



# richardvuduc

*“Science is always wrong. It never solves a problem without creating ten more.” —George Bernard Shaw*

MY RESEARCH IN HIGH-PERFORMANCE COMPUTING (HPC) SYSTEMS addresses fundamental questions of how to analyze, to tune, and to debug software automatically for complex and rapidly-evolving architectures, including current multicore and future manycore systems. I am broadly interested in architecture, compilers, statistical machine learning, and computational science.

## Research Experience

- Aug '07–present **Assistant Professor**, *Georgia Institute of Technology, Atlanta.*
- Nov '04–Jul '07 **Postdoctoral Scholar**, *Lawrence Livermore National Lab, California.*  
Custom optimizations and empirical tuning for ROSE, an open-source source-to-source compiler for C and C++. Implemented JITTERBUG, a tool to aid MPI application debugging ([best paper](#) at PADTAD/ISSTA 2006).
- Jan–Oct '04 **Postdoctoral Scholar**, *University of California, Berkeley.*  
Completed the open-source implementation of OSKI, including an experimental distributed memory implementation based on the PETSC framework.
- Jan '98–Jan '04 **Graduate Student Researcher; Post-doc**, *University of California, Berkeley.*  
Conducted basic research on performance modeling and automatic tuning of sparse matrix kernels ([4 best paper/presentation awards](#)).
- Jun '94–Jun '97 **Research Intern**, *Institute for Defense Analyses, Virginia.*  
Developed simulations for basic science applications in superfluorescence in gamma-ray lasers, thermal and magnetic techniques for mine-detection, and frost formation.

## Education

- Jan '04 **Ph.D., Computer Science**, *University of California, Berkeley.*
- May '97 **B.S., with Honors, Computer Science**, *Cornell University.*
- June '93 **Diploma**, *Thomas Jefferson H.S. for Science and Technology, Alexandria, Virginia.*

## Ph.D. Dissertation

- title *Automatic performance tuning of sparse matrix kernels.*
- advisors Profs. James Demmel and Katherine Yelick
- summary I developed an automated system to generate highly efficient, platform-adapted implementations of sparse matrix operations (“kernels”), which are frequent bottlenecks in diverse applications in scientific computing, economic modeling, and information retrieval. While these kernels typically run at 10% or less of peak machine speed, my implementations, automatically tuned using empirical modeling and search techniques, can achieve up to 31% of peak and run up to 4× faster. I have implemented these ideas in OSKI, an open-source library.

## Awards

- 2010 Best paper (software track) at Int'l. Parallel and Distributed Processing Symposium (IPDPS)
- 2009 R&D 100 Award for ROSE, joint with D. Quinlan at LLNL, M. Schordan, Q. Yi
- 2009 Finalist, Best paper at Supercomputing (SC)
- 2009 Raytheon Faculty Fellowship (joint with H. Kim)
- 2006 Best paper at Parallel and Distributed Testing and Debugging (PADTAD), at ISSTA
- 2004 Best paper at International Conference on Parallel Processing (ICPP)
- 2002 Finalist, Best student paper at SC
- 2002 Best student paper at Performance Optimization of High-Level Languages and Libraries (POHLL) Workshop, at the International Conference on Supercomputing (ICS)
- 2002 Best student presentation at POHLL/ICS
- 2000 Best presentation at Feedback-directed Dynamic Optimization workshop, at MICRO
- 1998 Outstanding Graduate Student Instructor Award, U.C. Berkeley
- 1997 Cornell Tradition Fellowship, Cornell University

## Teaching Experience

- Fall '09 **Assistant Professor**, *Georgia Institute of Technology*, CSE 6230, High-performance computing: Tools and applications.  
Taught a graduate course of 14 students on parallel architectures, programming models, and performance analysis and tuning for applications.
- Fall '08 **Assistant Professor**, *Georgia Institute of Technology*, CSE 6230, High-performance computing: Tools and applications.  
Taught a graduate course of 35 students on parallel architectures, programming models, and performance analysis and tuning for applications. **Overall teaching effectiveness rating: 4.1 / 5.0.**
- Spring '08 **Assistant Professor**, *Georgia Institute of Technology*, CSE 8803, Parallel numerical algorithms.  
Taught an advanced graduate topics course of 20 students on advanced numerical algorithms for scientific computing applications. **Overall teaching effectiveness rating: 4.6 / 5.0.**
- Sep–Dec '97 **Teaching Assistant**, *University of California, Berkeley*, Computer Science.  
Received a campus-wide **Outstanding Graduate Student Instructor Award**.
- Aug '96–May '97 **Teaching Assistant**, *Cornell University*, Dept. of Physics.  
Taught introductory engineering physics courses.
- Aug–Dec '95 **Teaching Assistant**, *Cornell University*, Dept. of Mathematics.  
Taught first-year calculus and linear algebra courses.

