Hewlett Packard
Enterprise

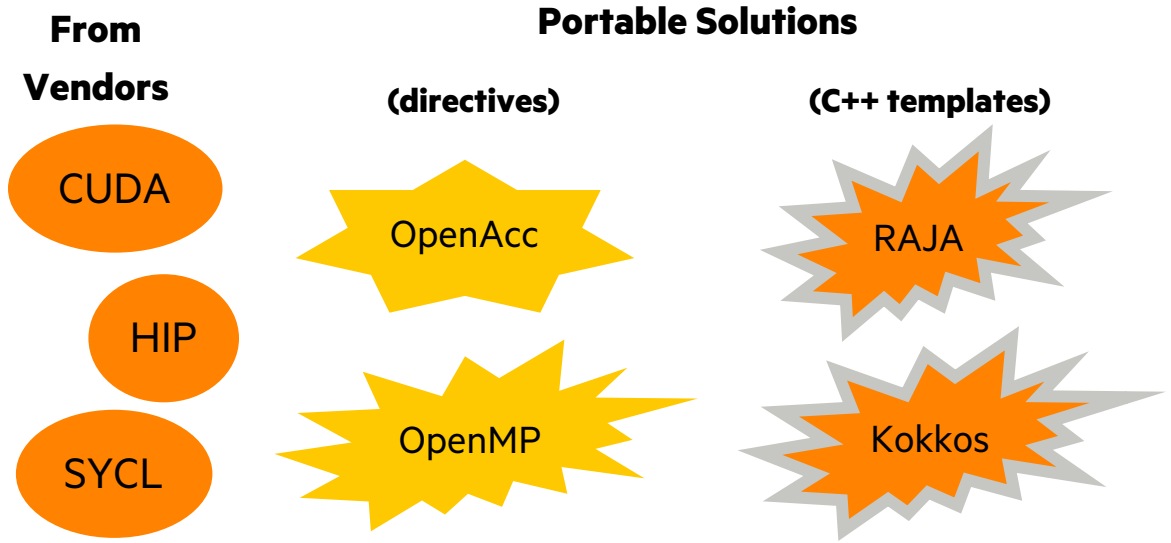
Vendor-Neutral GPU Programming in Chapel

Jade Abraham

April 16, 2024

GPUs are easy to find...but difficult to program

- AI has driven huge demand for GPUs



- Many GPU solutions are C/C++ based
  - Can be a non-starter *for scientists* to access GPU parallelism
- Using distributed GPUs requires additional support (e.g. MPI)

Chapel is an open-source alternative for productive distributed/shared memory GPU programming in a vendor-neutral way.

What is Chapel?

Chapel: A modern parallel programming language

- portable & scalable
- open-source & collaborative

chapel-lang.org

Goals:

- Support general parallel programming
- Make parallel programming at scale far more productive

What is Chapel?

Chapel works everywhere

- you can develop on your laptop and have the code scale on a supercomputer
- runs on Linux laptops/clusters, Cray systems, MacOS, WSL, AWS, Raspberry Pi
- shown to scale on Cray networks (Slingshot, Aries), InfiniBand, RDMA-Ethernet

Chapel makes distributed/shared memory parallel programming easy

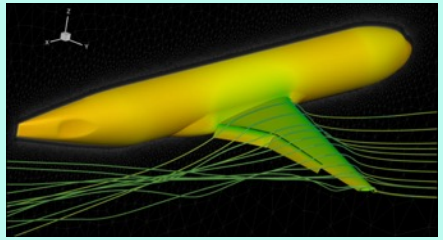
- data-parallel, locality-aware loops,
- ability to move execution to remote nodes,
- distributed arrays and bulk array operations

Chapel is GPU-ready

- clear, concise kernels
- the same Chapel features that target CPU parallelism target GPUs
- vendor neutral

Applications of Chapel

Active GPU efforts



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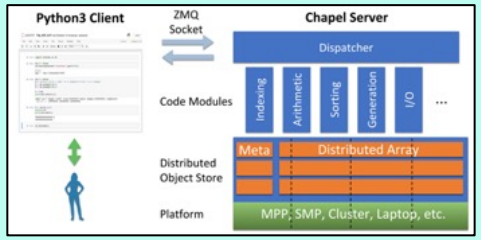

