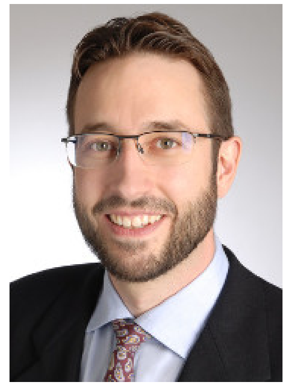
# Carsten Burstedde



## Academic career

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| 1995 - 2001 | Undergraduate studies, University of Cologne |
| 1997 | Vordiplom (intermediate diploma) in both Mathematics and Physics |
| 1997 -1998 | Exchange year (physics), University of Edinburgh, Scotland, UK |
| 2001 | Diploma of physics (with distinction); Master's equivalent |
| 2001 - 2006 | Graduate studies, University of Bonn |
| 2005 | Dr. rer. nat. (magna cum laude) |
| 2006 | Postdoc, RWTH Aachen |
| 2006 - 2008 | Postdoc, ICES, University of Texas, Austin, TX, USA |
| 2008 - 2010 | Research Associate, ICES, TX, USA |
| 2010 - 2011 | Research Scientist, ICES, TX, USA |
| Since 2011 | Professor (W2), University of Bonn |

## Honours

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| 2008 | NSF TeraGrid Capability Computing Challenge Award |
| 2009 | Best Poster Award at the ACM/IEEE SC Conference |
| 2011 | Springer CSE Prize |

## Invited Lectures

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| 2015 | Parallel adaptive mesh refinement for element based flow simulation. Invited presentation at the ICMS workshop on Galerkin methods with applications in weather and climate forecasting, Edinburgh, Scotland, UK |
| 2015 | Recent developments in forest-of-octrees AMR. Invited minisymposion keynote at the International Conference on Supercomputing (ICS), Frankfurt (Germany) |
| 2016 | Parallel Tree Algorithms for Adaptive Mesh Refinement. Plenary lecture at the Tetrahedron V Workshop on Grid Generation for Numerical Computations, Liège, Belgium |
| 2017 | Scientific Computing in the Geosciences. Invited lecture, GeoTag, RWTH Aachen (Germany) |

## Research Projects and Activities

Johannes Holke's work on tetrahedral AMR is sponsored by the Bonn International Graduate School as part of the Hausdorff Center for Mathematics.
Jose A. Fonseca is supported by the Collaborative Research Center SFB/TR 32. Both centers are funded by the German Research Foundation (DFG).
We have been awarded close to 14 million hours on the "Juqueen" supercomputer at the Jülich Supercomputing Centre in 2013 - 2018.

## Research profile

My research over the past years has been centered around developing fast and scalable algorithms to work with adaptive meshes on large parallel computers. A computational mesh is a collection of elements of primitive shapes, in this case (smoothly mapped) quadrilaterals (2D) or hexahedra (3D), together with a definition of the connectivity between neighboring elements. There are various constructions that allow for adaptivity, that is, non-uniform size- and spatial distribution of elements. The approach that has been most successful in our work is the synthesis of a coarse conforming mesh, where neighboring elements fully match along their boundary faces and edges, with a non-conforming recursive subdivision of each of these coarse mesh elements that is mathematically a tree. This scheme may conveniently be called a forest of elements. The key to efficient algorithms for refining, coarsening, partitioning, and traversing such a mesh, and identifying and numbering its faces, edges, and nodes, lies in exploiting the tree structure in favorable ways while respecting the reality of parallel hardware and its networking stack.

This research has led to new algorithms and their implementation in the publicly available software ”p4est”. In various collaborations over the past decade, these algorithms have been integrated with scientific applications. In addition to the simulation of earth's mantle convection and the propagation of elastic and acoustic waves using Galerkin discretizations, we have enabled finite volume methods for simulating atmospheric flow, semi-Lagrangian methods for the research of crystal growth, and Lattice-Boltzmann methods to simulate general fluid flow.

