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GPU Accelerated Adaptive Wave Propagation Algorithm

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Abstract

The GPU performance of the adaptive wave propagation algorithm is critical to its effectiveness in simulating wave propagation in complex media. This algorithm employs adaptive mesh refinement to improve resolution in areas where the wavefield is changing rapidly. The algorithm's performance is significantly improved by the use of graphics processing units (GPUs), which offer faster computation times than traditional central processing units (CPUs). According to the studies in this poster, GPU acceleration of the adaptive wave propagation algorithm provides significant improvements in simulation speed and scalability, as seen in the simulated examples: scalar advection, shallow water equations, euler, and acoustics. When compared to traditional CPU-based algorithms, the algorithm can handle larger models and produce higher resolution results at a faster rate. The algorithm's efficiency and effectiveness are determined by the specific hardware and software configuration of the GPU used; for this study, we used INL Borah.

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GPU accelerated adaptive wave propagation algorithm

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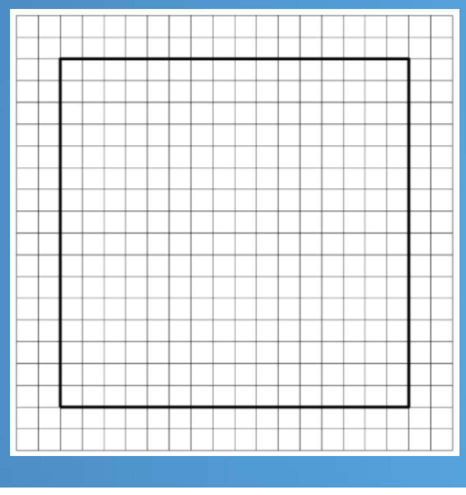
Key features of ForestClaw

ForestClaw is a parallel, multi-block library for solving PDEs on adaptively refined logically Cartesian meshes.

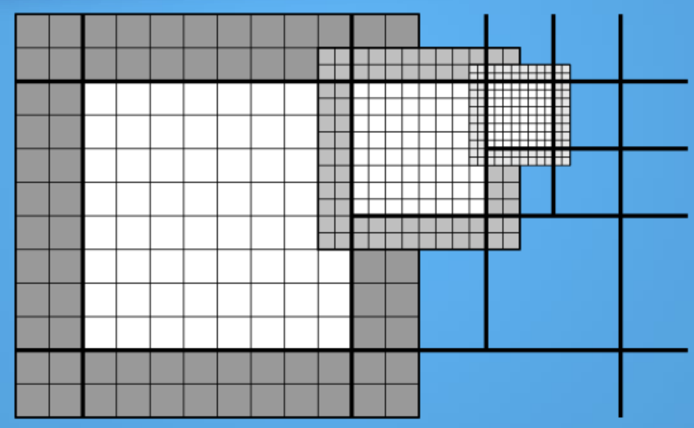
Some of the features of ForestClaw are :

1. Based on the **highly scalable** grid management library p4est (www.p4est.org)
2. **Multi-block** capabilities extends the usefulness of Cartesian mesh methods to many important domains, including the cubed sphere, and non-square rectangular regions.
3. **Quad-tree** adaptive meshing means that less meta-data is stored on each processor, and nearest-neighbors are easy to find.
4. Cartesian grid layout of each patch and regular neighbor patterns **greatly simplifies the development of novel numerical methods**.
5. **ForestClaw** has been extended by several popular libraries, such as **Clawpack** and **GeoClaw** (www.clawpack.org).

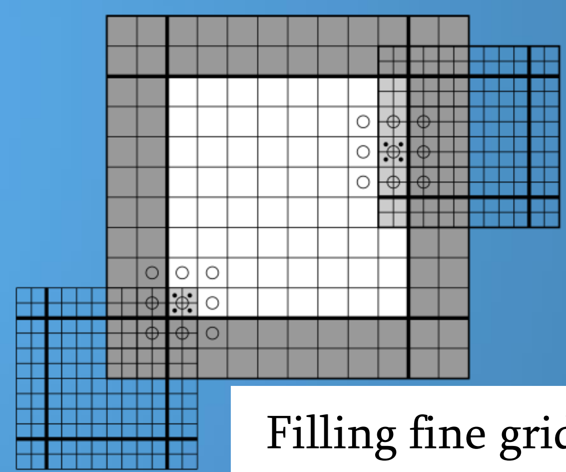
CPU : Hierarchy of equal size patches managed by p4est mesh



