Damaris/Viz: a Nonintrusive, Adaptable and User-Friendly In Situ Visualization Framework

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Outline

- In situ visualization
- Motivation/Damaris
- Damaris/Viz
  - Instrumentation details
  - Results

In Situ Terminology

- In situ visualization: Analysis and vis tasks run concurrent to a simulation
  - Bypasses storage system
  - Generates results while simulation runs
- In situ flavors:
  - Tightly-coupled: analysis+vis share simulation's resources
    - Time-partitioning: sim stops, vis code takes over
    - Space-partitioning: sim resources are dedicated to vis
  - Loosely-coupled: sim and vis resources are separated

Damaris/Vis

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Deployment of In Situ Techniques

- Who has the simulations? Domain scientists.
- What do they want? An in situ framework that has…
  - Low impact on the code
  - High adaptability
  - Low impact on run time
  - Optimized resource utilization

Damaris/Viz

- Reduce code impact while maximizing capabilities
  - Provide unified data management interface
  - Incorporate existing functionality through this interface
- Hide performance impact of in situ tasks

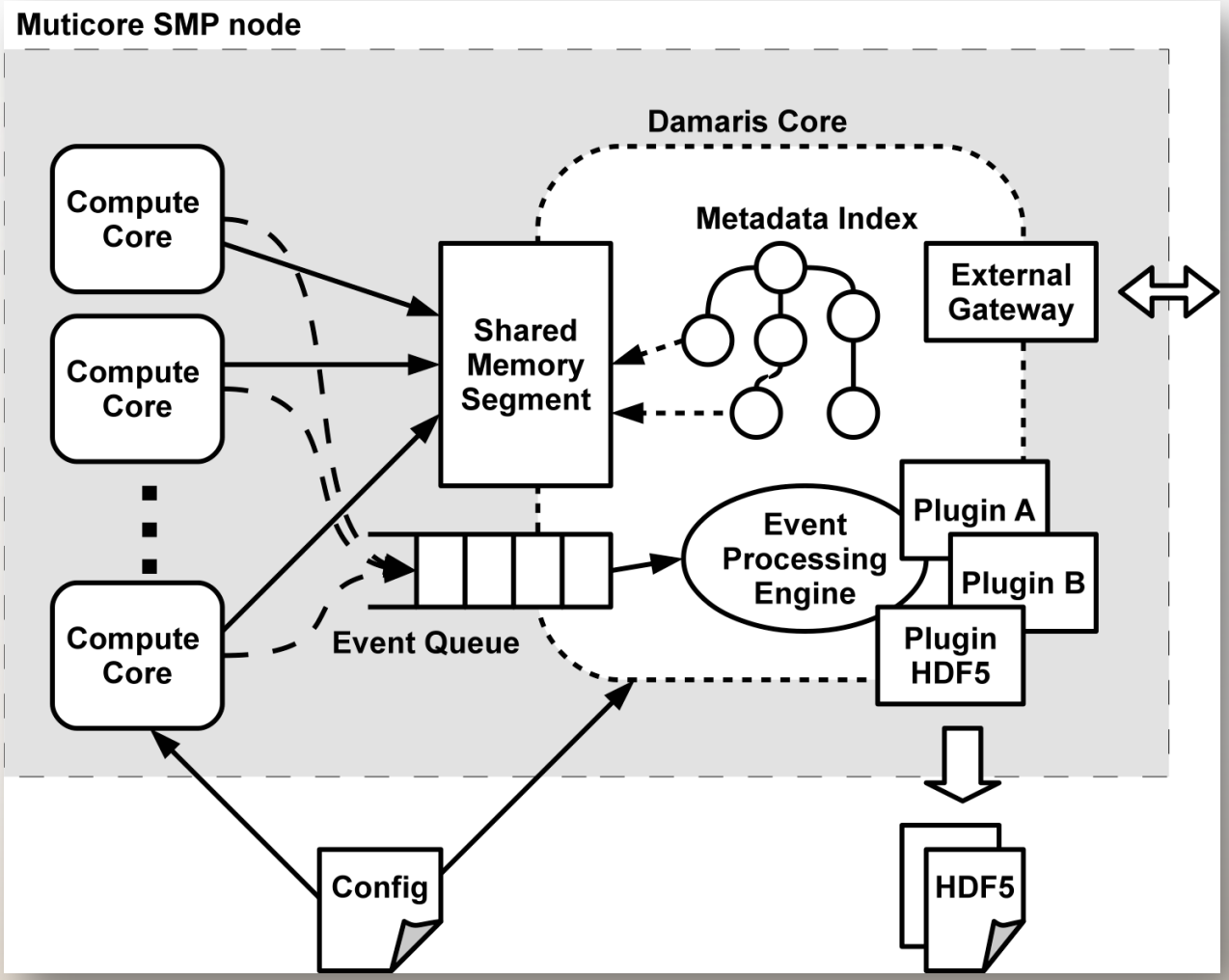
DAMARIS REVIEW

Damaris: I/O Middleware

Damaris -- **D**edicated **A**daptable **M**iddleware for **A**pplication **R**esources **I**nline **S**teering

