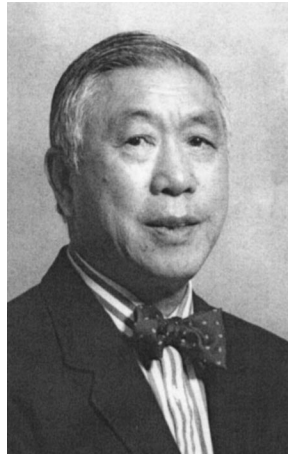


When applying for graduate school, I was contacted by Prof. A. T. Yang at UC Davis, but wound up at Stanford only to find decades later that my research is dominated by the mathematics of dual quaternions that Prof. Yang presented so clearly and completely to our community. Two years ago, I had the honor of describing this research, and the literally hundreds of millions of spatial linkages to which it applies, at a research symposium in honor of Prof. Yang's 80th birthday. A month ago I attended his memorial service and was touched to hear of his adventurous spirit and love of basketball, cards, friends and family. It is a profound honor to be part of a community of scholarship with colleagues such as Professor An Tsu Yang.

**J. Michael McCarthy**  
University of California, Irvine

## *IN MEMORIAM*



**Dr. An Tzu Yang**  
**1923–2003**

Dr. An Tzu (Andy) Yang, Professor Emeritus of Mechanical Engineering, University of California, Davis, passed away on November 21, 2003. Born on October 5th, 1923, in Shanghai, China, Professor Yang came from an academic family. His father, Pei-Feng Yang, was a Professor of Civil Engineering, and his sister, An-Jing Yang, was a Professor of Material Science, both at Jiao-Tong University in China. Andy is survived by his wife of fifty years, Ambassador Linda Tsao Yang, a former U.S. Executive Director to the Asian Development Bank in Manila, Philippines, and two sons and daughters-in-law: Yuelin T. and Trina Chin Yang of Singapore and Eton Y. and Jenny Wang Yang of Davis, California.

Professor Yang escaped from Japanese occupied Shanghai to Free China in 1942, making the one thousand mile journey on foot, by oxcart, mule, and train. He then enrolled at the Northwestern College of Engineering in Xi'an, China, where he received a Bachelor of Science degree in Mechanical Engineering in 1946. He came to the United States in early 1949 to study at Ohio State University and graduated with a Master's degree in Mechanical Engineering in 1950. Dr. Yang held several engineering positions with Babcock and Wilcox, and was Head of the Theoretical Analysis Section, and Senior Engineer, Research and Development Division, American Machine and Foundry Company. In 1959, Dr. Yang was a Visiting Professor in Applied Mathematics at the Institute of Mathematics, University de Rio Grande de Sul, Porto Alegre, Brazil.

Dr. Yang completed his Doctor of Engineering Science degree under the guidance of Professor Ferdinand Freudenstein at Columbia University in 1963. His milestone dissertation was entitled, "Application of Quaternion Algebra and Dual Numbers to the Analysis of Spatial Mechanisms." Within two years, the dissertation was adopted by Columbia University, Yale University, and the Massachusetts Institute of Technology as a text for graduate level courses in spatial kinematics. His treatise was considered a landmark contribution

that opened up the use of screw theory for researchers in mechanism design, rigid-body dynamics, robotics, biomechanics and computational geometry. Forty years after the publication of this dissertation, it remains one of the most commonly cited works in theoretical kinematics. Dr. Yang helped pioneer the revival of the theory of screws to obtain explicit, closed-form algebraic expressions for the displacements, velocities, accelerations, forces, and torques in spatial closed-loop mechanisms. He also authored or coauthored many outstanding archival publications over the past forty years. (See the list of technical publications following this memorial).

Dr. Yang joined the newly formed College of Engineering at the University of California, Davis, in 1964, as an Assistant Professor and was a founding member of the Department of Mechanical Engineering when it was established in 1965. His analytical work in mechanism design was quickly recognized by the research community, both nationally and internationally. Within five years of arriving at the University of California, Davis, he was a renowned researcher and considered a leading figure in the field of mechanisms, kinematics, and dynamics. He accelerated through the ranks, becoming a full Professor in 1971. Dr. Yang was a Visiting Associate Professor in Mechanical Engineering at Stanford University, California, in 1970, and a Visiting Professor in Mechanical Engineering at Jiao Tong University, Shanghai, China, in the Summer of 1979.