These applications benefit significantly from the flexibility offered by adaptive mesh refinement (AMR) and the speed and scalability of mesh-related operations.

In collaboration with PhD student Johannes Holke, we have recently proposed an extension of the so-called Morton- or Z-curve to triangular and tetrahedral elements and implemented basic algorithms for non-conforming simplicial AMR. Especially the 3D case is less obvious and more complex than the existing hexahedral logic. Encouraged by our initial results, we are working towards the long-term goal of non-conforming hybrid AMR, that is, allowing to mix shapes of many kinds in the same mesh, ideally offering a speed comparable to hex-only algorithms.

In collaboration with PhD student Jose A. Fonseca, we have introduced scalable mesh management into the ”ParFlow” community code for the simulation of subsurface flow. Our work has extended the scalability of the existing code such that it now runs efficiently on the full size of the ”Juqueen” supercomputer in Jülich. This allows for more highly resolved simulations of groundwater flow and thus more accurate research in computational hydrology. With respect to future applications, we are targeting the simulation of the transport of volcanic ash.

## Editorships

- Simula Research Laboratory (Scientific Advisory Board, 2014 – 2016)
- Archive of Numerical Software

**Research Area J** My contribution to Research Area J, ‘High-Dimensional problems and multi-scale methods’, is the development of efficient algorithms to solve multi-scale problems numerically. Multi-scale phenomena are one of the main drivers for using adaptive meshes, since the resolution required differs locally and over time as well, depending on the application. Our methods for adapting meshes in parallel, dynamically and scalable to the largest existing supercomputers, are among the best-known and highest performing worldwide.

## Supervised theses

PhD theses: 2, currently 2

## Selected publications


[1] Jose A.F̃onseca, Carsten Burstedde, and Stefan Kollet. Enhancing speed and scalability of the parflow simulation code. *Computational Geosciences*, 2017. Accepted for publication.

[2] Carsten Burstedde and Johannes Holke. Coarse mesh partitioning for tree-based amr. *SIAM Journal on Scientific Computing*, 39(5):C364–C392, 2017.

[3] Carsten Burstedde, Frederic Gibou, Arthur Guittet, and Mohammad Mirzadeh. Parallel level-set methods on adaptive tree-based grids. *J. Comput. Phys.*, 322:345–364, 2016.

[4] Carsten Burstedde and Johannes Holke. A tetrahedral space-filling curve for nonconforming adaptive meshes. *SIAM J. Sci. Comput.*, 38(5):C471–C503, 2016.

[5] Carsten Burstedde, Omar Ghattas, Tobin Isaac, and Lucas C. Wilcox. Recursive algorithms for distributed forests of octrees. *SIAM J. Sci. Comput.*, 37(5):C497–C531, 2015.

[6] Laura Alisic, Carsten Burstedde, Omar Ghattas, Michael Gurnis, Georg Stadler, Eh Tan, and Lucas C. Wilcox. Large-scale adaptive mantle convection simulation. *Geophysical Journal International*, 192(3):889–906, 2013.

[7] Carsten Burstedde, Omar Ghattas, James Martin, and Lucas C. Wilcox. A stochastic newton mcmc method for large-scale statistical inverse problems with application to seismic inversion. *SIAM J. Sci. Comput.*, 34(3):A1460–A1487, 2012.

[8] Wolfgang Bangerth, Carsten Burstedde, Timo Heister, and Martin Kronbichler. Algorithms and data structures for massively parallel generic adaptive finite element codes. *ACM Trans. Math. Software*, 38(2):Art. 14, 28, 2011.

[9] Carsten Burstedde, Omar Ghattas, and Lucas C. Wilcox. p4est: scalable algorithms for parallel adaptive mesh refinement on forests of octrees. *SIAM J. Sci. Comput.*, 33(3):1103–1133, 2011.