

A Memory-Efficient Data Handling for Octree-Like Grids

Miriam Mehl, Tobias Weinzierl, Tobias Neckel
June 2010

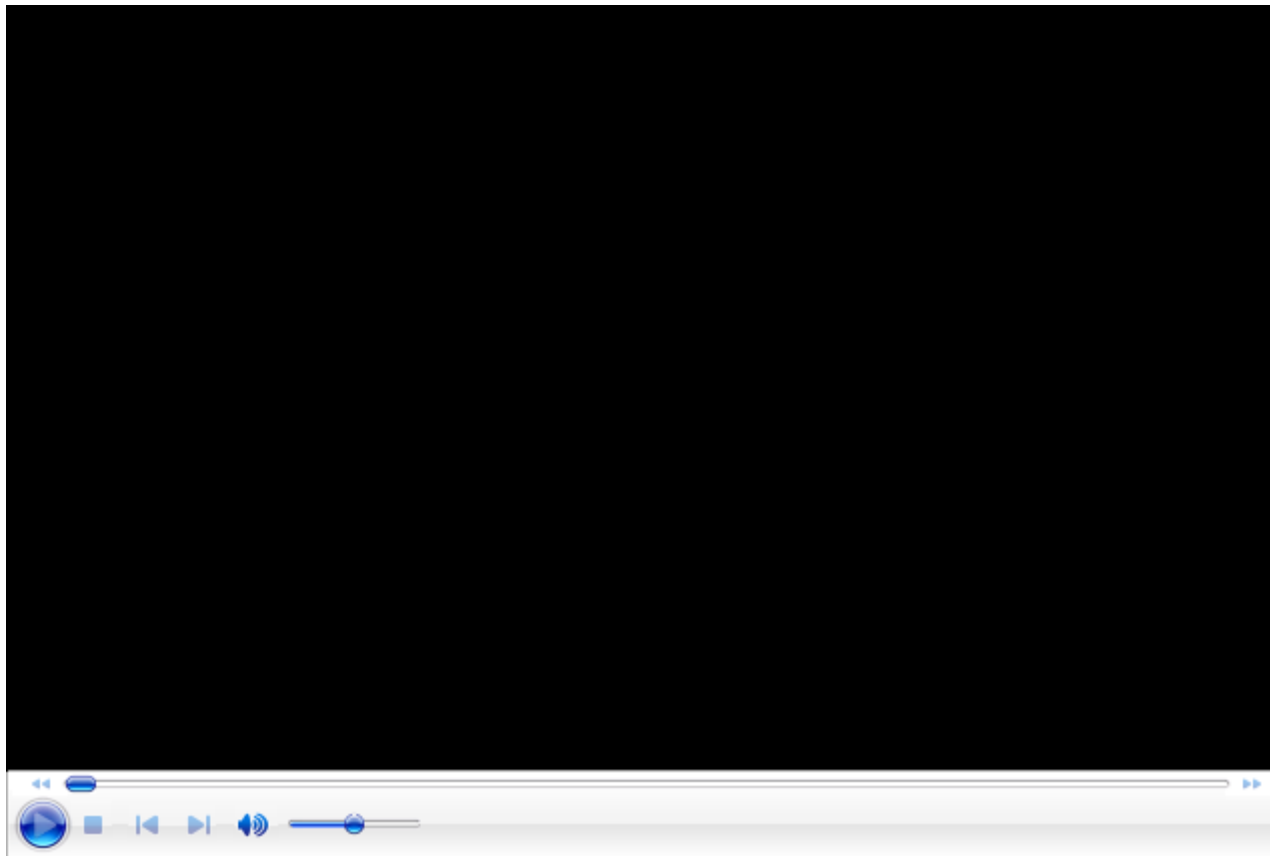
Outline

- **grid adaptivity for fluid-structure interactions**
- **our grid and data concept**
- **application examples**
- **conclusion**

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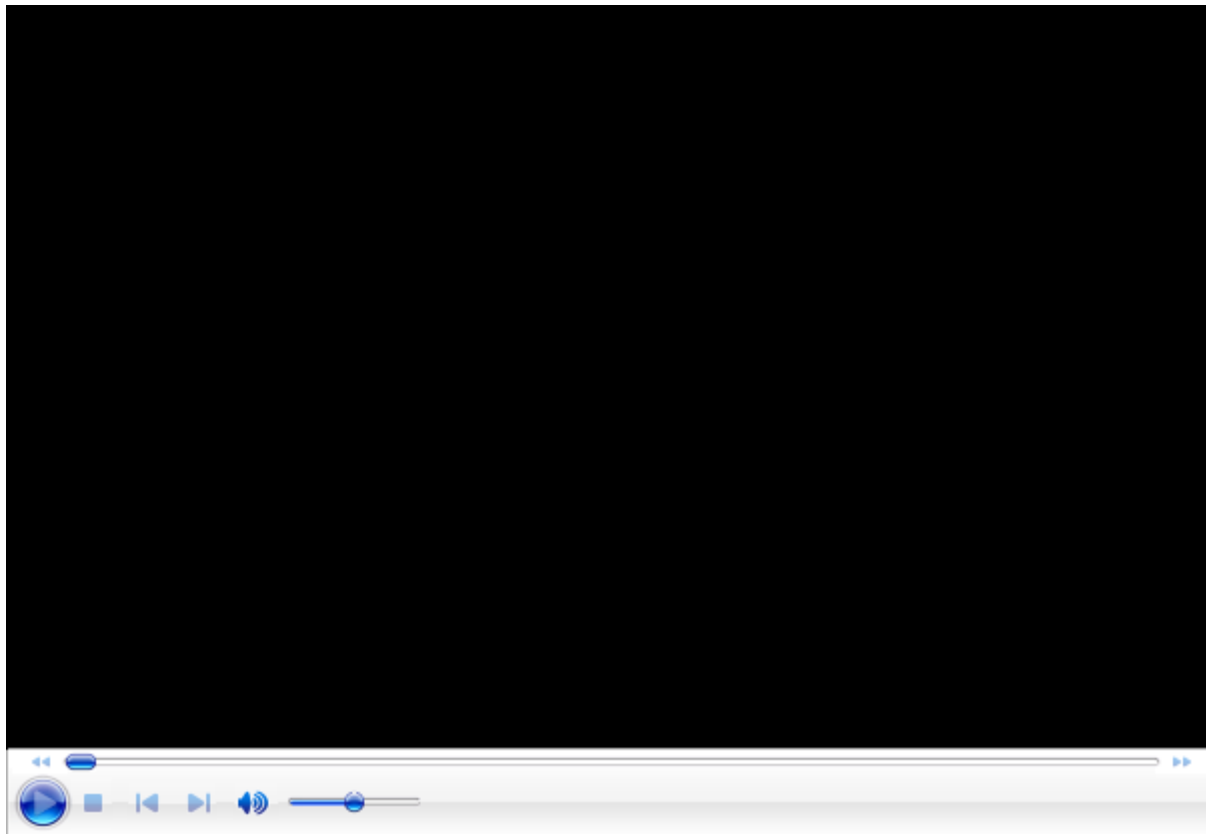
Grid Adaptivity for Fluid-Structure Interactions



moving
geometries

Source: Kristof Unterweger

Grid Adaptivity for Fluid-Structure Interactions

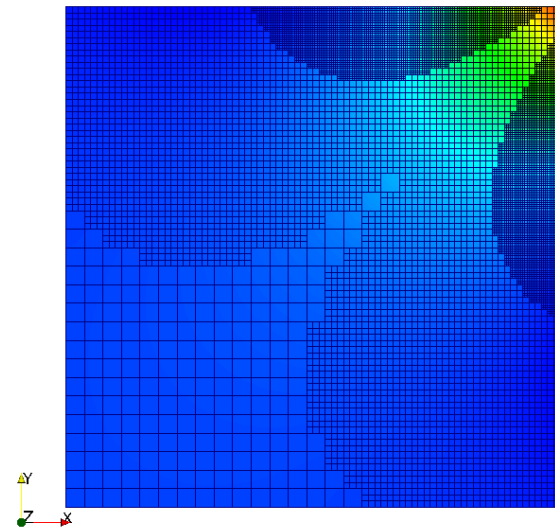
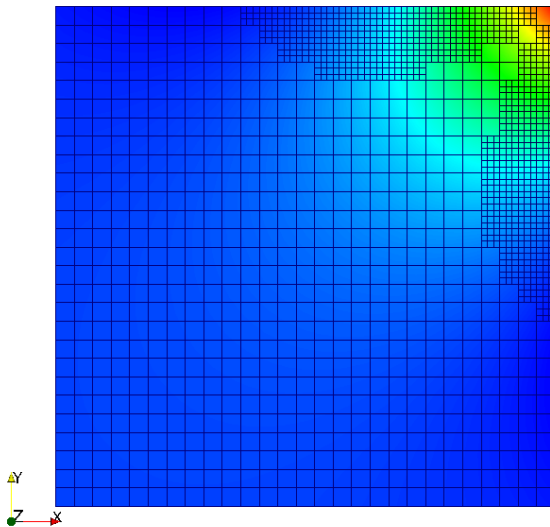


moving
geometries

Source: Bernhard Gatzhammer,
Janos Benk

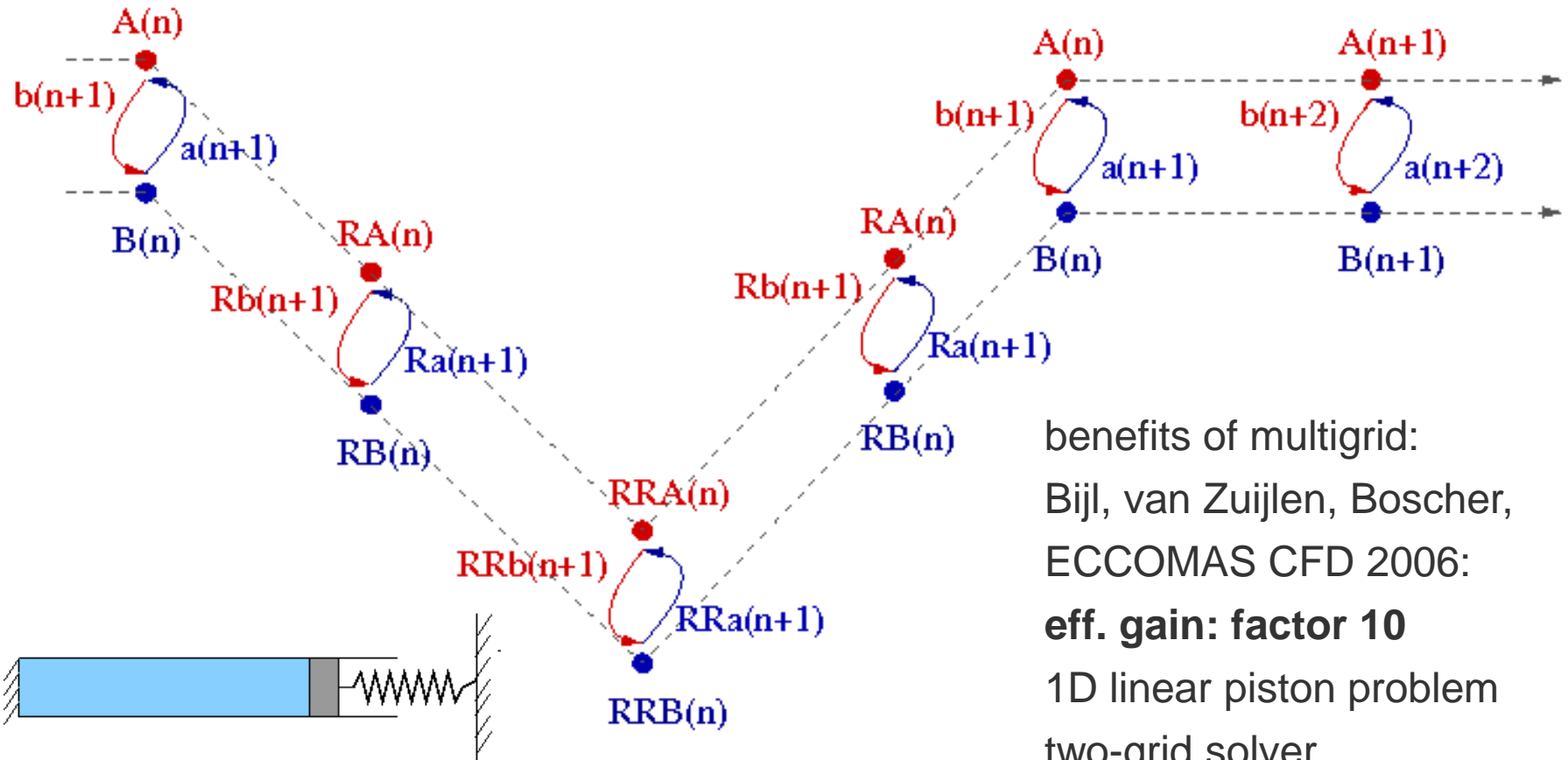
Grid Adaptivity for Fluid-Structure Interactions

