

## REFERENCES

- J. Aisbett, J. T. Rickard, and D. G. Morgenthaler, "Type-2 fuzzy sets as functions on spaces," *IEEE Trans. on Fuzzy Systems*, vol. 18, pp. 841–844, Aug. 2010.
- R. A. Aliev, W. Pedrycz, B. G. Guirimov, R. R. Aliev, U. Ilhan, M. Babagil, and S. Mamadli, "Type-2 fuzzy neural networks with fuzzy clustering and differential evolution optimization," *Information Sciences*, vol. 181, pp. 1591–1608, 2011.
- M. Biglarbegian, "On the design of robust intelligent controllers with application to mobile robot tracking," Proceedings of 2012 IEEE American Control Conf., Montreal, Canada, pp. 4879–4884, 2012.
- M. Biglarbegian, W. W. Melek, and J. M. Mendel, "Parametric design of stable type-2 TSK fuzzy systems," Proceedings of 2008 North American Information Processing Society Conf., New York, pp. 1–6, 2008.
- M. Biglarbegian, W. W. Melek, and J. M. Mendel, "A practical approach for design of PD and PI-like interval type-2 fuzzy controllers," Proceedings of 2009 IEEE Conf. on Systems, Man and Cybernetics, San Antonio, TX, pp. 255–261, 2009.
- M. Biglarbegian, W. W. Melek, and J. M. Mendel, "On the stability of interval type-2 TSK fuzzy logic control systems," *IEEE Trans. on Systems, Man and Cybernetics—Part B: Cybernetics*, vol. 40, pp. 798–818, June 2010.
- M. Biglarbegian, W. W. Melek, and J. M. Mendel, "Design of novel interval type-2 fuzzy controllers for modular and reconfigurable robots: Theory and experiments," *IEEE Trans. on Industrial Electronics*, vol. 58, pp. 1371–1384, April 2011.
- S. P. Boyd, L. E. Ghaoui, E. Feron, and V. Balakrishnan, *Linear Matrix Inequalities in System and Control Theory*, Philadelphia: SIAM, 1994.
- British Standards, *BS 5514 Reciprocating Internal Combustion Engines: Speed Governing*, 2nd ed., accessed at <http://www.bsonline.bsiglobal.com/server/index.jsp>.
- O. Castillo and P. Melin, "A review on the design and optimization of interval type-2 fuzzy controllers," *Applied Soft Computing*, vol. 12, no. 4, pp. 1267–1278, 2012.
- J. Castro, "Fuzzy logic controllers are universal approximators," *IEEE Trans. on Systems, Man and Cybernetics*, vol. 25, pp. 629–635, Apr. 1995.
- J. R. Castro, O. Castillo, P. Melin, and A. R.-Diaz, "A hybrid learning algorithm for a class of interval type-2 fuzzy neural networks," *Information Sciences*, vol. 179, pp. 2175–2193, 2009.
- L. Chua, M. Komuro, and T. Matsumoto, "The double scroll family," *IEEE Trans. on Circuits and Systems*, vol. 33, no. 11, pp. 1073–1118, 1986.

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*Introduction to Type-2 Fuzzy Logic Control: Theory and Applications*, First Edition.

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- L. Chua, C. W. Wu, A. Hunang, and G. Q. Zhong, "A universal circuit for studying and generating chaos-part I: Routes to chaos," *IEEE Trans. on Circuits and Systems-I: Fundamental Theory and Appl.*, vol. 40, no. 10, pp. 732–744, 1993.
- S. Chopra, R. Mitra, and V. Kumar, "Fuzzy controller: Choosing an appropriate and smallest rules set," *J. of Computational Cognition*, vol. 3, no. 4, pp. 73–79, 2005.
- S. Coupland and R. John, "Geometric type-1 and type-2 fuzzy logic systems," *IEEE Trans. on Fuzzy Systems*, vol. 15, pp. 3–15, Feb. 2007.
- T. M. Cover and J. A. Thomas, *Elements of Information Theory*, New York: Wiley, 1991.
- X. Du and H. Ying, "Deriving analytical structure of a type-2 fuzzy PD/PI controller," Proceedings of 2008 North American Information Processing Society Conf., New York, pp. 1–6, 2008.
