Timothy Y. Chow

Citizenship: USA `http://alum.mit.edu/www/tchow`

WORK EXPERIENCE

2005–present: Member of research staff at the Center for Communications Research, Princeton, New Jersey. Applied mathematical and computational research in cryptology and related disciplines. IDA Excellence Award, 2007.

2002–2005: Member of technical staff at MIT Lincoln Laboratory, Lexington, Massachusetts. High-level systems analysis of multiple-target radar tracking systems for military (DARPA, Navy) sponsors and biosensor networks for homeland security (HSARPA) sponsors.

1998–2002: Research engineer at the Tellabs Research Center (NASDAQ: TLAB). Research and development of mathematical programming and local search algorithms for large-scale combinatorial optimization of SONET, WDM, and MPLS networks, with emphasis on routing and wavelength assignment, traffic grooming, and network resiliency. Tellabs Best Practice Award, 1999; Key Contributor Award, 2000.

1995–1998: Assistant professor at the University of Michigan, Ann Arbor; also Mathematical Sciences Research Institute general member (1996–97) and National Science Foundation postdoctoral fellow. Taught Harvard reform calculus, a cooperative learning and discovery course in combinatorics to honors freshmen, a section of calculus using *Maple*, and a two-week intensive summer math camp (entitled "Infinity," designed from scratch, and using *Mathematica*) for gifted high school students.

Fall 1994: Instructor for MIT Experimental Study Group differential equations class of five students.

Summer 1994, 1995: Visiting advisor at Dr. J. Gallian's program (see Summer 1990 below).

1993–94: Graduate teaching assistant for differential equations course that used locally written computer software as a teaching aid. Duties included running recitations and exam review sessions, grading of tests and weekly problem sets, and office hours.

Summer 1990: Undergraduate mathematics research at the University of Minnesota, Duluth, with Dr. J. Gallian. Publications 4 and 5 below resulted from this work.

Summer 1988, 1989: Research and development of new computer image synthesis algorithms in C (for use in General Motors CAD software) at Carnegie Mellon University, with Dr. R. Thibadeau. Publications 1 and 2 below resulted from this work.

1988–91: Part-time computer consultant for UNIX, IBM 3081, IBM PC and Macintosh systems, Computing and Information Technology, Princeton University.

EDUCATION

Massachusetts Institute of Technology, Ph.D. in pure mathematics, 1995.

Thesis: "Symmetric function generalizations of graph polynomials" (under Prof. R. Stanley). The thesis includes the material in items 7 and 8 in the publications section below.

Awards:
- Housman teaching award
- National Science Foundation Graduate Fellowship

Princeton University, A.B. in mathematics, 1991.

Thesis: "Polyhedral combinatorics and the stable set problem" (under Prof. L. Lovász). The *stable set polytope* of a graph is the convex hull of all the incidence vectors of independent sets in the graph. Some results about the stable set polytopes of complete graphs are derived.

Awards:
- Valedictorian, Princeton University, Class of 1991

- Highest honors, Princeton University department of mathematics
- Princeton University Class of 1939 Prize for the senior with the highest academic standing
- William Lowell Putnam Mathematics Competition, 1987: Honorable Mention
- Pyka Prize for outstanding performance in freshman physics
- Barry Goldwater Scholarship, 1989

