

# Resume of Allen Tannenbaum

## Personal Data

Name: Allen Robert Tannenbaum.

Date and Place of Birth: January 25, 1953, New York City, New York.

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## Education

1. Columbia University, B.A. in Mathematics, June 1973.
2. Harvard University, Ph.D. in Mathematics, June 1976.  
Ph.D. advisor: Professor Heisuke Hironaka, Harvard University.  
Thesis title: *Deformations of 1-Cycles and the Chow Scheme*.

## Main Fields of Interest

Medical image analysis, computer vision, systems and control, image processing, controlled active vision, mathematical systems theory, bioinformatics, computer graphics, control of semiconductor fabrication processes, robotics, operator theory, functional analysis, algebraic geometry, differential geometry, invariant theory, and partial differential equations.

## Positions Held

1. Professor, Departments of Computer Science and Applied Mathematics, Stony Brook University, August 2013-present.
2. Adjunct Professor, Departments of Radiology and BMI, Stony Brook University, November 2013-present.
3. Interim Departmental Chairperson, ECE, UAB, August 2012-July 2013.
4. Bunn Professor, Comprehensive Cancer Center/ECE/Radiology, UAB, January 2012-July 2013.
5. Visiting Professor, Departments of Biomedical and Electrical/Computer Engineering, Boston University, July 2011-August 2012.
6. Adjunct Professor, School of Mathematics, Georgia Tech, September 2007-present.

7. Adjunct Professor, College of Computing, Georgia Tech, June 2007-present.
8. Adjunct Professor, Department of Radiology, Emory Medical School, January 2002-present.
9. Professor, Department of Electrical Engineering, Technion, Israel, March 2005 - September 2010.
10. Julian Hightower Professor, Departments of Electrical/Computer and Biomedical Engineering, Georgia Tech, Atlanta, Georgia, August 1999 - June 2011. Now Adjunct Professor of ECE.
11. Professor, Department of Electrical Engineering, Technion, Israel, October 1989 - October 1992.
12. Professor, Department of Electrical and Computer Engineering, University of Minnesota, Minneapolis, Minnesota, September 1986 - February 2002.
13. Visiting Professor, Department of Electrical Engineering, McGill University, Montreal, Canada, August 1985 - August 1986.
14. Associate Professor, Department of Mathematics, Ben-Gurion University of the Negev, Beer Sheva, Israel, September 1984 - August 1986.
15. Associate Professor, Center for Mathematical System Theory, Department of Mathematics, University of Florida, Gainesville, Florida, U.S.A., August 1982 - August 1984.
16. Senior Scientist, Department of Mathematics, Weizmann Institute of Science, Rehovot, Israel, October 1980 - August 1983.
17. Research Mathematician, Forschungsinstitut für Mathematik, E.T.H., Zürich, Switzerland, October 1978 - October 1980.
18. Visiting Researcher, Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette, France, January 1978 - May 1978.
19. Assistant Professor, Department of Mathematics, Weizmann Institute of Science, Rehovot, Israel, September 1976 - September 1978.
20. Research Assistant, Department of Mathematics, Harvard, September 1973 - June 1976.

## **Courses Taught**

1. Calculus (both elementary and advanced). Undergraduate
2. Differential Equations. Undergraduate
3. Algebraic Geometry. Graduate
4. Functions of One Complex Variable. Graduate
5. Several Complex Variables. Graduate
6. Lie Groups and Lie Algebras. Graduate
7. Commutative Algebra. Graduate
8. Digital Control. Graduate
9. Feedback and Control Theory. Undergraduate
10. State Space Methods in Control. Senior undergraduate/First year graduate
11. Optimal Control. Graduate
12. Robust Control. Graduate: I created this course.
13. Discrete Mathematics (for computer science). Undergraduate
14. Signals and Systems. Undergraduate
15. Image Processing. Senior undergraduate/First year graduate
16. Computer Vision. Senior undergraduate/Graduate. I created this course in computational computer vision.
17. Computer Engineering. Basic computer engineering course at Georgia Tech. It is course number ECE 2030.
18. Medical Imaging. Graduate. I created this course.
19. Problem Based Learning. Basic Undergraduate Course in BME.