## Professional Experience

- Jun '98–Dec '99 **Chief Technology Officer**, *Snailgram Greetings, Inc.*, Oakland, California.  
Implemented scalable back-end infrastructure for customized commercial card printing.
- Jun–Aug '93 **Software Engineer**, *Office of Naval Research*, Arlington, Virginia.  
Developed network administration tools.
- Jun '91–Jun '92 **Software Engineer (Intern)**, *Privac, Inc.*, Falls Church, Virginia.  
Built systems software for a novel supercomputer prototype.

## Publications *(Refereed except where noted.)*

— Autotuned algorithms and libraries —

- [1] Aparna Chandramowliswaran, Sam Williams, Leonid Oliker, Ilya Lashuk, George Biros, and **Richard Vuduc**. “Optimizing and tuning the fast multipole method for state-of-the-art multicore architectures.” In *Proc. IEEE Int’l. Parallel and Distributed Processing Symp. (IPDPS)*, Atlanta, GA, USA, April 2010. (to appear).
- [2] Jee Whan Choi, Amik Singh, and **Richard Vuduc**. “**Model-driven autotuning of sparse matrix-vector multiply on GPUs.**” In *Proc. ACM SIGPLAN Symp. Principles and Practice of Parallel Programming (PPoPP)*, Bangalore, India, January 2010.
- [3] **Finalist, Best Paper** Ilya Lashuk, Aparna Chandramowliswaran, Harper Langston, Tuan-Anh Nguyen, Rahul Sampath, Aashay Shringarpure, **Richard Vuduc**, Lexing Ying, Denis Zorin, and George Biros. “**A massively parallel adaptive fast multipole method on heterogeneous architectures.**” In *Proc. ACM/IEEE Conf. Supercomputing (SC)*, Portland, OR, USA, November 2009.
- [4] Nitin Arora, Aashay Shringarpure, and **Richard Vuduc**. “**Direct  $n$ -body kernels for multicore platforms.**” In *Proc. Int’l. Conf. Parallel Processing (ICPP)*, Vienna, Austria, September 2009.
- [5] Sundaresan Venkatasubramanian and **Richard Vuduc**. “**Tuned and wildly asynchronous stencil kernels for hybrid CPU/GPU platforms.**” In *Proc. ACM Int’l. Conf. Supercomputing (ICS)*, New York, NY, USA, June 2009.
- [6] Seunghwa Kang, David Bader, and **Richard Vuduc**. “**Understanding the design trade-offs among current multicore systems for numerical computations.**” In *Proc. IEEE Int’l. Parallel and Distributed Processing Symp. (IPDPS)*, Rome, Italy, May 2009.
- [7] Manisha Gajbe, Andrew Canning, John Shalf, Lin-Wang Wang, Harvey Wasserman, and **Richard Vuduc**. “Optimization and auto-tuning of 3D FFTs on the Cray XT4.” In *Proc. Cray User’s Group (CUG) Meeting*, Atlanta, GA, USA, May 2009.
- [8] **Most downloaded article, Q1 2009** Sam Williams, **Richard Vuduc**, Leonid Oliker, John Shalf, Katherine Yelick, and James Demmel. “**Optimizing sparse matrix-vector multiply on emerging multicore platforms.**” *Journal of Parallel Computing*, 35(3):178–194, March 2009.
- [9] Aparna Chandramowliswaran, Abhinav Karhu, Ketan Umare, and **Richard Vuduc**. “Numerical algorithms with tunable parallelism.” In *ACM/IEEE CGO Workshop on Software Tools for Multicore Systems (STMCS)*, Boston, MA, USA, April 2008.
- [10] Sam Williams, Lenny Oliker, **Richard Vuduc**, John Shalf, Katherine Yelick, and James Demmel. “**Optimization of sparse matrix-vector multiply on emerging multicore platforms.**” In *Proc. Supercomputing*, Reno, NV, USA, November 2007.
- [11] Rajesh Nishtala, **Richard Vuduc**, James W. Demmel, and Katherine A. Yelick. “**When cache blocking sparse matrix vector multiply works and why.**” *Applicable Algebra in Engineering, Communication, and Computing: Special Issue on Computational Linear Algebra and Sparse Matrix Computations*, March 2007.
- [12] **Richard Vuduc** and Hyun-Jin Moon. “**Fast sparse matrix vector multiplication by exploiting variable block structure.**” In *Proc. Int’l Conf. on High-Performance Computing and Communications*, LNCS 3726, pages 807–816, Sorrento, Italy, September 2005.
- [13] **Richard Vuduc**, James W. Demmel, and Katherine A. Yelick. “**OSKI: A library of automatically tuned sparse matrix kernels.**” In *Proc. SciDAC 2005*, Journal of Physics: Conference Series, San Francisco, CA, USA, June 2005. Institute of Physics Publishing.
- [14] James Demmel, Jack Dongarra, Victor Eijkhout, Erika Fuentes, Antoine Petitet, **Richard Vuduc**, R. Clint Whaley, and Katherine Yelick. “**Self-adapting linear algebra algorithms and software.**” In *Proc. IEEE: Special Issue on Program Generation, Optimization, and Adaptation*, February 2005.

