Seth Lloyd
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Seth Lloyd is Professor of Mechanical Engineering at the Massachusetts Insitute of Technology. He is the director of the WM Keck Center for Extreme Quantum Information Theory at MIT, the director of the Program in Quantum Information at the Institute for Scientific Interchange, and Miller Fellow at the Santa Fe Institute. Lloyd earned his A.B. degree in Physics from Harvard University, his Masters of Advanced Study in Mathematics and M.Phil. in History and Philosophy of Science from Cambridge University, and his Ph.D. in Physics from Rockefeller University. After postdoctoral fellowships at Caltech and at Los Alamos, he joined the MIT faculty in 1994. Professor Lloyd teaches and performs research in quantum information theory and complex systems.

Professor Lloyd's research focuses on the role of information in physical and mechanical systems, with an emphasis on quantum mechanical systems. He was the first to propose a technologically feasible design for a quantum computer, and has worked with groups at MIT and other institutions around the world to construct and operate quantum computers using quantum optics, nuclear magnetic resonance, quantum dots, and superconducting systems. Quantum computers are devices that store and process information at the level of individual atoms and elementary particles. At the quantum level, the wave nature of quantum mechanics allows information to be processed in ways that are not accessible to conventional computers that operate using classical logic. Professor Lloyd's collaborations resulted in the first experimental demonstrations of quantum algorithms (using NMR), the first demonstration of a quantum optical logic gate, and the first demonstration of superconducting quantum bits, and the first demonstration of coherent quantum feedback control.

As the fundamental theory of the way physical systems behave in extreme conditions, quantum mechanics sets the bound for the accuracy of sensing devices. Professor Lloyd's group has derived the fundamental limits to the accuracy of quantum sensors, detectors, and imagers, and has colloborated with experimentalists to attain some of these limits. Professor Lloyd is a co-discoverer of the theorem on the limits of channels to perform quantum communication. His group has derived a variety of bounds on the capacity of quantum channels, including the bound on the capacity of the ubiquitous lossy bosonic channel that underlies fiber optic and free space communications. He has proposed a variety of quantum techniques for enhancing sensing and imaging, notaby the use of entanglement to enhance sensing in highly lossy conditions, the process termed quantum illumination.

Professor Lloyd's research includes work on the characterization of complex systems, including problems of design and control of such systems. Recently, he has worked on the role of quantum coherence in living systems, participating in the demonstration that quantum coherence plays a crucial role in guaranteeing the efficiency of energy transport in photosynthesis.

Professor Lloyd is the author of over 150 papers in refereed journals, and of a book, 'Programming the Universe,' as well as of numberous contributions to refereed proceedings, articles in Science, Nature, and

Scientific American. He has mentored numerous graduate students and postdocs, many of whom currently hold faculty position in academia, including MIT, USC, University of Washington, Bristol University, Imperial College, Leeds University, University of Pavia, Dartmouth, Scuola Normale Superiore Pisa, National University of Singapore.

Professor Lloyd has received awards for research and teaching, including the Lindbergh and Edgerton prizes. He is a fellow of the American Physical Society and Miller Fellow at the Santa Fe Institute.

Seth Lloyd
Professor of Mechanical Engineering
Director, WM Keck Center in Extreme Quantum Information Theory
Massachusetts Institute of Technology

Education:

School	*Degree*	*Date*
Harvard University	AB	1982
Cambridge University	M.Adv.Stud.Math.	1983
Cambridge University	M.Phil.	1984

MIT Appointments:

Rank	*Beginning*	*Ending*
Assistant Professor	December 1994	June 1998
Finmeccanica Career Development Professorship	September 1996	present
Associate Professor (without tenure)	July 1998	June 2001
Associate Professor (with tenure)	June 2001	June 2002
Professor	June 2002	Present

Professional Service:

Activity	*Beginning*	*Ending*
Reviewer, Physical Review	September 1988	present
Reviewer, Physical Review Letters	September 1988	present
Co-chair, Information and Complexity Program, The Santa Fe Institute	September 1992	present
Reviewer, Nature	April 1994	present
Co-organizer, CEPI, Santa Fe Institute	May 1994	
Reviewer, Science	May 1994	present
Organizer, AAAS Symposium on Quantum Computing	February 1996	
Organizer, Experimental Realizations of Quantum Logic, Harvard	August 1996	
Scientific Committee, International Conference on Unconventional Methods for Computing, Auckland	June 1997	January 1998
Program Chair, Thermodynamics and Complexity, Gordon Conference, Castelvecchio	September 1998	April 1999
International Scientific Committee, WSES International Conference, Mathematics and Computers in Mechanical Engineering	September 1998	July 1999
Co-organizer, Nuclear Magnetic Resonance Quantum Computing, ARO Workshop, MIT/Harvard	February 1999	
Organizer, Complexity in Engineering MIT/Santa Fe Institute, Cambridge	November 1999	
Scientific Committee, International Conference on Unconventional Methods for Computing, Auckland	September 1999	December 2000
Co-Organizer, Mechanical Engineering in the Information Age, MIT	April 2000	

Scientific Committee, Quantum Information and Measurement	July 2000
Organizer, Innovations in Nanotechnology, MIT	September 2000
Organizer, Quantum Computing, Snowbird	January 2001
Co-Organizer, Quantum Information, Torino	June 2001
Organizer, Quantum Control, SIAM 2001	August 2001
Organizer, Biannual Cambridge/MIT QCI Meetings	2001-2006
Organizer, Quantum Computation, NEC/MIT	August 2005
Co-Organizer, Noise and Instability, ICTP	October 2005
Co-Organizer, Keenan Symposium, MIT	October 2007
Co-Organizer, Quantum Computation, NEC/MIT	November 2007
Co-Organizer, Difficult Problems in Quantum Information	November 2008
Co-Organizer, Quantum Computation, NEC/MIT	January 2009
Co-Organizer, QuEBS, Lisbon	August 2009
Co-Organizer, QuEBS, Harvard	August 2010
Organizer, Quantum Biology, Novara	July 2010
Organizer, Quantum Life, Santa Fe	February 2011

Awards Received:

Award	*Date*
Sargent Prize (Harvard)	1981
Marshall Scholarship	1982
Dirac Prize (Erice)	1985
Lindbergh Fellowship	1994
Finmeccanica Career Development Professorship	1996
Edgerton Prize	2001
Fellow of American Physical Society	2007

Publications of Seth Lloyd

Professor Lloyd is sole or co-author on more than 150 peer-reviewed journal publications. He has written a book, *Programming the Universe*, as well as numerous popular articles.

1. Books:
   1. *Programming the Universe*, Random House, March 2006.

2. Papers in Refereed Journals:

   1. Lloyd, S., "Difficulty in Detecting Deviations From Wave-Function Collapse," *Physical Review A* **38**, 3161-3165, 1988.
   2. Lloyd, S. and H. Pagels, "Complexity as Thermodynamic Depth," *Annals of Physics* **188**, 186-213, 1988.
   3. Lloyd, S., "Use of Mutual Information to Decrease Entropy: Implications for the Second Law of Thermodynamics," *Physical Review A* **39**, 5378-5386, 1989.
   4. Lloyd, S., "The Calculus of Intricacy," *The Sciences* **30**, 38-44, 1990.
   5. Lloyd, S., and W.H. Zurek, "Algorithmic Treatment of the Spin-Echo Effect," *Journal of Statistical Physics* **62**, 819-140, 1991.
   6. Lloyd, S., "Any Nonlinear Gate, with Linear Gates, Suffices for Computation," *Physics Letters A* **167**, 255-260, 1992.
   7. Lloyd, S., "Quantum Computers and Uncomputability," *Physical Review Letters* **71**, 943-946, 1993.
   8. Lloyd, S., "A Potentially Realizable Quantum Computer," *Science* **261**, 1569-1571, 1993.
   9. Lloyd, S., "Review of Quantum Computation," *Vistas in Astronomy* **37**, 291-295, 1993.
   10. Lloyd, S., "Necessary and Sufficient Conditions for Quantum Computation," *Journal of Modern Optics* **41**, 2503-2520, 1994.
   11. Lloyd, S., "Envisioning a Quantum Supercomputer," *Science* **263**, 695, 1994.
   12. Lloyd, S., "Almost Any Quantum Logic Gate is Universal," *Physical Review Letters* **75**, 346-349, 1995.
   13. Lloyd, S., "Quantum Mechanical Computers," *Scientific American* **273**, 140-145, October, 1995.
   14. Lloyd, S., and M. Gell-Mann, "Information Measures, Effective Complexity, and Total Information," *Complexity* **2/1**, 44-52, 1996.
   15. Lloyd, S., "Universal Quantum Simulators," *Science* **273**, 1073-1078, 1996.
   16. Lloyd, S., and J.J.E. Slotine, "Information Theoretic Tools for Stable Adapatation and Learning," *International Journal of Adaptive Control and Signal Processing* **10**, 499-530, 1996.
   17. Lloyd, S., "Capacity of the Noisy Quantum Channel," *Physical Review A* **55**, R1613-1622, 1997.
   18. Lloyd, S., "Universe as Quantum Computer," *Complexity*, **3/1**, 32-35, 1997.
   19. Abrams, D. and S. Lloyd, "Simulation of Many-Body Fermi Systems on a Universal Quantum Computer," *Physical Review Letters* **79**, 2586-2589, 1997.**
   20. Lloyd, S., "Quantum-Mechanical Maxwell's Demon," *Physical Review A* **56**, 3374-3382, 1997.
   21. Lloyd, S., "Microscopic Analogs of the Greenberger-Horne-Zeilinger Experiment," *Physical Review A* **57** R1473-1476, 1998.
   22. Lloyd, S., and J.J.-E. Slotine, "Analog Quantum Error Correction," *Physical Review Letters*, **80**, 4088-4091, 1998.
   23. Chuang, I.L., and L.M.K. Vandersypen, X. Zhou, D.W. Leung, S. Lloyd, "Experimental Realization of a Quantum Algorithm," *Nature* **393**, 143-146, 1998.
   24. Viola, L., and S. Lloyd "Dynamical Suppression of Decoherence in Two-State Quantum Systems," *Physical Review A* **58**, 2733-2744, 1998.**