Dr. Yang served the American Society of Mechanical Engineers (ASME), the International Federation for the Theory of Machines and Mechanisms (IFTToMM), and the National Science Foundation throughout his academic career. He was a member of the Mechanical Systems Program, National Science Foundation and a reviewer for the National Research Council in Washington, D.C. He served as an Associate Editor for Mechanism and Machine Theory, the Journal of IFTToMM, and an Associate Editor for the Journal of Mechanical Design, the Transactions of ASME. Professor Yang also served the State of California by being named to advisory subcommittees for two legislative committees: namely, the Assembly Committee on Economic Development and New Technologies, and the California Legislature's Joint Committee on Science and Technology.

Dr. Yang received several awards over the years, including the ASME Design Division Mechanisms Committee Award, a service award from the ASME Applied Mechanics Review, and Life Fellow status in ASME. He was also elected into the New York Academy of Science. Professor Yang retired in 1991 after twenty-seven years of teaching and research and making major contributions to the field of theoretical kinematics. During the next decade, however, he remained active in publishing, reviewing and advising.

Professor Yang was a dedicated educator and a true scholar in the finest tradition, he was highly respected by his students and fellow colleagues. He was one of the most learned people that I have had the privilege to know. For me, Dr. Yang will continue to be the standard for professional excellence. He offered sage advice and good criticisms and provided many with the enthusiasm and stimulus to move forward in the field of machine design. He was meticulous in the preparation of manuscripts for publication in archival journals. His writing was elegant and precise, the content was insightful, enriching and enduring.

In September 2002 at the 28th ASME International Design Engineering Technical Conferences in Montreal, Canada, his former doctoral students, colleagues, and friends honored him with a dinner for his 80th birthday. A special technical session was also dedicated to his research. Both of these events were a testimonial to a man who made significant contributions to mechanism and machine theory, in general, and spatial kinematics, in particular.

Dr. Yang was a humble man, devoted to his family, his friends, and his profession. He enjoyed the company of his friends and reminiscing about the influence his colleagues had on him during his early academic career. Andy will be greatly missed by those who knew him best, as well as by the scientific and engineering communities. He had that rare quality that altered your perspective and enriched your spirit with time spent in his company. He was a good, thoughtful and unassuming man. His works and technical contributions will continue to provide inspiration in the years to come.

Following this memorial is a list of Dr. Yang's technical publications.

**Gordon R. Pennock**  
Purdue University  
West Lafayette, Indiana

## Papers in Archival Journals and Transactions

1. "Harmonic Analysis of Spherical Four-Bar Mechanisms," *Journal of Applied Mechanics*, Trans. ASME, Series E, Vol. 29, No. 4, December 1962, pp. 683–688.
2. "Application of Dual-Number Quaternion Algebra to the Analysis of Spatial Mechanisms," (with F. Freudenstein), *Journal of Applied Mechanics*, Trans. ASME, Series E, Vol. 31, No. 2, June 1964, pp. 300–308.
3. "Static Force and Torque Analysis of Spherical Four-Bar Mechanisms," *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 87, No. 2, May 1965, pp. 221–227.
4. "Acceleration Analysis of Spatial Four-Link Mechanisms," *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 88, No. 3, August 1966, pp. 296–300.
5. "Application of Dual Quaternions to the Study of Gyrodynamics," *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 89, No. 1, February 1967, pp. 137–143.
6. "Displacement Analysis of Spatial Five-Link Mechanisms Using  $(3 \times 3)$  Matrices with Dual-Number Elements," *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 91, No. 1, February 1969, pp. 152–157.
7. "Analysis of an Offset Unsymmetric Gyroscope with Oblique Rotor Using  $(3 \times 3)$  Matrices with Dual-Number Elements," *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 91, No. 3, August 1969, pp. 535–542.
8. "Dynamics of Generalized Gyroscopic System," *Proceedings of Second World Congress on the Theory of Machines and Mechanisms*, Zakopane, Poland, September 1969.
9. "Dynamic Stability Analysis of Linkages with Elastic Members via Analog Simulation," (with J.A. Seevers), ASME Paper No. 70-Mech-48. Also in *Simulation*, Vol. 18, No. 2, February 1972, pp. 67–74.
10. "Inertia Force Analysis of Spatial Mechanisms," *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 93, No. 1, February 1971, pp. 27–33.
11. "Kinematics and Statics of a Coupled Epicyclic Spur-Gear Train," (with F. Freudenstein), International Federation for the Theory of Machines and Mechanisms, *Mechanism and Machine Theory*, Vol. 7, 1972, pp. 263–275.
12. "Mechanics of Epicyclic Bevel-Gear Trains," (with F. Freudenstein), *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 95, No. 2, May 1973, pp. 497–502.

