Available at: www.researchpublications.org

Recent Trends and Applications of Soft Computing: A Survey

Ridhima. A. Dhopte
Department of Computer Science & Engg,
Prof Ram Meghe College of Engg & Mgmt, Badnera
Amravati, India
ridhimadhopte13@gmail.com

Zeba Ali
Department of Computer Science & Engg,
Prof Ram Meghe College of Engg & Mgmt, Badnera
Amravati, India
zernainali@gmail.com

Hrishikesh. S. Dhopte
Department of Computer Science & Engg,
Prof Ram Meghe College of Engg & Research, Badnera
Amravati, India
hrishidhopte@gmail.com

Abstract: This paper is survey on the development of soft computing applications in various domains. Specifically, it briefly reviews main approaches of soft computing (in the wide sense) , the more recent development of soft computing, and finalise by presenting a panoramic view of applications: from the most abstract to the most practical ones. Within this context, fuzzy logic (FL), genetic algorithms (GA) and artificial neural networks (ANN), as well as their fusion are reviewed in order to examine the capability of soft computing methods and techniques to effectively address various hard-to-solve design tasks and issues. This paper presents applications of using different Soft Computation methods in both industrial, biological processes, in engineering design, in investment and financial Trading. It analyses the literature according to the style of soft computing used, the investment discipline used, the successes demonstrated, and the applicability of the research to real world trading.

Keywords: Engineering design; Soft computing; Fuzzy logic; Genetic algorithm; Neural networks; investment and financial trading

I. INTRODUCTION

Soft computing is kind of imprecision, uncertainty, partial truth, and approximation. In effect, the soft computing is inspired by human brain. The principle of soft computing is: Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost and solves the fundamental problem associated with the current technological development, the lack of the required intelligence of the recent information technology that enables human brain functionality. The basic ideas underlying soft computing in its current incarnation have links to many earlier influences.

The inclusion of neural computing and genetic computing in soft computing came at a later point. At this juncture, the principal constituents of Soft Computing [1] (SC) are: Fuzzy Systems (FS), including Fuzzy Logic (FL); Evolutionary Computation (EC), including Genetic Algorithms (GA); Neural Networks (NN), including Neural Computing (NC); Machine Learning (ML); Probabilistic Reasoning (PR).

Fuzzy theory plays an important role in soft computing and this stems from the fact that human reasoning is not crisp and admits degrees. What is important to note is that soft computing is not mishmash. Rather, it is a partnership in which each of the partners contributes a distinct methodology for addressing problems in its domain. In this perspective, the principal constituent methodologies in SC are complementary rather than competitive. Furthermore, soft computing may be viewed as a foundation component for the emerging field of conceptual intelligence.

II. APPLICATIONS OF SOFT COMPUTING

Activities in soft computing have increased since the field started. They do not only focus on theoretical descriptions, but also provide a collection of real-world problems and techniques that are used to solve them. Industry has benefited from adopting these techniques to address a variety of problems that can be seen also by the diverse range of products developed .The applications range from the purely theoretical ones, those which develop new lines in abstract mathematics or logic, passing across the areas of multimedia, reference modelling, information retrieval, hybrid intelligent systems, image processing, etc., to practical applications domains such as robotics and manufacturing, actuarial science, nuclear ,medical, industrial , biological processes , in engineering design , in investment and financial trading.[17,22]

A. Pure and Applied Mathematics

Many of the soft computing techniques originated from purely mathematical concept. The basic mathematical formalisms of fuzzy logic and soft computing have triggered a renewed interest in some old theories, such as that of resituated lattices or the theory of t-norms and copulas, and have initiated a complete redesign of well-established areas such as the theory of differential equations (with the addition of fuzziness), topology (including similarity spaces, tolerance spaces, approximation spaces), development and algebraic study of new logical systems for dealing with vagueness, imprecision and uncertainty.[8]

B. Fuzzy and Similarity Based Reasoning

Existing tools for knowledge representation and reasoning, such as Prolog-based implementations, are being extended to the framework of fuzzy logic or, even, lattice-valued logics. In this sense, we can cite the works. Some other approaches also include the adaptation of enhancements and specific optimization methods, such as the tabulation (or tabling) methods for logic programming.[7,11]