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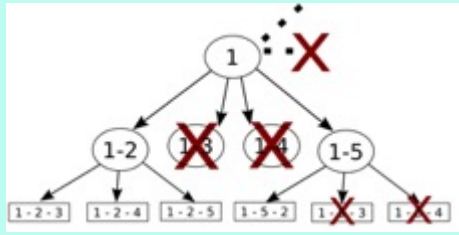

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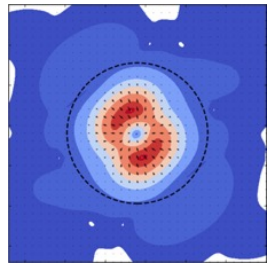

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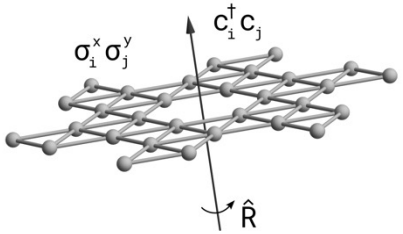

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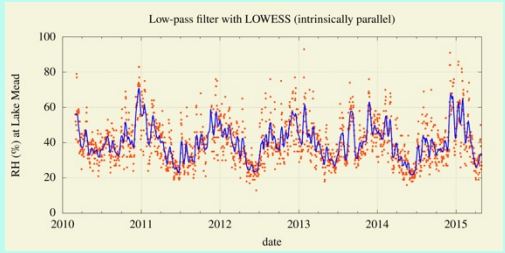

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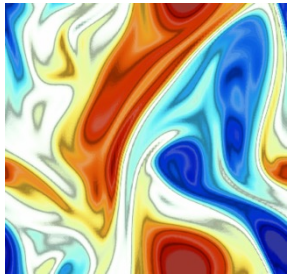

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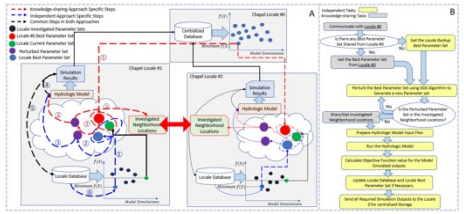

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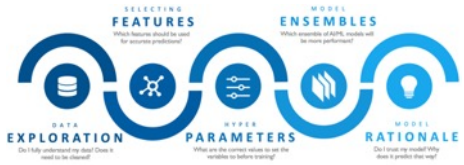

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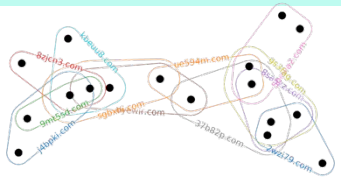

CHGL: Chapel Hypergraph Library
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PNNL

?

Your Application Here?

(images provided by their respective teams and used with permission)

Coding in Chapel

Multithread

```
config const nThreads = here.maxTaskPar, nPerThread = 4;
const n = nThreads * nPerThread;
var Arr: [0..<n] int;

coforall tid in 0..<nThreads {
  const startIdx = tid * nPerThread;

  Arr[startIdx..#nPerThread] = tid;
}
```

Configurable runtime constants with defaults

Query the current node for the maximum task concurrency

Declare the array ‘Arr’, indexed from ‘0’ to ‘n-1’

Create ‘nThreads’ number of tasks

Set a chunk of the array to the task’s ID

Multithread, Single GPU

```
config const nThreads = here.maxTaskPar, nPerThread = 4;
const n = nThreads * nPerThread;
var Arr: [0..<n] int;


coforall tid in 0..<nThreads do on here.gpus[0] {
  const startIdx = tid * nPerThread;
  var GpuArr = Arr[startIdx..#nPerThread];
  GpuArr = tid;
  Arr[startIdx..#nPerThread] = GpuArr;
}
```