dynamical grid adaptivity

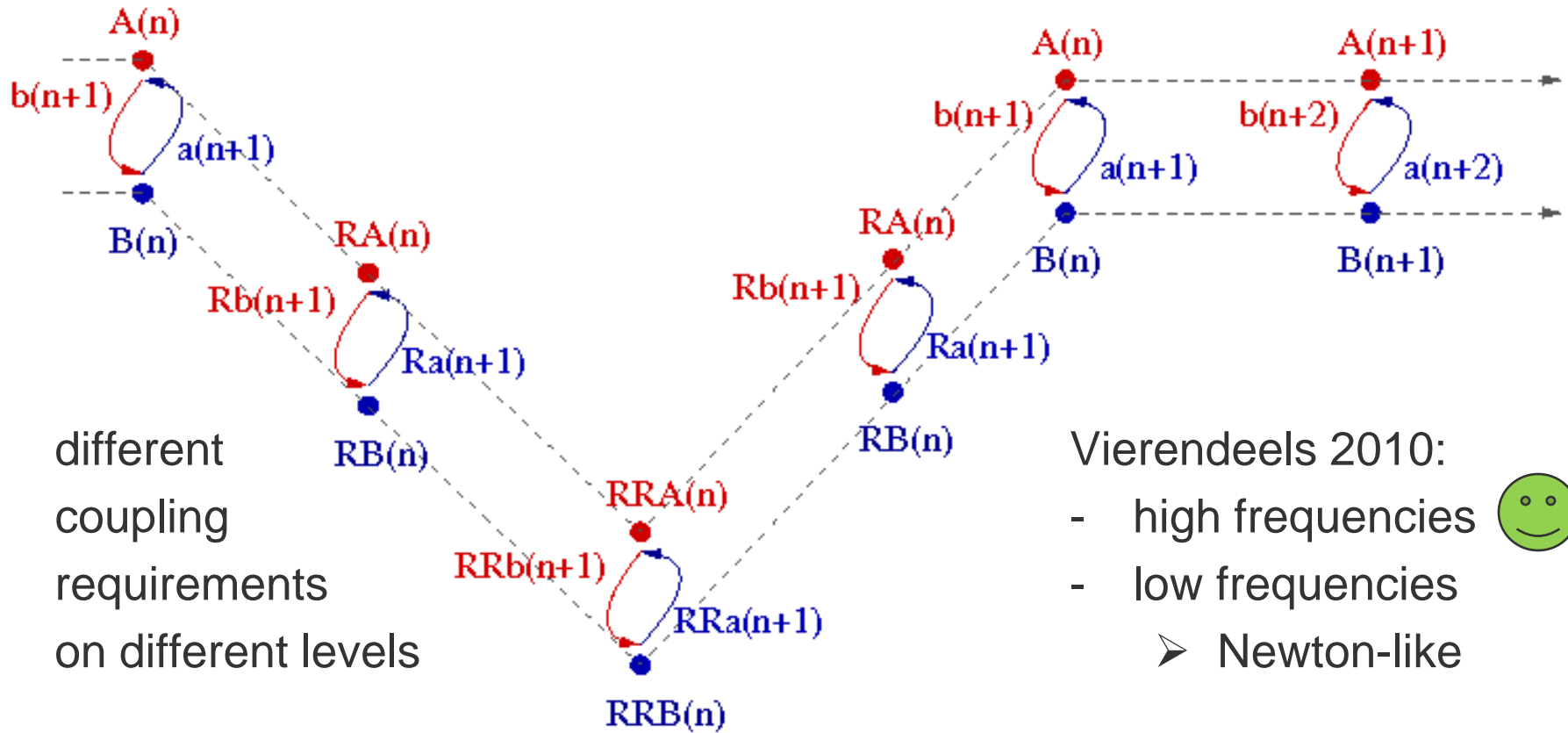


Source: Kaveh Rahnema

Grid Adaptivity for Fluid-Structure Interactions



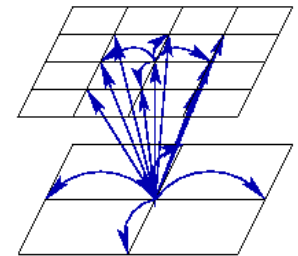
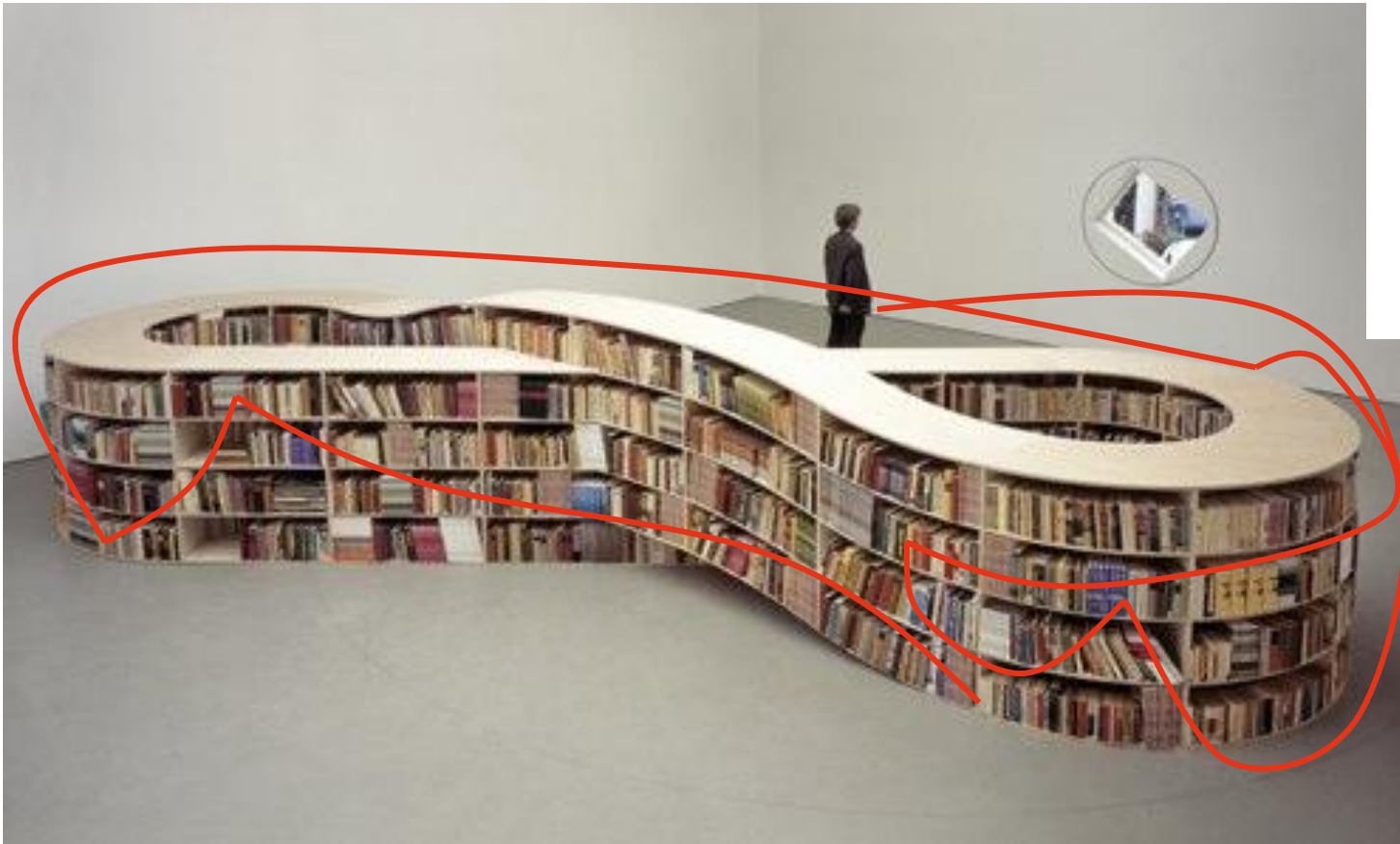
Different Coupling Requirements on Different Levels



Outline

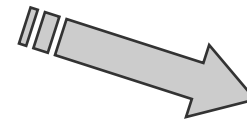
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Our Grid and Data Concept – What We Want to Avoid



