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Fuzzy risk analysis in poultry farming using a new similarity measure on generalized fuzzy numbers

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ABSTRACT

Similarity measure of fuzzy numbers plays an important role in the risk analysis problem. Generally, it is tool, which gives lingustic term to the risk obtained. In recent times, a vast numbers of literature are evident on application of similarity measure in risk analysis. It has been observed that the existing similarity measure on fuzzy numbers have numerous drawbacks and limitations. Hence, a robust method of similarity measure is necessary. With this point of view, a new method to measure the degree of similarity between fuzzy numbers has been proposed. The method has been discussed based on the concept of value, ambiguity, radius of gyration point, geometric distance and the height of fuzzy numbers. The concept of value and ambiguity have never been used in similarity measure of fuzzy numbers. However, the inclusion of these concepts value and ambiguity contributed in many ways in overcoming the limitations and drawbacks of the existing similarity measures. The out-performance of the proposed method is illustrated by comparing with existing methods of similarity measure. Further the proposed method is effectively applied in risk analysis of poultry farming.

1. Introduction

Fuzzy risk analysis has become very popular in recent times as the knowledge of expressing imprecise quantity in terms of fuzzy numbers has emerged. Most of the time similarity measure between fuzzy numbers is used in the risk analysis problem and other decision making problem. The similarity measures are defined on the different characteristic of the fuzzy number such as geometric distance, center of gravity (COG), area, radius of gyration (ROG) etc. Further, these measures are being generalized for use in different types of fuzzy numbers. It has been observed that the existing similarity measures on fuzzy numbers bear various limitations and drawbacks.

A review of some of the existing methods to measure the degree of similarity reveals various limitations and drawbacks. Chen (1996) defined a similarity measure based on the geometric distance. This definition does not carry the information about the shape of the fuzzy numbers such as triangular, trapezoidal, etc. Hence, in many circumstances this method fails to give a proper degree of similarity between fuzzy numbers. Hsieh and Chen (1999) proposed a similarity measure between two fuzzy numbers using graded mean integration representation distance. This method has no contribution from heights and shapes of the fuzzy numbers. Hence, the method is confined to normal fuzzy numbers. As like Hsieh and Chen's method Lee's (2002) method is just confined to normal fuzzy numbers. As such, it is not going to give correct similarity between fuzzy numbers having different heights and shapes. So far, the information about the heights is missing in the similarity measures. Hence, Chen and Chen (2001) developed a similarity measure for generalized fuzzy number (GFN) using the concept of the COG. Although this method seems to outperform in many situations, yet drawbacks are obtained in some situations as discussed in the Section 3. Replacing Chen and Chen's COG by ROG, Yong, Wenkang, Feng, and Qi (2004) proposed a new similarity measure and applied in pattern recognition problems. The method seems very promising. However, it fails to give proper similarity between crisp-valued fuzzy numbers. Wei and Chen (2009) proposed a measure based on the geometric distance and the perimeter of the fuzzy numbers. However, the method fails to give proper similarity between fuzzy numbers depicting similar shape located at different positions. Xu, Shang, Qian, and Shu (2010) again used the COG and the geometric distance in measuring the degree of similarity between GFNs. Although the method is based on GFNs yet it fails to measure similarity between fuzzy numbers depicting similar shape with different heights. Hejazi, Doostparast, and Hosseini (2011) used the concept of geometric distance, perimeter, area and height to discuss the degree of similarity. However, the drawbacks are pointed out by Patra and Mondal (2015). Recent study of similarity based on area, geometric distance and height

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Nomenclature

A_ω	fuzzy number with height ω
A_{ω_1,ω_2}	fuzzy number with left height ω_1 and right height ω_2
μ_A	membership function fuzzy number A
ar(A)	area of the fuzzy number A
Amb(A)	ambiguity of the fuzzy number A
Val(A)	value of the fuzzy number A
I_x	moment of inertia with respect to x-axis
I_y	moment of inertia with respect to y-axis
r_x	radius of gyration point with respect to x-axis
r_y	radius of gyration point with respect to y-axis
(x_A^*,y_A^*)	center of gravity point of the fuzzy number A
$P(A)$	perimeter of the fuzzy number A
(r_x^A,r_y^A)	radius of gyration point of the fuzzy number A
$S(A,B)$	similarity measure between fuzzy numbers A and B

was done by Patra and Mondal. In many situations, its drawbacks are obtained as discussed in Section 3. Moreover, a very recent study by Khorshidi and Nikfalazar (2017) clearly criticized the study by Patra and Mondal pointing out its drawbacks. Khorshidi and Nikfalazar (2017) in 2017 developed a modified method to measure the degree of similarity. This method is based on the existing concepts such as geometric distance, COG, areas, perimeters and heights of the GFNs. This method seems to outperform in many situations. Eventually, its drawback has been obtained as discussed in Section 3.

As mentioned earlier, similarity measure is often used in the risk analysis problem. Schmucke (1984) first introduced the fuzzy risk analysis in production system using the parameters probability of failure and severity of loss. Different researchers have proposed different methods at different times for the risk analysis problem. Most of the times, due to its nature the parameters involved in those risk analysis problems are expressed as linguistic terms. Kangari and Riggs (1989) proposed a method of risk analysis using linguistic terms. Some of the studies involving risk analysis are Chen (1996), Chen and Chen (2001, 2003, 2007), Tang and Chi (2005), Wang and Elhag (2006) etc. Even in recent years some study focused the idea on risk analysis expressing the linguistic terms in terms of interval-valued fuzzy numbers (Gorzalczany, 1987; Guijun & Xiaoping, 1998; Hong & Lee, 2002; Wang & Li, 1999).