- Started in 2010 by Matthieu Dorier during an internship at NCSA
- The purpose: decouple I/O and computation to enable scalable asynchronous I/O
- The approach: dedicated I/O core(s) on each node
  - Limits OST contention to the node level
  - Leverages shared memory for efficient interaction
  - When simulation “writes” data, Damaris utilizes shared memory to effectively aggregate writes to the “right” size

Damaris at a Glance

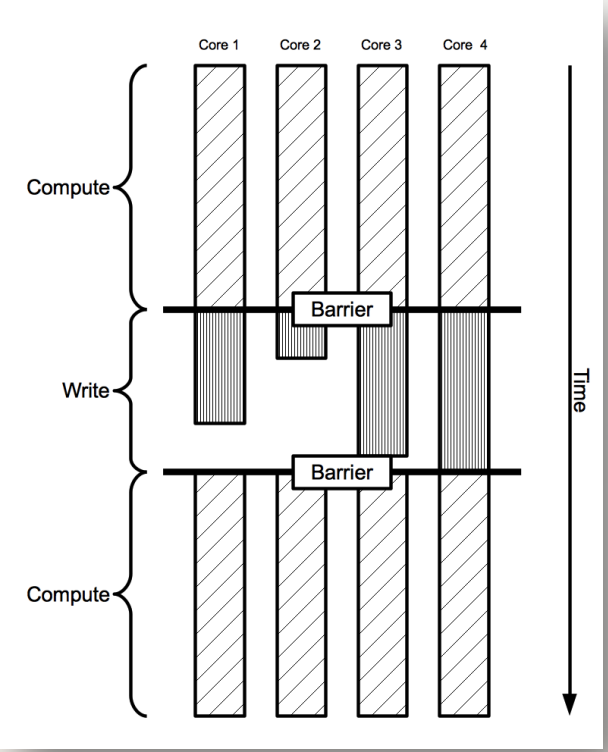


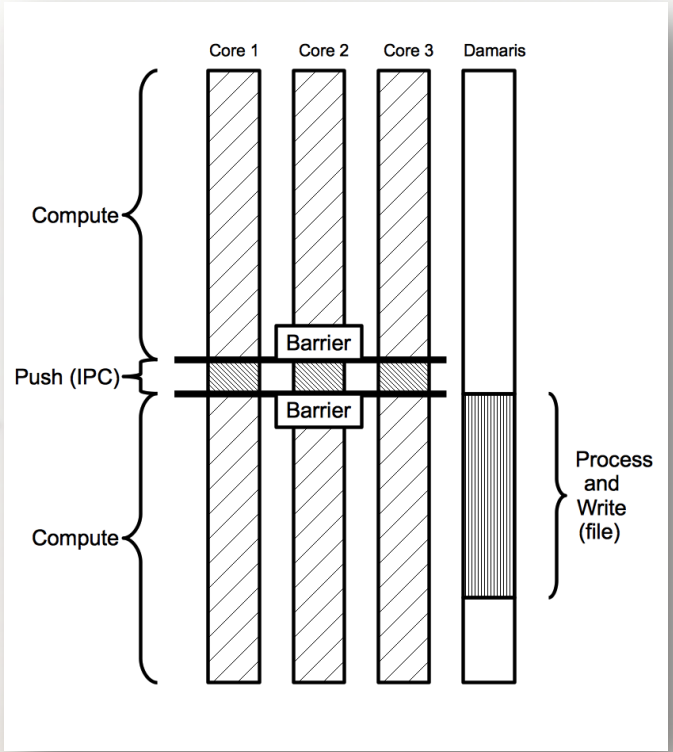
Application: Reducing I/O Jitter in CM1

- I/O **Jitter** is the variability in I/O operations that arise from any number of common interferences

- CM1
  - Atmospheric simulation
  - Uses serial and parallel HDF5
  - Tunable I/O