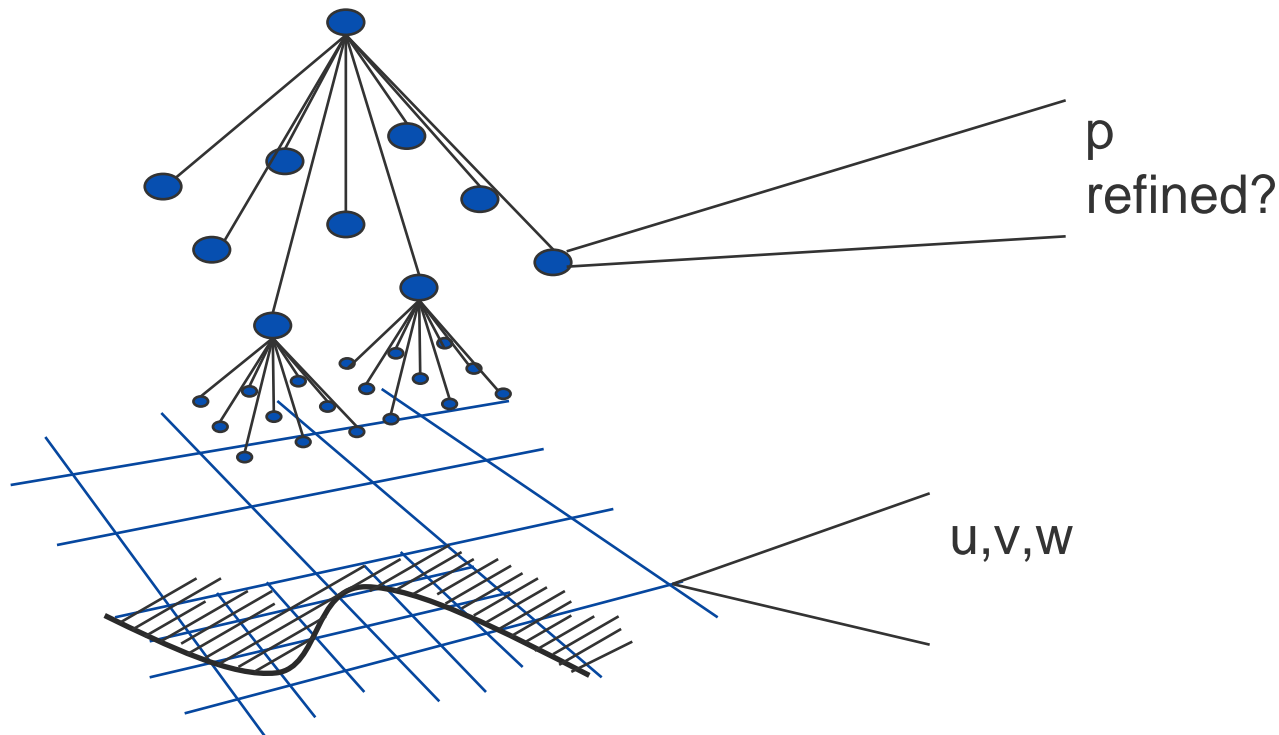
Artist:
Job Koelewijn

Our Grid and Data Concept – Storage Minimisation



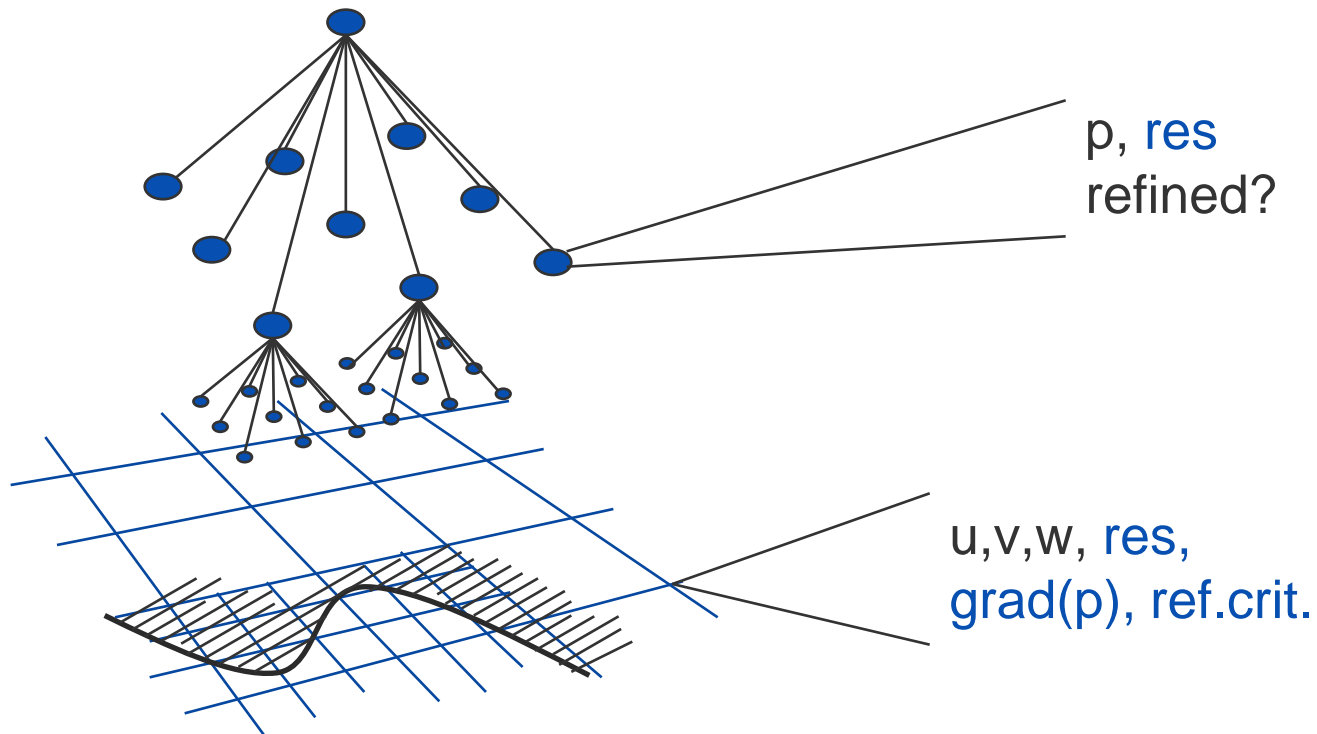
Our Grid and Data Concept – Storage Minimisation

- spacetree grids \rightarrow structured



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Our Grid and Data Concept – Storage Minimisation

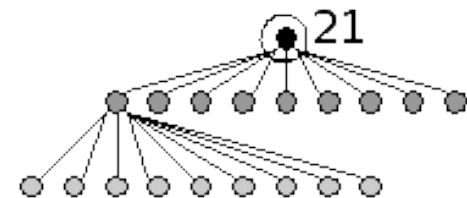
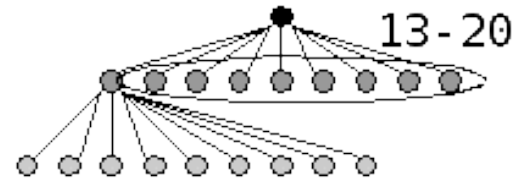
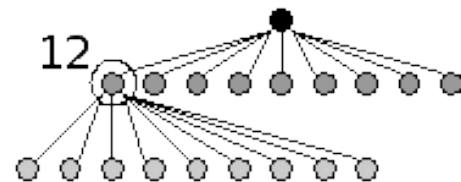
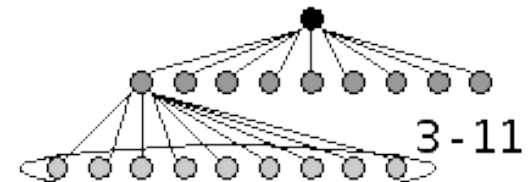
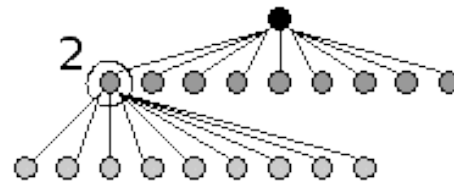
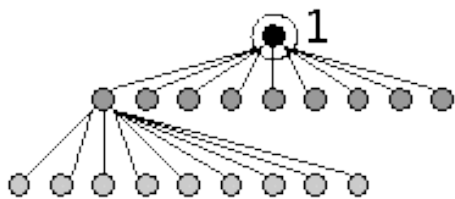
	bytes/Zelle	bytes/Knoten	
2D	6	2	Peano nur Gitter
		1317	Sundance nur Gitter
	14	20	Peano Strömungslöser
		1490	Sundance Poissonlöser
3D	10	2	Nur Gitter
	18	28	Strömungslöser

Our Grid and Data Concept – Streams and Stacks

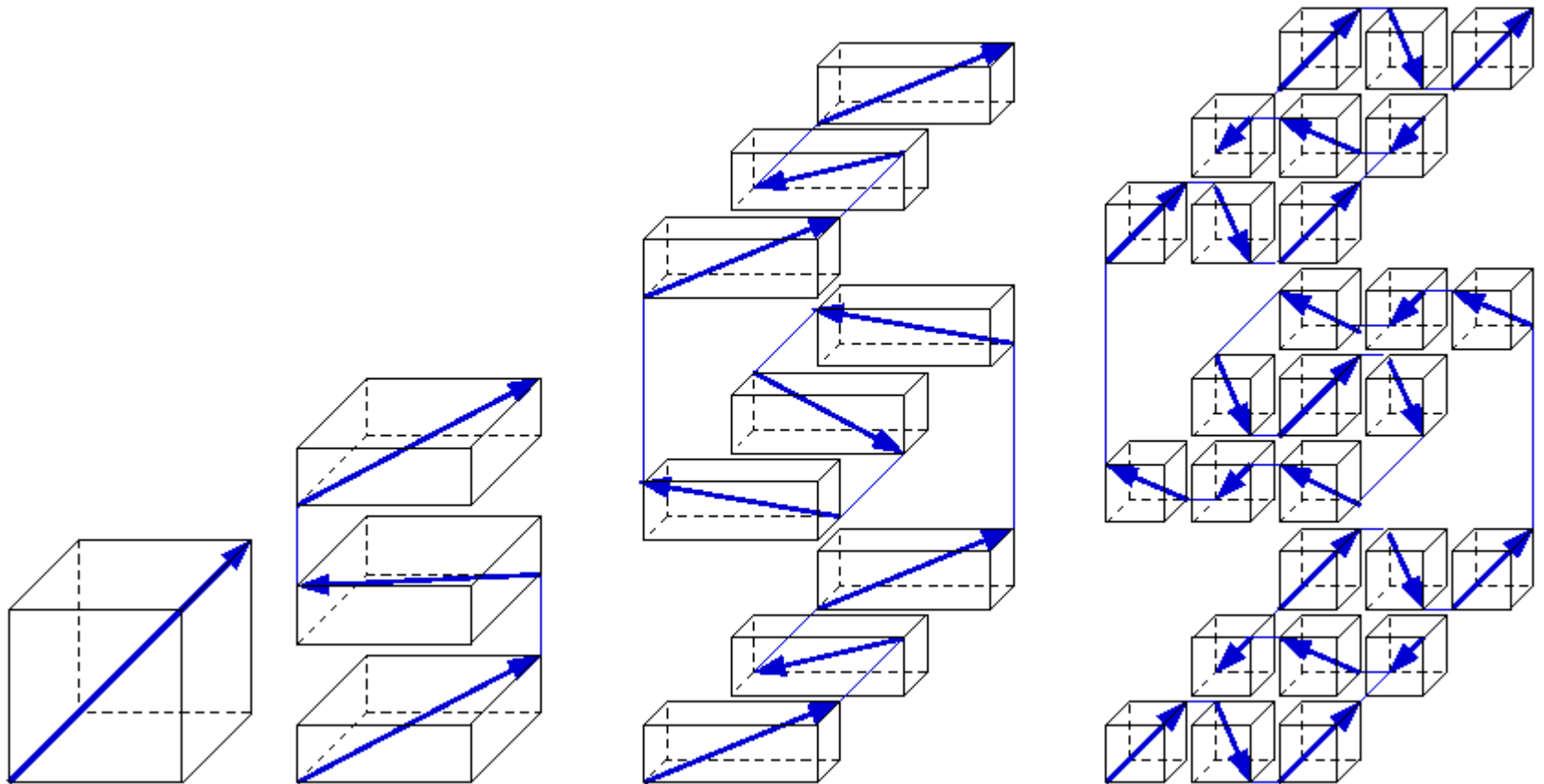


Our Grid and Data Concept – Streams and Stacks

- depth-first spacetree traversal
 - all grid levels available

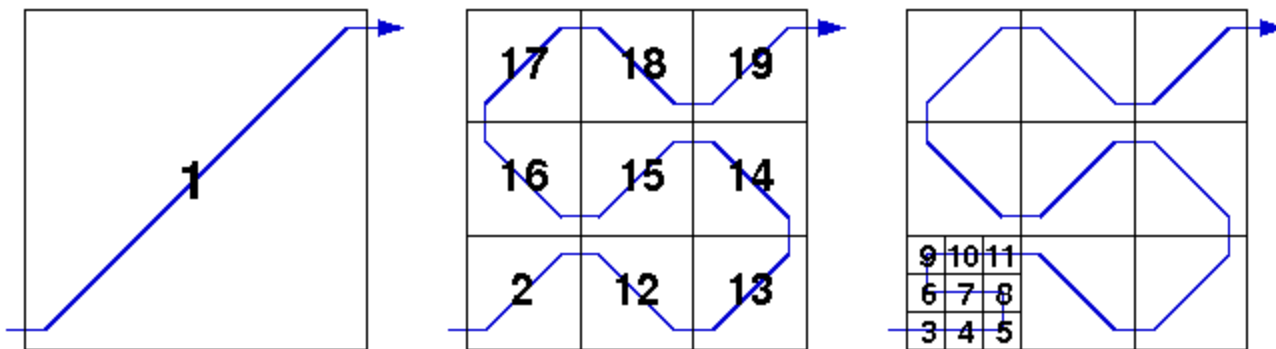


Our Grid and Data Concept – Streams and Stacks

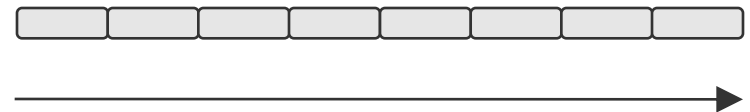
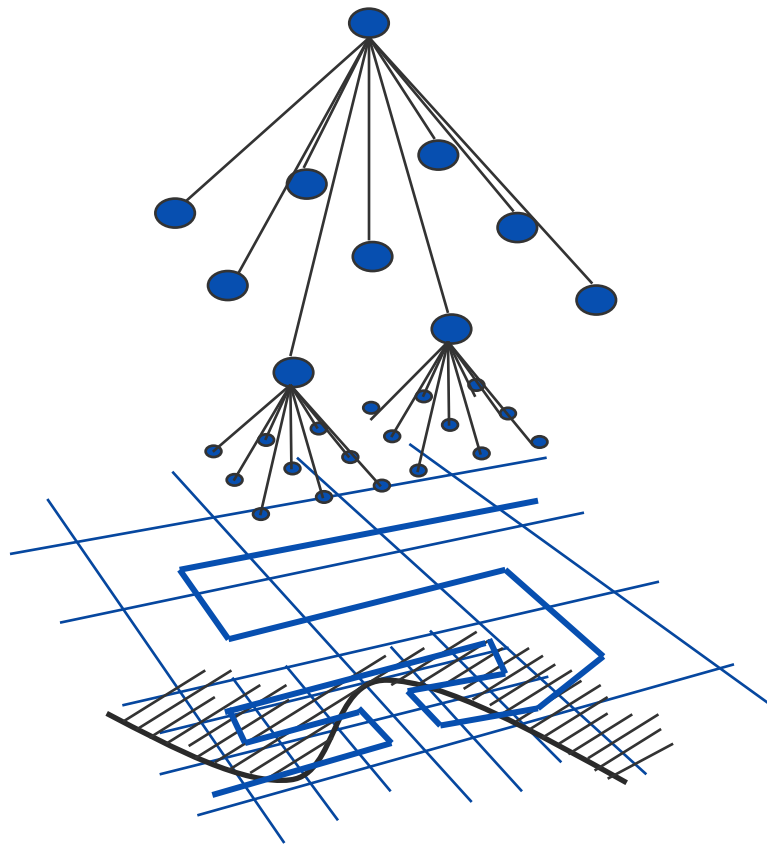