- [15] Eun-Jin Im, Katherine Yelick, and **Richard Vuduc**. “**SPARSITY: An optimization framework for sparse matrix kernels.**” *Int’l J. of High Performance Computing Applications*, 18(1):135–158, 2004.
- [16] **Richard Vuduc**, Attila Gyulassy, James W. Demmel, and Katherine A. Yelick. “**Memory hierarchy optimizations and bounds for sparse  $A^T Ax$ .**” In *Proc. ICCS Workshop on Parallel Linear Algebra*, volume LNCS, Melbourne, Australia, June 2003. Springer.
- [17] **Best presentation; Best student paper** **Richard Vuduc**, Shoaib Kamil, Jen Hsu, Rajesh Nishtala, James W. Demmel, and Katherine A. Yelick. “**Automatic performance tuning and analysis of sparse triangular solve.**” In *ICS Workshop on Performance Optimization via High-Level Languages and Libraries (POHLL)*, New York, USA, June 2002.
- [18] **Richard Vuduc** and James Demmel. “**Code generators for automatic tuning of numerical kernels: Experiences with FFTW.**” In *Proc. Workshop on Semantics, Application, and Implementation of Code Generators (SAIG)*, volume 1924 of LNCS, Montreal, Canada, September 2000. Springer-Verlag.

— *Programming models and compilers* —

- [19] **Best paper (software track)** Aparna Chandramowlishwaran, Kathleen Knobe, and **Richard Vuduc**. “Performance evaluation of Concurrent Collections on high-performance multicore computing systems.” In *Proc. IEEE Int’l. Parallel and Distributed Processing Symp. (IPDPS)*, Atlanta, GA, USA, April 2010. (to appear)
- [20] Aparna Chandramowlishwaran, Kathleen Knobe, and **Richard Vuduc**. “**Applying the Concurrent Collections programming model to asynchronous parallel dense linear algebra.**” In *Proc. ACM SIGPLAN Symp. Principles and Practice of Parallel Programming (PPoPP)*, Bangalore, India, January 2010. Poster.
- [21] Chunhua Liao, Daniel J. Quinlan, **Richard Vuduc**, and Thomas Panas. “Effective source-to-source outlining to support whole program empirical optimization.” In *Proc. Int’l. Wkshp. Languages and Compilers for Parallel Computing (LCPC)*, Newark, DE, USA, October 2009.
- [22] Qing Yi, Keith Seymour, Haihang You, **Richard Vuduc**, and Dan Quinlan. “**POET: Parameterized Optimizations for Empirical Tuning.**” In *IPDPS Workshop on Performance Optimization of High-Level Languages and Libraries (POHLL)*, Long Beach, CA, USA, March 2007.
- [23] Dan Quinlan, Markus Schordan, **Richard Vuduc**, and Qing Yi. “Annotating user-defined abstractions for optimization.” In *Proc. IPDPS Workshop on Performance Optimization of High-Level Languages and Libraries (POHLL)*, April 2006.
- [24] Yuan Zhao, Qing Yi, Ken Kennedy, Dan Quinlan, and **Richard Vuduc**. “Parameterizing loop fusion for automated empirical tuning.” Technical Report UCRL-TR-217808, Center for Applied Scientific Computing, Lawrence Livermore National Laboratory, December 2005.