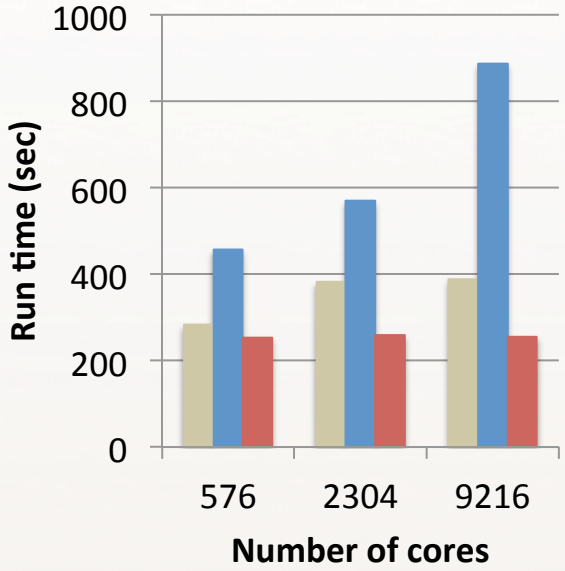
How Damaris Helps with I/O Jitter

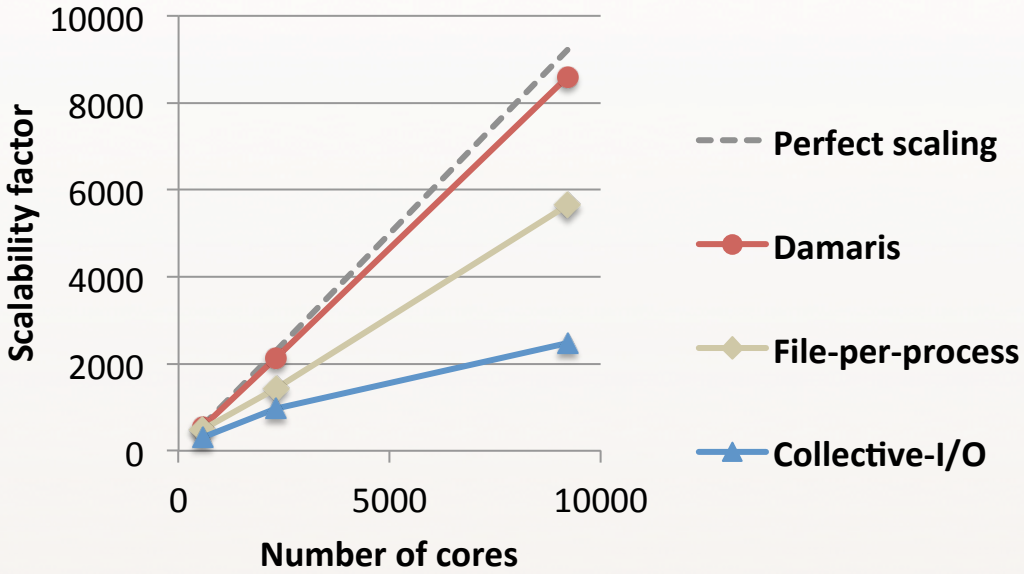




- Jitter is “moved” to the dedicated core
- Even with the reduction in number of cores performing computation, performance is not adversely affected, in fact….

Results: Damaris+CM1





- In these runs, Damaris spent at least 75% its time waiting!
- Plugins are intended to use this time

Weak scalability factor: $S = N \frac{T_{base}}{T}$

N: number of cores
T_{base}: time of an iteration on one core w/ write
T: time of an iteration + a write

The In Situ Framework

DAMARIS/VIZ

Damaris/Viz: The Components

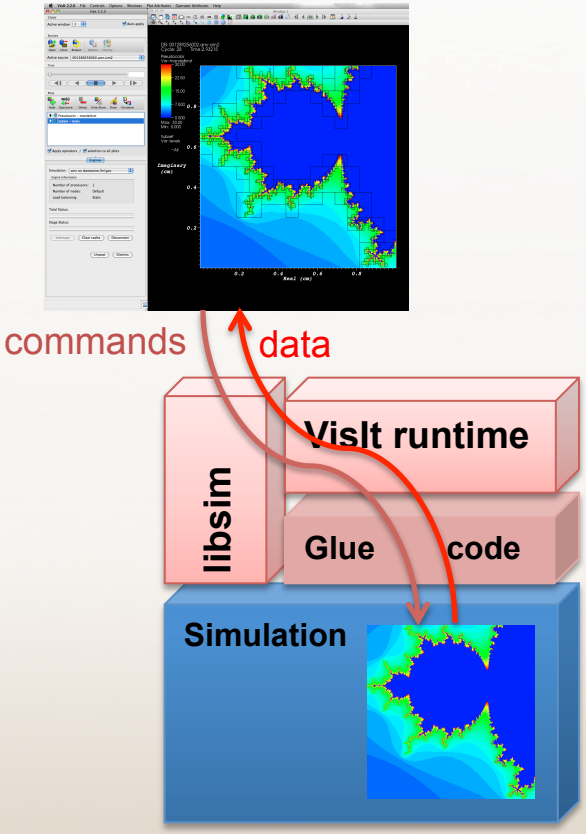
- Damaris client: the simulation
- Damaris server
  - Manages shared memory
  - Calls plugin to perform in situ tasks

In Situ Plugins: The State of Some of the State of the Art

- Add functions to your simulation that let VisIt connect
- Add functions to your simulation that expose your arrays as data VisIt will process
- Link your simulation with libsim