Our Grid and Data Concept – Streams and Stacks

- total order of all grid cells
 - good time locality

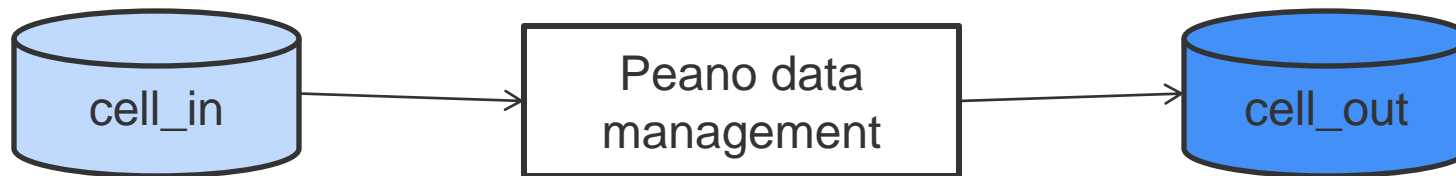


Our Grid and Data Concept – Streams and Stacks

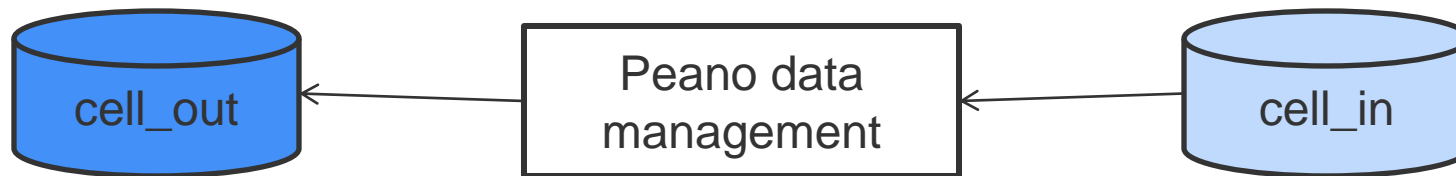


Peano order of cells

Our Grid and Data Concept – Cell Data



Our Grid and Data Concept – Cell Data



Our Grid and Data Concept – Vertex Data

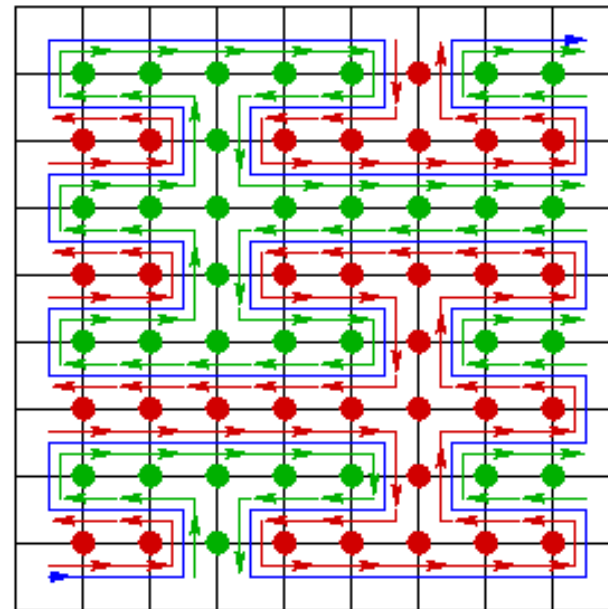


2D input
stack

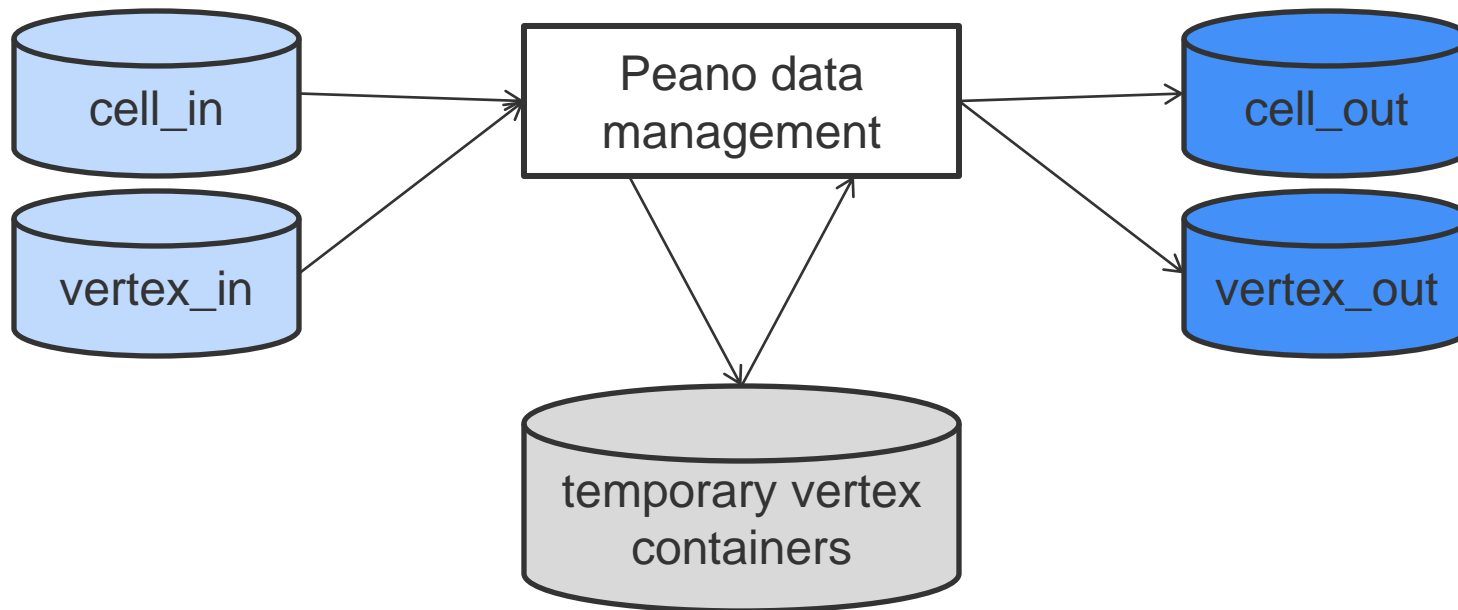
red line
stack

green line
stack

2D output
stack

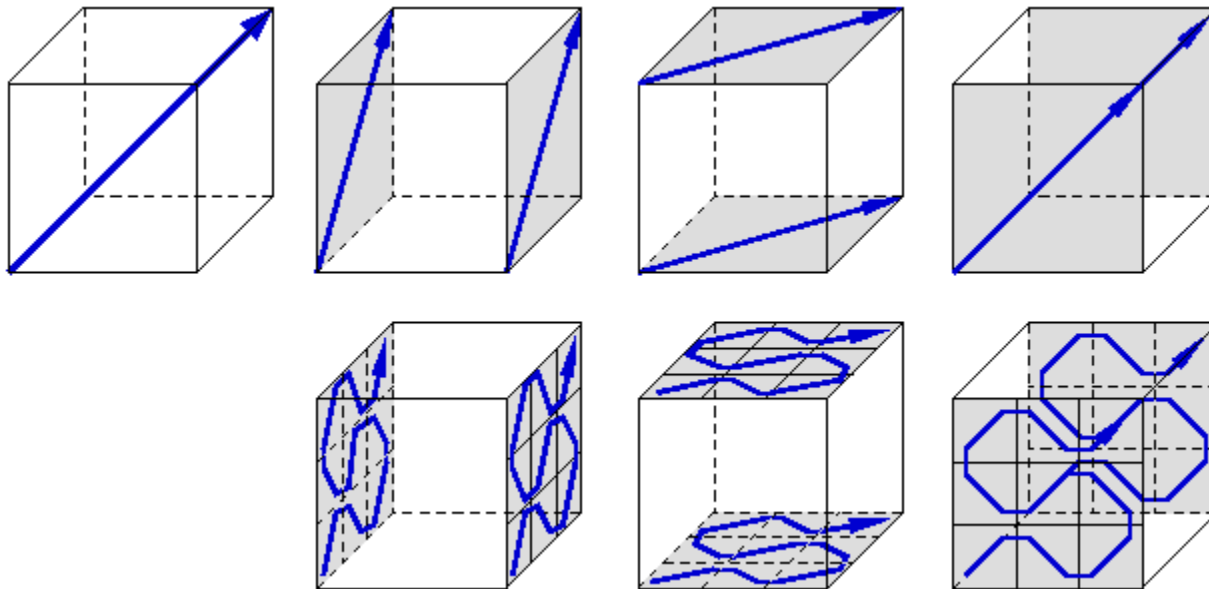


Streams and Stacks – Vertex Data



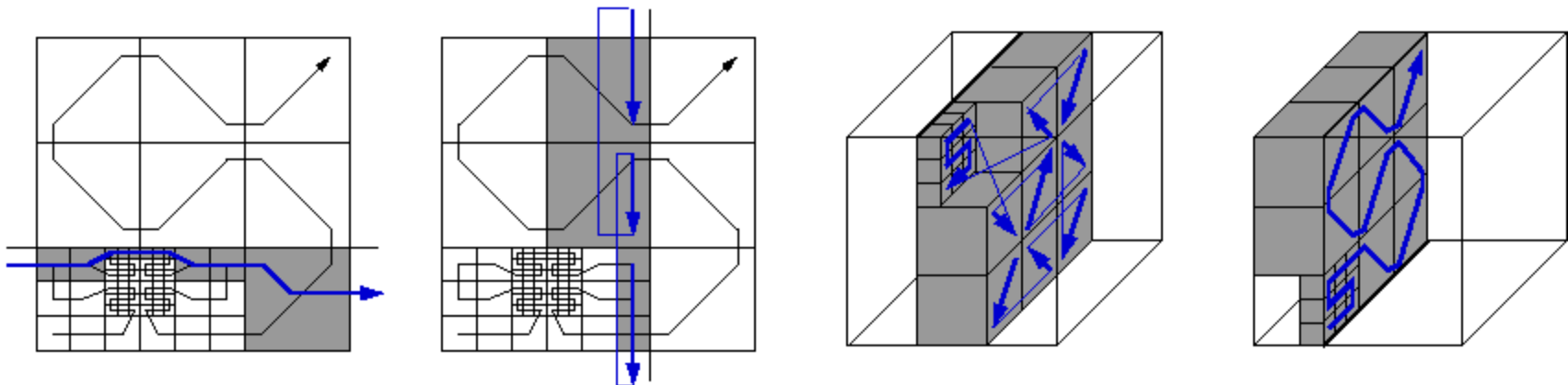
Our Grid and Data Concept – Vertex Data

- projection property for cell faces



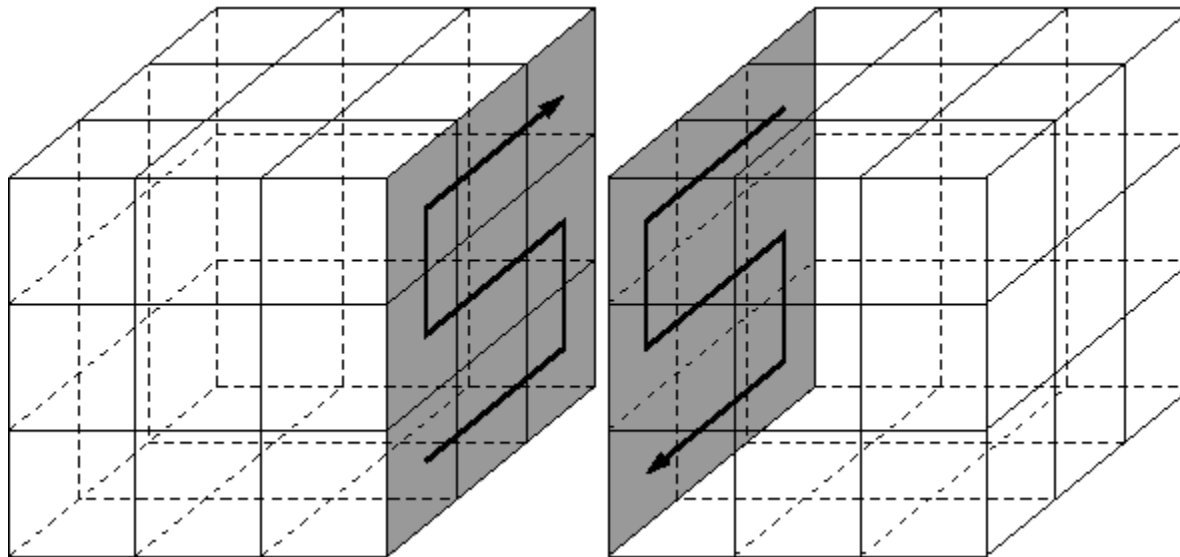
Our Grid and Data Concept – Vertex Data

- ...not for arbitrary hyperplanes!



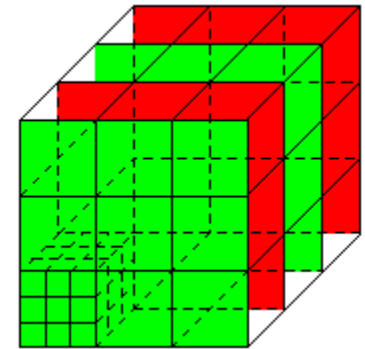
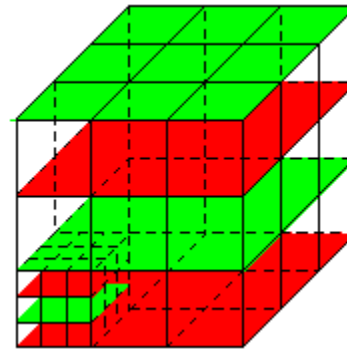
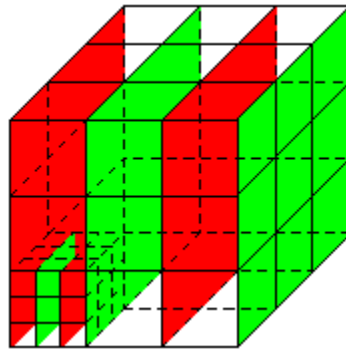