C. Case Based Reasoning

This model of reasoning incorporates problem solving, understanding and learning, and integrates all of them with memory processes. It involves adopting old solutions to meet new demands, using old cases to explain new situations or to justify new solutions, and reasoning from precedents to interpret a new situation. Recent research is demonstrating the role of soft computing tools, both individually and in combination, for performing different tasks of case based reasoning with real life applications.[5]

D. *Multimedia Processing*

Due to their strong learning and cognitive ability, soft computing techniques have found applications in multimedia processing and, nowadays, there is a wide range of research areas of soft computing in multimedia processing including video sequence, color quantization, image retrieval, meeting video, and document image analysis, image segmentation and biometric application. The increased possibilities to capture and analyze images have contributed to create the new scientific field of image processing that has numerous commercial, scientific, industrial and military applications. [24]

E. *Preference Modelling and Decision Making*

Although standard approaches to decision-making problems assumed by default that all the information is expressed in the same preference representation format, in real practice this is hardly possible. As a result, new fuzzy approaches to integrating different preference representation formats in decision-making are of great importance. Moreover, missing information poses additional difficulties that have to be addressed when dealing with real decision-making problems, which leads to topics that are naturally included within the boundaries of fuzzy logic and soft computing. In this respect, theoretical studies on areas such as extensions of fuzzy sets (type-2 fuzzy sets, L-fuzzy sets, interval-valued fuzzy sets, fuzzy rough sets) or aggregation operators (fuzzy measures, linguistic aggregators, inter-valued aggregators) are specially useful. Some specific application domains of preferences modelling are: data-base theory, classification and data mining, information retrieval, non-monotonic reasoning, recommendation systems.[34]

Knowledge engineering applications, with the advent of artificial intelligence, the emphasis on knowledge engineering moved from social and philosophical concepts to the problem of knowledge representation in computers. The inherent synergy of the different methods of soft computing allows to incorporate human knowledge effectively, deal with imprecision and uncertainty, and learn to adapt to unknown or changing environments for better performance. One can see applications to several areas related to management of knowledge, such as knowledge representation, knowledge acquisition, knowledge-based inference, modelling and developing knowledge-based systems, knowledge integration, and knowledge discovery.

F. *Ontologies and Semantic Web*

When analyzing information on the web one has to note the difference between information produced primarily for human consumption and that produced mainly or machines; on the other hand, one has to keep track of information uncertainty. The increasing interest in ontology-based, standard representations of belief-based, possibility and probabilistic information, as well as other types of uncertainty, is bringing soft computing techniques for uncertainty representation and processing to the forefront of semantic web research. In the last few years, a number of seminal workshops and seminars have spread the interest for these issues within both the Semantic Web and the fuzzy logic or soft computing communities. Fuzzy logic has been used to bridge the gap among intuitive knowledge and machine-readable knowledge systems. Much research is also being done on techniques for extracting incomplete, partial or uncertain knowledge, as well as on handling uncertainty when representing extracted information using ontologies, e.g. to achieve semantic interoperability among heterogeneous systems. Semantic Web demands the management of large amounts of fuzzy data and the extraction of fuzzy information. Therefore, automatic tools for reasoning about fuzzy dependencies are necessary, in this line we can cite.[40]

G. *Business and Economics*

Soft computing methods can be used in an uncertain economic decision environment to deal with the vagueness of human thought and the difficulties in estimating inputs. There is a plethora of applications of soft computing in business and economics, which range from marketing (analysis of customer's purchasing attitudes, fraud detection, service quality), to finance (stock market predicting schemes, portfolio selection, risk management, loan assessment systems), electronic business (e-commerce decisions, personalization, risk analysis in e-commerce).

