Demonstrating Innovative Reservoir Modeling Workflows Enabled by a GPU-Accelerated Implicit Simulator

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- First fine-grained implementation of petroleum reservoir simulator

- Talk focuses on implications of exceptional speed in workflows
Background: Reservoir Simulation

- Reservoir Simulation

- Generate a (predictive) model of production for economic recovery

- The workflow is more than just compute cycles...
Motivation for Compute Acceleration

- Unstructured grids; irregular memory access patterns

- Linear solver $\approx 80\%$ of total time, hundreds of other kernels

- Very many simulation realizations are required for most workflows
### Algorithms Come First

- Choose the right GPU solvers (GAMPACK, AMGx)

<table>
<thead>
<tr>
<th>Method</th>
<th>GPU</th>
<th>CPU</th>
<th>Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG Solver</td>
<td>24.6 s</td>
<td>246.6 s</td>
<td>4589</td>
</tr>
<tr>
<td>AMG Solver</td>
<td>0.7 s</td>
<td>5 s</td>
<td>8</td>
</tr>
</tbody>
</table>

- ...then confront Amdahl’s law directly to achieve >10x
## Example Performance on Real Assets

<table>
<thead>
<tr>
<th>Model</th>
<th># cells</th>
<th>#CPU cores</th>
<th>#K40s</th>
<th>time</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.36M</td>
<td>32 (1)</td>
<td>2</td>
<td>26h/53m</td>
<td>45x</td>
</tr>
<tr>
<td>B</td>
<td>20M</td>
<td>48 (2)</td>
<td>8</td>
<td>14h/1.2h</td>
<td>12x</td>
</tr>
</tbody>
</table>

- **Total** application acceleration + better-suited solvers = >10x factor
- Validation within 1% of current commercial standard

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![Graphs showing BHP and oil production rate over time.](https://www.stoneridgetechnology.com)
Example Problem

16M cells for 20 years @31 day intervals

Many uncertainties in model; want to explore them

40ft x 40ft x 4ft
12.2m x 12.2m x 1.2m
Example Problem

≈1.6km
≈3.2km

4 GPUS  20 MIN  32 X
Total Compute Time For Workflow

12 x E5-2687  VS  4 x K40s

45 d  VS  1.5 d
Total Compute Cost For Workflow

CPU: $1.44/hr = $1536

GPU: $9.28/hr = $310

VS
Creating a Downstream Deluge

- 600 mins: commercial simulator runs once, creates 6 min of work

100:1

- 600 mins: our simulator runs 32 times, creates 192 mins of work

3:1
Everything new is newer again

- Total workflow acceleration from the ground-up...

68% : 32%
What Now?

- How can we deal with 100 files?
- How can we represent data in clear, compelling ways?
- How do we share and collaborate?
Implication for Workflow

- Loading a model grid can be painful - 109s for this model

- (Most) existing tools are not designed to (help you) work this way...

- Fundamentally : How can we help but stay out of the way?
Implication for Workflow

- Make choosing/loading many simulations easier

Simulation Ensembles

- 75/
  - 90.5 GB
  - Permian Wolfcamp Study - RSS Study
    - Asset #211A, Initial Project Evaluation
    - History-matched to scenario Alpha 2b, infills for region A & S, with schedule variants for wells #6A and #27B

- PERMIAN-RSS/
  - 22.2 GB

- SPE10-tuple/
  - 3.7 GB

www.stoneridgetechnology.com
Typical User Interface

- Legend clutter, disambiguation

- Lack of plot interactivity, traditional loading styles, anti-aliasing

- Can we make this accessible or (ideally) unnecessary?
Instead Consider…

- Provide a means to disambiguate large ensemble results
Clarity of Results

- Pixel vs vector plotting, anti-aliasing, interactivity
Typical Color Palette (Difference Plots)
Better Color Choices, Faster Interpretation
• Preserve local relative differences, design for color-blindness
Color Blindness: 8-12% Males

Tritanopia (blue deficiency)
Results Anywhere

- Distributed workload, remote clients, results anywhere

- Send colleagues an interactive graph; not static PDFs
A New Approach to Workflows

- Accelerated applications can cause post-processing data deluges

- Total application acceleration: new workflow/interaction challenges!

- We are re-thinking the way the tools behave, interact with GPU apps
Whole Systems Approach

- Key is understanding workflow impacts

- Fresh thinking on engineering tools around workflow optimization
The Team

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All other images have been generated by Stone Ridge Technology
Paul Tol’s work on palettes is a great resource!

Normal

Deuteranopia

Protanopia

Can choose colors such that printers can reproduce: ISO-12647-2
Slide Vault: Color is more than perception!

- Publication-quality figures need well-chosen color spaces

- What happens when great color figures are printed in B&W?