- X. Du and H. Ying, "Derivation and analysis of the analytical structures of the interval type-2 fuzzy-PI and PD controllers," *IEEE Trans. on Fuzzy Systems*, vol. 18, pp. 802–814, Aug. 2010.
- K. Duran, H. Bernal, and M. Melgarejo, "Improved iterative algorithm for computing the generalized centroid of an interval type-2 fuzzy set," Proceedings of 2008 North American Information Processing Society Conf., New York, Paper 50056, 2008.
- G. Feng, "A survey on analysis and design of model-based fuzzy control systems," *IEEE Trans. on Fuzzy Systems*, vol. 14, pp. 676–697, Oct. 2006.
- J. Figueroa, J. Posada, J. Soriano, M. Melgarejo, and S. Roj, "A type-2 fuzzy logic controller for tracking mobile objects in the context of robotic soccer games," Proceedings of 2005 IEEE Int'l. Conf. on Fuzzy Systems, Reno, NV, pp. 359–364, 2005.
- D. E. Goldberg, *Genetic Algorithms in Search, Optimization and Machine Learning*, Reading, MA: Addison Wesley, 1989.
- M. Grant and S. Boyd, "Graph implementations for non-smooth convex programs," in V. Blondel, S. Boyd, and H. Kimura (Eds.), *Recent Advances in Learning and Control, Lecture Notes in Control and Information Sciences*, pp. 95–110, London: Springer-Verlag Limited, 2008.
- M. Grant and S. Boyd, "CVX: Matlab software for disciplined convex programming, version 1.21"; accessed at <http://stanford.edu/~boyd/cvx>, 2011.
- H. Hagras, "A hierarchical type-2 fuzzy logic control architecture for autonomous mobile robots," *IEEE Trans. on Fuzzy Systems*, vol. 12, pp. 524–539, Aug. 2004.
- H. Hagras, "Comments on dynamical optimal training for interval type-2 fuzzy neural network" *IEEE Trans. on Systems, Man and Cybernetics, Part B: Cybernetics*, Vol. 36, pp. 1206–1209, Oct. 2006.
- H. Hagras, "Type-2 FLCs: A new generation of fuzzy controllers," *IEEE Computational Intelligence Mag.*, vol. 2, pp. 30–43, Feb. 2007.
- H. Hagras and C. Wagner, "Towards the wide spread use of type-2 fuzzy logic systems in real world applications," *IEEE Computational Intelligence Mag.*, vol. 7, pp. 14–24, Aug. 2012.
- H. Hagras, F. Doctor, A. Lopez, and V. Callaghan, "An incremental adaptive life long learning approach for type-2 fuzzy embedded agents in ambient intelligent environments," *IEEE Trans. on Fuzzy Systems*, vol. 15, pp. 41–55, Feb. 2007.
- D. Hidalgo, P. Melin, and O. Castillo, "An optimization method for designing type-2 fuzzy inference systems based on the footprint of uncertainty using genetic algorithms," *Expert Systems Applications*, vol. 39, no. 4, pp. 4590–4598, 2012.

- K. Hirota, "History of industrial applications of fuzzy logic in Japan," in J. Yen, R. Langari, and L. A. Zadeh (Eds.), *Industrial Applications of Fuzzy Logic and Intelligent Systems*, Piscataway, NJ: IEEE Press, pp. 43–54, 1995.
- J. C. Holland, *Adaptation in Natural and Artificial Systems*, Ann Arbor, MI: Univ. of Michigan Press, 1975 (as of 1992, available from the MIT Press).
- L. Holmblad and I. Ostergaard, "Control of a cement kiln by fuzzy logic," in *Fuzzy Information and Decision-Processes*, M. M. Gupta and E. Sanchez (Eds.), Amsterdam: North-Holland, pp. 389–399, 1982.
- S. Horikawa, T. Furahashi, and Y. Uchikawa, "On fuzzy modeling using fuzzy neural networks with back-propagation slgorithm," *IEEE Trans. on Neural Networks*, vol. 3, pp. 801–806, Sept., 1992.
- H. Hu, Y. Wang, and Y. Cai, "Advantages of the enhanced opposite direction searching algorithm for computing the centroid of an interval type-2 fuzzy set," *Asian J. of Control*, vol. 14, no. 6, pp. 1–9, Nov. 2012
- J.-S. R. Jang, "Self-learning fuzzy controllers based on temporal back-propagation," *IEEE Trans. on Neural Networks*, vol. 3, pp. 714–723, Sept., 1992.