H. *Medical Engineering*

Successful diagnoses and surgical outcomes depend on the experience and skill of examiners with it the risk of failure. Teaching these feelings to beginners is a very difficult task, because the skill of diagnose the feelings is based on subjective evaluation. Thus, the Medical industry requires new engineering technologies, such as soft computing techniques, to assess information objectively. While recent developments in Medical engineering have been achieved by state-of-the-art of intelligent computing techniques, including computer-aided diagnosis, computer-aided radiography, computer-assisted surgery, developments in soft computing, including Information processing, signal/image processing, and data mining seems to be Specially promising in this field.

I. *Information Retrieval*

Information retrieval aims at defining systems able to provide a fast and effective content-based access to a large amount of stored information. Currently, soft computing techniques are being used to model subjectivity and partiality in order to provide a adaptative environment of information retrieval, one which learns the user's concept of relevance. The modelling is performed by the knowledge representation components of SC such as fuzzy logic, probabilistic reasoning, and rough sets. This way, the application of soft computing techniques can be of help to obtain greater exibility in IR systems

J. *Fuzzy Control Applications*

The first application of fuzzy logic to control systems was the design of a fuzzy algorithm for regulating a steam engine by given Mamdani and Assilian. After this starting point, the research and applications of fuzzy control progressed rapidly. Hard computing methodologies are not useful for the construction of the robot control systems of acceptable cost; it is the use of soft computing techniques what allows to overcome the problem of complexity of control systems and, in addition, provides them with abilities of tolerance for imprecise data, and high efficiency and performance.[31]

K. *Robotics*

This field has a number of subareas which can profit from soft computing techniques. For instance, the drive control of a robot is often performed by a neuro-fuzzy system that generates action commands to the motors, the input of this systems comes from the surrounding information, in terms of data obtained by the vision subsystem and the goal identifying device. Then, fuzzy inference mechanisms are usually provided by neural networks. Moreover, the systems are taught how to behave by means of adjusting its knowledge base by a neural network learning technique.

L. *Investment and Finance Trading*

The arena of investment trading is one such field where there is an abundance of noisy data. It is in this area that traditional computing typically gives way to soft computing, as the rigid conditions applied by traditional computing cannot be met. This is particularly evident where the same sets of input conditions may appear to invoke different outcomes, or there is an abundance of

missing or poor quality data. There are a number of approaches within the literatures which deal with applying soft computing techniques to investment and trading. Although there appears to be no formal segmentation of these different approaches, this paper classifies the literature into the topics proposed by Tan, and augments these classifications with one more category, namely, Hybrid. These categories of soft computing,[43] then, are:

1. Time Series – forecasting future data points using historical data sets. Research reviewed in this area generally attempts to predict the future values of some time series. Possible time series include: Base time series data (e.g. Closing Prices), or time series derived from base data, (e.g. Indicators - frequently used in technical Analysis).
2. Pattern Recognition and Classification – attempts to classify observations into categories, generally by learning patterns in the data. Research reviewed in this area involved the detection of patterns, and segregation of base data into 'winner' and 'loser' categories.
3. Optimization – involves solving problems where patterns in the data are not known, often non-polynomial (NP)-complete problems. Research reviewed in this area covered the optimal selection of parameters, and determining the optimal point at which to enter transactions.
4. Hybrid – this category was used to distinguish research which attempted to exploit the synergy effect by combining more than one of the above styles.

There is a wide acceptance of the benefit of the synergy effect, whereby the whole is seen as being greater than the sum of the individual parts.

M. Aerospace Applications

In the early 1990s, Werbos developed on linear optimal neuro control (adaptive critics). It has been applied to aerospace and aircraft control system. Soft computing (neuro, fuzzy, and evolutionary computing) is used for aerospace systems because of the high degrees, of nonlinearity uncertainty, and complexity of these problems and because of the involvement of human being.[48]

Berenji proposed the application of soft computing to NASA space projects such as the orbital operations of the space shuttle, including attitude control and rendezvous docking operations.[48] Alvarez *et al.* used fuzzy approaches for continuous driving of long-range autonomous planetary micro-rovers, which required maximization of the range and number of interesting scientific sites visited during a limited lifetime. They used a complete set of techniques including fuzzy-based control, real-time reasoning, and fast and robust rover position estimation based on odometry, angular rate sensing, and efficient stereo vision.[48]

N. Communications System

Since communication systems involve human beings, soft computing can be effectively applied to such systems. Soft computing enables solutions to be obtained for problems that have not been able to be solved satisfactorily by hard computing methods.