## **Key Professional Activities and Service**

1. Director MINERVA Lab for Medical Imaging, Georgia Tech.
2. Co-Director of the Center for Control and Dynamical Systems (University of Minnesota), 1990-1995.
3. Technical consultant for Honeywell, Storagetek, 3M Corporation, GE Medical Systems, Polaris, UTRC, Siemens, Science Partners, Trex Enterprises, tOSC, MZA, Tempest Tech, and Mayo Clinic.
4. Former associate editor of *Systems and Control Letters*, *International Journal of Robust and Nonlinear Control*, and *SIAM Journal of Control and Optimization*. Editorial board of *SIAM Journal on Imaging Science* and *SIAM Book Series on Control and Dynamical Systems*.
5. Reviewer for *Mathematical Reviews* and *Zentralblatt für Mathematik*.
6. Have given numerous invited lectures at universities, conferences, and companies in Argentina, Australia, Belgium, Brazil, Britain, Canada, China, France, Germany, Greece, Holland, India, Israel, Italy, Japan, Norway, Poland, Portugal, Russia, Singapore, Spain, Sweden, Switzerland, Uruguay, and the United States.
7. Co-organizer (with Professors David Mumford, Peter Olver, and Dr. Guillermo Sapiro) of workshop on computer vision held at Geometry Center of University of Minnesota in 1995.
8. On organizing committee for US-China Control Conference held in 1997.
9. Co-organizer (with Prof. Tryphon Georgiou) of AFOSR Contractors' Meeting held in Minneapolis in 1995.
10. On the organizing committee of the 1996 and 1997 SPIE Conferences in San Diego.
11. Member of SIAM Reid Prize Committee 1996-1999.
12. Guest editor (with J. Morel and G. Sapiro) of special issue of *IEEE Trans. on Image Processing* on partial differential equation methods.
13. Organizing committee for MBI (Ohio State) program in biomedical imaging in 2014.

14. Organizing committee for IMA (University of Minnesota) year in control in 2015.
15. Organizing committee for MSRI (Berkeley) workshop on “Fluid mechanics, Hamiltonian dynamics, and Numerical Aspects of Optimal Transportation” in 2013.
16. NSF and NIH review panels.
17. Reviewer for ARO, NSF, and AFOSR proposals.
18. Referee for numerous mathematics and engineering journals including *IEEE PAMI*, *IEEE Trans. Image Processing*, *IEEE Aut. Control*, *Int. Journal of Computer Vision*, *Pattern Recognition*, *IEEE Trans. Medical Imaging*, *Journal of AMS*, *Transactions of AMS*, *SIAM Control and Optimization*.
19. Program Committees for CDC, CVPR, MICCAI, SPIE, ICCV.
20. Consultant for Neuroscience and Alcoholism for the NIAAA. This is completely new program for NIH in which we are looking for more daring DARPA-like projects.
21. Study Panel for U54 Grants on Physics-Oncology Centers for NIH/NCI.
22. Interim Departmental Chairperson for ECE at University of Alabama, Birmingham (2012-2013). Led the department through a successful ABET review.
23. Biomedical Informatics Hiring Committee at Stony Brook University (2013-present).
24. Affiliate of Institute for Advanced Computational Science, Stony Brook University; involved in recruitment of candidates for center.

### **Awards and Honors**

1. Phi beta kappa.
2. Graduated *summa cum laude* from Columbia University.
3. Kennedy Research Prize.

4. NSF Research Initiation Award.
5. Fellow Award, Japanese Mathematical Society.
6. Plenary Speaker at International Conference on Partial Differential Equations and Distributed Control (1991).
7. Principal Lecturer for the CRM (University of Montreal) Summer School in Optimization and Control (1992).
8. Keynote Speaker at American Mathematical Society Annual Meeting (1994).
9. Plenary Speaker at American Mathematical Society Meeting (1997).
10. George Taylor Research Award (University of Minnesota).
11. Plenary Speaker for SIAM Conference on Control (1998).
12. Plenary Speaker for AFOSR Conference on Optimal Design and Control (1997).
13. Takeda Best Paper Award for “New solution to the two block  $H^\infty$  problem for infinite dimensional stable plants” (K. Hirata, Y. Yamamoto, T. Katayama, A. Tannenbaum), *Trans. of the Society of Instrument and Control Engineers* **32** (1996), pp. 1416–1424.
14. Plenary Speaker for IEEE Conference on Decision and Control, December 2000.
15. Best Paper Award for FOAM 2000 Conference from Society of Plastics Engineers for “New algorithms for 3D analysis of open-celled foams,” (M. Montminy, C. Macosko, and A. Tannenbaum).
16. Keynote Speaker at MTNS 2002.
17. IEEE Fellow.
18. Zaborszky Lecturer, Washington University, 2003.
19. Best Paper Award, MICCAI 2006 for “Shape-driven surface segmentation using spherical wavelets” (D. Nain, S. Haker, A. Bobick, and A. Tannenbaum).

