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Belief rule base inference method based on gradient descent with momentum

FIRST A. AUTHOR[1], (Fellow, IEEE), SECOND B. AUTHOR[2], AND THIRD C. AUTHOR, JR.[3], (Member, IEEE)

[1]National Institute of Standards and Technology, Boulder, CO 80305 USA (e-mail: author@boulder.nist.gov)
[2]Department of Physics, Colorado State University, Fort Collins, CO 80523 USA (e-mail: author@lamar.colostate.edu)
[3]Electrical Engineering Department, University of Colorado, Boulder, CO 80309 USA

Corresponding author: First A. Author (e-mail: author@ boulder.nist.gov).

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ABSTRACT

The belief-rule-base(BRB) inference methodology using evidential reasonging(ER) approach is widely used in different fields, such as fault diagnosis, system identification and decision analysis. In this paper, we propose a new belief rule structure and its training method, aiming to solve zero activation during the inference process and improve inference accuray. We first used the Gaussian function to calculate the similarity of each attribute instead of the original method. Then we introduce corresponding attribute weight for each rule and cancel the rule weight parameter at the same time. Finally, we use the stochastic gradient descent method for parameters training based on the new rule structure. Experiments on several public classification datasets are conducted to validate the proposed approach compared with some recent existing works. The experimental results show that the proposed approach have a better performence in accuray and time consumption.

INDEX TERMS belief rule base, structure optimization, stochastic gradient descent, momentum optimization.

I. INTRODUCTION

The belief rule-based inference methodology using evidential reasonging approach(RIMER) proposed by Yang [1] baesd on traditional IF-THEN rules [2], Dempster-Shafer theory of evidence [3], [4], decision theory [5] and fuzzy set theory [6]. By introducing a belief distribution structure in the rules, this methodology can effectively handle incomplete and uncertain information involved in the datasets and widely used in various problem in different fields such as oil pipeline leak detection [7], military capability estimation [8], consumer behavior prediction [9] and so on.

In the inference process of the BRB system, the attribute weight, rule weight, belief distribution and other parameters directly affect the final accuray. Yang [10] proposed optimization models for training BRB system using fmincon solver in Matlab, Chang [11], [12] proposed an algorithm for training parameters in BRB system based on gradient and dichotomy methods, Wu [13] used the accelerating of gradient algorithm to improve the convergence accuray and convergence speed. There are also a series of intelligent algorithms such as the particle swarm algorithm proposed by Su [14] and the differential evolution algorithm proposed by Wang [15] have excellent training effects on the BRB system. Liu [16] introduces the belief distribution structure into the antecedent attributes and uses training data to build an extended belief rule base(EBRB) system, which simplifies the construction of the rule base and improves the inference speed.

At present, the parameter optimization model of the BRB system is mostly based on various intelligent algorithms. Their process is complicated and there are many intermediate training parameters. When the traditional gradient method is used to train the parameters of the BRB system, the step size is restricted by a variety of constraints, and other methods are needed to find the optimal step size. The EBRB system does not introduce a parameter training process, which makes the system have higher requirements for the representativeness of the training data selected to build the rule base. In the case of a large number of rules, it is necessary to perform rule reduction or use the data structure to optimize the storage

and activation process of the rules. Because the traditional BRB system includes the rule attribute reference level setting, its potential zero activation problem may cause the inference system to fail.

In response to the above problems, we have proposed a series of optimization modifications to the system structure and reasoning process, including:

1) We propose a new antecedent structure that does not need to set the attribute reference level, and proposed a Gaussian function-based rule weight activation method for the new rule antecedent structure, which can effectively avoid the zero activation problem and has the feature of generating rules from the training data like EBRB.

2) We change the method of setting the weight of the global same antecedent attribute in the traditional BRB system, and set the corresponding rule attribute weight parameter for each rule, so that each rule has a finer activation granularity. On this basis, the rule weight and its related normalization process are cancelled, which simplifies the evidential reasoning process.

3) We further introduce the linear rectification function and the normalized exponential function to preprocess the restricted parameters to avoid the problem of parameter failure during the parameter training process.

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Be aware of the different meanings of the homophones "affect" (usually a verb) and "effect" (usually a noun), "complement" and "compliment," "discreet" and "discrete," "principal" (e.g., "principal investigator") and "principle" (e.g., "principle of measurement"). Do not confuse "imply" and "infer."

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4) Tables

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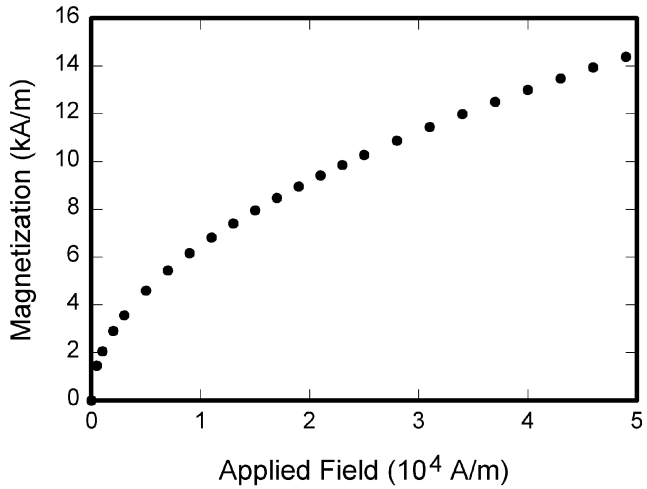

FIGURE 1. Magnetization as a function of applied field. It is good practice to explain the significance of the figure in the caption.