Chaos computing is effectively used for modulation and synchronization of spread sequences in digital communication systems. Neuro-fuzzy approaches are utilized for equalizers and data compression. Network topologies are determined using evolutionary computation. Soft computing is also expected to play an important role in the development of wireless communication systems.

O. Chemical Industries

Different kinds of neural networks and showed that a multilayer perceptron, a radial basis function neural network, and Kohonen feature maps have been innovatively applied to static and dynamic fault diagnosis and to the control of industrial processes, and have been very profitable for the process industry.[39]

Their is two-stage neural network as the basic structure of a fault detection system. The first stage of the network detected the dynamic trend of each measurement, and the second stage diagnosed the fault. Their system was experimentally applied to fault detection and diagnosis of a well-stirred tank reactor and it showed satisfactory performance.[32]

Some expert developed a fuzzy optimization control system for a fluidized catalytic cracking unit (FCCU) in an oil refinery to optimize the cracking product distribution under a variable production environment. First, an adaptive fuzzy relational model with self-learning and prediction control that could interact with a skilled human operator was devised. Then, the structure of fuzzy reasoning was constructed as a total fuzzy expert system. It was successfully tested in a large-scale FCCU and the results showed significant benefits through fuzzy optimization control.[50]

P. Paper Industries

Some expert developed a model for a paper forming process using a neural network. The new model yielded data corresponding to data obtainable along arbitrary scanning lines in planar stochastic fibrous structures, providing profiles, variances, histograms of local area density, and histograms of local free-fiber lengths. These results are very similar to the experimental data from commercial paper samples obtained from radiographic or optical transmission images subjected to image analysis.[49]

III. CONCLUSION

In this paper we have given the information of soft computing application domain . Through this paper expert can choose their work for particular domain. This paper will helpful for the people who wants to contribute for this work field.

ACKNOWLEDGMENT

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression, "One of us (R.B.G.) thanks . . ." Instead, try "R.B.G. thanks". Put applicable sponsor acknowledgments here; DO NOT place them on the first page of your paper or as a footnote.

REFERENCES

List and number all bibliographical references in 9-point Times, single-spaced, at the end of your paper. When referenced in the text, enclose the citation number in square brackets, for example [1]. Where appropriate, include the name(s) of editors of referenced books. The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] was the first . . ."

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors' names; do not use "et al.". Papers that have not been published, even if they have been submitted for publication, should be cited as "unpublished" [4]. Papers that have been accepted for publication should be cited as "in press" [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

[1] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955.

[2] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[3] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[4] K. Elissa, "Title of paper if known," unpublished.

F. T. Martins-Bede, L. Godo, S. Sandri, C. C. Freitas, L. V. Dutra, R. J. P. S. prevalence using fuzzy case-based reasoning. In Proc of IWANN'09 (this issue),

[5] F. T. Martins-Bede, L. Godo, S. Sandri, C. C. Freitas, L. V. Dutra, R. J. P. S. prevalence using fuzzy case-based reasoning. In Proc of IWANN'09 (this issue),2009

[6] Guimar~aes, R. S. Amaral, and O. S. Carvalho. Classi_cation of schistosomiasis

[7] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[8] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[9] P. Juli□an and C. Rubio-Manzano. A similarity-based wam for bousi-prolog. In

[10] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[11] J. Medina. Overcoming non-commutativity in multi-adjoint concept lattices. In proc of IWANN'09.

[12] Electronic Publication: Digital Object Identifiers (DOIs):

[13] S. Munoz-Hernandez, V. Pablos Ceruelo, and H. Strass. Rfuzzy: an expressive

In Proc of IWANN'09 (this issue), 2009.