20. Best Paper Award (O. Hugo Schuck Award), ACC 2007 for “Tracking deformable objects with unscented Kalman filtering and geometric active contours ” (S. Dambreville, Y. Rathi, Allen Tannenbaum).
21. Plenary Speaker for SciCADE’07, July 2007.
22. Hurwitz Lecturer, ETH, Zurich, 2010.
23. Plenary Speaker for MTNS, 2012.
24. Keynote Speaker for MICCAI Workshop on Interactive Methods, 2014.

### **Graduate Students and Postdocs Since 2004**

1. Lei Zhu (Ph.D.; BME; Georgia Tech; 2004; On Visualizing Branched Surfaces;” Siemens, China)
2. Marc Niethammer (Ph.D.; ECE; Georgia Tech; 2004; Dynamic Level Sets for Visual Tracking;” Associate Professor at UNC)
3. Eric Pichon (Ph.D.; ECE; Georgia Tech; 2005; Novel Methods for Multidimensional Image Segmentation; GE France)
4. Delphine Nain (Ph.D.; CoC; Georgia Tech; joint with Aaron Bobick; 2006; Scale-based decomposable shape representations for probabilistic medical imaging segmentation; McKinsey)
5. Yan Yang (Ph.D.; BME; Georgia Tech; joint with Don Giddens; 2006; Image Segmentation and Shape Analysis of Blood Vessels with Applications to Coronary Atherosclerosis;” Vital Images)
6. Yogesh Rathi (Ph.D.; ECE; Georgia Tech; 2007; Filtering for Closed Curves; Assistant Professor at Harvard Medical School)
7. Jincheol Ha (Ph.D.; Aerospace; Georgia Tech; 2007; joint with Eric Johnson; Vision-Based Tracking of UAVs; Guided Systems Technology)
8. Samuel Dambreville (Ph.D.; ECE; Georgia Tech; 2008; Statistical and Geometric Methods for Shape-driven Segmentation and Tracking; Management Consulting in Zurich, Switzerland)

9. John Melonakos (Ph.D.; ECE; Georgia Tech; 2008; Geodesic Tractography Segmentation for Directional Medical Image Analysis;” President of Accelereyes; Start-up company)
10. Shawn Lankton (Ph.D.; ECE; Georgia Tech; 2009; Localized Statistical Models in Computer Vision; McKinsey)
11. Tauseef ur Rehman (Ph.D.; ECE; Georgia Tech; 2009; Efficient Numerical Method for Solution of L2 Optimal Mass Transport Problem; associate professor in Islamabad, Pakistan)
12. Xavier LeFaucheur (Ph.D.; ECE; Georgia Tech; 2010; Statistical Methods for Feature Extraction in Shape Analysis and Bioinformatics; McKinsey)
13. James Malcolm (Ph.D.; ECE; Georgia Tech; 2010; Particle Filtering for Tractography; VP Engineering of Accelereyes; Start-up company)
14. Yi Gao (Ph.D.; BME; Georgia Tech; 2010; joint with Don Giddens; Geometric Statistically Based Methods for the Segmentation and Registration of Medical Imagery; assistant professor at Stony Brook BMI)
15. Vandana Mohan (Ph.D.; ECE; Georgia Tech; 2010; Computer Vision and Machine Learning Methods for the Analysis of Brain and Cardiac Imagery; McKinsey)
16. Romeil Sandhu (Ph.D.; ECE; Georgia Tech; 2010; Statistical Methods for 2D Image Segmentation and 3D Pose Estimation; Postdoc at Stony Brook)
17. Jehoon Lee (Ph.D.; ECE; Georgia Tech; 2011; Statistical and Geometric Methods for Visual Tracking with Occlusion Handling and Target Reacquisition;” Samsung, South Korea)
18. Ivan Kolesov (Ph.D.; ECE; Georgia Tech; 2012; Statistical Methods for Coupling Expert Knowledge and Automatic Image Segmentation and Registration; postdoc at Stony Brook)
19. Peter Karasev (Ph.D.; ECE; Georgia Tech; 2013; joint with Patricio Vela; Feedback Augmentation of Image Segmentation using Application-Specific Exogenous Input; Agilent, CA)



