Information Sciences 343–344 (2016) 15–40

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

A novel similarity measure between intuitionistic fuzzy sets based on the centroid points of transformed fuzzy numbers with applications to pattern recognition

Shyi-Ming Chen[a,*], Shou-Hsiung Cheng[b,c], Tzu-Chun Lan[a]

[a] Department of Computer Science and Information Engineering, National Taiwan University of Science and Technology, Taipei, Taiwan
[b] Department of Information Management, Chienkuo Technology University, Changhua, Taiwan
[c] Department of Kinesiology Health Leisure Studies, Chienkuo Technology University, Changhua, Taiwan

ARTICLE INFO

Article history:
Received 6 April 2015
Revised 13 January 2016
Accepted 18 January 2016
Available online 1 February 2016

Keywords:
Centroid points
Intuitionistic fuzzy values
Intuitionistic fuzzy sets
Right-angled triangular fuzzy numbers
Similarity measures

ABSTRACT

In this paper, we propose a new similarity measure between intuitionistic fuzzy values based on the centroid points of transformed right-angled triangular fuzzy numbers. We also prove some properties of the proposed similarity measure between intuitionistic fuzzy values. Based on the proposed similarity measure between intuitionistic fuzzy values, we propose a new similarity measure between intuitionistic fuzzy sets. We also apply the proposed similarity measure between intuitionistic fuzzy sets to deal with pattern recognition problems. The experimental results show that the proposed similarity measure between intuitionistic fuzzy sets can overcome the drawbacks of the existing similarity measures. The proposed similarity measure provides us with a useful way for dealing with pattern recognition problems in intuitionistic fuzzy environments.

1. Introduction

In [1], Atanassov proposed the concepts of intuitionistic fuzzy sets based on the concepts of fuzzy sets [51], where an intuitionistic fuzzy set is characterized by a membership function and a non-membership function. Intuitionistic fuzzy sets have widely been applied to many fields, such as cluster analysis [6,42,43,45,53], pattern recognition [4,8–15,26,34–36,46,50], medical diagnosis [4,8–15,36], decision-making [12,13,20,22–24,37,40,44,46,48,49]. In [19], Gau and Buehrer presented the concept of vague sets. In [5], Bustince and Burillo have pointed out that vague sets are intuitionistic fuzzy sets. In recent years, some methods [2–4,7–9,11,14,16,18,21,25–36,38,39,41,47,50,52] have been presented to deal with similarity measures between intuitionistic fuzzy sets. Baccour et al. [2] reviewed some similarity measures between intuitionistic fuzzy sets. Beliakov et al. [3] presented a vector-valued similarity measure for intuitionistic fuzzy sets, where they used a two-component vector for the representation of the similarity measure between intuitionistic fuzzy sets: one of which assesses the actual similarity and the other assesses the hesitancy aspects. Boran and Akay [4] presented a bi-parametric similarity measure between intuitionistic fuzzy sets. Chen [7] presented some similarity measures between vague sets and between elements. Chen and Chang [8] presented a similarity measure between intuitionistic fuzzy sets based on transformation techniques with applications to pattern recognition. Chen and Randyanto [9] presented a similarity measure between

* Corresponding author. Tel.: +886 2 27376417; fax: +886 2 27301081.
E-mail address: smchen@mail.ntust.edu.tw (S.-M. Chen).