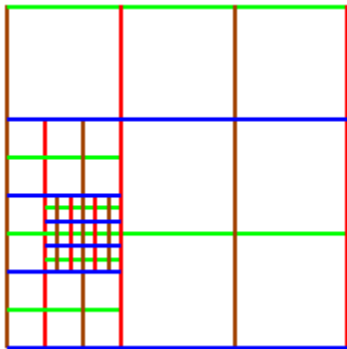
Our Grid and Data Concept – Vertex Data

- palindrome property for cell faces



Our Grid and Data Concept – Vertex Data

- alternating face colouring → 2d stacks (Weinzierl, 2007)

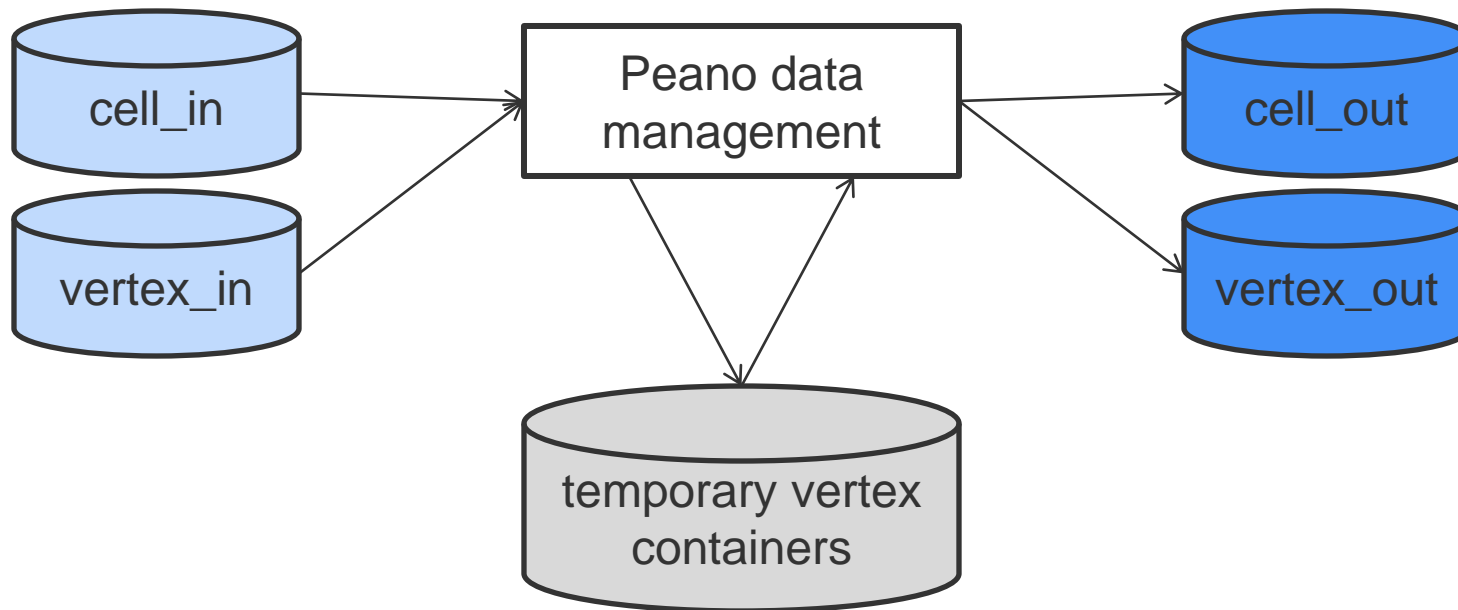


Our Grid and Data Concept – Vertex Data

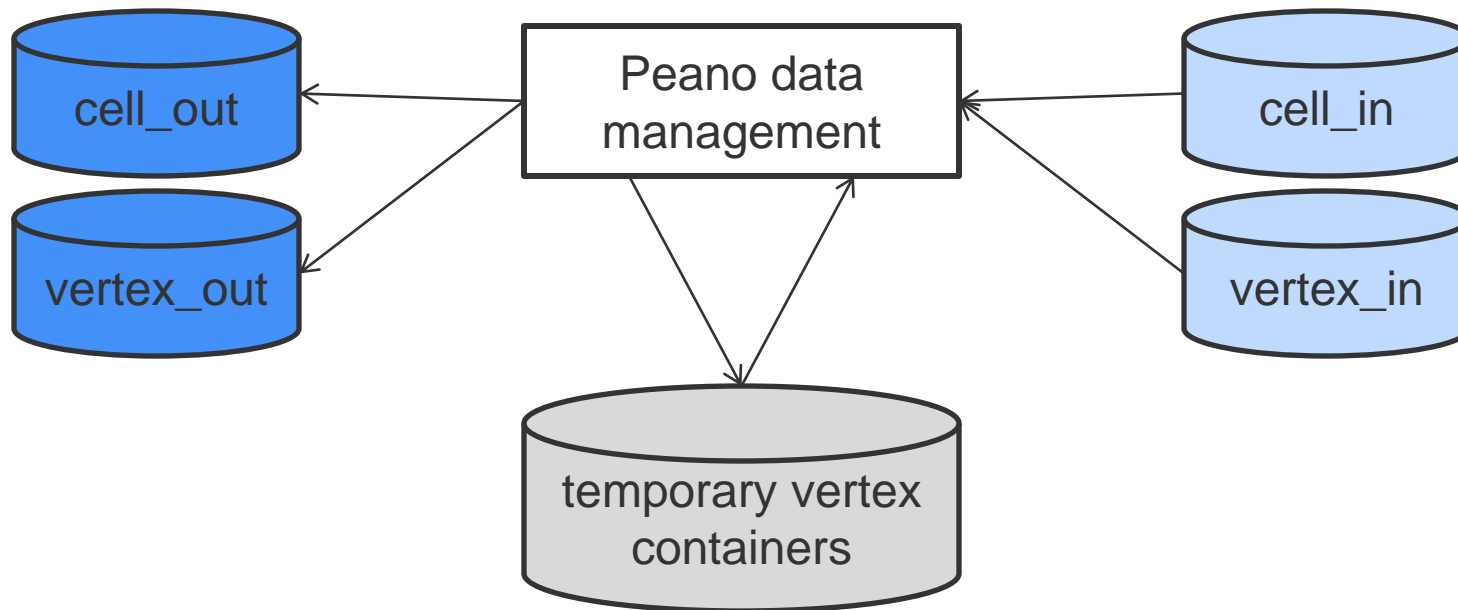
- face-connectivity
 - next visiting cell connected via a (hyper-)face
- leave cell: write vertex data to the stack of the next visiting face
- enter cell: read vertex data from the stack of the last visiting face

- proof: SIAM SISC, special issue of the *11th Copper Mountain Conference on Iterative Methods*, submitted

Our Grid and Data Concept – Vertex Data

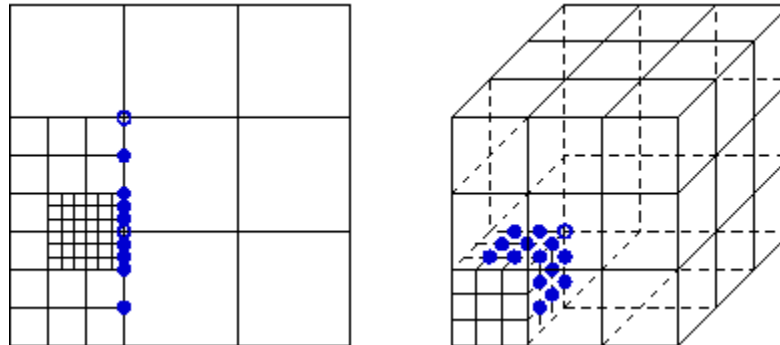


Our Grid and Data Concept – Vertex Data



Our Grid and Data Concept – Vertex Data

- hanging nodes
 - no degrees of freedom
 - created on-the-fly (interpolation)
 - not written to output stream