- C.-F. Juang and Y.-W. Tsao, "A type-2 self-organizing neural fuzzy system and its FPGA implementation," *IEEE Trans. on Systems, Man, and Cybernetics—Part B: Cybernetics*, vol. 38, no. 6, pp. 1537–1548, 2008.
- N. N. Karnik and J. M. Mendel, "Centroid of a type-2 fuzzy set," *Information Sciences*, vol. 132, pp. 195–220, 2001a.
- N. N. Karnik and J. M. Mendel, "Operations on type-2 fuzzy sets," *Fuzzy Sets and Systems*, vol. 122, pp. 327–348, 2001b.
- N. N. Karnik, J. M. Mendel, and Q. Liang "Type-2 fuzzy logic systems," *IEEE Trans. on Fuzzy Systems*, vol. 7, pp. 643–658, Dec. 1999.
- J. Kennedy and R. Eberhart, "Particle swarm optimization," Proc. of IEEE Int'l. Conf. on Neural Networks, pp. 1942–1948, 1995.
- K. H. Khalal, *Nonlinear Systems*, 2nd, ed., Englewood Cliffs, NJ: Prentice-Hall, 1996.
- G. J. Klir and B. Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications* (Chapter 1), Englewood Cliffs, NJ: Prentice-Hall, 1995.
- B. Kosko, "Fuzzy systems are universal approximators," *IEEE Trans. on Computers*, vol. 43, pp. 1329–1333, Nov. 1994.
- V. Kreinovich, G. C. Mouzouris, and H. T. Nguyen, "Fuzzy rule based modeling as a universal approximation tool," in H. T. Nguyen and M. Sugeno (Eds.), *Fuzzy Systems: Modeling and Control*, Boston: Kluwer Academic, 1998.
- P. M. Larsen, "Industrial applications of fuzzy logic control," *Int. J. Man, Mach. Studies*, vol. 12, no. 1, pp. 3–10, 1980.
- C. C. Lee, "Fuzzy logic in control systems: Fuzzy logic controller-Part I," *IEEE Trans. on Systems, Man, and Cybernetics*, vol. 20, no. 2, pp. 404–418, 1990.
- F. L. Lewis, S. Jagannathan, and A. Yesildirek, *Neural Network Control of Robot Manipulators and Nonlinear Systems*, New York: Taylor & Francis, 1999.
- Q. Liang and J. M. Mendel, "Interval type-2 fuzzy logic systems: theory and design," *IEEE Trans. on Fuzzy Systems*, vol. 8, pp. 535–550, Oct. 2000.
- Q. Liang and J. M. Mendel, "MPEG VBR video traffic modeling and classification using fuzzy techniques," *IEEE Trans. on Fuzzy Systems*, vol. 9, pp. 183–193, Feb. 2001.

- C.-T. Lin and C. S. G. Lee, *Neural Fuzzy Systems*, Englewood Cliffs, NJ: Prentice-Hall, 1996.
- P. Lin, C. Hsu, and T. Lee, "Type-2 fuzzy logic controller design for buck DC-DC converters," Proceedings of 2005 IEEE Int'l. Conf. on Fuzzy Systems, Reno, NV, pp. 365–370, 2005.
- T.-C. Lin and M.-C. Chen, "Adaptive hybrid type-2 intelligent sliding model control for uncertain nonlinear multivariable dynamical systems," *Fuzzy Sets and Systems*, vol. 171, pp. 44–71, 2011.
- O. Linda and M. Manic, "Monotone centroid flow algorithm for type-reduction of general type-2 fuzzy sets," *IEEE Trans. on Fuzzy Systems*, vol. 20, pp. 805–819, Oct. 2012.
- F. Liu, "An efficient centroid type-reduction strategy for general type-2 fuzzy logic system," *Information Sciences*, vol. 178, pp. 2224–2236, 2008.
- F. Liu and J. M. Mendel, "Aggregation using the fuzzy weighted average, as computed by the KM algorithms," *IEEE Trans. on Fuzzy Systems*, vol. 16, pp. 1–12, Feb. 2008.