Enable GPU diagnostics to visualize what is happening

Migrate execution to a GPU

Copy the array chunk between the host and device

Demo

Multithread, Multi GPU

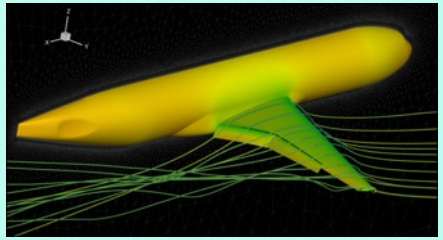
```
use GpuDiagnostics;

config const nGpus = here.gpus.size, nPerGpu = 4;
const n = nGpus * nPerGpu;
var Arr: [0..<n] int;

startVerboseGpu();
coforall gid in 0..<nGpus do on here.gpus[gid] {
  const startIdx = gid * nPerGpu;
  var GpuArr = Arr[startIdx..#nPerGpu];
  GpuArr = gid;
  Arr[startIdx..#nPerGpu] = GpuArr;
}
stopVerboseGpu();
```

Create a task for each GPU

Demo

Applications of Chapel

Active GPU efforts



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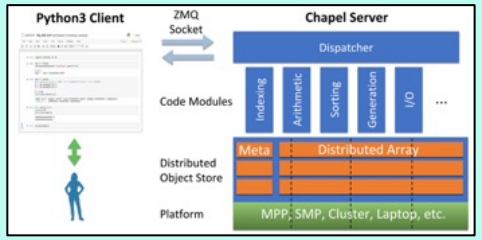

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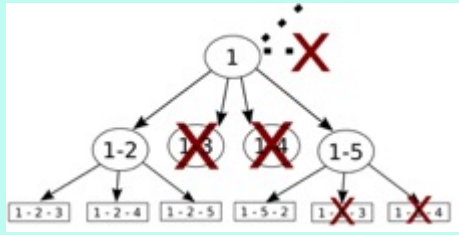

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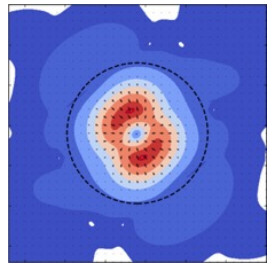

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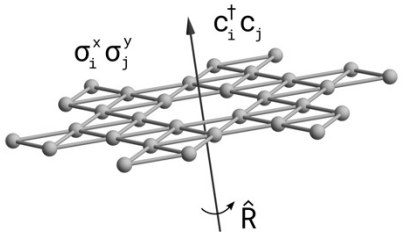

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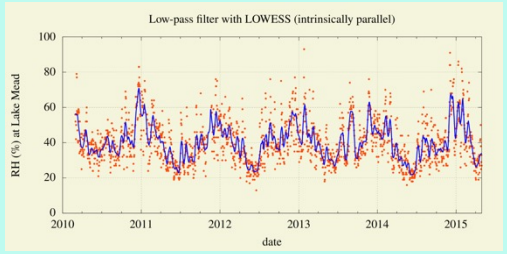

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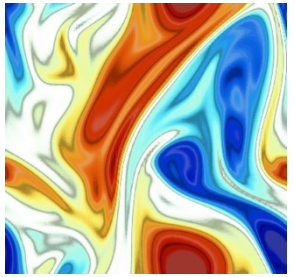

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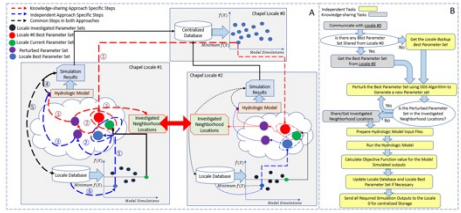

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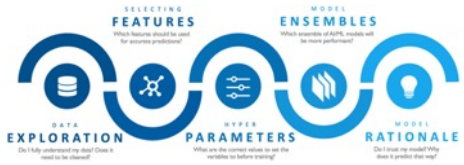

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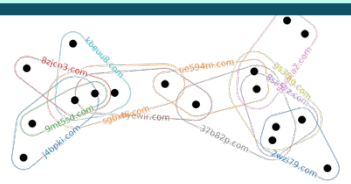