INVITED TALKS

1. "The path-cycle symmetric function of a digraph," combinatorics seminar, Northeastern University, Boston, 10/94.
2. "Symmetric function generalizations of graph polynomials," combinatorics seminar, University of Minnesota, Minneapolis, 7/95.
3. "Spectral methods for spanning tree enumeration," Enumeration and Posets Workshop, Mathematical Sciences Research Institute, Berkeley, 10/96.
4. "A homemaker outsmarts expert mathematicians," public lecture, Malaspina University-College, Nanaimo, 3/97.
5. "What does a mathematician know about optimizing optical networks?" computer science seminar, University of Victoria, Victoria, 3/97.
6. "k-Sperner sets: a snapshot of modern combinatorics," American Mathematical Society Special Session on Algebraic Combinatorics, Wayne State University, Detroit, 5/97.
7. "How much about sieves and zeta functions can we steal from the number theorists?" combinatorics seminar, Massachusetts Institute of Technology, Cambridge, 11/98.
8. "Symplectic matroids the easy way," combinatorics seminar, Georgia Institute of Technology, 3/99.
9. "Symplectic matroids the easy way," American Mathematical Society Special Session on Algebraic and Geometric Combinatorics, University of Florida, Gainesville, 3/99.
10. "Towards a Robinson-Schensted algorithm for $(3+1)$-free posets," Thirty-fourth Combinatorists of New England Conference on Combinatorics and Graph Theory, Smith College, Northampton, 4/99.
11. "Symplectic matroids the easy way," American Mathematical Society Special Session on Combinatorics and Graph Theory, SUNY Buffalo, Buffalo, 4/99.
12. "The ring grooming problem," combinatorics seminar, University of Michigan at Ann Arbor, 9/01.
13. "How to leave academics and stay in mathematics," Math at Work seminar, Brandeis University, 11/01.
14. "The ring grooming problem," combinatorics seminar, Georgia Institute of Technology, 11/01.
15. "The ring grooming problem," combinatorics and number theory seminar, SUNY Binghamton, 12/01.
16. "Generalizing Rota's basis conjecture to Young diagrams," American Mathematical Society Special Session on Algebraic Combinatorics, Georgia Institute of Technology, 3/02.
17. "Wide partitions, Latin tableaux, and Rota's basis conjecture," AMS/IMA/SIAM Joint Summer Research Conference on Graph Coloring and Symmetry, Mt. Holyoke College, 7/02.
18. "Rota's basis conjecture and wide partitions," Wesleyan University Combinatorics Colloquium, 4/03.
19. "Perfect matching conjectures and their relationship to $P \neq NP$," Retrospective in Combinatorics Honoring Stanley's 60th Birthday, 6/04.
20. "Chess tableaux," combinatorics seminar, Georgia Institute of Technology, 9/05.
21. "Chess tableaux and chess problems," experimental mathematics seminar, Rutgers University, 11/06.

22. "Counting lattice paths that avoid a boundary," Bi-College Mathematics Colloquium, Haverford College, 4/07.

23. "Rota's basis conjecture and the wide partition conjecture," Communicating Mathematics: A Conference in Honor of Joseph Gallian's 65th Birthday, University of Minnesota, Duluth, 7/07.

24. "Almost-natural proofs," Theory of Computation Seminar, Massachusetts Institute of Technology, 9/08.

25. "Almost-natural proofs," DIMACS CS-Theory Seminar, Rutgers University, 10/08.

26. "Almost-natural proofs," Computer Science/Discrete Math Seminar, Institute for Advanced Study, 11/08.

27. "Exact enumeration of lattice paths avoiding a staircase boundary," Combinatorics Seminar, Indiana University, Bloomington, 3/09.

28. "Simple enumerative formulas for lattice paths avoiding periodic staircase boundaries," AMS Special Session on Enumerative Combinatorics, Florida Atlantic University, Boca Raton, 10/09.

29. "Recent progress on Rota's basis conjecture," Combinatorics Seminar, Indiana University, Bloomington, 3/12.

30. "Some open problems on lattice path enumeration and graph coloring," Stanley@70, A Conference in Honor of Richard P. Stanley's 70th Birthday, Massachusetts Institute of Technology, Cambridge, 6/14.

JOURNAL ARTICLES

1. T. Chow, "A new characterization of the Fibonacci-free partition," *Fibonacci Quart.* **29** (1991), 174–180. The Fibonacci-free partition is the unique partition of the integers into two sets such that no two distinct integers from the same set sum to a Fibonacci number. Two surprising characterizations are given.

2. T. Chow, "Distances forbidden by two-colorings of $\mathbb{Q}^3$ and A_n," *Discrete Math.* **115** (1993), 95–102. For $X = \mathbb{Q}^3$ or A_n (where A_n is the set of points in $\mathbb{Q}^n$ whose coordinates have odd denominators), we characterize all sets of distances $D \subset \mathbb{R}^+$ with the following property: there exists some two-coloring of X such that, for all $d \in D$, no two points in X that are a distance d apart are the same color. We also find all numbers $d_0 \in \mathbb{R}^+$ such that all sets of distances $D \subset \mathbb{R}^+$ with this property retain the property under multiplication or division by d_0.

3. T. Chow, "Penny-packings with minimal second moments," *Combinatorica* **15** (1995), 151–158. We prove that Graham and Sloane's greedy algorithm for constructing hexagonal packings of unit disks in the plane with low moments of inertia produces approximately circular packings. The greedy algorithm does not always produce optimal hexagonal packings; we give an efficient algorithm that does.