- X. Liu and J. M. Mendel, "Connect Karnik–Mendel algorithms to root-finding for computing the centroid of an interval type-2 fuzzy set," *IEEE Trans. on Fuzzy Systems*, vol. 19, pp. 652–665, Aug. 2011.
- C. Lynch, H. Hagras, and V. Callaghan, "Embedded type-2 FLC for real-time speed control of marine and traction diesel engines," Proceedings of 2005 IEEE Int'l. Conf. on Fuzzy Systems, Reno, NV, pp. 347–352, 2005.
- C. Lynch, H. Hagras, and V. Callaghan, "Embedded interval type-2 neuro-fuzzy speed controller for marine diesel engines," Proceedings of 2006 Information Processing and Management of Uncertainty in Knowledge-Based Systems Conf., Paris, France, pp. 1340–1347, 2006a.
- C. Lynch, H. Hagras, and V. Callaghan, "Using uncertainty bounds in the design of embedded real-time type-2 neuro-fuzzy speed controller for marine diesel engines," Proceedings of 2006 IEEE Int'l. Conf. on Fuzzy Systems, Vancouver, Canada, pp. 7217–7224, 2006b.
- E. H. Mamdani, "Applications of fuzzy algorithms for simple dynamic plant," *Proc. IEEE*, vol. 121, pp. 1585–1588, 1974.
- E. H. Mamdani, "Fuzzy control—a misconception of theory and application," *IEEE Expert-A Fuzzy Logic Symposium*, vol. 9, no. 4, pp. 27–28, 1994.
- E. H. Mamdani and S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller," *Int. J. of Machine Studies*, vol. 7, pp. 1–13, 1975.
- R. Martínez, O. Castillo, and L. T. Aguilar, "Optimization with genetic algorithms of interval type-2 fuzzy logic controllers for an autonomous wheeled mobile robot: A comparison under different kinds of perturbations," Proceedings of 2008 IEEE Int'l. Conf. on Fuzzy Systems, Paper FS0225, Hong Kong, China, June 2008.
- R. Martínez, O. Castillo, and L. T. Aguilar, "Optimization of interval type-2 fuzzy logic controllers for a perturbed autonomous wheeled mobile robot using genetic algorithms," *Information Sciences*, vol. 179, pp. 2158–2174, 2009.
- M. C. A. Melgarejo, "A fast recursive method to compute the generalized centroid of an interval type-2 fuzzy set," Proceedings of 2007 North American Fuzzy Info. Processing Society Conf., San Diego, CA, pp. 190–194, 2007.
- P. Melin, L. Astudillo, O. Castillo, F. Valdez, and M. Garcia, "Optimal design of type-2 and type-1 fuzzy tracking controllers for autonomous mobile robots under perturbed torques

- using a new chemical optimization paradigm," *Expert Systems Applications*, vol. 40, no. 8, pp. 3185–3195, 2013.
- J. M. Mendel, "Fuzzy logic systems for engineering: a tutorial," *IEEE Proc.*, Vol. 83, pp. 345–377, Mar. 1995.
- J. M. Mendel, *Uncertain Rule-Based Fuzzy Logic Systems: Introduction and New Directions*, Upper-Saddle River, NJ: Prentice-Hall, 2001.
- J. M. Mendel, "Computing derivatives in interval type-2 fuzzy logic systems," *IEEE Trans. on Fuzzy Systems*, vol. 12, pp. 84–98, Feb. 2004
- J. M. Mendel, "Type-2 fuzzy sets and systems: an overview," *IEEE Computational Intelligence Mag.*, vol. 2, pp. 20–29, Feb. 2007.
- J. M. Mendel, "Comments on ‘ $\alpha$ -plane representation for type-2 fuzzy sets: theory and applications," *IEEE Trans. on Fuzzy Systems*, vol. 18, pp. 229–230, Feb. 2010.
- J. M. Mendel, "Plotting 2-1/2 D figures for general type-2 fuzzy sets by hand or by PowerPoint," Proceedings of 2012 IEEE Int'l. Conf. on Fuzzy Systems, Brisbane, Australia, pp. 1490–1497, June 2012.
- J. M. Mendel, "On KM algorithms for solving type-2 fuzzy set problems," *IEEE Trans. on Fuzzy Systems*, vol. 21, pp. 426–446, June 2013.
- J. M. Mendel, "General type-2 fuzzy logic systems made simple: a tutorial," *IEEE Trans. on Fuzzy Systems*, vol. 22, 2014.