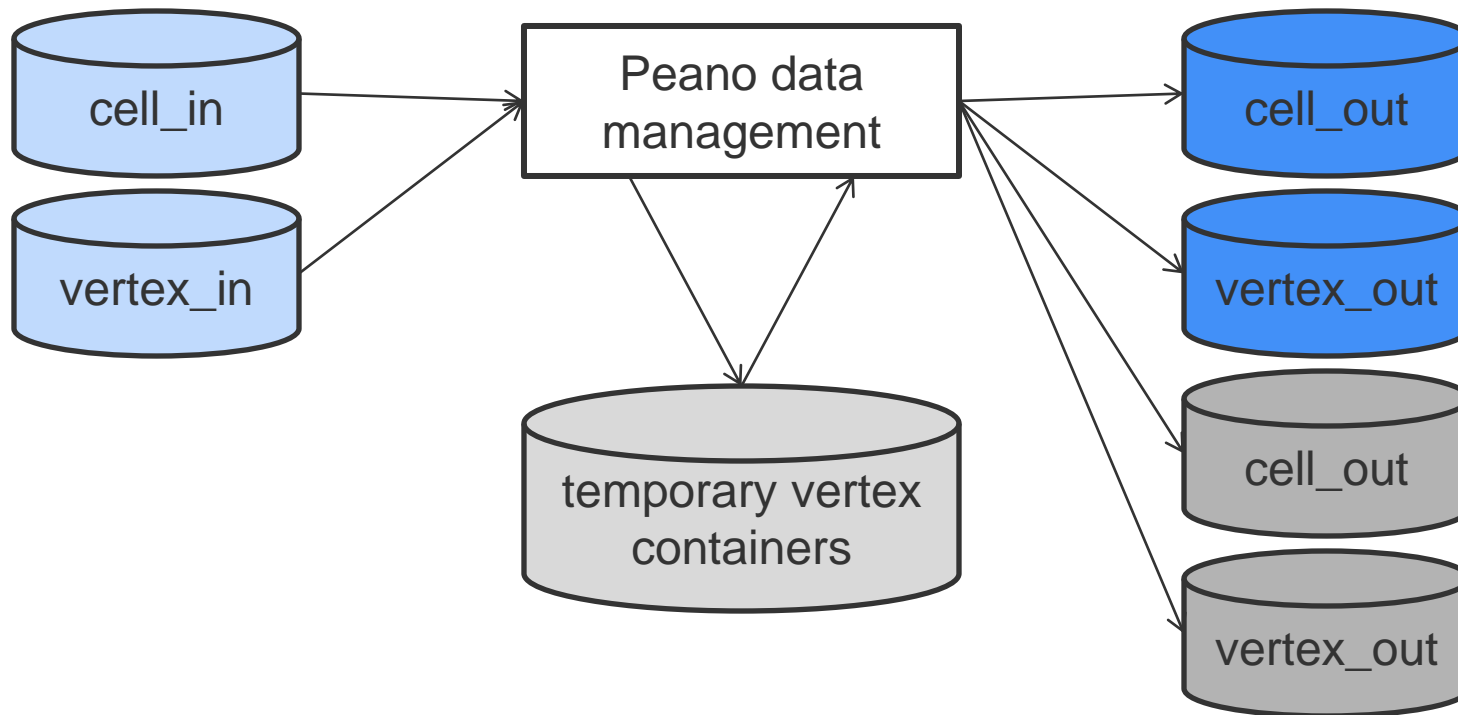


Our Grid and Data Concept – Numerical Results

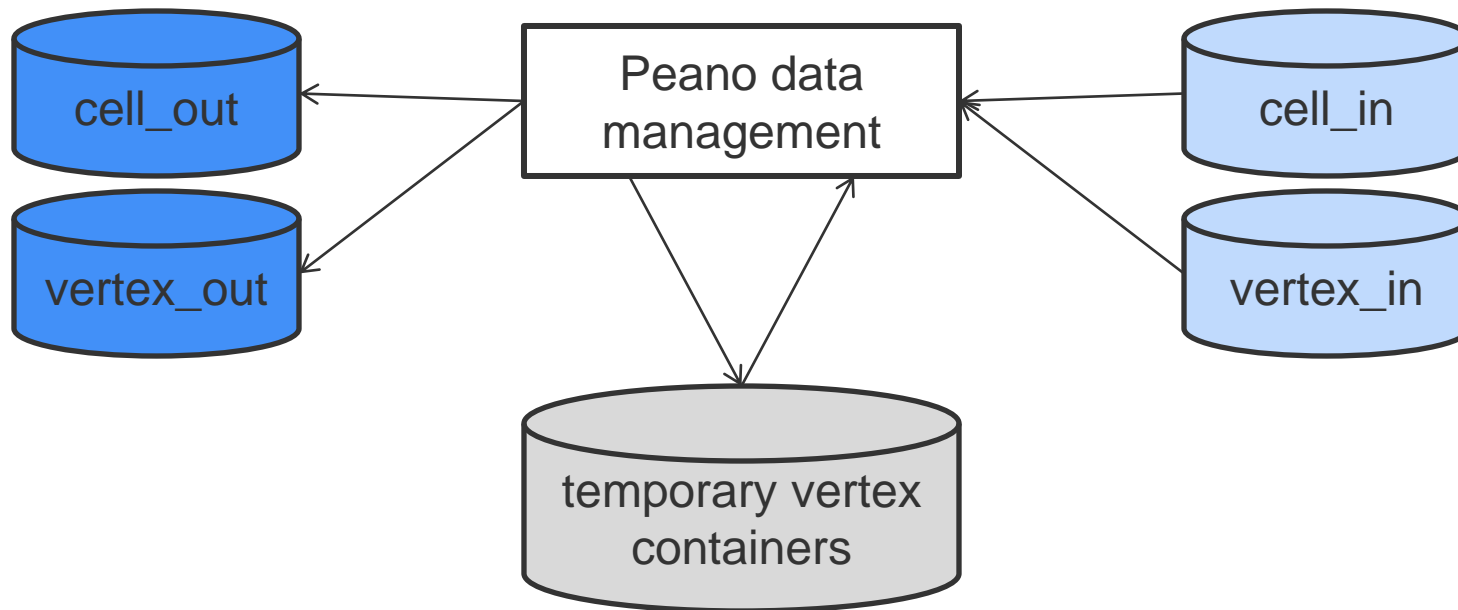
==19243== D refs:	7,249,842,728	(4,026,485,237 rd + 3,223,357,491 wr)
==19243== D1 misses:	1,249,032	(621,413 rd + 627,619 wr)
==19243== L2d misses:	632,162	(301,283 rd + 330,879 wr)
==19243== D1 miss rate:	0.0%	(0.0% + 0.0%)
==19243== L2d miss rate:	0.0%	(0.0% + 0.0%)
==19243==		
==19243== L2 refs:	19,559,185	(18,931,566 rd + 627,619 wr)
==19243== L2 misses:	646,343	(315,464 rd + 330,879 wr)
==19243== L2 miss rate:	0.0%	(0.0% + 0.0%)

2D Poisson equation, 1,000,000 degrees of freedom, Pentium 4,
1MB L2 Cache, Cachegrind simulation

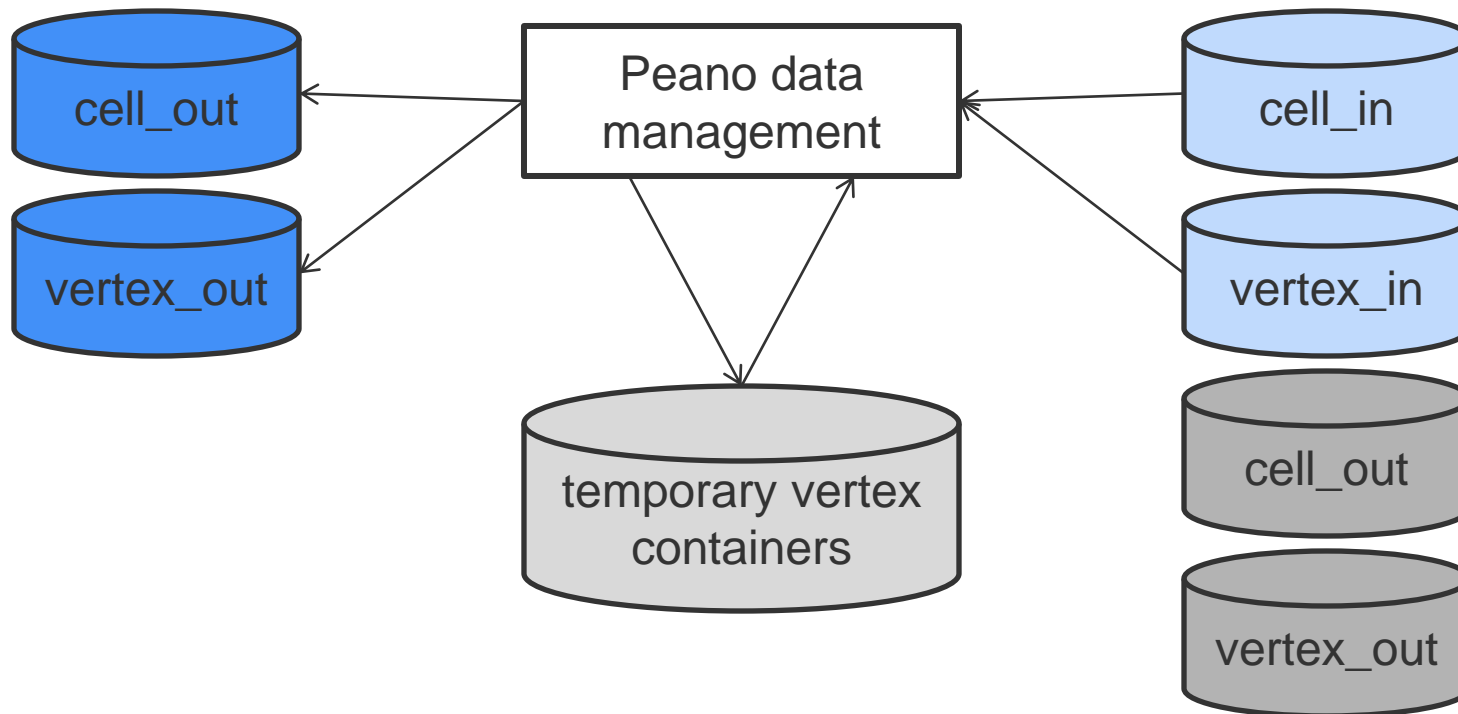
Our Grid and Data Concept – Dynamical Adaptivity



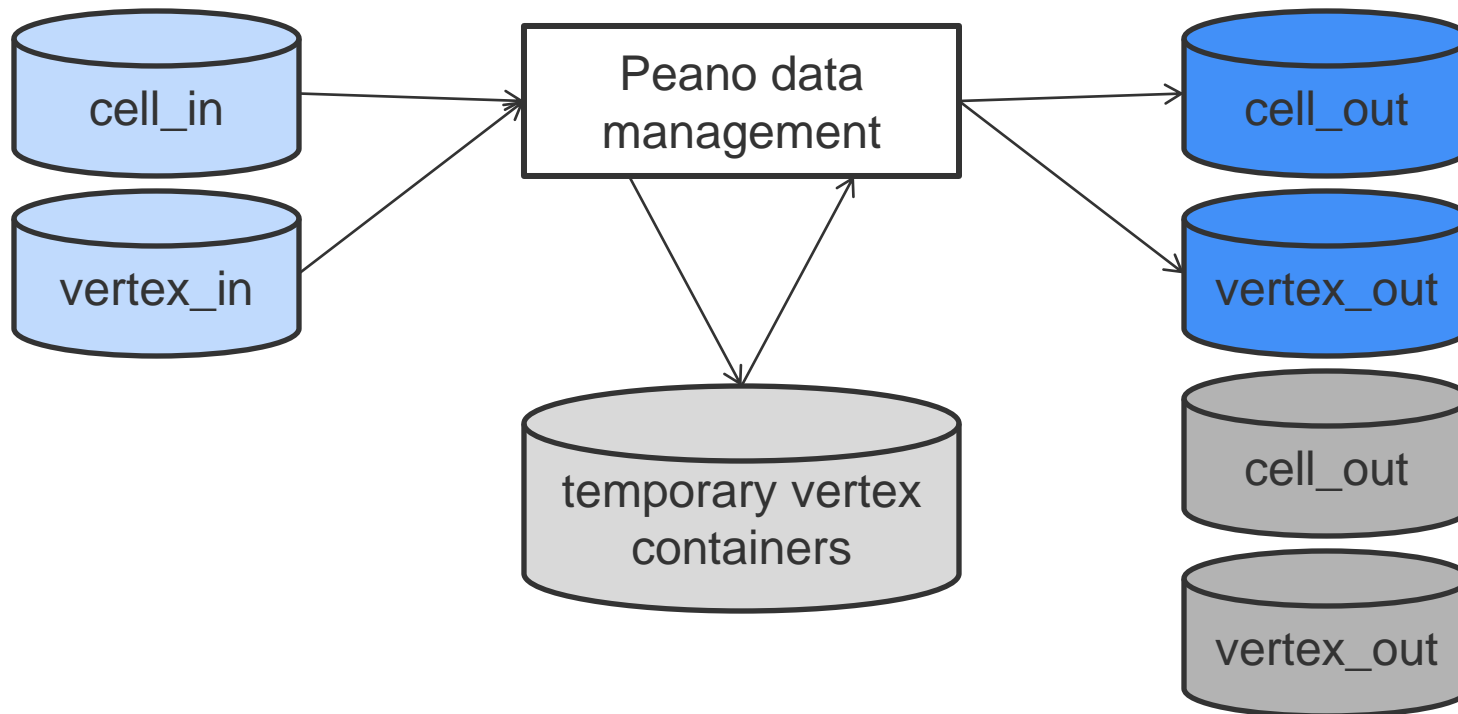
Our Grid and Data Concept – Dynamical Adaptivity