20. Liangjia Zhu (Ph.D.; ECE; Georgia Tech; 2012; Automatic Segmentation of Wall Structures from Cardiac Images; postdoc at Stony Brook)
21. Ayelet Dominitz (Ph.D.; EE; Technion; 2011; Surface and Volume Mapping via Mass Transport; Elbit, Israel)
22. Arie Nakhmani (Ph.D.; EE; Technion; 2011; joint with Ezra Zeev; Visual Tracking: A Particle Filter/Template Matching Approach; assistant professor UAB)
23. Behnood Gholami (Ph.D.; Aerospace; 2013; joint with Wassim Haddad; Clinical Decisions using Machine Learning; start-up company)
24. Gozde Unal (Postdoc: 2004-2005; now associate professor in Bilkent University)
25. Amir Betser (Postdoc: 2003-2004; now project manager at Rafael, Israel)
26. Namrata Vaswani (Postdoc: 2004-2006; now associate professor at Iowa State)
27. Oleg Michailovich (Postdoc: 2003-2006; now associate professor at Waterloo University)
28. Eli Hershkovits (Postdoc/Research Scientist: 2005-2010)
29. Ivan Kolesov (Postdoc: 2012-present)
30. LiangJia Zhu (Postdoc: 2012-present)
31. Vadim Ratner (Postdoc: 2013-present)
32. Mahsa Torkaman (Ph.D. student; CS; Spring 2014-present)
33. Maryam Pouryahya (Ph.D. student; AMS; Spring 2014-present)
34. Jeremy Lerner (Ph.D. Student; AMS; Spring 2014-present)

### LIST OF PUBLICATIONS

1. “Degenerations of curves in  $\mathbf{P}^3$ ,” *Proc. Am. Math. Soc.* **65** (1978), 6-10.

2. "Irreducible components of the Chow Scheme of space curves," *Math. Zeitschrift* **162** (1978), 287-294.
3. "On the geometric genera of projective curves," *Math. Annalen* **240** (1979), 213-221.
4. "Deformations of space curves," *Archiv der Mathematik* **34** (1980), 37-42.
5. "Families of algebraic curves with nodes," *Compositio Mathematica* **41** (1980), 107-126.
6. "Feedback stabilization of linear dynamical plants with uncertainty in the gain factor," *International Journal of Control* **32** (1980), 1-16.
7. "Castelnuovo curves and unobstructed deformations," *Math. Zeitschrift* **174** (1980), 141-147.
8. "Families of curves with nodes on K-3 surfaces," *Math. Annalen* **280** (1982), 239-253.
9. "On the stabilizer subgroup of a pair of matrices," *Linear Algebra and its Applications* (Special Issue on Linear Control Theory) **50** (1983), 527-544.
10. "Modified Nevanlinna-Pick interpolation and stabilization of linear plants with uncertainty in the gain factor," *International Journal of Control* **36** (1982), 331-336.
11. "On pole assignability over polynomial rings," *Systems and Control Letters* **2** (1982), 13-16.
12. "A note on linear systems on K-3 surfaces," *Proc. Am. Math. Soc.* **86** (1982), 6-9.
13. "On the classical characteristic linear series of plane curves with nodes and cuspidal points: two examples of Beniamino Segre," *Compositio Mathematica* **51** (1984), 169-183.
14. "Polynomial rings over arbitrary fields in two or more variables are not pole assignable," *Systems and Control Letters* **2** (1982), 222-226.
15. "Linear systems on curves," *Bulletin of the Canadian Math. Soc.* **27** (1984), 371-375.