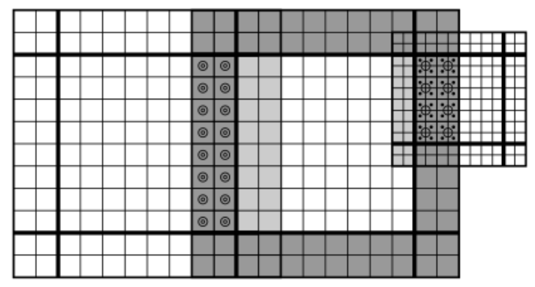
ForestClaw patches with ghost cells



Quadtree of patches



Filling fine grid patches by interpolation

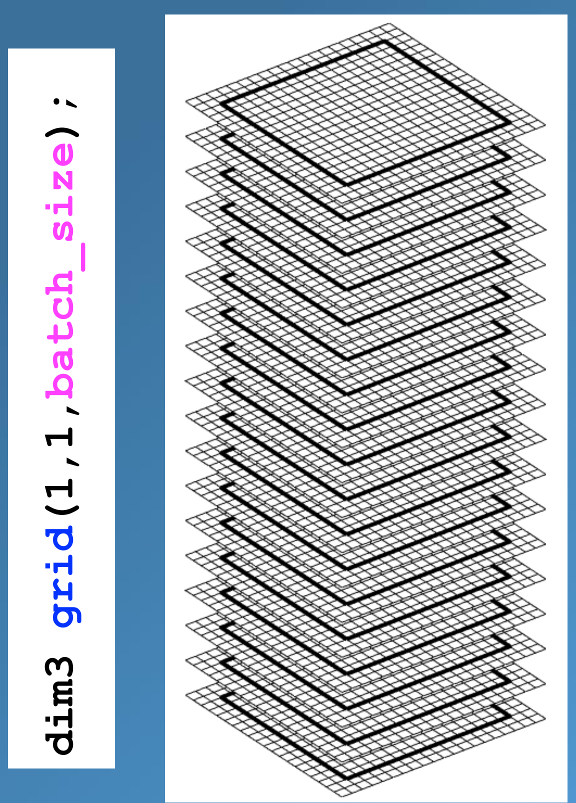


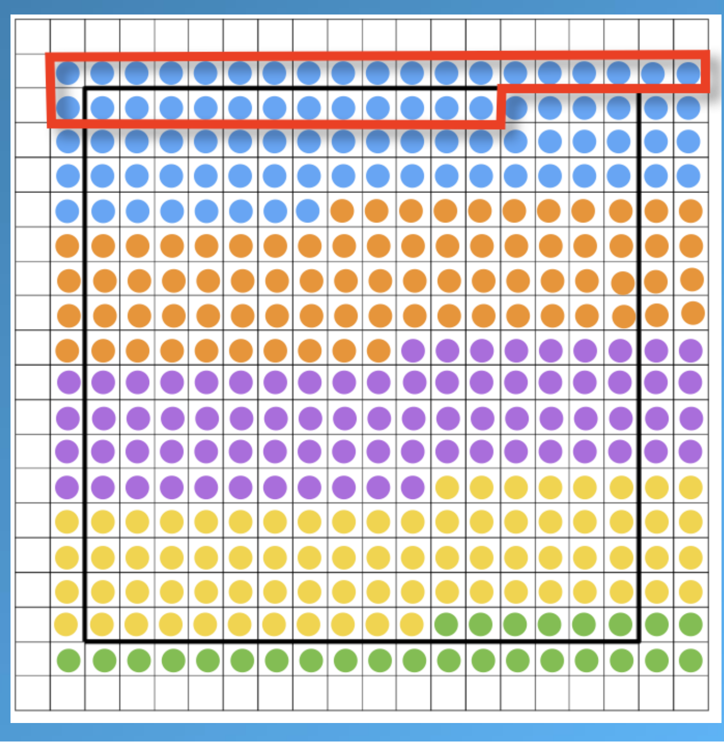
Filling coarse grid ghost cells by averaging

GPU : Explicit single time step done in parallel via GPU threads

```
block_size = 128;  batch_size = 4000;
mwork = 9*meqn + 9*maux + mwaves + meqn*mwaves;
bytes_per_thread = sizeof(double)*mwork;
bytes = bytes_per_thread*block_size;

dim3 block(block_size,1,1);
dim3 grid(1,1,batch_size);
claw_flux2<<<grid,block,bytes>>>(mx,my,meqn,..)
```





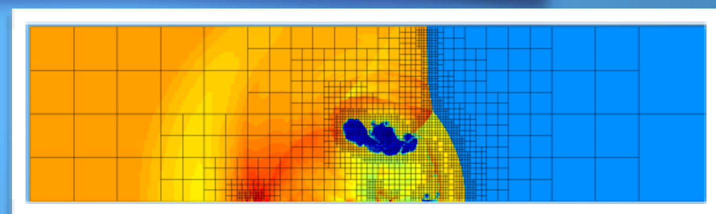
Single thread block reused per patch.
Warp of 32 threads run simultaneously