— *Analytical and statistical performance modeling* —

- [25] **Best paper** Benjamin C. Lee, **Richard Vuduc**, James Demmel, and Katherine Yelick. “**Performance models for evaluation and automatic tuning of symmetric sparse matrix-vector multiply.**” In *Proc. Int’l Conf. on Parallel Processing*, Montreal, Canada, August 2004.
- [26] **Richard Vuduc**, James Demmel, and Jeff Bilmes. “**Statistical models for empirical search-based performance tuning.**” *Int’l J. of High Performance Computing Applications*, 18(1):65–94, 2004.
- [27] **Finalist, Best student paper** **Richard Vuduc**, James W. Demmel, Katherine A. Yelick, Shoaib Kamil, Rajesh Nishtala, and Benjamin Lee. “**Performance optimizations and bounds for sparse matrix-vector multiply.**” In *Proc. Supercomputing*, Baltimore, MD, USA, November 2002.

- [28] **Richard Vuduc**, James W. Demmel, and Jeff A. Bilmes. “Statistical models for automatic performance tuning.” In *Proc. Int’l Conf. on Computational Science*, volume 2073 of LNCS, pages 117–126, San Francisco, CA, May 2001. Springer.
- [29] **Best presentation** **Richard Vuduc**, James Demmel, and Jeff Bilmes. “Statistical modeling of feedback data in an automatic tuning system.” In *MICRO-33: Third ACM Workshop on Feedback-Directed Dynamic Optimization*, Monterey, CA, December 2000.

— *Testing and debugging* —

- [30] Sangmin Park, **Richard Vuduc**, and Mary Jean Harrold. “FALCON: Fault localization for concurrent programs.” In *Proc. ACM/IEEE Int’l. Conf. Software Eng. (ICSE)*, Cape Town, South Africa, May 2010. (*accepted*).
- [31] Dan Quinlan, **Richard Vuduc**, and Ghassan Mishergahi. “**Techniques for specifying bug patterns.**” In *Proc. Parallel and Distributed Testing and Debugging (PADTAD)*, London, England, July 2007.
- [32] Thomas Panas, Tom Epperly, Dan Quinlan, Andreas Sæbjørnsen, and **Richard Vuduc**. “Communicating software architecture using a unified single-view visualization.” In *Proc. 12th Int’l Conf. on Engineering of Complex Computer Systems (ICECCS)*, Auckland, New Zealand, July 2007.
- [33] Thomas Panas, Dan Quinlan, and **Richard Vuduc**. “Analyzing and visualizing whole program architectures.” In *Proc. Int’l Conf. on Software Engineering, 3rd Workshop on Aerospace Software Engineering (AeroSE)*, Minneapolis, MN, USA, May 2007.
- [34] Thomas Panas, Dan Quinlan, and **Richard Vuduc**. “**Tool support for inspecting the code quality of HPC applications.**” In *Proc. Int’l Conf. on Software Engineering, 3rd Workshop on Software Engineering for High-Performance Computing Applications (SE-HPC)*, Minneapolis, MN, USA, May 2007.
- [35] **Best paper** **Richard Vuduc**, Martin Schulz, Dan Quinlan, and Bronis de Supinski. “**Improving distributed memory applications testing by message perturbation.**” In *Proc. Int’l Symp. on Software Testing and Analysis (ISSTA), 4th Workshop on Parallel and Distributed Systems: Testing and Debugging (PADTAD-IV)*, Portland, ME, USA, July 2006.
- [36] Dan Quinlan, **Richard Vuduc**, Thomas Panas, Jochen Härdtlein, and Andreas Sæbjørnsen. “**Support for whole-program analysis and verification of the One-Definition Rule in C++.**” In *Proc. Static Analysis Summit*, Gaithersburg, MD, USA, June 2006. National Institute of Standards and Technology Special Publication.
- [37] Dan Quinlan, Shmuel Ur, and **Richard Vuduc**. “**An extensible open-source compiler infrastructure for testing.**” In *Proc. IBM Haifa Verification Conf.*, volume LNCS 3875, pages 116–133, Haifa, Israel, November 2005.