[14] D. Kornack and P. Rakic, "Cell Proliferation without Neurogenesis in Adult Primate Neocortex," Science, vol

. 52, 2006.

94, Dec. 2001, pp. 2127-2130, doi:10.1126/science.1065467. **(Article in a journal)**

[15] H. Goto, Y. Hasegawa, and M. Tanaka, "Efficient Scheduling Focusing on the Duality of MPL Representatives," Proc. IEEE Symp. Computational Intelligence in Scheduling (SCIS 07), IEEE Press, Dec. 2007, pp. 57-64, doi:10.1109/SCIS.2007.357670. **(Article in a conference proceedings).**

[16] Tan , C.N.W. **,** Artificial Neural Network:Application **in** Financial Distress Prediction And Foriegn Exchange Trading . 2001, gold coast ,QLD: Wilberto

[17] Chan, K.C.C. and K.T. Foo. Enhancing TechnicalAnalysis in the Forex market using Neural Networks. In IEEE International Conference on Neural Networks 1995.

[18] Yao, J. and H.-L. Poh. Forecasting the KLSE index

using Neural Networks. in IEEE International Conference on Neural Networks. 1995.

[19] Hobbs, A. and N.G. Bourbakis. A Neurofuzzy Arbitrage

Simulator for Stock Investing. in Computational Intelligence for Financial Engineering (CIFER). 1995. New York.

[20] Austin, M., C. Looney, and J. Zhuo, Security Market

timing using Neural Network Models. New Review of

Applied Expert Systems, 1997. 3: p. 3-14. Mathematical Point of View. Vieweg-Verlag, 1993.

[21] S. Guadarrama, S. Mu~noz, and C. Vaucheret. Fuzzy prolog: a new approach using

soft constraints propagation. Fuzzy Sets and Systems, 144(1):127{150, 2004.

1. P. H_ajek. Metamathematics of Fuzzy Logic. Kluwer, 1998.

[22] Z.-G. Hou, M. M. Polycarpou, and H. He. Special issue on neural networks for

pattern recognition and data mining. Soft Computing, 12(7), 2008.

[23] M. Jamshidi. Special issue on neural networks and fuzzy logic: theory and applications

in robotics and manufacturing. Comput. Electr. Eng., 19(4), 1993.

[24] C. Lopez-Molina, E. Barrenechea, H. Bustince, P. Couto, B. D. Baets, and

J. Fern_andez. Edge detection based on gravitational forces. In Proc of IWANN'09

(this issue), 2009.

[25] P. Juli_an, G. Moreno, and J. Penabad. On the declarative semantics of multiadjoint

logic programs. In Proc of IWANN'09 (this issue), 2009.

[26] P. Juli_an and C. Rubio-Manzano. A similarity-based wam for bousi-prolog. In

Proc of IWANN'09 (this issue), 2009.

[27] J. Kennedy and R. C. Eberhart. Particle swarm optimization. In IEEE Interna-

tional Conference on Neural Networks, pages 1942{1948, 1995.

[28] S. W. Kercel. Industrial applications of soft computing. IEEE Transactions on

Systems, Man and Cybernetics, 36(4):450{452, 2006.

[29] H. Takagi, "R&D in intelligent technologies: Fusion of NN, FL, GA,

chaos, and human," in Half-Day Tutorial/Workshop, IEEE Int. Conf.

Systems, Man, and Cybernetics, Orlando, FL, 1997.

[30] S. J. Ovaska, Y. Dote, T. Furuhashi, A. Kamiya, and H. F. VanLandingham,

"Fusion of soft computing and hard computing techniques: A review of applications," in Proc. IEEE Int. Conf. Systems, Man, and Cybernetics, Tokyo, Japan, 1999, pp. 370–375.

[31] E. H. Mamdani and S. Assilian. An experiment in linguistic synthesis with a fuzzy

[32] Y. Maki and K. A. Loparo, "A neural-network approach to fault detection and diagnosis in industrial processes," *IEEE Trans. Contr. Syst. Technol.*, vol. 5, pp. 529–541, Nov. 1997. logic controller. Int. J. Man-Machine Studies, 7:1{13, 1975.