** Outgrowth of supervised student research

25. Lloyd, S., and N. Forbes, "Quantum Computing: Stepping Closer to Reality," *Computers in Physics* **12**, No. 1, 8-11, 1998.
26. Abrams, D., and S. Lloyd "Nonlinear Quantum Mechanics Implies the Polynomial-Time Solution of NP-Complete and # P Problems," *Physical Review Letters*, **81**, 3992-3995, 1998.**
27. Brassard, G., and I.L. Chuang, S. Lloyd, C. Monroe, "Quantum Computing," *Proceedings of the National Academy of Sciences USA* **95**: (19) 11032-11033, 1998.
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31. Mooij, J.E., and T.P. Orlando, L. Levitov, Lin Tian, Caspar H. van der Wal, S. Lloyd "Josephson Persistent-Current Qubit," *Science* **285**, 1036-1039, 1999.**
32. Lloyd, S., "Quantum Search Without Entanglement," *Physical Review A* **6001**, 010301, 1999.
33. Viola, L., and E. Knill, S. Lloyd, "Universal Control of Decoupled Quantum Systems," *Physical Review Letters* **83** 4888-4891, 1999.**
34. Mooij, J.E., and T.P. Orlando, L. Tian, C.H. van der Wal, L. Levitov, S. Lloyd, J. Mazo, "Josephson Persistent-Current Qubit," *Physical Review B* **60**, 15398-15413, 1999.**
35. Abrams, D., and S. Lloyd "Computational Complexity and Physical Law," *Lecture Notes on Computer Science* **1509**, 167-173, 1999.**
36. Nelson, R.J., and D.G. Cory, S. Lloyd, "Experimental Demonstration of Greenberger-Horne-Zeilinger Correlations Using Nuclear Magnetic Resonance," *Physical Review A* **61**, 022106-1-5, 2000.**
37. Abrams, D., and S. Lloyd "A quantum algorithm providing exponential speed increase for finding eigenvalues and eigenvectors," *Physical Review Letters* **83**, 5162-5165, 2000.**
38. Touchette, H., and S. Lloyd, "Information-Theoretic Limits of Control," *Physical Review Letters* **84**, 1156-1159, 2000.**
39. Lloyd, S., and J.-J.E. Slotine, "Quantum Feedback with Weak Measurement," *Physical Review A* **6201**, 2307, 2000.
40. Viola, L., and E.M. Fortunato, S. Lloyd, C.H. Tseng, D.G. Cory, "Stochastic Resonance and Nonlinear Response by NMR Spectroscopy," *Physical Review Letters* **84**, 5466-5469, 2000.**
41. Lloyd, S., "Coherent Quantum Feedback" *Physical Review A* **6202**, 2108, 2000.
42. Lloyd, S., "Ultimate Physical Limits to Computation," *Nature* **406**, 1047-1054, 2000.
43. Tian, L., and S. Lloyd, "Resonant Cancellation of Off-Resonant Effects in a Multilevel Qubit," *Physical Review A* **6205**, 0301, 2000.**
44. Nelson, R.J., and Y. Weinstein, D. Cory, S. Lloyd, "Demonstration of Coherent Quantum Feedback," *Physical Review Letters* **85**, 3045-3048, 2000 .**
45. Viola, L., and E. Knill, S. Lloyd, "Dynamical Generation of Noiseless Quantum Subsystems," *Physical Review Letters* **85**, 3520-3523, 2000.**
46. van der Wal, C.H., and A.C.J. ter Haar, F.K. Wilhelm, R.N. Schouten, C.J.P.M. Harmans, T.P. Orlando, S. Lloyd, J.E. Mooij, "Quantum Superposition of Macroscopic Persistent-Current States," *Science* **290**, 773-777, 2000 .
47. Cory D.G., and R. Laflamme, E. Knill, L. Viola, T.F. Havel, N. Boulant, G. Boutis, E. Fortunato, S. Lloyd, R. Martinez, C. Negrevergne, M. Pravia, Y. Sharf, G. Teklemariam, Y.S. Weinstein, W.H. Zurek, "NMR based quantum information processing: Achievements and prospects" *Fortschritte der Physik* **48**, 875-907, 2000.