- Run the simulation and connect with VisIt
  - You will be able to perform any of VisIt's operations on your simulation data
  - Advance the simulation and watch your plots update

- libsim features
  - Species
  - Vector,Tensor data
  - AMR meshes
  - CSG meshes
  - Users don't allocate memory
  - Additional error checking
  - Write in C, Fortran, or Python
  - Windows support



libsim, Informally

- Time-partitioning
- VisIt treats running simulation as a VisIt engine
  - Fully functioning VisIt is at your control
  - Instrumentation requires enough to convince VisIt there is a fully functioning engine available

Instrumenting libsim

	libsim Code
Simulation	**C**
curve.c	144 lines
mesh.c	167 lines
var.c	271 lines
life.c	305 lines

Damaris plugin: “VisIt”

Current Plugins

- VisIt
- ParaView (under development)

- Python

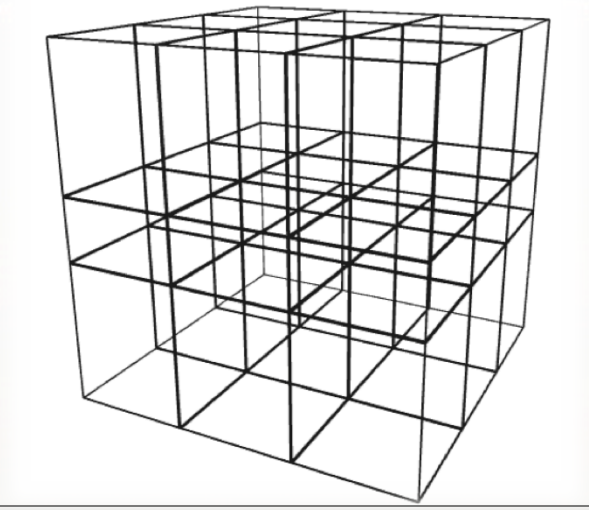
```
var = damaris.open("temperature")
for chunks in var.select( iteration = 1 )
    print numpy.average(chunks.data)
```

Using Damaris/Viz

- Create XML description of data
- Instrument simulation with Damaris code
  - Simulation uses provided Damaris API
  - Allows Damaris to correctly manage shared memory
- Call in situ plugin
  - Set up necessary data structures, etc.

XML Data Files

- Generic description of structures to visualize
  - Meshes, points, curves, scalars, etc.
- Data model based on survey of existing in situ interfaces
  - ParaView, VisIt, ezViz, VTK



Example Data File

```
<variable name="mesh_x" .../>
<variable name="mesh_y" .../>
<variable name="mesh_z" .../>

<mesh type="rectilinear" name="my mesh">
<coord name="mesh_x" unit="cm" label="width" />
<coord name="mesh_y" unit="cm" label="height"/>
<coord name="mesh_z" unit="cm" label="depth" />
</mesh>

<variable name="temperature" mesh="my_mesh" ../>
```

Describing Data

	libsim Code	Damaris Code	
Simulation	**C**	**XML**	
curve.c	144 lines	31 lines	
mesh.c	167 lines	39 lines	
var.c	271 lines	53 lines	
life.c	305 lines	39 lines	

Instrumentation

```
float* mesh_x = dc_alloc("mesh x");
float* mesh_y = dc_alloc("mesh y");
float* mesh_z = dc_alloc("mesh z");
double*  temp = dc_alloc("temperature");
...
dc_commit("temperature");
...
dc_end_iteration ();
```

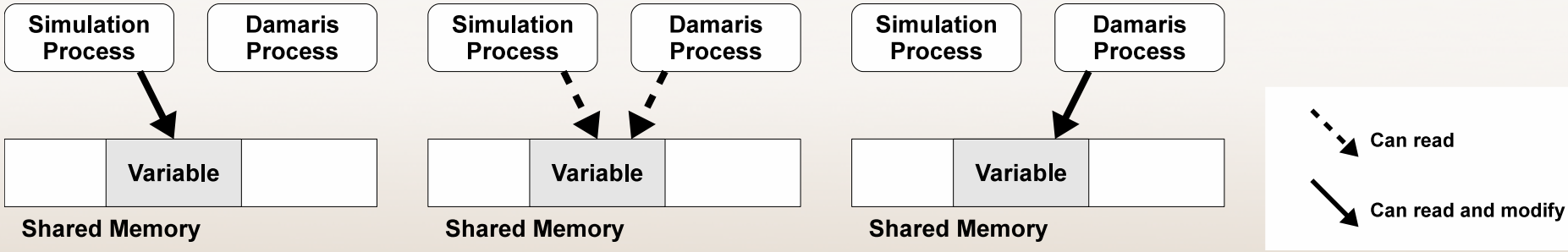
Code Impact

	libsim Code	Damaris Code	
Simulation	**C**	**XML**	**C**
curve.c	144 lines	31 lines	6 lines
mesh.c	167 lines	39 lines	10 lines
var.c	271 lines	53 lines	12 lines
life.c	305 lines	39 lines	8 lines

These code changes are compatible with any Damaris in situ plugin!