4. T. Chow, "On the Dinitz conjecture and related conjectures," *Discrete Math.* **145** (1995), 73–82. Special cases of the Dinitz conjecture and the closely related basis and Latin square conjectures are proved. Using the Nullstellensatz we give a reformulation of the basis conjecture.

5. T. Chow, "A short proof of the rook reciprocity theorem," *Electronic J. Combin.* **3** (1996), R10. A combinatorial proof of the relationship between rook numbers of complementary boards is given.

6. T. Chow, "The path-cycle symmetric function of a digraph," *Advances in Math.* **118** (1996), 71–98. The cover polynomial of Chung and Graham is generalized to a symmetric function. Generalizations and analogues of known results on related polynomials and symmetric functions are proved, as well as a combinatorial reciprocity theorem that answers a question of Chung and Graham and that connects in a surprising way several scattered results in the literature. A new symmetric function basis is proposed as the natural generalization of a certain well-known polynomial basis.

7. T. Chow, "The Q-spectrum and spanning trees of tensor products of bipartite graphs," *Proc. Amer. Math. Soc.* **125** (1997), 3155–3161. Stanley conjectured, and Knuth and Ciucu independently proved, that the complexity (number of spanning trees) of one connected component of the tensor product of two paths

is four times the complexity of the other connected component. This result is generalized to the tensor product of arbitrary weighted bipartite multigraphs, using a little-known variant of the matrix-tree theorem (the standard matrix-tree theorem does not quite work).

8. T. Chow, "The surprise examination or unexpected hanging paradox," *Amer. Math. Monthly* **105** (1998), 41–51. We discuss the mathematical issues and the enormous philosophical literature related to this apparently trifling paradox, presenting some new perspectives and results.

9. T. Chow, "The combinatorics behind number-theoretic sieves," *Advances in Math.* **138** (1998), 293–305. Some of the deeper sieve methods in number theory that have been developed since Brun's pioneering work are shown to carry over readily to many combinatorial settings, and some potential applications are sketched, e.g., the enumeration of Latin squares.

10. T. Chow and C. Long, "Additive partitions and continued fractions," *Ramanujan J.* **3** (1999), 55–72. The result in publication 3 above is vastly generalized to include sequences studied by Alladi, Erdös, Hoggatt, and Evans by exploiting a previously unnoticed connection with continued fractions.

11. T. Chow, "Descents, quasi-symmetric functions, Robinson-Schensted for posets, and the chromatic symmetric function," *J. Algebraic Combin.* **10** (1999), 227–240. Some consequences of Stanley's expansion of the chromatic symmetric function in terms of Gessel's fundamental quasi-symmetric functions are derived. It is suggested that an RSK algorithm for (3+1)-free posets should respect descents.

12. T. Chow and J. West, "Forbidden subsequences and Chebyshev polynomials," *Discrete Math.* **204** (1999), 119–128. The generating function for the number of permutations avoiding a certain pair of patterns is shown to be a quotient of Chebyshev polynomials; this reveals connections with the enumeration of several other combinatorial objects.

13. T. Chow, "What is a closed-form number?" *Amer. Math. Monthly* **106** (1999), 440–448. Much has been written about closed-form expressions for *functions,* but surprisingly little has been written about closed-form expressions for *numbers*. We propose a definition of a closed-form number that we hope will become standard. With our definition, the question of whether the root of $x = \cos(x)$ has a closed form is, perhaps surprisingly, still open. We show that Schanuel's conjecture in transcendental number theory resolves questions like this, and we also sketch some connections with Tarski's problem of the decidability of the first-order theory of the reals with exponentiation.

14. T. Chow, "Symplectic matroids, independent sets, and signed graphs," *Discrete Math.* **263** (2003), 35–45. An elementary independent-set axiomatization of Gelfand-Serganova symplectic matroids is formulated and proved. A new class of examples coming from signed graphs is described, and a conjectured basis exchange axiom for symplectic matroids is stated and partially proved.

15. T. Chow, C. K. Fan, M. X. Goemans, and J. Vondrak, "Wide partitions, Latin tableaux, and Rota's basis conjecture," *Advances in Applied Math.* **31** (2003), 334–358. Rota's basis conjecture states that if $B_1, B_2, \ldots, B_n$ is any sequence of n bases of an n-dimensional vector space V, then there exists an $n \times n$ grid of vectors such that for all i, the set of n vectors in the ith row is B_i, and the set of n vectors in the ith column is a basis of V. Brian Taylor and the first author have suggested that it may help to generalize the conjecture to certain "wide" partitions other than square grids. We present some partial results towards this generalized conjecture.