** Outgrowth of supervised student research

48. Weinstein, Y., and S. Lloyd, M.A. Pravia, E.M. Fortunato, D.G. Cory, "Implementation of the Quantum Fourier Transform," *Physical Review Letters* **86**, 1889-1891, 2001.**
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72. Segall, K., Crankshaw, D., Nakada, D., Lloyd, S., et al., 'Impact of time-ordered measurements of the two states in a niobium superconducting qubit structure,' *Phys. Rev. B***67**, Art. No. 220506 (2003).**
73. Giovannetti, V., and S. Lloyd, L. Maccone, 'The role of entanglement in dynamical evolution,' *Europhys. Lett.* **62** 615, 2003.
74. Zanardi, P., and S. Lloyd, 'Topological Protection and Quantum Noiseless Subsystems,' *Phys. Rev. Lett.* **90** 067902, 2003.
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87. Emerson J., S. Lloyd, D. Poulin, et al. 'Estimation of the local density of states on a quantum computer,' *Phys. Rev. A* **69** (5): Art. No. 050305, 2004.**
88. Giovannetti V., S. Lloyd. 'Additivity properties of a Gaussian channel,' *Phys. Rev. A* **69** (6): Art. No. 062307, 2004.
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90. Giovannetti V., S. Lloyd, L. Maccone, 'Capacity of nonlinear bosonic systems,' *Phys. Rev. A* **70**(1): Art. No. 012307, 2004.
91. Giovannetti V., S. Lloyd, L. Maccone, *et al.*, 'Minimum Renyi and Wehrl entropies at the output of bosonic channels,' *Phys. Rev. A* **70**(2): Art. No. 022328, 2004.
92. Lloyd S., V. Giovannetti, L. Maccone, 'Physical limits to communication,' *Phys. Rev. Lett.* **93**(10): Art. No. 100501, 2004.
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95. Giovannetti, V., S. Lloyd, 'Additivity properties of a Gaussian Channel,' *Phys. Rev. A* **69**, 062307 (2004); quant-ph/0403075.
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98. D. Aharonov, W. van Dam, J. Kempe, Z. Landau, S. Lloyd, O. Regev, 'Adiabatic Quantum Computation is Equivalent to Standard Quantum Computation,' Proceedings of the 45th Annual IEEE Symposium on Foundations of Computer Science (FOCS'04), 42-51 (2004); quant-ph/0405098.
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100. Lloyd, S., J.H. Shapiro, N.C. Wong, *et al.*, 'Infrastructure for the quantum Internet,' *Comp. Com. Rev.***34**, 9-20 (2004). **
101. Giovannetti, V., S. Guha, S. Lloyd, *et al.* 'Classical capacity of free-space optical communication,' *Quant. Inf. Comp.* **4**, 489-499 (2004). **
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