More on Instrumentation

- `dc_alloc`("variable") – allocate shared memory, still only visible to simulation
- `dc_commit`("variable") – simulation is finished writing data, Damaris can now read
- `dc_end_iteration`("variable") – lets Damaris know that variable may be processed, stored, removed, etc.



(a) After dc_alloc (b) After dc_commit (c) After dc_end_iteration

Blocking, Non-blocking, and Revisiting In Situ Terminology

- Blocking
  - If shared memory is full, `dc_alloc` waits
  - Intuitive space-partitioning, nothing is lost
- Non-Blocking
  - If shared memory is full, `dc_alloc` uses “local memory”
  - `dc_commit` has no effect
  - `dc_end_iteration` frees memory
  - In situ plugin never runs on this data
  - Our default space-partitioning

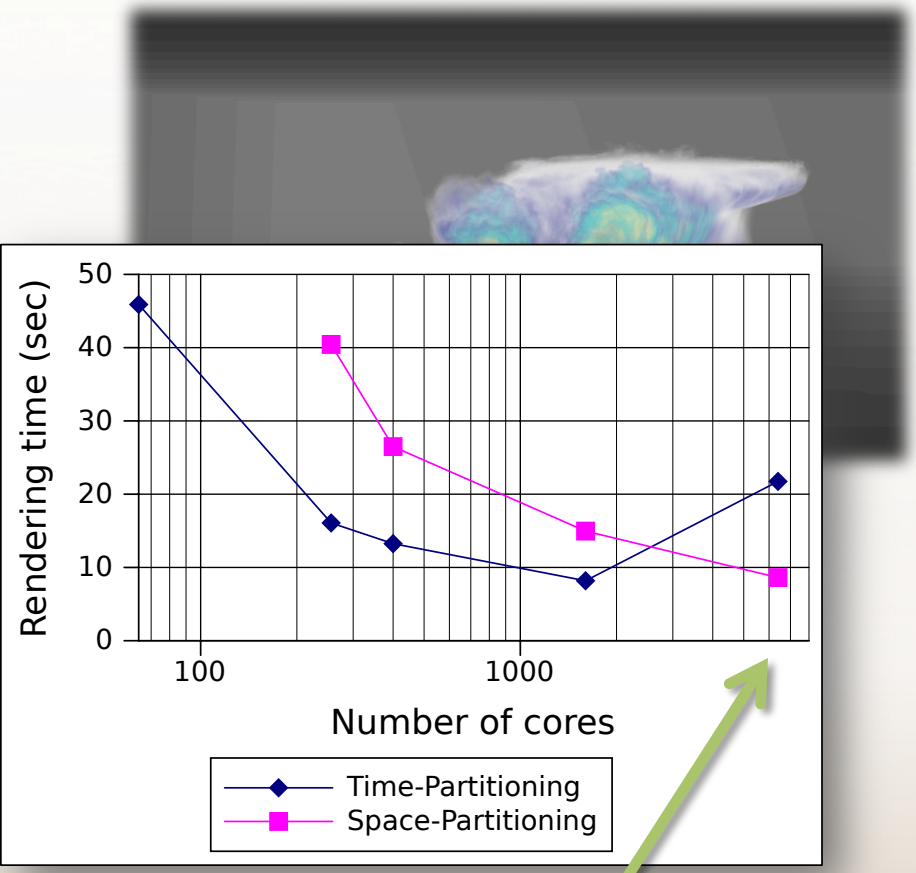
Results

PERFORMANCE EVALUATION

Time vs. Space

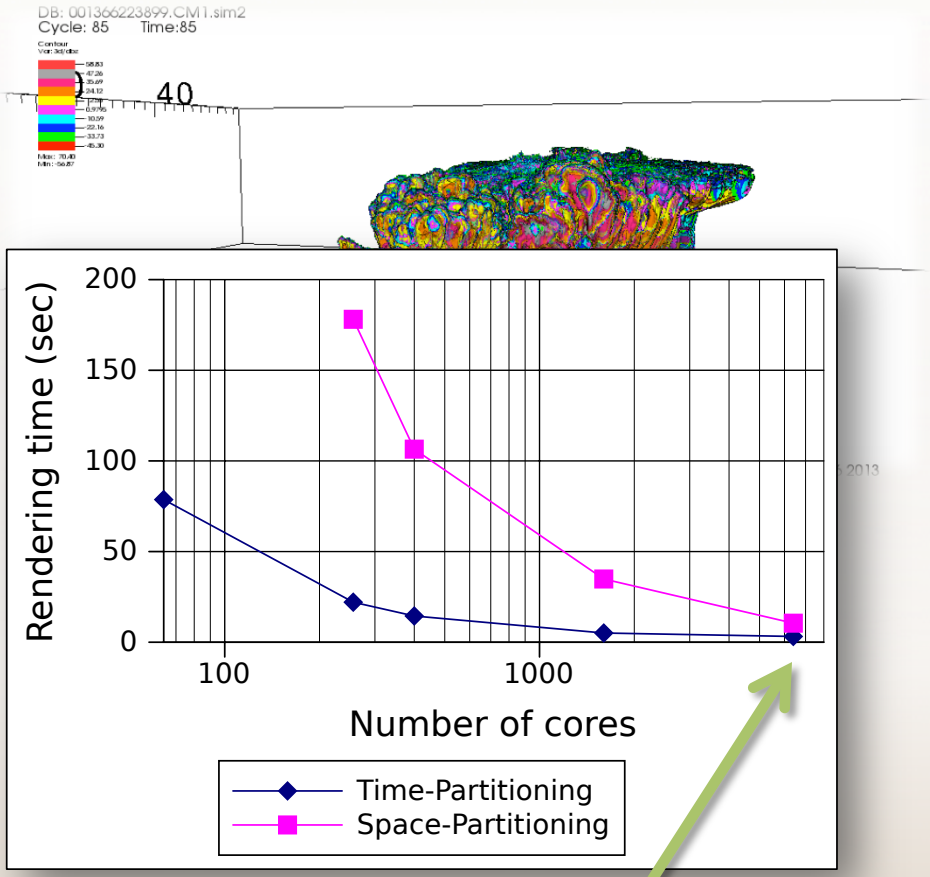
- Test applicability of space-partitioning (dependent on vis algorithm scalability)
- Setup:
  - CM1 I/O kernel
    - Avoid low probability of something interesting happening
    - Avoid wait in the event it does
    - Data grid size: 3840x3840x400
    - Run on Blue Waters from 16 to 6400 cores (ppn=16)
  - Two visualization scenarios using VisIt to view *dbz* field
    - Ray cast volume rendering
    - 10-level contour plot

Volume Rendering



Space-partitioning faster!

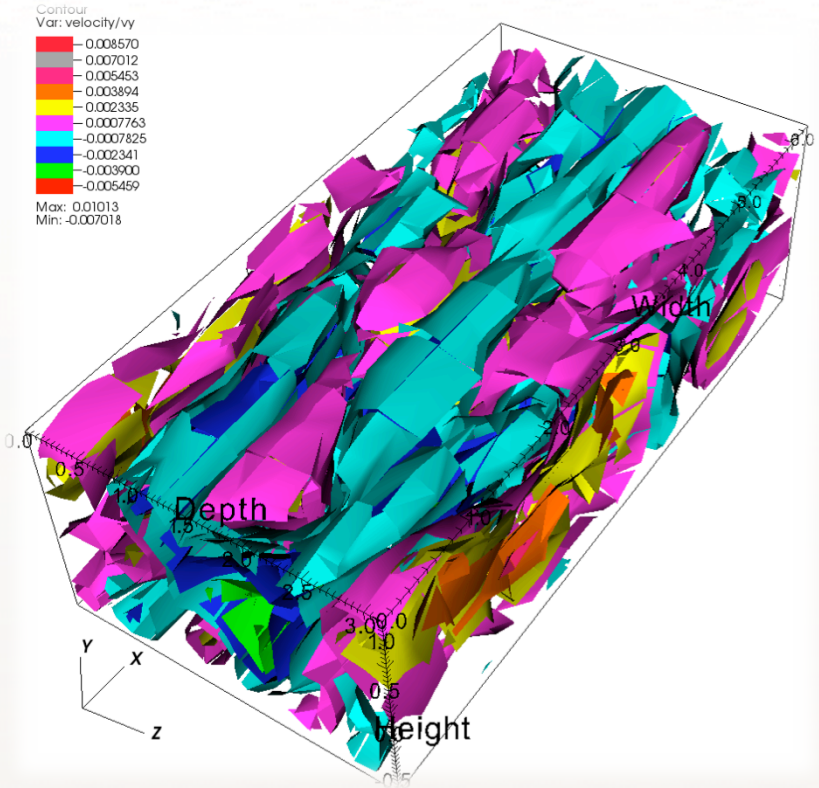
Contours



Space-partitioning 16X more efficient!