This study conveys that a proper and efficient method to measure the degree of similarity is lacking. Hence, a robust method of similarity measure of GFNs has been proposed. The proposed method is based on the concepts of geometric distance, value, ambiguity, area and heights of the GFN. The proposed method seems to outperform in all situations as discussed by the numerical examples in the comparative study in Section 5. The method has been discussed using the concept of GFN with different left heights and right heights. The method is not just confined to GFN with different left heights and right heights, but also can handle all types of fuzzy numbers. Further, effort has been made to apply the proposed similarity measure in the risk analysis problem. A real-life problem of risk analysis in poultry farming has been demonstrated. The parameters probability of failure and severity of loss are expressed by linguistic terms. Under the assumed parameters the total risk of probability of failure using the proposed similarity measure turn out to be 'Fairly low'. Hence, under such circumstances a farmer can successfully establish a poultry farm for self-employment.

The rest of the paper is organized as follows. Section 2 introduces the basic definitions of GFN and also related definitions to the discussions. Section 3 refers to a brief review of the existing method of similarity measure and also the limitations and drawbacks are pointed out. Section 4 proposes a new similarity measure of GFN. Also, its properties and main characteristic are discussed. In Section 5 a comparative study through numerical examples to highlight the advantages of the proposed similarity measure has been performed. In Section 6 a risk analysis on real-life problem on poultry farming has been performed. Finally, in Section 7 conclusions and main features of the proposed method are highlighted.

2. Definitions and notations

In this section, brief review of some concepts of GFN with different left height and right height are put forwarded.

Definition 2.1. If X is a collection of objects, then a fuzzy set A in X is a set of ordered pairs:

$$A = \{(x,\mu_A(x)): x \in X, \mu_A: X \to [0,1]\}. \tag{1}$$

Definition 2.2 (*Basu, 2005*). A null set is denoted by Φ, and is that fuzzy set for which the membership grade for each element is zero. Thus,

$$\Phi = \{(x,\mu_A(x)): x \in X, \mu_A(x) = 0\}. \tag{2}$$

Definition 2.3. A fuzzy number A_ω is an ordered pair $(\underline{A}_\omega(r),\overline{A}_\omega(r))$ of functions $\underline{A}_\omega(r)$ and $\overline{A}_\omega(r), 0 \leqslant r \leqslant \omega$, satisfying the following properties:

(1) $\underline{A}_\omega(r)$ is a bounded monotonic increasing left continuous function over the interval $[0,\omega]$,
(2) $\overline{A}_\omega(r)$ is a bounded monotonic decreasing left continuous function over the interval $[0,\omega]$,

where $0 \leqslant \omega \leqslant 1$ is the height.

Consider a trapezoidal fuzzy number $A_\omega = (a_1,a_2,a_3,a_4;\omega)$ with height ω, then the membership function is defined as

$$\mu_{A_\omega}(x) = \begin{cases} \frac{\omega(x-a_1)}{a_2-a_1}, & \text{if } a_1 \leqslant x \leqslant a_2, \\ \omega, & \text{if } a_2 \leqslant x \leqslant a_3, \\ \frac{\omega(a_4-x)}{a_4-a_3}, & \text{if } a_3 \leqslant x \leqslant a_4, \\ 0, & \text{otherwise,} \end{cases} \tag{3}$$

where ω is the height of the fuzzy number. Then, the functions $\underline{A}_\omega(r)$ and $\overline{A}_\omega(r)$ are defined as

$$\underline{A}_\omega(r) = a_1 + \frac{r}{\omega}(a_2-a_1), \overline{A}_\omega(r) = a_4 - \frac{r}{\omega}(a_4-a_3). \tag{4}$$

respectively. If $\omega = 1$, then the fuzzy number A_ω is called as normal fuzzy number otherwise non-normal fuzzy number. If $a_2 = a_3$, then it is non-normal triangular fuzzy number.

Chen, Munif, Chen, Liu, and Kuo (2012) first proposed the concept of GFN with different left heights and right heights. Later its parametric form has been defined by Chutia and Chutia (2017). Let A_{ω_1,ω_2} is represented by $A_{\omega_1,\omega_2} = (a_1,a_2,a_3,a_4;\omega_1,\omega_2)$ on the real line $\mathbb{R}$ is called a GFN with different left heights and right heights, where a_1,a_2,a_3 and a_4 are real values, ω_1 is called the left height and ω_2 is called the right height of it where $\omega_1 \in [0,1]$ and $\omega_2 \in [0,1]$. If $\omega_1 = \omega_2 = 1$, then the GFN A_{ω_1,ω_2} reduces to a normal trapezoidal fuzzy number. If $0 \leqslant \omega_1 = \omega_2 \leqslant 1$, then the fuzzy number A_{ω_1,ω_2} is simply a GFN proposed by Chen (1985).

Definition 2.4. A GFN A_{ω_1,ω_2} with different heights ω_1 and ω_2 for $0 \leqslant r \leqslant \max(\omega_1,\omega_2)$ is represented as follows:

(1) if $\omega_1 < \omega_2$, then

$$p(r) = \begin{cases} [\underline{A}_{\omega_1,\omega_2}(r),\overline{A}_{\omega_1,\omega_2}(r)], & \text{if } 0 \leqslant r \leqslant \omega_1, \\ [\widetilde{A}_{\omega_1,\omega_2}(r),\overline{A}_{\omega_1,\omega_2}(r)], & \text{if } \omega_1 \leqslant r \leqslant \omega_2, \end{cases} \tag{5}$$