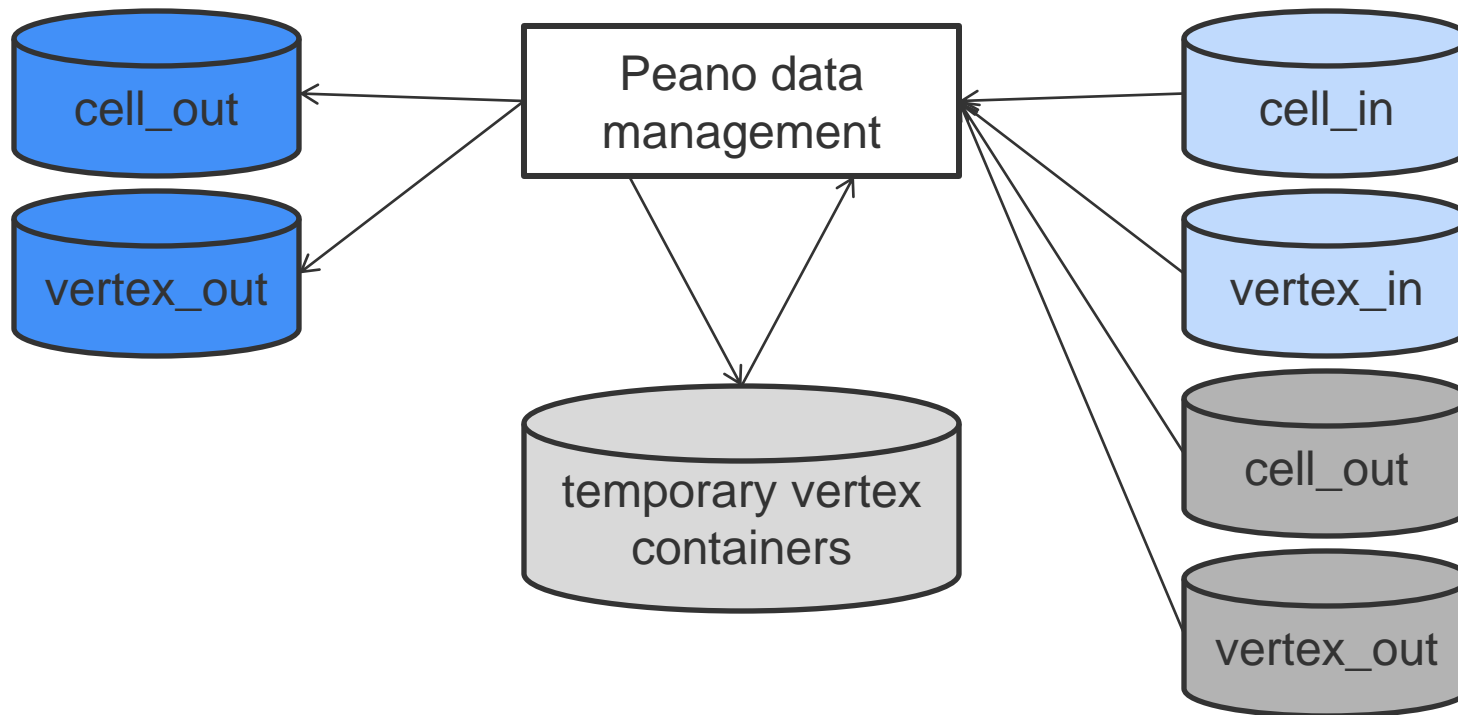
Our Grid and Data Concept – Dynamical Adaptivity



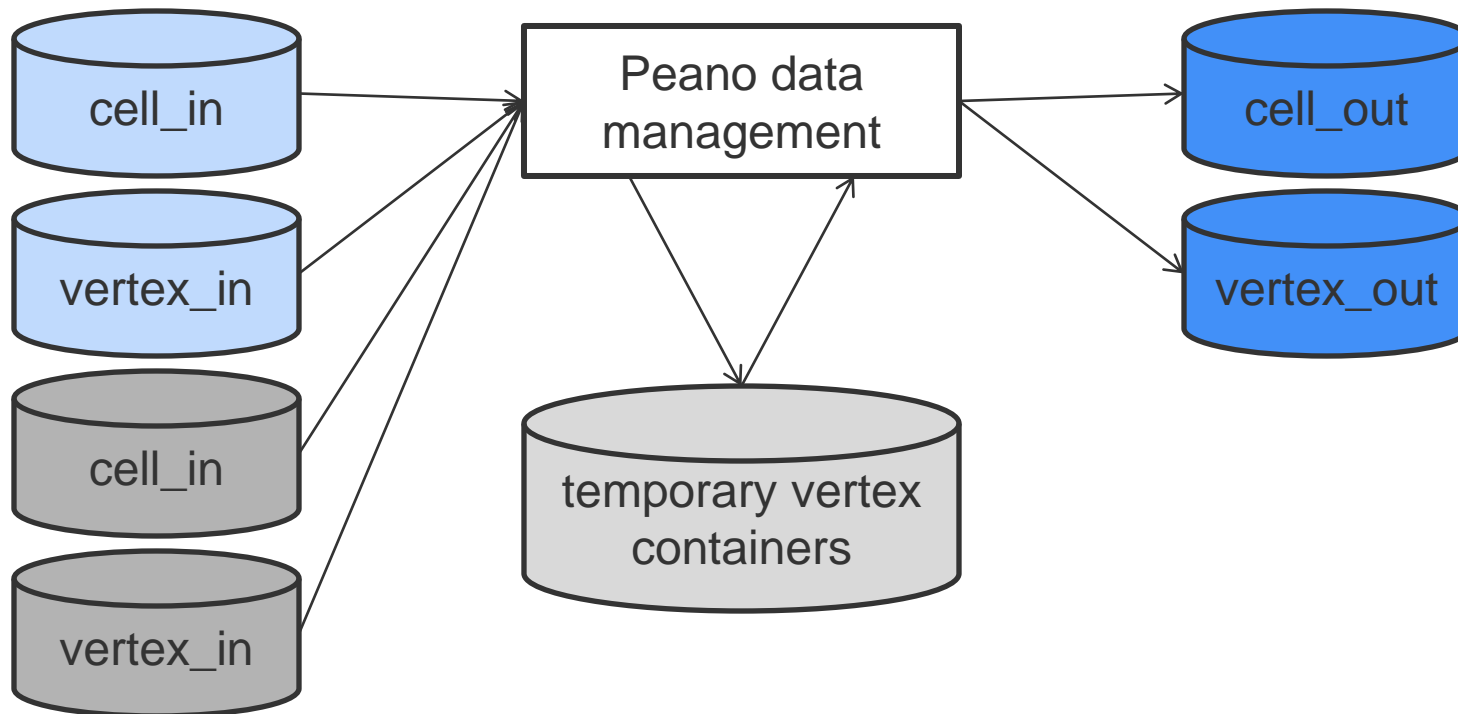
Our Grid and Data Concept – Dynamical Adaptivity



Our Grid and Data Concept – Dynamical Adaptivity



Our Grid and Data Concept – Dynamical Adaptivity

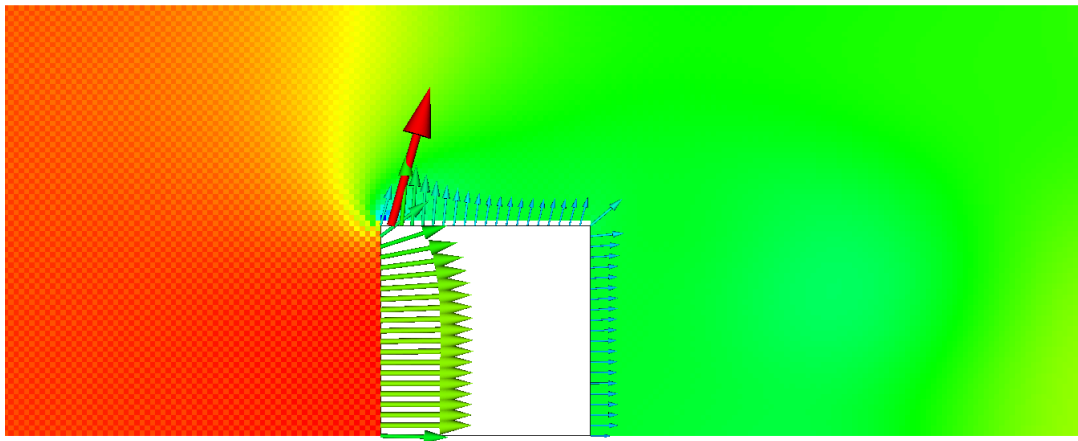
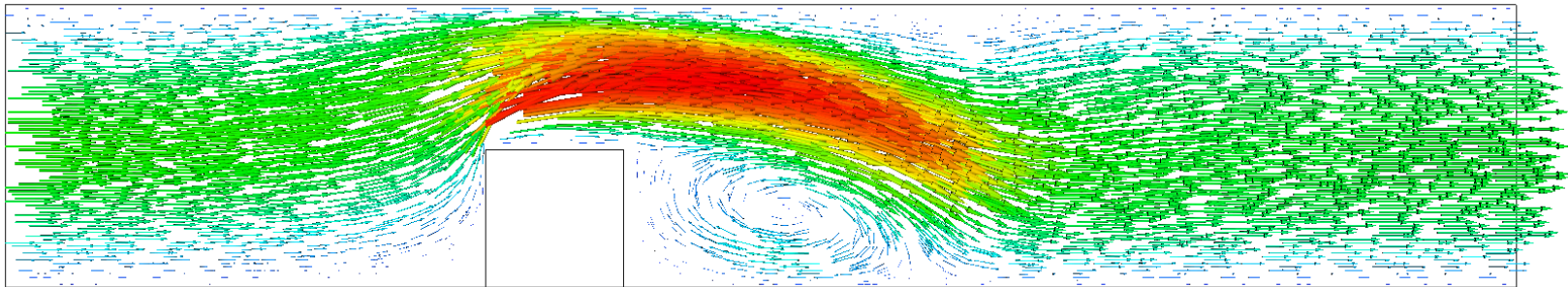