13. "Higher-Order Path Curvature in Spherical Kinematics," (with B. Roth), *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 95, No. 2, May 1973, pp. 612–616.
14. "Dynamic Analysis of a Bi-Pole Stepping Switch," *Proceedings of the Third Applied Mechanisms Conference*, Oklahoma State University, Stillwater, Oklahoma, November 1973.
15. "Calculus of Screws," (an invited paper), *Basic Questions of Design Theory*, Part 3, North Holland Publishing Company, Amsterdam, 1974, pp. 265–281.
16. "A Brief Survey of Space Mechanisms," (an invited paper), *Proceedings of the Design Technology Transfer Conference*, pp. 315–322, Columbia University, New York, October, 1974. Sponsored by the Design Engineering Division, ASME.
17. "On a Kinematic Curvature Theory for Ruled Surfaces," (with Y. Kirson and B. Roth), *Proceedings of the Fourth World Congress on the Theory of Machines and Mechanisms*, Newcastle-Upon-Tyne, England, September 1975, pp. 737–742.
18. "The Application of Instantaneous Invariants to the Analysis and Synthesis of Mechanisms," (with B. Roth), *Journal of Engineering for Industry*, Trans. ASME, Series B, Vol. 99, No. 1, February 1977, pp. 97–103.
19. "Instantaneous Invariants in Three-Dimensional Kinematics," (with Y. Kirson), *Journal of Applied Mechanics*, Trans. ASME, Series E, Vol. 45, No. 2, June 1978, pp. 409–414.
20. "Multi-Stage Geared Geneva Mechanisms," (with L.M. Hsia), *Journal of Mechanical Design*, Trans. ASME, Vol. 101, No. 1, January 1979, pp. 41–46.
21. "On the Principle of Transference in Three-Dimensional Kinematics," (with L.M. Hsia), *Journal of Mechanical Design*, Trans. ASME, Vol. 103, No. 3, July 1981, pp. 652–656.
22. "Stress Fluctuations in High Speed Mechanisms," (with G.R. Pennock and L.M. Hsia), *Journal of Mechanical Design*, Trans. ASME, Vol. 103, No. 4, October 1981, pp. 736–742.
23. "A Simulation Procedure for Human Motion Studies," (with M.R. Ramey), *Journal of Biomechanics*, Affiliated with the American Society of Biomechanics, the European Society of Biomechanics and the International Society of Biomechanics, Pergamon Press, Vol. 14, No. 4, 1981, pp. 203–213.
24. "Dynamic Analysis of a Multi-Rigid-Body Open-Chain System," (with G.R. Pennock), *Journal of Mechanisms, Transmissions, and Automation in Design*, Trans. ASME, Vol. 105, No. 1, March 1983, pp. 28–34.
25. "Dynamic Force and Torque Analysis of Spherical Four-Bar Mechanisms," (with S. Zhishang), *Journal of Mechanisms, Transmissions, and Automation in Design*, Trans. ASME, Vol. 105, No. 3, September 1983, pp. 492–497.
26. "Instantaneous Kinematics of Three-Parameter Motions," (with G.R. Pennock), *Journal of Mechanisms, Transmissions, and Automation in Design*, Trans. ASME, Vol. 107, No. 2, June 1985, pp. 157–162.
27. "Application of Dual-Number Matrices to the Inverse Kinematics Problem of Robot Manipulators," (with G.R. Pennock), *Journal of Mechanisms, Transmissions, and Automation in Design*, Trans. ASME, Vol. 107, No. 2, June 1985, pp. 201–208.
28. "On the Intrinsic Properties of Point Trajectories in Three-Dimensional Kinematics," (with L.M. Hsia), *Journal of Mechanisms, Transmissions, and Automation in Design*, Trans. ASME, Vol. 107, No. 3, September 1985, pp. 401–405.
29. "Kinematics of Three-Dimensional Gearing," (with Da Zhun Xiao), *International Federation for the Theory of Machines and Mechanisms, Mechanism and Machine Theory*, Vol. 24, 1989, pp. 245–255.
30. "Kinematic Geometry of Spherical Evolutes," (with J.A. Schaaf), *Journal of Mechanical Design*, Trans. ASME, Vol. 114, No. 1, March 1992, pp. 109–116.
31. "Theory of Contact for Geometric Continuity of Parametric Curves," (with C. Lee and B. Ravani), *Journal of the Visual Computer*, Vol. 8, December 1992, pp. 338–350, Springer-Verlag.
32. "Coordinate System Independent Form of Instantaneous Invariants in Spatial Kinematics," (with C. Lee and B. Ravani), *Journal of Mechanical Design*, Trans. ASME, Vol. 115, No. 4, December 1993, pp. 946–952.
33. "Instantaneous Invariants and Curvature Analysis of a Planar Four-Link Mechanism," (with G.R. Pennock and L.M. Hsia), *Journal of Mechanical Design*, Trans. ASME, Vol. 116, No. 4, December 1994, pp. 1173–1176.