Borehole Acoustic Wavefield Modeling with a “Cluster-in-a-Box”

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About the Author

- Kristoffer Walker
  - 2 years, Senior Research Petrophysicist, Chevron
  - 5 years, Acoustic Algorithms and Data Processing Team Lead, Halliburton
  - 10 years, Green Scholar and Research Geophysicist, IGPP, Scripps Institution of Oceanography, Univ. of California, San Diego
  - Masters/PhD, Stanford, 2000/03
  - Interests: Borehole Acoustics, Seismology, DAS, Anisotropy, Rock Physics, Geomechanics, Fishing, Running
Acknowledgements

• Feature advice and feedback: Alexei Bolshakov
• Modeling code development: Thor Johnsen, Robert Mallan
• Sonic3DGUI app development support: Bin Qiu
• Azure cloud-based support: Bhavani Kambham, Raymond Laganao, Xin Dong, Mason Edwards, Bin Qiu, Tony Sutippantupat, and Stefan Hertel
• MATLAB license support: Keith Droge, Dave Blackman, and Anne Draucker
Motivation

• How does Chevron “win in any environment” in Borehole Acoustics?

• We need to know if vendor data products are accurate. This is a challenge!

• So we seek “ground truth” tests that we then feed into their algorithms to evaluate the answers they produce.

• Ground truth data is expensive and sometimes impossible to acquire.

• **Numerical** wavefield simulation provides the best ground truth and it works in ANY environment.
Important Modeling Features

- Must be able to handle borehole acoustic modeling for frequencies up to 40 kHz
- Hard and soft rocks
- Anisotropy up to orthorhombic symmetry with tilt
- Handles any source/receiver geometry
- Handles any borehole shape (elliptical, circular, rugose)
- Handles interbedding with strike/dip
Important Solution Features

- Do not “reinvent the wheel”
- Very fast (one simulation within an hour)
- User and computationally scalable
- Generalized for flexible usage
- Point-and-click and one-stop-shopping
- Use cloud’s pay-as-you-go usage model
Borehole Acoustic Logging

- Borehole drilled through formations, with or without casing and cement
- Wireline and LWD tools have sources and receiver arrays
- Source fires a pulse into the water, which goes into formations
- Some energy returns to the receiver array
- Array processing techniques are used to measure elastic properties of the formation and its pore fluids
- Relates to drilling safety, borehole stability, formation evaluation, reservoir characterization, and completion planning
Sonic3D Description

- Create 3D models of compressional velocity, shear velocity, and density
- Discretization of model into tens of “mega pixels”
- Impart receivers at specific location(s)
- Impart source(s) at specific location(s)
- Create source function(s) that will be transmitted at each source location
- Solve full elastic wave equation for stresses and particle velocities using an explicit method (finite difference time domain)
- Iterate for tens of thousands of time steps
- Absorb the reflections that would normally occur at the model boundaries
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Sonic3D Borehole Acoustic Wavefield Modeling Software Package

- Define models
- Start/stop cloud-based resources
- Send simulations to cloud
- Monitor simulations in cloud
- Download results from cloud
- Analyze results (animations, semblance, spectral processing)

Virtual Machine 1: 72 cores
- Job 1: Sonic3D.exe, ModelBuilder.exe, ASCII config files
- Job 1: ASCII and binary data, log file, Wave formatted waveforms

Virtual Machine 2: 72 cores
- Job 2: Sonic3D.exe, ModelBuilder.exe, ASCII config files
- Job 2: ASCII and binary data, log file, Wave formatted waveforms

Sonic3DGUI.exe MatLab

Sonic3D.exe C++
- Kris Walker's Borehole Acoustic Classes
- Robert Mallan's Perfectly Matched Layer Class
- Thor Johnsen's Mjolnir Cache Blocking Classes
Programmatically Starting/Stopping Cloud-Based Resources with MATLAB’s System Command

- To start/stop resources, you first need to acquire your Access Token (also called Authentication Token)
- We send a REST POST command to the VM manager using the ubiquitous “Curl” program to get the Access Token as well as start/stop the VM’s
- We execute the following “Curl” command via MATLAB’s system command to obtain the Access Token:

```
curl -X POST -d
"grant_type=client_credentials&client_id=[APPLICATION_ID]&client_secret=[PASSWORD]&resource=https%3A%2F%2Fmanagement.azure.com%2F"
https://login.microsoftonline.com/[TENANT_ID]/oauth2/token
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```
Programmatically Starting Cloud-Based Resources with MATLAB’s System Command

- In the curl command you pass your Access Token as a header (with -H)
- You pass the Application ID and Password as data variables (-d)
- Lastly, you pass the Subscription ID, Resource Group, and VM Name as part of the URL string.
- You keep a map between IP address and VM Name
- The command is shown below. The key command being executed here is called “start”.

```bash
```
Programmatically Stopping Cloud-Based Resources with MATLAB’s System Command

- Shutting down your VM also requires the Access Token, as well as the other parameters described in Starting your VM.
- Only difference is instead of executing a “start”, you are executing a “deallocate”
- Warning: if you use “powerOff”, machine will remain “allocated” and continue to incur usage costs

```
curl -X POST -H "Authorization: Bearer [TOKEN]" -d 
"grant_type=client_credentials&client_id=[APPLICATION_ID]&client_secret=[PASSWORD]&resource=https%3A%2F%2Fmanagement.azure.com%2F" 
```
Sonic3D: Main Window

Once a model is complete and downloaded, the Analysis tools can be used on it by clicking on that row and selecting the analysis button.

Each row is a Simulation

Multiple jobs (up to 10) can be simultaneously monitored

All model data is stored in a database archive directory of your choosing using the “Set Home” button

Control Cloud Based Resources

Model Building

Job Control

Analysis

Utilities
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MATLAB Specific Development Notes

- Sonic3D GUI developed with GUIDE
- GUIDE being replaced by App Designer
- Both are feature rich
- Both are easy to use and expand upon, but I’ve found App Designer to be much easier to use
- App Designer’s responsiveness is faster than GUIDE’s
- App Designer has buttons to:
  - Convert to a stand-alone *.exe
  - Deploy the GUI to a VM as a “Web App”
- Pluses of using App Designer grossly outweigh those for GUIDE