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Application Examples

computational fluid dynamics with force computation

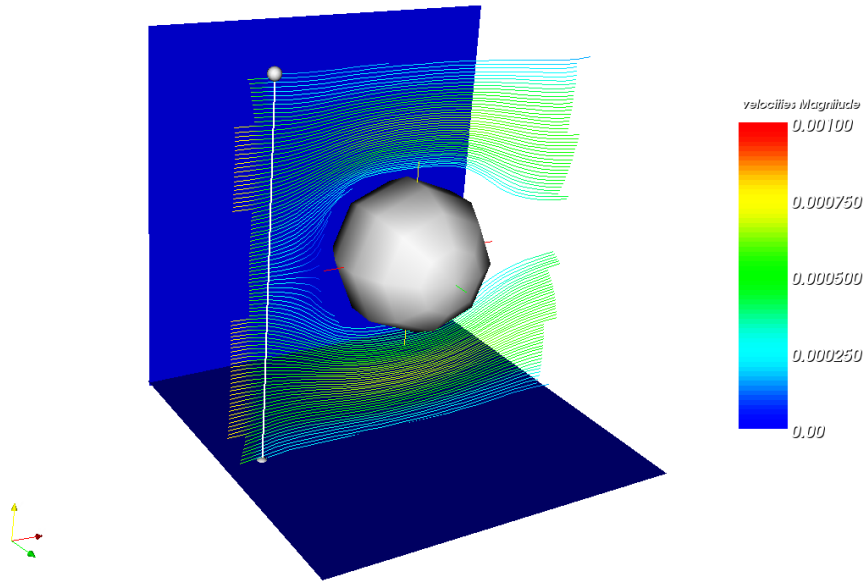


Source: Bernhard Gatzhammer

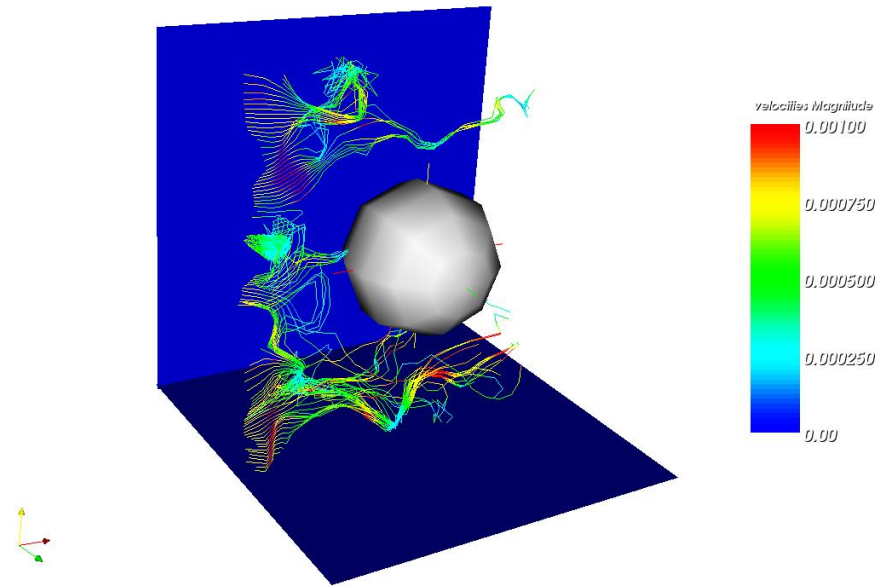
Application Examples

Lattice Boltzmann on adaptive grids

without fluctuations



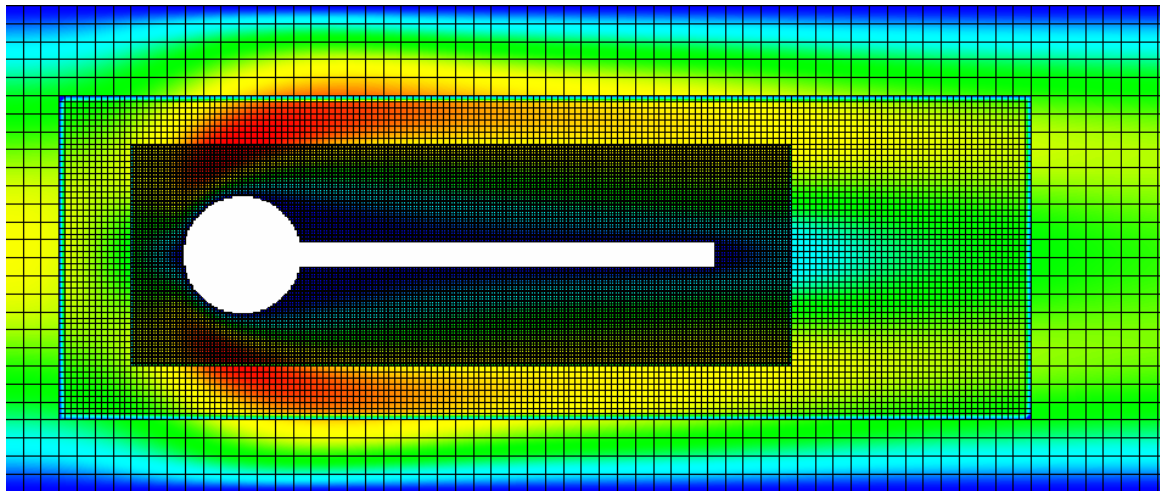
with fluctuations



Source: Philipp Neumann

Application Examples

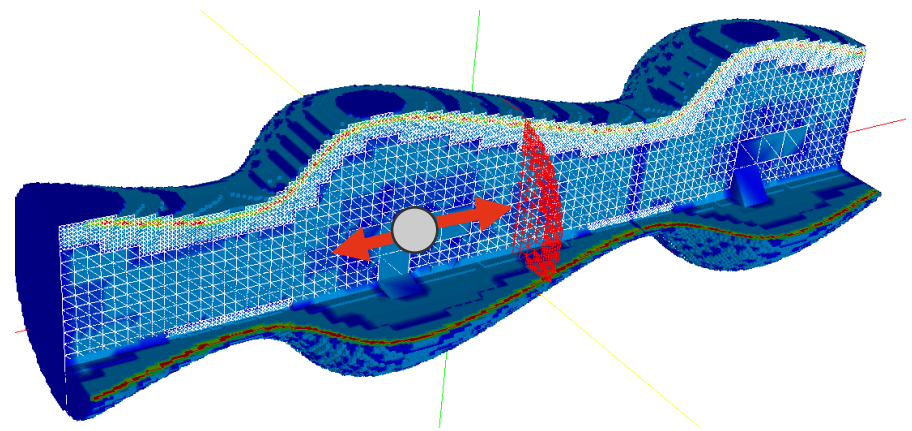
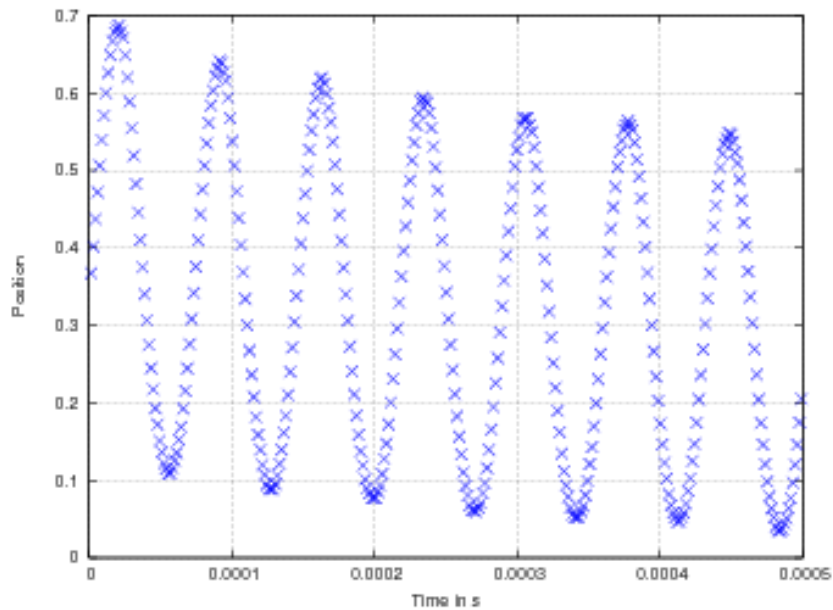
Fluid-Structure Interaction



Source: Tobias Neckel

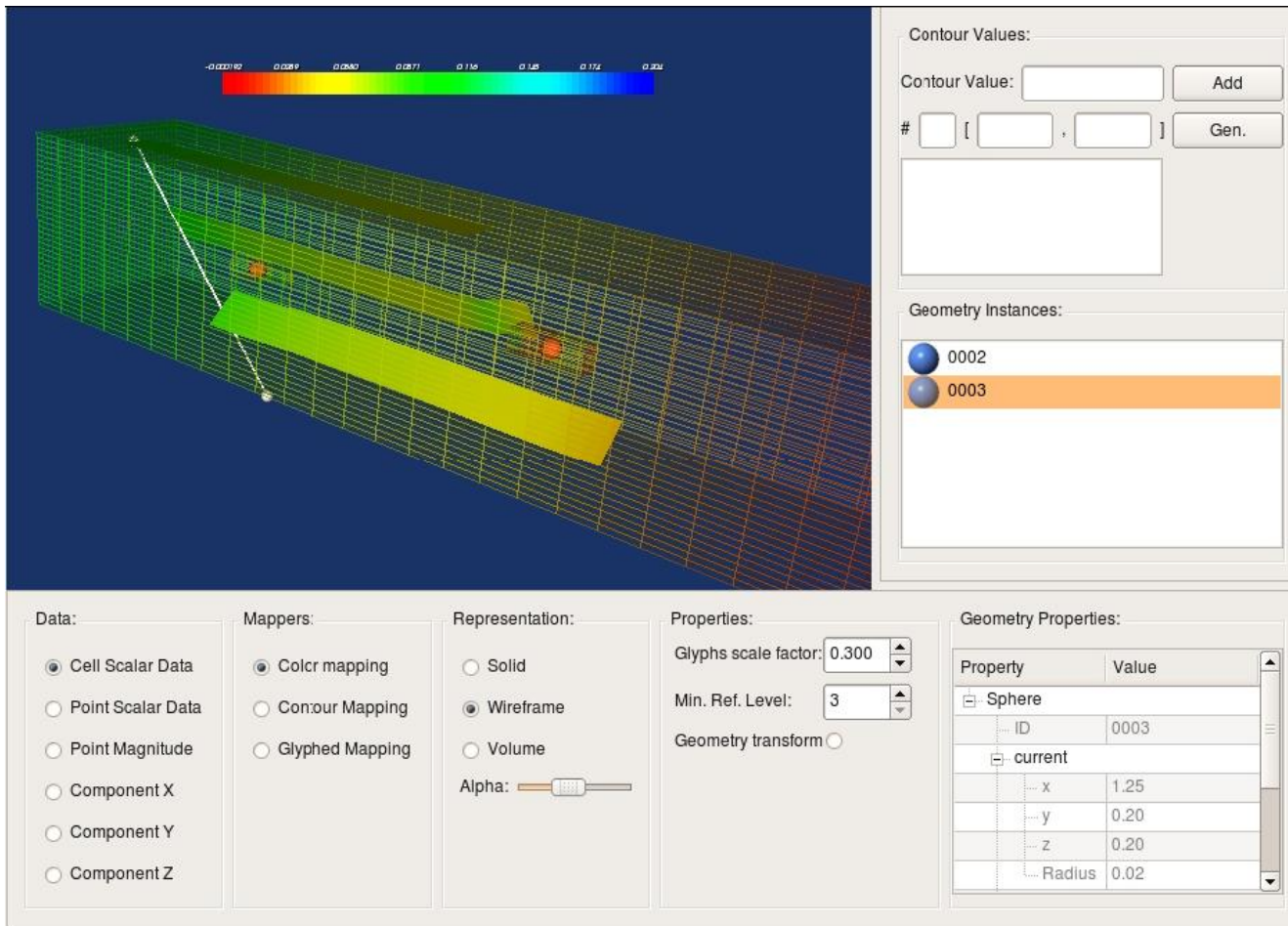
Application Examples

Fluid Flow in Complex Geometries



Source: Tobias Weinzierl,
Ionel Muntean

Application Examples



The screenshot displays a 3D visualization of a rectangular domain with a wireframe grid. A color bar at the top indicates scalar values ranging from -0.020192 to 0.182. The domain contains a yellow and green region. The interface includes several control panels:

- Contour Values:**
 - Contour Value:
 - Add
 - # [,]
- Geometry Instances:**
 - 0002
 - 0003
- Data:**
 - Cell Scalar Data
 - Point Scalar Data
 - Point Magnitude
 - Component X
 - Component Y
 - Component Z
- Mappers:**
 - Color mapping
 - Contour Mapping
 - Glyphed Mapping
- Representation:**
 - Solid
 - Wireframe
 - Volume
 - Alpha:
- Properties:**
 - Glyphs scale factor:
 - Min. Ref. Level:
 - Geometry transform
- Geometry Properties:**

Property	Value
[-] Sphere	
ID	0003
[-] current	
x	1.25
y	0.20
z	0.20
Radius	0.02

Computational Steering

Source: Atanas Atanasov

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Conclusion