16. "Pointwise stability and feedback control of linear systems with non-commensurate delays" (with E. W. Kamen and P. P. Khargonekar), *Acta Math.* **2** (1984), 159-184.
17. "On a certain class of real algebras which are projective-free," *Archiv der Mathematik* **42** (1984), 474-478.
18. "Stabilization of time-delay systems using finite-dimensional compensators" (with E. W. Kamen and P. P. Khargonekar), *IEEE Trans. on Aut. Control* **AC-30**, January 1985, 74-78.
19. "Noneuclidean metrics and the robust stabilization of systems with parameter uncertainty" (with P. P. Khargonekar), *IEEE Trans. on Aut. Control* **AC-30**, October 1985, 1005-1013.
20. "Robust control of linear time-invariant plants using periodic compensation" (with P. P. Khargonekar and K. Poolla), *IEEE Trans. on Aut. Control* **AC-30**, November 1985, 1088-1096.
21. "Stable Bezout factorizations and feedback control of time-delay systems," (with E. W. Kamen and P. P. Khargonekar), *International Journal of Control* **43** (1986), 837-857.
22. "On the multivariable gain margin problem," *Automatica* **22** (1986), 381-384.
23. "On the sensitivity minimization problem for linear time-varying periodic systems" (with A. Feintuch and P. P. Khargonekar), *SIAM Journal on Control and Optimization* **24** (1986), 1076-1085.
24. "Gain optimization for distributed systems" (with A. Feintuch), *Systems and Control Letters* **6** (1986), 295-301.
25. "Robotic manipulators and the geometry of real semi-algebraic sets" (with Y. Yomdin), *IEEE Journal of Robotics and Automation* **RA-3** (1987), 301-308.
26. "Weighted sensitivity minimization for delay systems" (with C. Foias and G. Zames), *IEEE Trans. on Automatic Control* **AC-31** August 1986, 763-766.
27. "On the  $H^\infty$ -optimal sensitivity problem for systems with delays" (with C. Foias and G. Zames), *SIAM Journal on Control and Optimization* **25** (1987), 686-706.

28. “On decoupling the  $H^\infty$ -optimal sensitivity problem for products of plants” (with C. Foias and G. Zames), *Systems and Control Letters* **7** (1986), 239-246.
29. “On the Nehari problem for a certain class of  $L^\infty$ -functions appearing in control theory” (with C. Foias), *Journal of Functional Analysis* **74** (1987), 146-159.
30. “Sensitivity minimization for arbitrary SISO distributed plants” (with C. Foias and G. Zames), *Systems and Control Letters* **8** (1987), 189-195.
31. “On the uniqueness of a minimal norm representative of an operator in the commutant of the compressed shift” (with C. Foias), *Proceedings of the American Mathematical Society* **101** (1987), 687-692.
32. “On a local nonlinear commutant lifting theorem” (with J. Ball, C. Foias, J. W. Helton), *Indiana Univ. Journal of Mathematics* **36** (1987), 693-709.
33. “On the Nehari problem for a certain class of  $L^\infty$ -functions appearing in control, II” (with C. Foias), *Journal of Functional Analysis* **81** (1988), 207-218.
34. “Weighted sensitivity minimization: general plants in  $H^\infty$  and rational weights” (with T. Lypchuk and M. Smith), *Linear Algebra and its Applications* **109** (1988), 71-90.
35. “Optimal sensitivity theory for multivariate distributed plants” (with C. Foias), *International Journal of Control* **47** (1988), 985-992.
36. “Generalized interpolation theory in control” (with B. Francis), *Mathematical Intelligencer* **10** (1988), 48-53.
37. “On skew Toeplitz operators, I” (with H. Bercovici and C. Foias), *Operator Theory: Advances and Applications* **29** (1988), 21-45.
38. “A Poincaré-Dulac approach to a nonlinear Beurling-Lax-Halmos theorem” (with J. Ball, C. Foias, and J. W. Helton), *Journal of Math. Analysis and Applications* **139** (1989), 496-514.
39. “Some explicit formulae for the singular values of certain Hankel operators with factorizable symbol” (with C. Foias and G. Zames), *SIAM J. Mathematical Analysis* **19** (1988), 1081-1091.