- J. M. Mendel and R. I. John, "Type-2 fuzzy sets made simple," *IEEE Trans. on Fuzzy Systems*, vol. 10, pp. 117–127, Apr. 2002a.
- J. M. Mendel and R. I. John, "Footprint of uncertainty and its importance to type-2 fuzzy sets," Proceedings of 6th IASTED Int'l. Conf. on Artificial Intelligence and Soft Computing, Banff, Alberta, Canada, pp. 587–592, July 2002b.
- J. M. Mendel and F. Liu, "Super-exponential convergence of the Karnik-Mendel algorithms for computing the centroid of an interval type-2 fuzzy set," *IEEE Trans. on Fuzzy Systems*, vol. 15, pp. 309–320, Apr. 2007.
- J. M. Mendel and X. Liu, "Simplified interval type-2 fuzzy logic systems," *IEEE Trans. on Fuzzy Systems*, vol. 21, pp. 1056–1069, Dec. 2013.
- J. M. Mendel and D. Wu, *Perceptual Computing: Aiding People in Making Subjective Judgments*, Hoboken, NJ: Wiley and IEEE Press, 2010.
- J. M. Mendel and H. Wu, "Type-2 fuzzistics for symmetric interval type-2 fuzzy sets: Part 1, forward problems," *IEEE Trans. on Fuzzy Systems*, vol. 14, pp. 781–792, Dec. 2006.
- J. M. Mendel and H. Wu, "Type-2 fuzzistics for non-symmetric interval type-2 fuzzy sets: forward problems," *IEEE Trans. on Fuzzy Systems*, vol. 15, pp. 916–930, Oct., 2007a.
- J. M. Mendel and H. Wu, "New results about the centroid of an interval type-2 fuzzy set, including the centroid of a fuzzy granule," *Information Sciences*, vol. 177, pp. 360–377, 2007b.
- J. M. Mendel, R. I. John, and F. Liu, "Interval type-2 fuzzy logic systems made simple," *IEEE Trans. on Fuzzy Systems*, vol. 14, pp. 808–821, Dec. 2006.
- J. M. Mendel, F. Liu, and D. Zhai, "Alpha-plane representation for type-2 fuzzy sets: Theory and applications," *IEEE Trans. on Fuzzy Systems*, vol. 17, pp. 1189–1207, Oct. 2009.
- G. Mendez, L. Leduc-Lezama, R. Colas, G. Murillo-Perez, J. Ramirez-Cuellar and J. Lopez, "Modelling and control of coiling entry temperature using interval type-2 fuzzy logic systems," *J. of Iron Making and Steel Making*, vol. 37, pp. 126–134, Feb. 2010.

- Y. Moldonado, O. Castillo, and P. Melin, "Particle swarm optimization of interval type-2 fuzzy systems for FPGA applications," *Applied Soft Computing*, vol. 13, no. 1, pp. 496–508, 2013.
- T. Munakata and Y. Jani, "Fuzzy systems: An overview," *Communications of the ACM*, vol. 37, pp. 69–96, Mar. 1994.
- M. Nie and W. W. Tan, "Towards an efficient type-reduction method for interval type-2 fuzzy logic systems," Proceeding of 2008 IEEE Int'l. Conf. on Fuzzy Systems, Hong Kong, China, Paper FS0339, 2008.
- M. Nie and W. W. Tan, "Derivation of the analytical structure of symmetrical IT2 fuzzy PD and PI controllers," Proceedings of 2010 IEEE Int'l. Conf. on Fuzzy Systems, Barcelona, Spain, pp. 1–8, July 2010.
- M. Nie and W. W. Tan, "Analytical structure and characteristics of symmetric Karnik-Mendel type-reduced interval type-2 fuzzy PI and PD controllers," *IEEE Trans. on Fuzzy Systems*, vol. 20, pp. 416–430, 2012.
- A. O'Dwyer, *Handbook of PI and PI Controller Tuning Rules*, London: Imperial College Press, 2003.
- R. Palm, "Sliding mode fuzzy control," Proceedings of 1992 IEEE Int'l. Conf. on Fuzzy Systems, San Diego, CA, pp. 519–526, 1992.