— *Additional papers* —

- [39] Nitin Arora, Ryan Russell, and **Richard Vuduc**. “Fast sensitivity computations for numerical optimizations.” In *Proc. AAS/AIAA Astrodynamics Specialist Conference*, Pittsburgh, PA, USA, August 2009. (*unrefereed*).
- [40] Rajesh Nishtala, **Richard Vuduc**, James W. Demmel, and Katherine A. Yelick. “**Performance modeling and analysis of cache blocking in sparse matrix-vector multiply.**” Technical Report UCB/CSD-04-1335, U.C. Berkeley, June 2004. (*unrefereed*).
- [41] Benjamin C. Lee, **Richard Vuduc**, James W. Demmel, Katherine A. Yelick, Michael de Lorimier, and Lijue Zhong. “**Performance optimizations and bounds for sparse symmetric matrix-multiple vector multiply.**” Technical Report UCB/CSD-03-1297, U.C. Berkeley, November 2003. (*unrefereed*).
- [42] **Richard Vuduc**, Attila Gyulassy, James W. Demmel, and Katherine A. Yelick. “**Memory hierarchy optimizations and performance bounds for sparse  $A^T Ax$ .**” Technical Report UCB/CSD-03-1232, U.C. Berkeley, February 2003. (*unrefereed*).

- [43] Danyel Fisher, Kris Hildrum, Jason Hong, Mark Newman, Megan Thomas, and **Richard Vuduc**. “**SWAMI: A framework for collaborative filtering algorithm development and evaluation.**” In *Proc. SIGIR*, Athens, Greece, July 2000.
- [44] E. Jason Riedy and **Richard Vuduc**. “**Microbenchmarking the Tera MTA.**” Technical report, University of California, Berkeley, May 1999. (*unpublished manuscript*).
- [45] Bohdan Balko, Irvin Kay, **Richard Vuduc**, and John Neuberger. “**Recovery of superfluorescence in inhomogeneously broadened systems through rapid relaxation.**” *Physical Review B*, 55(12079), 1997.
- [46] Bohdan Balko, Irvin Kay, J.D. Silk, and **Richard Vuduc**. “Superfluorescence (sf) in the presence of inhomogeneous broadening and relaxation.” *Hyperfine Interactions: Special Issue on the Gamma-Ray Laser*, June 1997.
- [47] Bohdan Balko, Irvin Kay, **Richard Vuduc**, and John Neuberger. “An investigation of the possible enhancement of nuclear superfluorescence.” In *Proc. Lasers '95*, page 308, 1996.

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## Invited Talks, Lectures, and Tutorials

- 2009 NIPS **Workshop on Large-scale Machine Learning: Parallelism and Massive Datasets**, Vancouver, Canada
- 2009 Los Alamos Computer Science Symposium (LACSS), **Workshop on Performance Analysis of Extreme-Scale Systems and Applications**, Santa Fe, NM, USA
- 2009 SIAM Conf. on Computational Science and Engineering, Miami, FL, USA
- 2008 DARPA Exascale Study at Georgia Tech
- 2008 Lua Workshop, George Washington University, Washington, DC
- 2008 Intel Corporation
- 2008 Courant Institute, New York University
- 2008 Workshop on Parallel Matrix Algorithms and Applications (PMAA), Neuchâtel, Switzerland
- 2008 Oak Ridge National Laboratory, Tennessee
- 2008 SIAM Conf. on Parallel Processing, Atlanta, Georgia
- 2006 Keynote, International Workshop on Automatic Performance Tuning (iWAPT), Tōkyō, Japan
- 2006 Kyōto University, Kyōto, Japan
- 2006 High-Performance Computing Seminar, Pomona College
- 2006 Bay Area Scientific Computing Day, Livermore, California
- 2005 University of Rome, “Tor Vegata,” Italy
- 2005 Tutorial on “The ROSE C/C++ source-to-source translator” at the Conference on Parallel Architectures and Compilation Techniques (PACT)