TABLE 1. Units for Magnetic Properties

Symbol	Quantity	Conversion from Gaussian and CGS EMU to SI [a]
Φ	magnetic flux	1 Mx $\rightarrow 10^{-8}$ Wb $= 10^{-8}$ V·s
B	magnetic flux density, magnetic induction	1 G $\rightarrow 10^{-4}$ T $= 10^{-4}$ Wb/m^2
H	magnetic field strength	1 Oe $\rightarrow 10^3/(4\pi)$ A/m
m	magnetic moment	1 erg/G $=$ 1 emu $\rightarrow 10^{-3}$ A·m^2 $= 10^{-3}$ J/T
M	magnetization	1 erg/(G·cm^3) $=$ 1 emu/cm^3 $\rightarrow 10^3$ A/m
$4\pi M$	magnetization	1 G $\rightarrow 10^3/(4\pi)$ A/m
σ	specific magnetization	1 erg/(G·g) $=$ 1 emu/g $\rightarrow$ 1 A·m^2/kg
j	magnetic dipole moment	1 erg/G $=$ 1 emu $\rightarrow 4\pi \times 10^{-10}$ Wb·m
J	magnetic polarization	1 erg/(G·cm^3) $=$ 1 emu/cm^3 $\rightarrow 4\pi \times 10^{-4}$ T
χ, κ	susceptibility	1 $\rightarrow 4\pi$
χ_ρ	mass susceptibility	1 cm^3/g $\rightarrow 4\pi \times 10^{-3}$ m^3/kg
μ	permeability	1 $\rightarrow 4\pi \times 10^{-7}$ H/m $= 4\pi \times 10^{-7}$ Wb/(A·m)
μ_r	relative permeability	$\mu \rightarrow \mu_r$
w, W	energy density	1 erg/cm^3 $\rightarrow 10^{-1}$ J/m^3
N, D	demagnetizing factor	1 $\rightarrow 1/(4\pi)$

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.

[a]Gaussian units are the same as cg emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

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Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity "Magnetization," or "Magnetization M," not just "M." Put units in parentheses. Do not label axes only with units. As in Fig. 1, for example, write "Magnetization (A/m)" or "Magnetization ($A \cdot m^{-1}$)," not just "A/m." Do not label axes with a ratio of quantities and units. For example, write "Temperature (K)," not "Temperature/K."

Multipliers can be especially confusing. Write "Magnetization (kA/m)" or "Magnetization (10^3 A/m)." Do not write "Magnetization (A/m) $\times$ 1000" because the reader would not know whether the top axis label in Fig. 1 meant 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 10 point type.

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SECOND B. AUTHOR was born in Greenwich Village, New York, NY, USA in 1977. He received the B.S. and M.S. degrees in aerospace engineering from the University of Virginia, Charlottesville, in 2001 and the Ph.D. degree in mechanical engineering from Drexel University, Philadelphia, PA, in 2008.

From 2001 to 2004, he was a Research Assistant with the Princeton Plasma Physics Laboratory. Since 2009, he has been an Assistant Professor with the Mechanical Engineering Department, Texas A&M University, College Station. He is the author of three books, more than 150 articles, and more than 70 inventions. His research interests include high-pressure and high-density nonthermal plasma discharge processes and applications, microscale plasma discharges, discharges in liquids, spectroscopic diagnostics, plasma propulsion, and innovation plasma applications. He is an Associate Editor of the journal *Earth, Moon, Planets*, and holds two patents.

Dr. Author was a recipient of the International Association of Geomagnetism and Aeronomy Young Scientist Award for Excellence in 2008, and the IEEE Electromagnetic Compatibility Society Best Symposium Paper Award in 2011.

THIRD C. AUTHOR, JR. (M'87) received the B.S. degree in mechanical engineering from National Chung Cheng University, Chiayi, Taiwan, in 2004 and the M.S. degree in mechanical engineering from National Tsing Hua University, Hsinchu, Taiwan, in 2006. He is currently pursuing the Ph.D. degree in mechanical engineering at Texas A&M University, College Station, TX, USA.

From 2008 to 2009, he was a Research Assistant with the Institute of Physics, Academia Sinica, Tapei, Taiwan. His research interest includes the development of surface processing and biological/medical treatment techniques using nonthermal atmospheric pressure plasmas, fundamental study of plasma sources, and fabrication of micro- or nanostructured surfaces.

Mr. Author's awards and honors include the Frew Fellowship (Australian Academy of Science), the I. I. Rabi Prize (APS), the European Frequency and Time Forum Award, the Carl Zeiss Research Award, the William F. Meggers Award and the Adolph Lomb Medal (OSA).