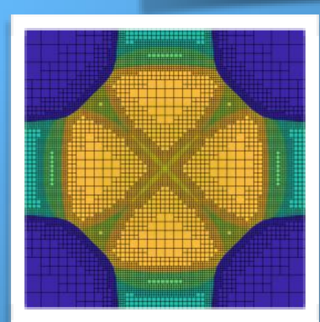
Results : Four examples

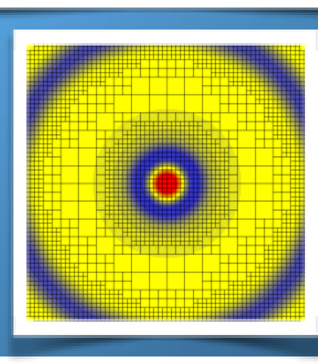
Scalar advection, SWE, Euler, Acoustics

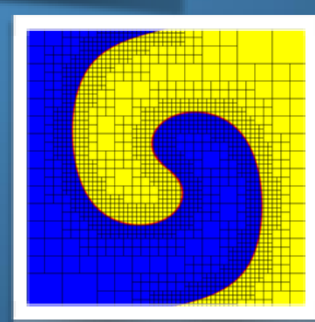
example	procs / device	1	2	4	8	16
bump	CPU	7469620	3734810	1867400	933702	466851
	GPU	7469620	3734810	1867400	933702	466851
radial	CPU	1058390	529196	264598	132299	66150
	GPU	1058390	529196	264598	132299	66150
shockbubble	CPU	2411600	1205800	602900	301450	150725
	GPU	2411605	1205805	602900	301450	150725
swirl	CPU	10127600	5063800	2531900	1265950	632975
	GPU	10127600	5063800	2531900	1265950	632975

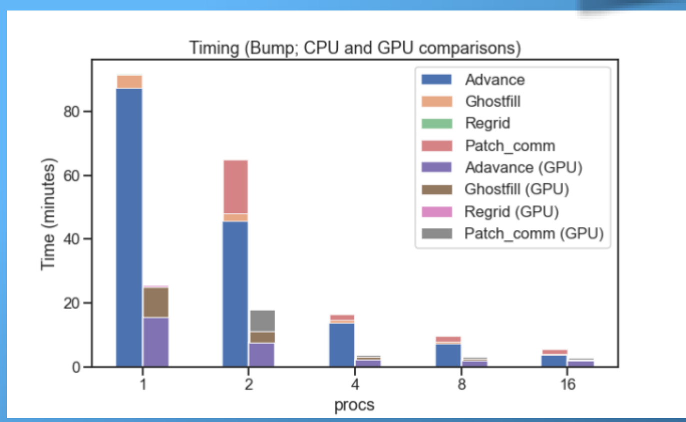
Advance steps counter

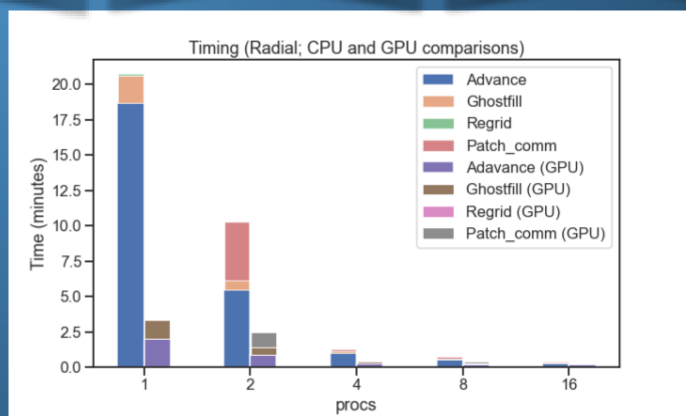


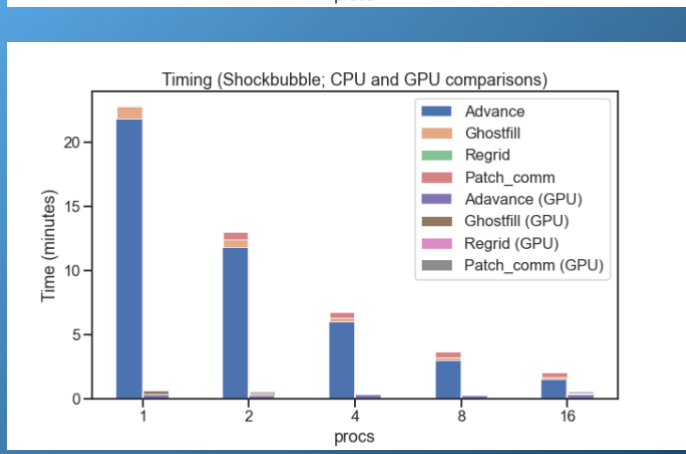


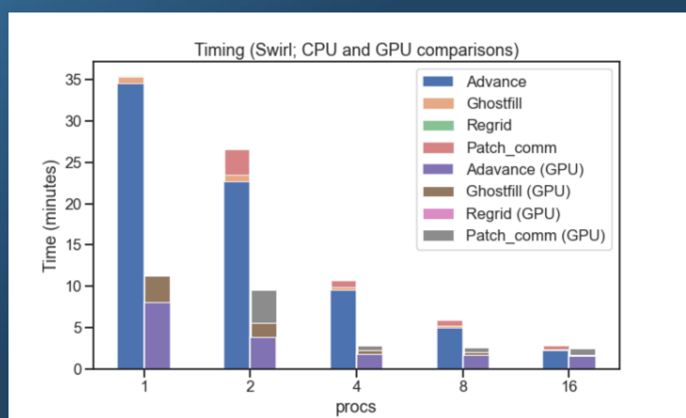












www.forestclaw.org

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