40. "On the four block problem, I," (with C. Foias), *Operator Theory: Advances and Applications* **32** (1988), 93-112.
41. "Iterated commutant lifting for systems with rational symbol" (with C. Foias), *Operator Theory: Advances and Applications* **41** (1989), 255-277.
42. "On the parametrization of the suboptimal solutions in generalized interpolation" (with C. Foias), *Linear Algebra and its Applications* **124** (1989), 145-164.
43. "On the four block problem, II: the singular system" (with C. Foias), *Integral Equations and Operator Theory* **11** (1988), 726-767.
44. "Weighted sensitivity optimization for nonlinear systems" (with C. Foias), *SIAM Journal on Control and Optimization* **27** (1989), 842-860.
45. "Some remarks on optimal interpolation" (with C. Foias), *Systems and Control Letters* **11** (1988), 259-264.
46. "Skew Toeplitz approach to the  $H^\infty$ -control of multivariate distributed systems" (with H. Özbay), *SIAM J. Control and Optimization* **28** (1990), 653-670.
47. "A strong Parrot theorem" (with C. Foias), *Proceedings of the American Mathematical Society* **106** (1989), 777-784.
48. "Control of slowly time-varying linear systems" (with E. Kamen and P. Khargonekar), *IEEE Transactions Automatic Control* **AC-34** (1989), 1283-1286.
49. "Four block problem : stable weights and rational weightings" (with P. Khargonekar and H. Özbay), *International Journal of Control* **50** (1989), 1013-1023.
50. "On the structure of suboptimal  $H^\infty$  controllers in the sensitivity minimization for distributed stable plants" (with H. Özbay), *Automatica* **27** (1991), 293-305.
51. "A spectral commutant lifting theorem" (with H. Bercovici and C. Foias), *Transactions of the AMS* **325** (1991), 741-763.

52. “On certain minimal entropy extensions appearing in dilation theory” (with C. Foias and A. Frazho), *Linear Algebra and Its Applications* **137** (1990), 213-238.
53. “On spectral tangential Nevanlinna-Pick interpolation” (with H. Bercovici and C. Foias), *Journal of Math. Analysis and Applications* **155** (1991), 156-176.
54. “The invariant subspaces of a uniform Jordan operator” (with H. Bercovici), *Journal Math. Analysis and Applications* **156** (1991), 220-230.
55. “Frequency domain analysis and robust control design for an ideal flexible beam” (with K. Lenz, H. Özbay, J. Turi, B. Morton), *Automatica* **27** (1991), 947-961.
56. “Mixed sensitivity optimization for unstable infinite dimensional systems” (with H. Özbay and M. Smith), *Linear Algebra and Its Applications* **178** (1993), 43-83.
57. “On the evolution of curves via a function of curvature, I: the classical case” (with B. Kimia and S. Zucker), *Journal of Math. Analysis and Applications* **163** (1992), 438-458.
58. “Structured interpolation theory” (with H. Bercovici and C. Foias), *Operator Theory: Advances and Applications* **47** (1990), 195-220.
59. “On the optimal solutions in spectral commutant lifting theory” (with H. Bercovici and C. Foias), *Journal of Functional Analysis* **101** (1991), 38-49.
60. “On a causal linear optimization theorem” (with C. Foias and C. Gu), *Journal of Math. Analysis and Applications* **182** (1994), pp. 555–565.
61. “Abstract model and controller design for an unstable aircraft,” (with D. Enns and H. Özbay), *AIAA Journal on Guidance, Control, and Dynamics* **15** (1992), 498-508.
62. “Some mathematical problems in computer vision” (with A. Bruckstein), *Acta Math. Appl.* **30** (1993).
63. “Causality in commutant lifting theory” (with C. Foias), *Journal of Functional Analysis* **118** (1993), 407–441.

64. “A lifting technique for linear periodic systems with applications to sampled-data control” (with B. Bamieh, B. Francis, J. B. Pearson), *Systems and Control Letters* **17** (1991), 79-88.
65. “On combined  $H^\infty$ - $H^2$  suboptimal interpolants” (with C. Foias and A. Frazho), *Linear Algebra and Its Applications* **203-204** (1994), pp. 443-469.
66. “On affine plane curve evolution” (with G. Sapiro), *Journal of Functional Analysis* **119** (1994), pp. 79-120.
67. “Intertwining dilations, intertwining extensions, and causality” (with C. Foias and C. Gu), *Acta Sci. Math. (Szeged)* **56** (1993), pp. 101-123.
68. “Nonlinear  $H^\infty$  optimization: a causal power series approach,” *SIAM J. Control and Optimization* **33** (1995), pp. 185-207.
69. “Nonlinearity in  $H^\infty$  theory, causality in commutant lifting theory, and extension of intertwining operators” (with C. Foias and C. Gu), *Integral Equations and Operator Theory* **23** (1995), 89-100.
70. “Shapes, shocks, and deformations, I: the components of shape and the reaction-diffusion space” (with B. Kimia and S. Zucker), *International Journal of Computer Vision* **15** (1995), 189-224.
71. “Affine invariant scale-space (with G. Sapiro), *International Journal of Computer Vision* **11** (1993), 25-44.
72. “On invariant curve evolution and image analysis” (with G. Sapiro), *Indiana Univ. Journal of Mathematics* **42** (1993), 985-1009.
73. “A relative Toeplitz-Hausdorff theorem” (with H. Bercovici and C. Foias), *Operator Theory: Advances and Applications* **71** (1994), pp. 29-34.
74. “Continuity of the spectrum on closed similarity orbits” (with H. Bercovici and C. Foias), *Integral Equations and Operator Theory* **18** (1994), 242-246.
75. “On area and length preserving geometric invariant curve evolutions” (with G. Sapiro), *IEEE Trans. on Pattern Analysis and Machine Intelligence* **17** (1995), pp. 67-72.