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## Professional Activities

### — Societies —

- Member Society for Industrial and Applied Mathematics (SIAM)
- Member Association for Computing Machinery (ACM)
- Member Institute of Electrical and Electronics Engineers (IEEE)

### — Positions —

- 2010–2012 Secretary (**elected**), SIAM Activity Group on Supercomputing (SIAM/SC)

— *Refereeing* —

- 2000 Reviewer, ACM Conf. Principles of Programming Languages (POPL)
- 2001 Reviewer, Int'l. Conf. on Computational Science (ICCS)
- 2001 Reviewer, J. of Functional Programming (JFP)
- 2002 Reviewer, Int'l. J. of High Performance Computing Applications (IJHPCA)
- 2003 Reviewer, Programming Language Design and Implementation (PLDI)
- 2003 Reviewer, ACM Symp. on Parallel Algorithms and Architectures (SPAA)
- 2004 Reviewer, SPAA
- 2004 Reviewer, Proc. IEEE
- 2004 Reviewer, Parallel Processing Letters
- 2005 Reviewer, Combinatorial Scientific Computing
- 2005 Poster Committee, ACM/IEEE Conf. Supercomputing (SC)
- 2006 Program Committee, Performance Optimization of High-Level Languages and Libraries (POHLL)
- 2006 Reviewer, Euro-Par (2006)
- 2006 Co-organizer, Mini-symposium on Adaptive Tools and Frameworks for High Performance Numerical Computations, SIAM Parallel Processing
- 2006 Reviewer, Network and Parallel Computing (NPC)
- 2007 Program Committee, Workshop on Statistical and Machine learning applied to Architecture and Compilation (SMART)
- 2007 Program Committee, POHLL
- 2007 Program Committee, Int'l. Workshop on Automatic Performance Tuning (iWAPT)
- 2007 Reviewer, International Conference on Supercomputing (ICS)
- 2007 Reviewer, SC
- 2007 Reviewer, Int'l Conference on High-Performance Computing and Communications (HPCC)
- 2007 Reviewer, Concurrency and Computation: Practice and Experience (CC:PE)
- 2008 Program Committee, SMART
- 2008 Reviewer, Computing Frontiers (CF)
- 2008 Reviewer, Software: Practice and Experience
- 2008 Program Committee, IEEE Int'l. Conf. on Computational Science and Engineering (CSE)
- 2008 Program Committee, IEEE Int'l. Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC)
- 2008 Reviewer, J. Parallel and Distributed Computing (JPDC)
- 2008 Reviewer, ACM Trans. Mathematical Software (ACM-TOMS)
- 2008 Program Committee, Int'l. Conf. High-Performance Computing (HiPC)
- 2008 Reviewer, Int'l. Symp. Computer Architecture (ISCA)
- 2008 Co-organizer, Workshop on Autotuning for Petascale Systems, for US Dept. of Energy (DOE) Center for Scalable Application Development Software (CScADS)
- 2008 Program Committee, iWAPT
- 2008 Reviewer, CRC Press

- 2008 NSF Panelist
- 2008 Reviewer, SIAM J. Scientific Computing (SISC)
- 2008 Reviewer, J. Parallel Computing (ParCo)
- 2009 Program Committee, iWAPT
- 2009 Program Committee, SC
- 2009 Co-organizer, Workshop on Libraries and Autotuning for Petascale Systems, for US DOE CScADS
- 2009 Reviewer, Winter Simulation Conference (WSC)
- 2009 Reviewer, IJHPCA
- 2009 Reviewer, ACM Transactions on Architecture and Code Optimization (ACM TACO)
- 2010 Program Committee, ACM SIGPLAN Symp. Principles and Practice of Parallel Programming (PPoPP)
- 2010 Program Committee, USENIX Workshop on Hot Topics in Parallelism (HotPar)
- 2010 Steering Committee, SMART
- 2010 Program Committee, ACM Int'l. Conf. Computing Frontiers (CF)
- 2010 Program Committee, Int'l. Mtg. on High-Performance Computing for Computational Science (VECPAR)

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## References

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