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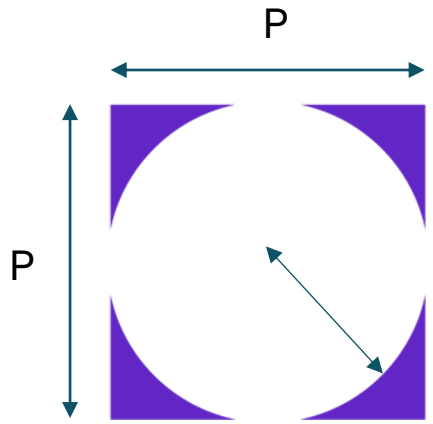
Coral Reef Spectral Biodiversity

1. Read in a (M x N) raster image of habitat data

2. Create a (P x P) mask to find all points within a given radius.

3. Convolve this mask over the entire domain and perform a weighted reduce at each location.

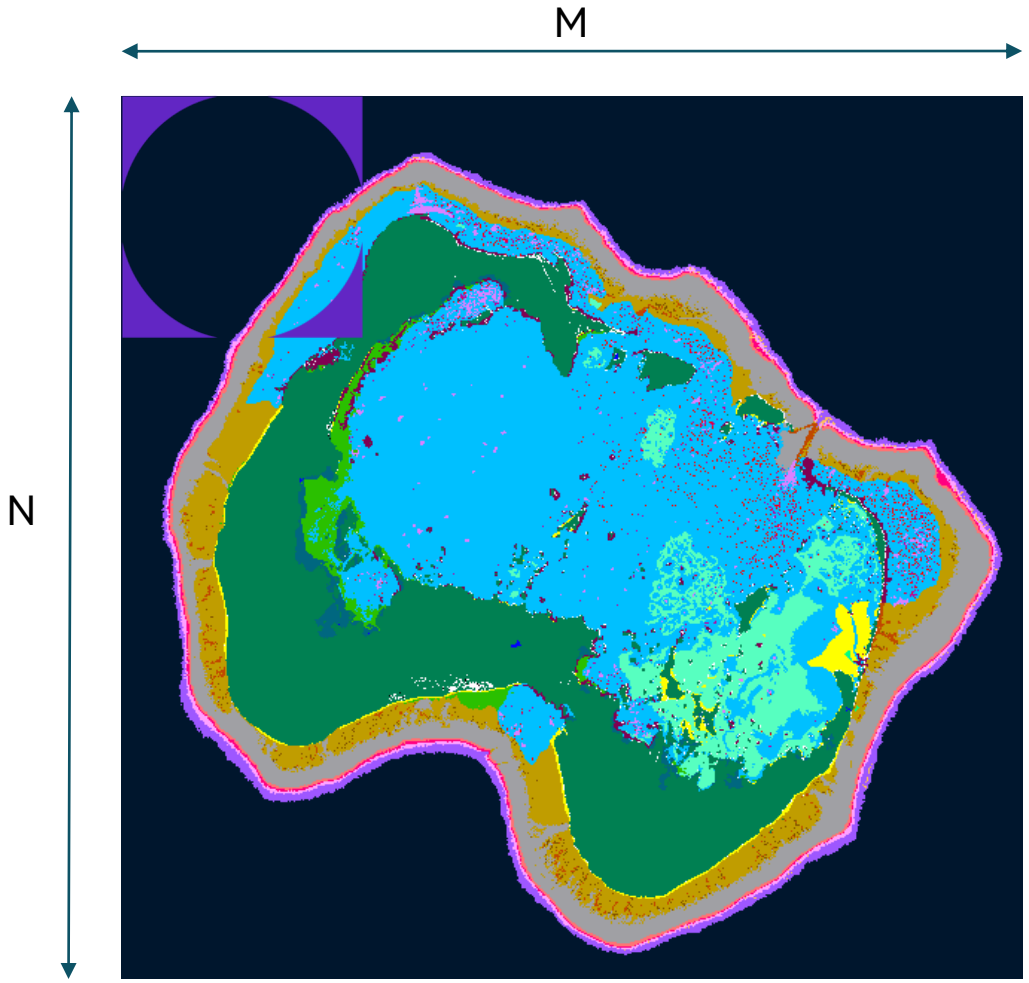


Algorithmic complexity: $O(MNP^3)$

Typically:

- M, N > 10,000

- P ~ 400



Coral Reef Spectral Biodiversity

```
proc convolve(InputArr, OutputArr) {   // 3D Input, 2D Output
 for ... {
  tonOfMath();
 }
}
proc main() {
 var InputArr: ...;
 var OutputArr: ...;

 convolve(InputArr, OutputArr);
}
```

Coral Reef Spectral Biodiversity

```
proc convolve(InputArr, OutputArr) {   // 3D Input, 2D Output
 foreach ... {
  tonOfMath();
 }
}
proc main() {
 var InputArr: ...;
 var OutputArr: ...;

 coforall loc in Locales do on loc {
  coforall gpu in here.gpus do on gpu {
   coforall task in 0..#numWorkers {
    var MyInputArr = InputArr[...];
    var MyOutputArr: ...;
    convolve(MyInputArr, MyOutputArr);
    OutputArr[...] = MyOutputArr;
}}}}
```

Using a different loop flavor to enable GPU execution.

Multi-node, multi-GPU, multi-thread parallelism are expressed using the same language constructs.

// use all nodes in parallel…
// using GPUs on this node in parallel…
// using numWorkers on this GPU in parallel.

High-level, intuitive array operations work across nodes and/or devices

Coral Reef Spectral Biodiversity

```
proc convolve(InputArr, OutputArr) {   // 3D Inp
 foreach ... {
  tonOfMath();
 }
}
proc main() {
 var InputArr: ...;
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   coforall task in 0..#numWorkers { // using pa
    var MyInputArr = InputArr[...];
    var MyOutputArr: ...;
    convolve(MyInputArr, OutputArr);
    OutputArr[...] = MyOutputArr;
}}}}
```
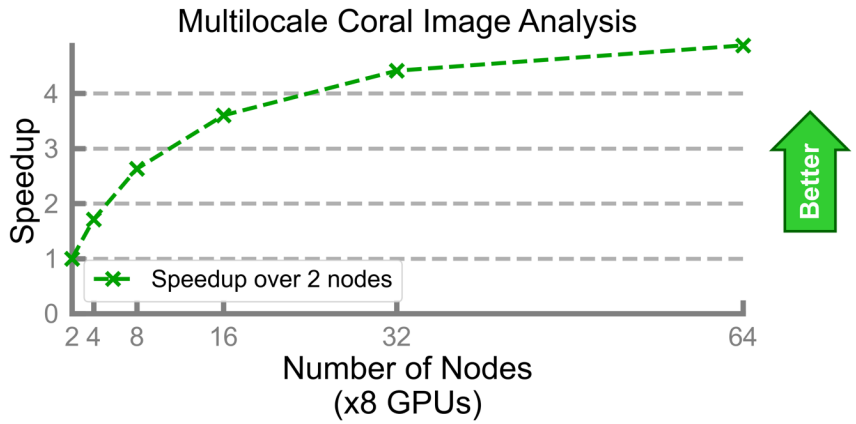

Ready to run on multiple nodes on Frontier!

- 5x improvement going from 2 to 64 nodes
  - (from 16 to 512 GPUs)
- Straightforward code changes:
  - from sequential Chapel code
  - to GPU-enabled one
  - to multi-node, multi-GPU, multi-thread



- Scalability improvements coming soon!

Get Connected with Chapel

- ChapelCon – free virtual event (https://chapel-lang.org/ChapelCon24.html)
  - June 5th – Tutorial Day
  - June 6th – Coding Day
  - June 7th – Conference Day

Registration for ChapelCon

https://shorturl.at/hvEW1

- Come code with us!
  - Github - https://github.com/chapel-lang/chapel
  - Gitter - https://gitter.im/chapel-lang/chapel
  - Discourse - https://chapel.discourse.group
  - StackOverflow - https://stackoverflow.com/questions/tagged/chapel

- Follow us on social media
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Thank you