76. “Stability margin optimization via interpolation and conformal mappings” (with J. Cockburn and Y. Sidar), *IEEE Trans. Aut. Control* **40** (1995), pp. 1066–1070.
77. “On a lifting theorem for the structured singular value” (with H. Bercovici, C. Foias, and P. Khargonekar), *Journal of Math. Analysis and Applications* **187** (1994), pp. 617–627.
78. “Classification and uniqueness of invariant geometric flows” (with P. Olver and G. Sapiro), *Comptes Rendus Acad. Sci. (Paris)* **319** (1994), pp. 339–344.
79. “Multivariable stability margin optimization: a spectral tangential interpolation approach” (with Juan Cockburn), *Int. J. Control* **63** (1996), pp. 557–590.
80. “The structured singular value for linear input/output systems,” (with H. Bercovici and C. Foias), *SIAM J. Control and Optimization* **34** (1996), pp. 1392–1404.
81. “Invariant geometric evolutions of surfaces and volumetric smoothing” (with P. Olver and G. Sapiro), *SIAM J. Applied Math.* **57** (1997), pp. 176–194.
82. “Optical flow: a curve evolution approach” (with A. Kumar and G. Balas), *IEEE Trans. Image Processing* **5** (1996), pp. 598–611.
83. “Conformal curvature flows: from phase transitions to active contours” (with S. Kichenesamy, A. Kumar, P. Olver, and A. Yezzi), *Archive for Rational Mechanics and Analysis* **134** (1996), pp. 275–301.
84. “The equivalence among the solutions of the  $H^\infty$  optimal sensitivity computation problem” (with K. Hirata and Y. Yamamoto), *Trans. of the Society of Instrument and Control Engineers* **31** (1995), pp. 1954–1961.
85. “Three snippets of curve evolution theory in computer vision,” *Mathematical and Computer Modelling Journal* **24** (1996), pp. 103–119.
86. “On skew Toeplitz operators, II” (with H. Bercovici and C. Foias), *Operator Theory: Advances and Applications* **103** (1997).



87. “Behavioral analysis of anisotropic diffusion in image processing” (with Y. You, M. Kaveh, W. Xu), *IEEE Trans. Image Processing* **5** (1996), pp. 1539–1553.
88. “Affine geometry, curve flows and invariant numerical approximations” (with E. Calabi and P. Olver), *Advances in Mathematics* **124** (1996), pp. 154–196.
89. “New solution to the two block  $H^\infty$  problem for infinite dimensional stable plants” (with K. Hirata, Y. Yamamoto, T. Katayama), *Trans. of the Society of Instrument and Control Engineers* **32** (1996), pp. 1416–1424.
90. “Affine invariant detection: edge maps, anisotropic diffusion, and active contours” (with P. Olver and G. Sapiro), *Acta Math. Appl.* **59** (1999), pp. 45–77.
91. “Geometric active contours for segmentation of medical imagery,” (with S. Kichenesamy, A. Kumar, P. Olver, and A. Yezzi), *IEEE Trans. Medical Imaging* **16** (1997), pp. 199–209.
92. “Differential and numerically invariant signature curves applied to object recognition” (with E. Calabi, P. Olver, C. Shakiban), *International Journal of Computer Vision* **26** (1998), pp. 107–135.
93. “Some remarks on Hamiltonians and the infinite-dimensional one block  $H^\infty$  problem” (with K. Hirata and Y. Yamamoto), *Systems and Control Letters* **29** (1996), pp. 111–117.
94. “Area and length minimizing flows for segmentation” (with Y. Lauziere, K. Siddiqi, and S. Zucker), *IEEE Trans. Image Processing* **7** (1998), pp. 433–444.
95. “Introduction to special issue of *IEEE Trans. Image Processing* on partial differential equation methods in image processing” (with V. Caselles, J. M. Morel, and G. Sapiro), *IEEE Trans. Image Processing* **7** (1998), pp. 269–274.
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### Book Reviews

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### Patents

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### Funding Since 2004

1. “Atmospheric propagation of high energy lasers: modeling, simulation, tracking, and control,” PI at Georgia Tech (PI at UCLA is Stephen Gibson), HEL MRI, 2002-2008; Tannenbaum’s share is about \$1,100,000. (Total grant is about \$5,000,000.)