- Q. Ren, L. Baron, K. Jemielniak, and M. Balazinski, "Modeling of dynamic micro-milling cutting forces using type-2 fuzzy rule-based system," Proceedings of 2010 IEEE Int'l. Conf. on Fuzzy Systems, Barcelona, Spain, pp. 1–7, 2010.
- P. C. Shill, M. F. Amin, M. A. H. Akhand, and K. Murase, "Optimization of interval type-2 fuzzy logic controller using quantum genetic algorithms," Proc. FUZZ-IEEE 2012, Brisbane, Australia, pp. 1027–1034, June 2012.
- M. Sugeno, "An introductory survey of fuzzy control," *Information Sciences*, vol. 36, pp. 59–83, July–Aug. 1985.
- T. Takagi and M. Sugeno, "Fuzzy identification of systems and its application to modeling and control," *IEEE Trans. on Systems, Man and Cybernetics*, vol. 15, pp. 116–132, Jan/Feb. 1985.
- K. Tanaka and M. Sano, "Trajectory stabilization of a model car via fuzzy control," *Fuzzy Sets and Systems*, vol. 70, no. 2–3, pp. 155–170, 1995.
- K. Tanaka and M. Sugeno, "Introduction to fuzzy modeling," in H. T. Nguyen and M. Sugeno (Eds.), *Fuzzy Systems Modeling and Control*, Boston: Kluwer Academic, 1998, pp. 63–89.
- K. Tanaka, M. Sano, and H. Watanabe, "Modeling and control of carbon monoxide concentration using a neuro-fuzzy technique," *IEEE Trans. Fuzzy Systems*, vol. 3, pp. 271–279, Aug. 1995.
- L. Teo, M. Khalid, and R. Yusof, "Self-tuning neuro-fuzzy control by genetic algorithms with an application to a coupled-tank liquid-level control system," *Eng. Appl. of Artificial Intelligence*, vol. 11, pp. 517–529, Aug. 1998.
- M. Tripathy and S. Mishra, "Interval type-2-based thyristor controlled series capacitor to improve power system stability," *Generation, Transmission & Distribution*, vol. 5, pp. 209–222, Feb. 2011.
- C. Wagner, "Juzzy—A Java based toolkit for type-2 fuzzy logic," Proc. of IEEE Symposium on Advances in Type-2 Fuzzy Logic Systems, Singapore, Apr. 2013.

- C. Wagner and H. Hagras, “A genetic algorithm based architecture for evolving type-2 fuzzy logic controllers for real world autonomous mobile robots,” Proceedings of 2007 IEEE Int’l. Conf. on Fuzzy Systems, pp. 193–198, London, July 2007.
- C. Wagner and H. Hagras, “zSlices—towards bridging the gap between interval and general type-2 fuzzy logic,” Proceedings of 2008 IEEE Int’l. Conf. on Fuzzy Systems, Hong Kong, pp. 489–497, 2008.
- C. Wagner and H. Hagras, “Towards general type-2 fuzzy logic systems based on zSlices,” *IEEE Trans. on Fuzzy Systems*, vol. 18, pp. 637–660, Aug. 2010.
- C. Wang, C. Cheng, and T. Lee, “Dynamical optimal training for interval type-2 fuzzy neural network (T2FNN),” *IEEE Trans. on Systems, Man and Cybernetics Part B: Cybernetics*, vol. 34, pp. 1462–1477, June 2004.
- H. O. Wang and K. Tanaka, “An LMI-based stable fuzzy control of nonlinear systems and its application to control of chaos,” Proceedings of 1996 IEEE Int’l. Conf. on Fuzzy Systems, New Orleans, pp. 1433–1438, 1996.
- L.-X. Wang, “Fuzzy systems are universal approximators,” Proc. International Conference on Fuzzy Systems, San Diego, CA, 1992.
- L.-X. Wang, *A Course in Fuzzy Systems and Control*, Englewood Cliffs, NJ: Prentice-Hall, 1997.
- L.-X. Wang and J. M. Mendel, “Fuzzy basis functions, universal approximation, and orthogonal least squares learning,” *IEEE Trans. on Neural Networks*, vol. 3, pp. 807–813, Sept. 1992a.
- L.-X. Wang and J. M. Mendel, “Back-propagation of fuzzy systems as non-linear dynamic system identifiers,” Proceedings of 1992 IEEE Int’l. Conference on Fuzzy Systems, San Diego, CA, pp. 1409–1418, 1992b.