http://dx.doi.org/10.1016/j.ins.2016.01.040
0020-0255/

intuitionistic fuzzy sets based on the medians of intervals, the Hausdorff distance, and the ratio of the uncertainty degrees of intuitionistic fuzzy values. Grzegorzewski [21] presented some distance measures between intuitionistic fuzzy sets based on the Hausdorff metric. However, in [11], Chen pointed out some errors of Lemma 4 presented by Grzegorzewski [21] by counterexamples, where he found that the inequalities of the Euclidean distances and the normalized Euclidean distances for intuitionistic fuzzy sets are not valid. Dengfeng and Chuntian [16] presented several similarity measures between intuitionistic fuzzy sets with applications to pattern recognition. Fan and Zhangyan [18] presented a similarity measure between intuitionistic fuzzy sets. Hong and Kim [25] presented some similarity measures between vague sets and between elements. Hung and Yang [26] presented some similarity measures between intuitionistic fuzzy sets based on the Hausdorff distance. Hung and Yang [27] presented some similarity measures between intuitionistic fuzzy sets and applied them to evaluate students' answerscripts. Hwang et al. [28] presented a similarity measure between intuitionistic fuzzy sets based on the Sugeno integral with applications to pattern recognition. Iancu [29] presented some similarity measures between intuitionistic fuzzy sets based on the Frank family of t-norms. Li et al. [30] discussed the relationship between similarity measures and the entropy of intuitionistic fuzzy sets and presented new similarity measures based on the entropy of intuitionistic fuzzy sets. Li et al. [31] compared and analyzed some similarity measures between intuitionistic fuzzy (vague) sets. Li et al. [32] presented a similarity measure between vague sets. Liang and Shi [33] presented some similarity measures between intuitionistic fuzzy sets. Liu [34] presented similarity measures between intuitionistic fuzzy sets and between elements. Mitchell [35] presented a similarity measure between intuitionistic fuzzy sets to overcome the drawback of Dengfeng and Chuntian's similarity measure [16], where he pointed out that Dengfeng and Chuntian's operator may get counter-intuitive results in some situations. Papakostas et al. [36] made an analysis of the distance and similarity measures for intuitionistic fuzzy sets from a pattern recognition point of view. Szmidt and Kacprzyk [38] presented a method to measure the degree of similarity between intuitionistic fuzzy sets based on the normalized Hamming distance and the normalized Euclidean distance. Wang and Chen [39] presented a method to evaluate students' answerscripts based on the similarity measure between vague sets. Wang and Xin [41] presented some distance measures between intuitionistic fuzzy sets with applications to pattern recognition. Xu [47] presented some similarity measures between intuitionistic fuzzy sets and applied these similarity measures to multiple attribute decision making under intuitionistic fuzzy environments. Ye [50] presented a cosine similarity measure and a weighted cosine similarity measure between intuitionistic fuzzy sets and applied these similarity measures to pattern recognition and medical diagnosis. Zhang and Yu [52] presented two distance measures between intuitionistic fuzzy sets and compared them with some existing distance measures. However, because the existing similarity measures [4,7–9,16,25,26,32–35,50,52] between intuitionistic fuzzy sets cannot determine the classification result of an unknown pattern in some situations for dealing with pattern recognition problems, we need to develop a new similarity measure between intuitionistic fuzzy sets to overcome the drawbacks of the existing similarity measures for dealing with pattern recognition problems.

In this paper, we propose a new method to measure the degree of similarity between intuitionistic fuzzy sets based on the centroid points of the transformed right-angled triangular fuzzy numbers. We also apply the proposed similarity measure between intuitionistic fuzzy sets to deal with pattern recognition problems. First, we transform intuitionistic fuzzy values into right-angled triangular fuzzy numbers. Then, we propose a new similarity measure between intuitionistic fuzzy values based on the centroid points of the transformed right-angled triangular fuzzy numbers. We also prove some properties of the proposed similarity measure between intuitionistic fuzzy values. Then, based on the proposed similarity measure between intuitionistic fuzzy values, we propose a new similarity measure between intuitionistic fuzzy sets. Then, we use some examples to illustrate that the proposed similarity measure between intuitionistic fuzzy sets can overcome the drawbacks of the existing similarity measures. Finally, we apply the proposed similarity measure between intuitionistic fuzzy sets to deal with pattern recognition problems and medical diagnosis problems. The main contribution of this paper is that we propose a similarity measure between intuitionistic fuzzy sets to overcome the drawbacks of the existing similarity measures [4,7–9,16,18,25,26,32–35,50,52] for dealing with pattern recognition problems.

The rest of this paper is organized as follows. In Section 2, we briefly review some concepts of intuitionistic fuzzy sets [1] and the properties of similarity measures [27] between intuitionistic fuzzy sets. In Section 3, we briefly review some existing similarity measures between intuitionistic fuzzy sets. In Section 4, we analyze the drawback of Chen and Cheng's similarity measure [8]. In Section 5, we propose a new similarity measure between intuitionistic fuzzy values based on the centroid points of the transformed right-angled triangular fuzzy numbers. We also propose a new similarity measure between intuitionistic fuzzy sets based on the proposed similarity measure between intuitionistic fuzzy values. In Section 6, we compare the experimental results of the proposed similarity measure and the ones of the existing similarity measures. In Section 7, we apply the proposed similarity measure of intuitionistic fuzzy sets for dealing with pattern recognition problems and medical diagnostic problems. The conclusions are discussed in Section 8.

2. Preliminaries

In this section, we briefly review some concepts of intuitionistic fuzzy sets [1] and the properties of similarity measures [27] between intuitionistic fuzzy sets.

Definition 2.1 [1]. Let $\tilde{A}$ be an intuitionistic fuzzy set in the universe of discourse X, where $X = \{x_1, x_2, \ldots, x_n\}$, $\tilde{A} = \{\langle x_i,\ \mu_{\tilde{A}}(x_i),\ \upsilon_{\tilde{A}}(x_i)\rangle | x_i \in X\}$, $\mu_{\tilde{A}} : X \to [0,\ 1]$, $\upsilon_{\tilde{A}} : X \to [0, 1]$, $\mu_{\tilde{A}}(x_i)$ and $\upsilon_{\tilde{A}}(x_i)$ denote the degree of membership and