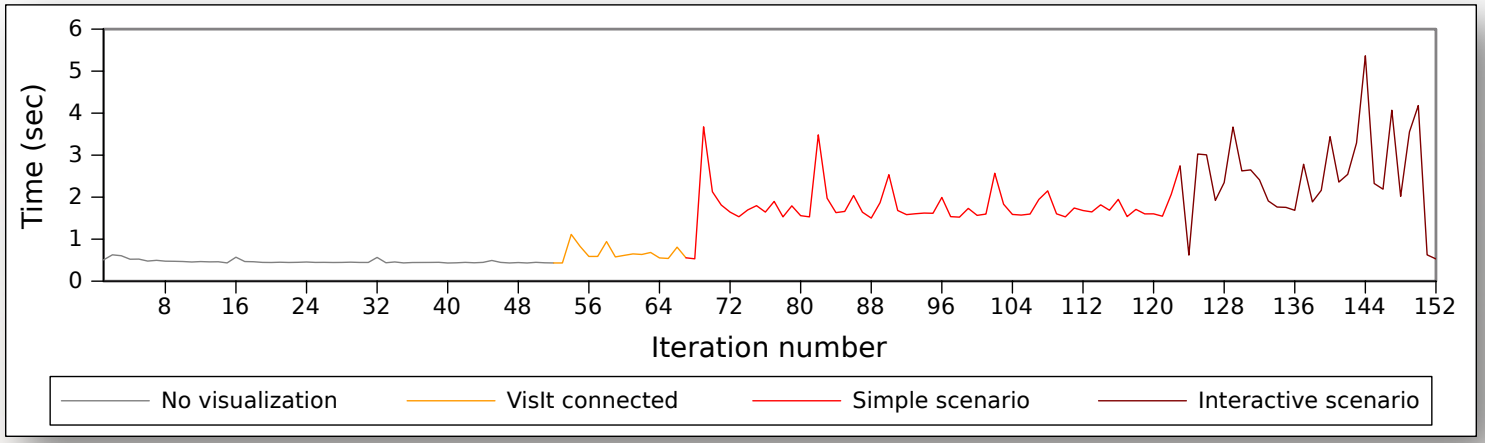
LDAV
2013
IEEE Symposium on Large-Scale
Data Analysis and Visualization

Space in Practice



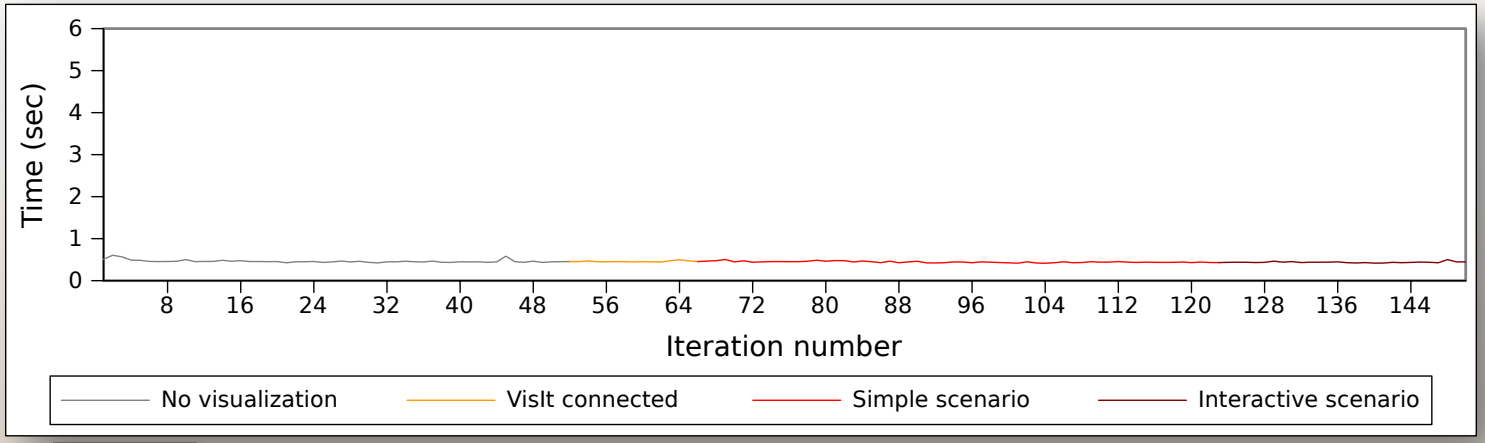
- Nek5000
  - CFD
  - Fortran 77
  - Curvilinear mesh
- This experiment:
  - TurbChannel configuration (designed for 32 to 64 cores)
  - Run on Reims *stremi* cluster of French Grid'5000 48 cores (ppn = 24)