2. “Geometric methods for visual tracking,” Principal Investigator, NSF, 2006-2010, \$240,000.
3. “Optimal transport for visual tracking and nonlinear control,” NSF, 2003-2006, \$150,000.
4. “Geometric observers and particle filtering for controlled active vision,” Principal Investigator, ARO, 2006-2010, \$344,000.
5. “Geometric variational methods for controlled active vision,” ARO, 2003-2006, \$230,000.
6. “Neuroanalysis Center,” Site PI (PI at Harvard Medical School is Ron Kikinis), NIH Grant, 2006-2011; Tannenbaum’s share is about \$324,000. (Total grant is about \$7.5 million.) (This is a continuing grant. See next item.)
7. “Neuroanalysis Center,” Site PI (PI at Harvard Medical School is Ron Kikinis), NIH Grant, 2012-2017; Tannenbaum’s share is about \$680,000. (Total grant is about \$6.5 million.)
8. “Active vision control systems for complex adversarial 3-D environments,” (Eric Johnson, Allen Tannenbaum, Anthony Calise, Anthony Yezzi), MURI Grant, 2003-2008; Tannenbaum’s share is about \$1,000,000. (Total grant is about \$4.0 million).
9. “National Computational Biology Center,” Site PI (overall PI at Harvard Medical School is Ron Kikinis), NIH Grant, 2004-2010; Tannenbaum’s share is about \$1,055,000. (Total grant is about \$21 million.) (This is a continuing grant. See next item.)
10. “National Computational Biology Center,” Site PI (overall PI at Harvard Medical School is Ron Kikinis), NIH Grant, 2010-2014; Tannenbaum’s share is about \$733,000. (Total grant is about \$25 million.)
11. “Geometric variational methods for problems in visual control,” Principal Investigator, AFOSR Grant, \$420,000, 2008-2011.
12. “Statistical and variational methods for problems in visual control,” Principal Investigator, AFOSR Grant, \$381,053, 2005-2008.
13. “Optimal mass transport for problems in control and signal processing,” Co-Principal Investigator, AFOSR Grant, \$867,000, 2012-2015;

Tannenbaum's share is about \$439,000. **Renewal has been applied for.**

14. "Plaque analysis from CTA data," Siemens Grant, \$35,000, 2008-2009.
15. "Fire and smoke detection from video data," ONR Grant through UTRC, \$199,998, 2010-2012.
16. "Visual tracking using 3D data and region-based active contours", ARO Grant, \$390,000, 2010-2013. **Renewal has been applied for.**
17. "Tracking maneuverable targets," Polaris/MDA, \$176,000, 2013-2015. Phase 2 approved.
18. "Neuroanalysis Center," Site PI (PI at Harvard Medical School is Ron Kikinis), NIH Grant, 2008-2013; Tannenbaum's share is about \$324,000. (Total grant is about \$7.5 million.) (This is a continuing grant. See next item.)
19. "Neuroanalysis Center," Site PI (PI at Harvard Medical School is Ron Kikinis), NIH Grant, 2013-2018; Tannenbaum's share is about \$450,000. (Total grant is about \$6.5 million.)
20. "Image Feature Extraction for Improved EW Classification," SSCI/ONR, \$224,983, 2013-2015.
21. "Tools to analyze morphology and spatially mapped molecular data," (Tannenbaum is co-Investigator; overall PI is Joel Saltz), NIH, 2014-2019. Total grant is \$3.2 million. Tannenbaum's share is about \$300,000.
22. "Geometry of probability distributions with applications to estimation, sensing, surveillance, and navigation," Principal Investigator (Tryphon Georgiou is co-PI), AFOSR, 2015-2018. Total is about \$713,314. Tannenbaum's share is about \$367,000.