- X. Wang, Y. He, L. Dong, and H. Zhao, “Particle swarm optimization for determining fuzzy measures from data,” *Information Sciences*, vol. 181, pp. 4230–4252, Oct. 2011.
- F. Wei, S. Jun, X. Z.-Ping, and W.-B. Xu, “Convergence analysis of quantum-behaved particle swarm optimization algorithm and study on its control parameter,” *Acta Phys. Sin.*, vol. 59, no. 6, pp. 3686–3694, 2010.
- D. Wu, “An interval type-2 fuzzy logic system cannot be implemented by traditional type-1 fuzzy logic systems,” Proceedings of 2011 World Conference on Soft Computing, San Francisco, 2011.
- D. Wu, “Approaches for reducing the computational cost of interval type-2 fuzzy logic systems: overview and comparisons,” *IEEE Trans. on Fuzzy Systems*, vol. 21, pp. 80–99, Feb. 2013.
- D. Wu, “On the fundamental differences between interval type-2 and type-1 fuzzy logic controllers,” *IEEE Transactions on Fuzzy Systems*, Vol. 20, pp. 832–848, Oct. 2012.
- D. Wu and J. M. Mendel, “Enhanced Karnik-Mendel algorithms,” *IEEE Trans. on Fuzzy Systems*, vol. 17, pp. 923–934, Aug. 2009.
- D. Wu and J. M. Mendel, “On the continuity of type-1 and interval type-2 fuzzy logic systems,” *IEEE Trans. on Fuzzy Systems*, vol. 19, pp. 179–192, Feb. 2011.
- D. Wu and M. Nie, “Comparison and practical implementations of type-reduction algorithms for type-2 fuzzy sets and systems,” Proceedings of 2011 IEEE Int’l. Conf. on Fuzzy Systems, Taipei, Taiwan, pp. 2131–2138, 2011.
- D. Wu and W. Tan, “Type-2 fuzzy logic controller for the liquid-level process,” Proceedings of 2004 IEEE Int’l. Conf. on Fuzzy Systems, Budapest, Hungary, pp. 248–253, 2004.

- D. Wu and W. Tan, "Type-2 FLS modeling capability analysis," Proceedings of 2005 IEEE Int'l. Conf. on Fuzzy Systems, Reno, NV, pp. 242–247, 2005.
- D. R. Wu and W. W. Tan, "Genetic learning and performance evaluation of type-2 fuzzy logic controllers," *Engineering Applications of Artificial Intelligence*, vol. 19, no. 8, pp. 829–841, 2006.
- D. Wu and W. W. Tan, "Interval type-2 fuzzy PI controllers: Why they are more robust," Proceedings of 2010 IEEE Int'l. Conf. on Granular Computing, San Jose, CA, pp. 802–807, 2010.
- H. Wu and J. M. Mendel, "Uncertainty bounds and their use in the design of interval type-2 fuzzy logic systems," *IEEE Trans. on Fuzzy Systems*, vol. 10, pp. 622–639, Oct. 2002.
- R. R. Yager and D. P. Filev, *Essentials of Fuzzy Modeling and Control*, New York: Wiley, 1994.
- S. Yasunobu and S. Miyamoto, "Automatic train operation by fuzzy predictive control," in M. Sugeno (Ed.), *Industrial Applications of Fuzzy Control*, Amsterdam: North Holland, 1985.
- C.-Y. Yeh, W.-H. Roger Jeng, and S.-J. Lee, "An enhanced type-reduction algorithm for type-2 fuzzy sets," *IEEE Trans. on Fuzzy Systems*, vol. 19, pp. 227–240, Apr. 2011.
- J. Yen and R. Langari, *Fuzzy Logic: Intelligence, Control and Information*, Upper Saddle River, NJ: Prentice-Hall, 1999.
- H. Ying, "The simplest fuzzy controllers using different inference methods are different nonlinear proportional–integral controllers with variable gains," *Automatica*, vol. 29, pp. 1579–1589, March 1993a.
- H. Ying, "A fuzzy controller with linear rules is the sum of a global two-dimensional multilevel relay and a local nonlinear proportional-integral controller," *Automatica*, vol. 29, pp. 499–505, March 1993b.
