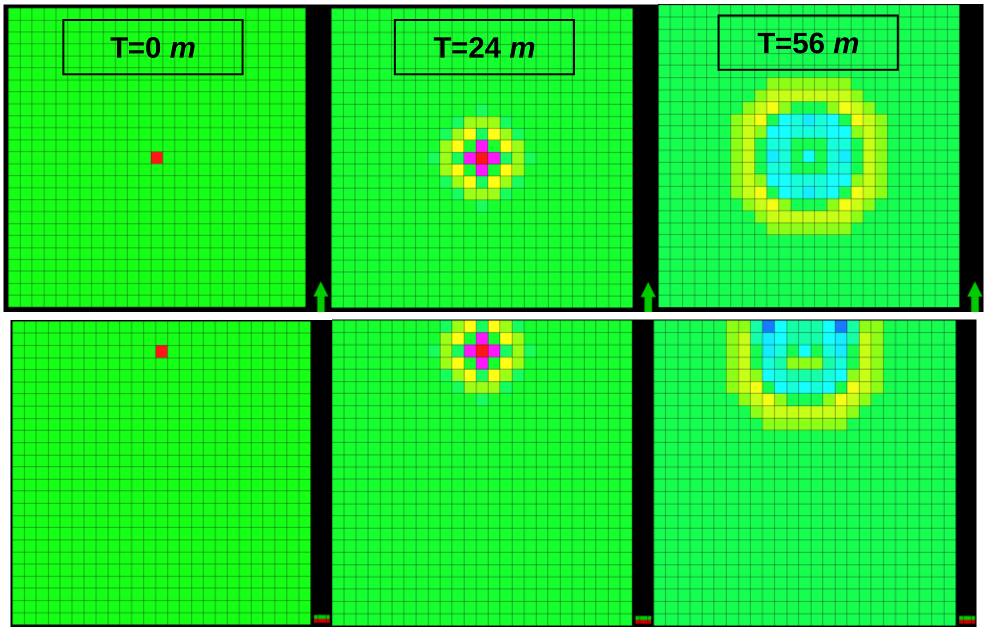


Figure 3: First row: top view; second row: side view section profiles

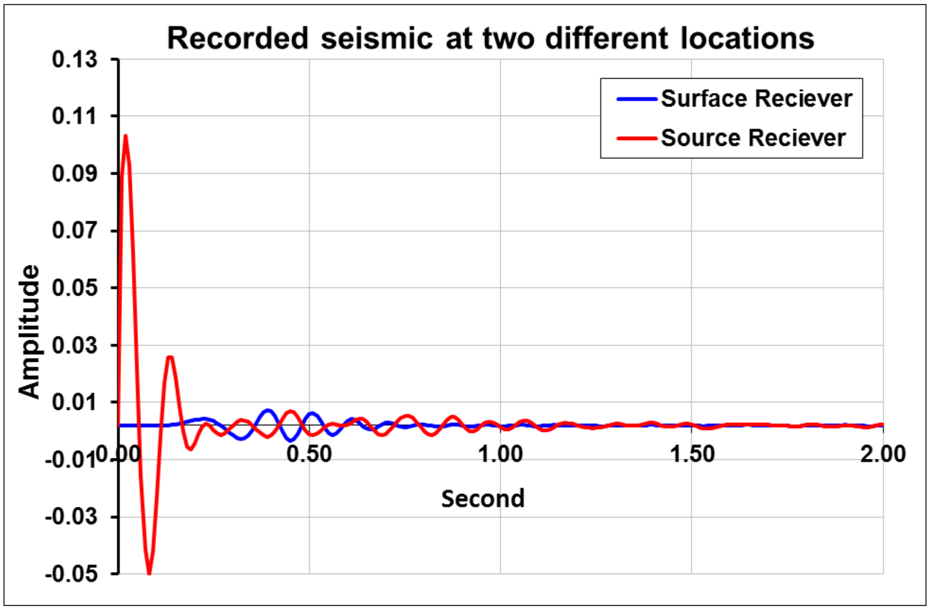


Figure 4: Seismic response

References

Cokar, M., Kallos, M.S., Gates, I.D (2013) A New Thermogeomechanical Theory for Gravity Drainage in Steam-Assisted Gravity, SPE 163136, SPE Journal, Volume 18, Number 4, pp 736-742

Gassmann, F., 1951, Über die elastizität poröser medien: Vierteljahrss-chrift der Naturforschenden Gesellschaft in Zurich, 96, 1-23

Lie, K.A., Nilsen, H M., Rasmussen, A F., Raynaud, X (2013) Fast Simulation of Polymer Injection in Heavy Oil Reservoir Based on Topological Sorting and Sequential Splitting, SPE 163599, Reservoir Simulation Symposium, February 18-20, The Woodlands, TX, USA

Mishev, I., Shaw, J., Lu, P (2011) Numerical Experiments with AMG Solver in Reservoir Simulation, SPE 141765, SPE Reservoir Simulation Symposium, 21-23 February 2011, The Woodlands, TX, USA

Moinfar, A., Varavei, A., Sepehrnoori, K., Johns, R.T (2013) Development of a Coupled Dual Continuum and Discrete Fracture Model for the Simulation of Unconventional Reservoirs, SPE 163647, , SPE Reservoir Simulation Symposium, February 18-20, The Woodlands, TX, USA

Nwosa O. C., 2013, Extending the petrel model builder for educational and research purposes, M Sc. Thesis, Texas A&M University

Pravilnikov, V., Diyankov, O., Diyankova, S., Beckner, B L., Mishev, I.D (2013) An Efficient Multicore Linear Solver for Reservoir Simulation Applications, SPE Reservoir Simulation Symposium, February 18-20, The Woodlands, TX, USA

Yan, B., Killough, J., Wang, Y., Cao, Y (2013) Novel Approaches for the Simulation of Unconventional Reservoirs, SPE 168786, Unconventional Resources Technology Conference, 12-14 August 2013, Denver, Colorado, USA