16. T. Chow, F. Chudak, and A. M. Ffrench, "Fast optical layer mesh protection using pre-cross-connected trails," *IEEE/ACM Trans. Networking,* **12** (2004), 539–548. We argue that ring protection is fast not because of a ring-like topology per se, but because its protection paths are pre-cross-connected. This leads to the concept of a pre-cross-connected trail or PXT, a structure that is more flexible than rings or p-cycles and that adapts readily to both path-based and link-based schemes and to both static and dynamic traffic. We show that a PXT protection scheme achieves both high restoration speed and bandwidth efficiency that is comparable to that of conventional shared mesh protection schemes.

17. T. Chow and P. J. Lin, "The ring grooming problem," *Networks* **44** (2004), 194–202. The ring grooming problem is the problem of routing and grooming traffic demands on a SONET BLSR-over-WDM network so as to minimize ADM count. We derive a new lower bound that is within a constant factor of the

optimum if the traffic is quasi-uniform (in contrast with the integrality gap, which is unbounded). We also show that ring grooming with a fixed ring size is solvable in polynomial time, but it remains open whether it is fixed-parameter tractable.

18. T. Chow, H. Eriksson, and C. K. Fan, "Chess tableaux," *Electronic J. Combin.* (Stanley Festschrift) **11(2)** (2004–2005), #A3. A chess tableaux is a standard Young tableau (SYT) in which orthogonally adjacent entries have opposite parity. We establish an unexpected bijection between certain chess tableaux with three rows and Dulucq-Guibert nonconsecutive tableaux (SYT in which i and $i+1$ never appear in the same row) with three rows. An attractive corollary is that the number of $3 \times n$ chess tableaux equals the number of Baxter permutations of $n-1$.

19. T. Chow, "You could have invented spectral sequences," *Notices Amer. Math. Soc.* **53(1)** (2006), 15–19. An exposition of spectral sequences that hopefully makes readers feel they could have invented spectral sequences themselves.

20. R. J. Chapman, T. Chow, A. Khetan, D. P. Moulton, and R. J. Waters, "Simple formulas for lattice paths avoiding certain periodic staircase boundaries," *J. Combin. Theory Ser. A* **116** (2009), 205–214. There is a classical simple formula for the number of lattice paths in the plane avoiding the line $x = ky$ when k is an integer. If k is not an integer then no simple formula seems to exist. We show that if the straight line boundary is replaced by a periodic staircase with average slope k, then the simple formula generalizes to any rational k, provided the endpoints are chosen carefully.

21. T. Chow, "A beginner's guide to forcing," in *Communicating Mathematics, Contemp. Math.* **479** (2009), 25–40. This is an expository article that attempts to give an overview of Cohen's method of forcing.

22. T. Chow, "Reduction of Rota's basis conjecture to a problem on three bases," *SIAM J. Discrete Math.* **23** (2009), 369–371. It is shown that Rota's basis conjecture (see item 15 above) follows from a similar conjecture that involves just three bases instead of n bases.

23. T. Chow, "Almost-natural proofs," *J. Comput. Sys. Sci.* **77** (2011), 728–737. We show that if the largeness condition in the Razborov-Rudich theorem on natural proofs is weakened to "almost large," then, under the same pseudorandomness hypothesis they make, there is provably a constructive, almost large property separating *NP* from *P/poly*. Thus the naturalization barrier may be less formidable than it is commonly believed to be.

24. T. Chow, "What is. . . a natural proof?" *Notices Amer. Math. Soc.* **58** (2011), 1586–87. Expository article about natural proofs.

25. P. Brosnan and T. Chow, "Unit interval orders and the dot action on the cohomology of regular semisimple Hessenberg varieties," *Advances in Math.* **329** (2018), 955–1001. We prove a conjecture of Shareshian and Wachs that the character of the dot action of the symmetric group on the cohomology of a regular semisimple Hessenberg variety is given by (omega of) the chromatic quasisymmetric function of the corresponding indifference graph. This answers a question of Tymoczko and is a significant partial result towards the (3+1)-free conjecture of Stanley and Stembridge.

CONFERENCE PAPERS AND TECHNICAL REPORTS

1. R. Thibadeau, T. Chow, S. Handerson, D. Tin-Nyo, "CMU Raytracer," Technical report CMU-RI-TR-88-18, The Robotics Institute, Carnegie Mellon University, 1988. Technical details of the implementation of a photorealistic image synthesis program.