- H. Ying, "Sufficient conditions on general fuzzy systems as function approximators," *Automatica*, vol. 30, pp. 521–525, March 1994a.
- H. Ying, "Practical design of nonlinear fuzzy controllers with stability analysis for regulating processes with unknown mathematical models," *Automatica*, vol. 30, pp. 1185–1195, July 1994b.
- H. Ying, "Sufficient conditions on uniform approximation of multivariate functions by general Takagi-Sugeno fuzzy systems with linear rule consequent," *IEEE Trans. on Systems, Man, and Cybernetics*, vol. 28, pp. 515–520, July 1998a.
- H. Ying, "The Takagi-Sugeno fuzzy controllers using the simplified linear control rules are nonlinear variable gain controllers," *Automatica*, vol. 34, pp. 157–167, February 1998b.
- H. Ying, "Constructing nonlinear variable gain controllers via the Takagi-Sugeno fuzzy control," *IEEE Trans. on Fuzzy Systems*, Vol. 6, pp. 226–234, May 1998c.
- H. Ying, *Fuzzy Control and Modeling: Analytical Foundations and Applications*, Piscataway, NJ: IEEE Press, 2000.
- H. Ying, "Deriving analytical input–output relationship for fuzzy controllers using arbitrary input fuzzy sets and Zadeh fuzzy AND operator," *IEEE Trans. on Fuzzy Systems*, vol. 14, pp. 654–662, October 2006.
- H. Ying, "General interval type-2 Mamdani fuzzy systems are universal approximators," Proceedings of 2008 North American Fuzzy Information Processing Society Conf., New York, pp. 1–6, 2008.

- H. Ying, "Interval type-2 Takagi-Sugeno fuzzy systems with linear rule consequent are universal approximators," Proceedings of 2009 North American Fuzzy Information Processing Society Conf., Cincinnati, OH, pp. 1–5, 2009.
- H. Ying, M. McEachern, D. Eddleman, and L. C. Sheppard, "Fuzzy control of mean arterial pressure in postsurgical patients with sodium nitroprusside infusion," *IEEE Trans. on Biomedical Engineering*, vol. 39, pp. 1060–1070, Oct. 1992.
- H. Ying, W. Siler, and J. J. Buckley, "Fuzzy control-theory—a nonlinear case," *Automatica*, vol. 26, pp. 513–520, May 1990.
- L. A. Zadeh, "Outline of a new approach to the analysis of complex systems and decision processes," *IEEE Trans. on Systems, Man, and Cybernetics*, vol. SMC-3, pp. 28–44, Jan. 1973.
- L. A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning—1," *Information Sciences*, vol. 8, pp. 199–249, 1975.
- S. Zaheer and J. Kim, "Type-2 fuzzy airplane altitude control: A comparative study," Proceedings of 2011 IEEE Int'l. Conf. on Fuzzy Systems, Taipei, Taiwan, pp. 2170–2176, 2011.
- D. Zhai and J. M. Mendel, "Computing the centroid of a general type-2 fuzzy set by means of the centroid flow algorithm," *IEEE Trans. on Fuzzy Systems*, vol. 19, pp. 401–422, June 2011a.
- D. Zhai and J. M. Mendel, "Uncertainty measures for general type-2 fuzzy sets," *Information Sciences*, vol. 181, pp. 503–518, 2011b.
- D. Zhai and J. M. Mendel, "Enhanced centroid-flow algorithm for computing the centroid of general type-2 fuzzy sets," *IEEE Trans. on Fuzzy Systems*, vol. 20, pp. 939–956, Oct. 2012.
- H. Zhou and H. Ying, "Deriving the input–output mathematical relationship for a class of interval type-2 Mamdani fuzzy controllers," Proceedings of 2011 IEEE Int'l. Conf. on Fuzzy Systems, Taipei, Taiwan, pp. 2589–2593, 2011.
- H. Zhou and H. Ying, "A technique for deriving analytical structure of a general class of interval type-2 TS fuzzy controllers," Proceedings of 2012 North American Fuzzy Information Processing Society Conf., Berkeley, CA, pp. 1–6, 2012.
- H. Zhou and H. Ying, "A method for deriving the analytical structure of a broad class of typical interval type-2 Mamdani fuzzy controllers," *IEEE Trans. on Fuzzy Systems*, Vol. 21, pp. 447–458, June 2013.