[33] A. Kamiya, K. Kawai, I. Ono, and S. Kobayashi, "Adaptive-edge

search for power plant start-up scheduling," IEEE Trans. Syst., Man, Cybern. C, vol. 29, pp. 518–530, Nov. 1999.

[34] J. Wen, S. Cheng, and O. P. Malik, "A synchronous generator fuzzy

excitation controller optimally designed with a genetic algorithm," IEEE Trans. Power Syst., vol. 13, pp. 884–889, Aug. 1998.

[35] C.-W. Liu, M.-C. Su, S.-S. Tsay, and Y.-J. Wang, "Application of a

novel fuzzy neural network to real-time transient stability swings prediction based on synchronized phasor measurements," IEEE Trans. Power Syst., vol. 14, pp. 6 85–692, May 1999.

[36] P. Juli_an, G. Moreno, and J. Penabad. On the declarative semantics of multiadjoint logic programs. In Proc of IWANN'09 (this issue), 2009.

[37] A. L. B. do Bomfim, G. N. Taranto, and D. M. Falcano, "Simultaneous

tuning of power system damping controllers using genetic

algorithms," IEEE Trans. Power Syst., vol. 15, pp. 163–169, Feb. 2000.

[38] R. Segal, M. L. Kothari, and S. Madnani, "Radial basis function

(RBF) network adaptive power systems stabilizer," IEEE Trans. Power Syst., vol. 15, pp. 722–727, May 2000.

.

[39] H. N. Koivo, "Neural networks in automation-fault diagnosis and control," in *Proc. IEEE Int.Workshop on Soft Computing in Industry*, Muroran, Japan, 1993, pp. 10–17.

[40] K.-H. Kim, H.-S. Youn, and Y.-C. Kang, "Short-term load forecasting

for special days in anomalous load conditions using neural

networks and fuzzy inference method," IEEE Trans. Power Syst., vol. 15, pp. 459–565, May 2000.

[41] P.Cordero, M.Enciso, A. Mora, and I. de Guzm_an. A complete logic for fuzzy functional

dependencies over domains with similarity relations. In Proc of IWANN'09.

.

[42] Tan, C.N.W., Artificial Neural Networks: Applications

in Financial Distress Prediction and Foreign Exchange

Trading. 2001, Gold Coast, QLD: Wilberto

[43] I. F. MacGill and R. J. Kaye, "Decentralized coordination of power

system operation using dual evolutionary programming," IEEE Trans. Power Syst., vol. 14, pp. 112–119, Feb. 1999.

[44] M. A. Matos, N. D. Hatziargyriou, and J. A. P. Lopes, "Multi-contingency

steady state security evaluation using fuzzy clustering techniques," IEEE Trans. Power Syst., vol. 15, pp. 177–183, Feb. 2000.

[45] K. O.Wong and J.Yuryevich, "Evolutionary-programming-based algorithm

for environmentally-constrained economic dispatch," IEEE Trans. Power Syst., vol. 13, pp. 301–306, May 1998.

[46] C. W. Richter and G. B. Sheble, "A profit-based unit commitment

GA for the competitive environment,," IEEE Trans. Power Syst., vol. 15, pp. 715–721, May 2000.

[47] H. R. Berenji, "Computational intelligence and soft computing for space applications," *IEEE Aerosp. Electron. Syst. Mag.*, vol. 11, no. 8, pp. 8–10, 1996

[48] J. Huang and C.-L. Huang, "Application of genetic-based neural

networks to thermal unit commitment," IEEE Trans. Power Syst., vol. 12, pp. 654–660, May 1997.

.

[49] J. Scharcanski and C. T. J. Dodson, "Neural network model for paper-forming process," *IEEE Trans. Ind. Applicat.*, vol. 33, pp.826–839, May/June 1997

[50] Y.-Z. Lu, M. He, and C.-W. Xu, "Fuzzy modeling and expert optimization

control for industrial processes," IEEE Trans. Contr. Syst.

Technol., vol. 5, p. 212, Jan. 1997.