2. R. Thibadeau, P. Hsiung, D. Thuel, T. Chow, M. Siegel, "An experiment in perfectly realistic graphics," *1989 Annual Research Review,* The Robotics Institute, Carnegie Mellon University. Summary of several new ideas and algorithms in image synthesis.

3. D. W. Jenkins, T. Chow, P. Lin, J. Mills, J. Beierle, P. Hatton, J. Call, "Network design utilizing optical networking: Evolution to an optimal network," National Fiber Optic Engineers Conference 1999. Tellabs designed a Bell Atlantic network; some results are presented.

4. V. R. Konda and T. Chow, "Algorithm for traffic grooming in optical networks to minimize the number of transceivers," Proc. IEEE 2001 Workshop on High Performance Switching and Routing: 29–31 May 2001, Dallas, Texas, 218–221. A traffic grooming problem on an arbitrary mesh network is reduced to a multicommodity flow problem. A greedy algorithm based on duality is given and some experimental results are presented.
5. T. Chow, "Statistical independence of high range resolution measurements of a moving ground vehicle from diverse aspects," MIT Lincoln Laboratory Project Memorandum 46PM-SSA-0001, February 6, 2003.
6. T. Chow, "Airborne feature-aided tracking of moving ground vehicles across terrain obscurations," MIT Lincoln Laboratory Project Memorandum 46PM-SSA-0002, March 21, 2003.
7. S. D. Campbell, T. Y. Chow, S. E. Holster, M. A. Weiner, and T. J. Dasey, "Urban outdoor biosensor requirements analysis," MIT Lincoln Laboratory Project Report HS-3, May 19, 2006.
8. T. Chow and C. K. Fan, "The power of multifolds: Folding the algebraic closure of the rational numbers," in *Origami*^{4}, Proceedings of the Fourth International Conference on Origami in Science, Mathematics, and Education (4OSME), September 8–10, 2006, ed. Robert J. Lang, A. K. Peters, 2009, pp. 395–404. We define the n-parameter multifold and show how to use one-parameter multifolds to get the algebraic closure of the rational numbers.
9. T. Chow, T. Kelly, and D. Reeves, "Estimating cache hit rates from the miss sequence," Hewlett Packard Technical Report HPL-2007-155, September 17, 2007. Is it possible to estimate the cache hit rate of an LRU (Least Recently Used) stack by observing the sequence of cache misses? We solve some simple cases and sketch some ideas for a general approach.
10. T. Chow, "Almost-natural proofs," Proceedings of the 49th Annual Symposium on Foundations of Computer Science (FOCS 2008), October 25–28, 2008. See journal version above for a summary.

PATENTS

1. V. Sharma, T. Y. Chow, C. E. Rohrs, S. Dunstan, and J. Cerra, Method and Apparatus to Switch Data Flows Using Parallel Switch Fabrics, US Patent 7123581 (October 17, 2006). Continuation, US Patent 7859994 (December 28, 2010).
2. T. Y. Chow, P. J. Lin, and J. D. Mills, Method and System for Designing Ring-based Telecommunications Networks, US Patent 7133410 (November 7, 2006). Continuation, US Patent 7668184 (February 23, 2010).
3. T. Y. Chow, P. J. Lin, and J. D. Mills, Inter-Working Mesh Telecommunications Networks, US Patent 7289428 (October 30, 2007).
4. T. Y. Chow, F. Chudak, and A. M. Ffrench, Method and Apparatus for Allocating Protection Bandwidth in a Telecommunications Mesh Network, US Patent 7308198 (December 11, 2007).
5. P. J. Lin, T. Y. Chow, and J. D. Mills, Method and Apparatus for Allocating Working and Protection Bandwidth in a Telecommunications Mesh Network, patent pending, US Publications 20020194339 and 20030065811.
6. T. Y. Chow, G. S. Elias, C. K. Fan, R. C. Garfield, Codeword Matching Game Using a Mass Media Network, patent pending, US Publication 20060183549.

OTHER INFORMATION

• Fluent in Chinese (Mandarin, Cantonese, Hakka); reading knowledge of French.
• Maple, MATLAB, Mathematica, Magma, AMPL/CPLEX, C.
• Published chess problems: *Problemesis* **33**, F159; *StrateGems* **23**, F0419; "Ein Kleines Schach," *Math. Intelligencer* **28(2)** (2006), pp. 49 and 69.
• Leader of Stone Hill Church's Haiti Team (traveled multiple times to Haiti for earthquake relief)
• Selected for listing in *Marquis Who's Who in America*, 2005–.