Time-partitioning



Negative performance impact

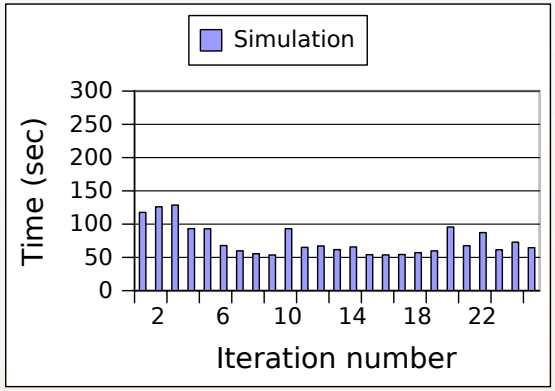
Space-partitioning



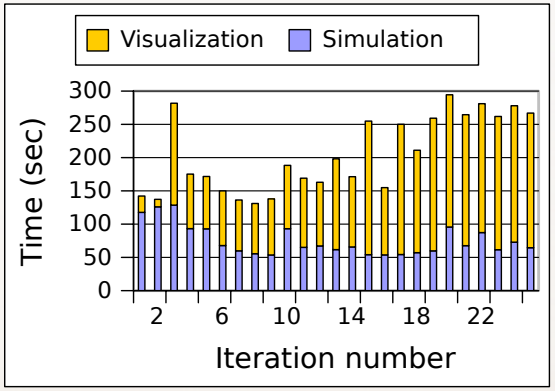
In situ completely transparent!

Providing a (Low-calorie) Free Lunch

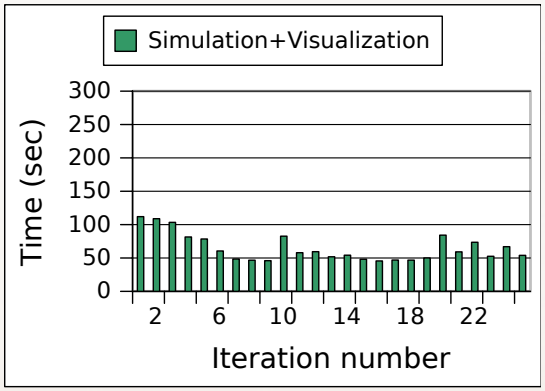
- Nek5000 MATiS configuration
  - Designed for 512 to 2048 cores
  - Run on 816 cores



No Vis:
Average iteration:
~1 minute



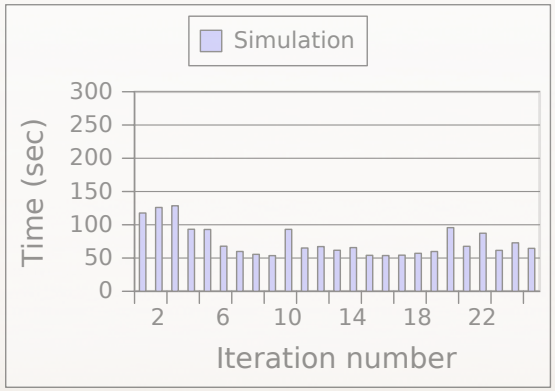
Lots of Vis:
Average iteration:
~3.5 minutes



Some Vis:
Average iteration:
~1 minute

How Much Vis?

- 1 image per ~25 iterations
  - Acceptable to Nek5000 users
  - Free! Free! Free!



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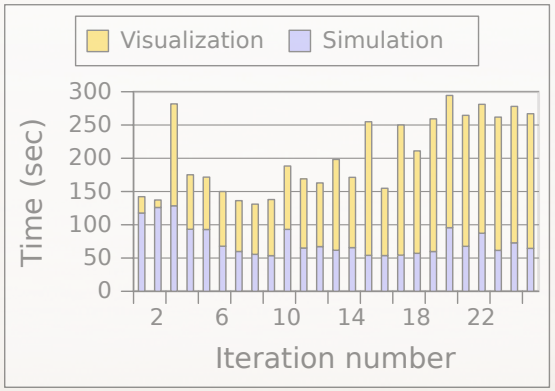

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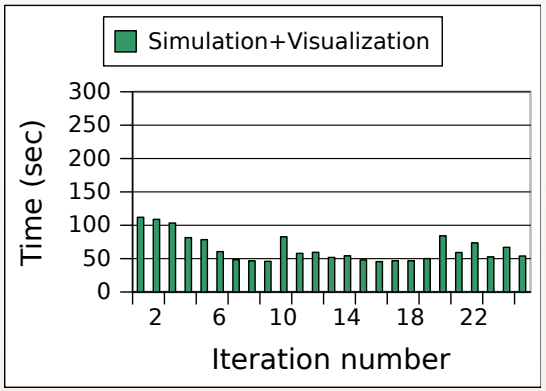

Some Vis:
Average iteration:
~1 minute

The Last Slide

- Regardless of in situ's issues – it presents an import direction for research (as doom approaches)
- The core concepts in this work represent target areas for refinement
  - These double as directives for adoption
  - More free-er the better

- Check out Damaris:
  - http://damaris.gforge.inria.fr/doku.php