Applied Mathematics and Computation 324 (2018) 202–217

Contents lists available at ScienceDirect

Applied Mathematics and Computation

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

# Stable strategies analysis based on the utility of Z-number in the evolutionary games

Bingyi Kang[a], Gyan Chhipi-Shrestha[b], Yong Deng[a,b,c,*], Kasun Hewage[b], Rehan Sadiq[b]

[a] Institute of Fundamental and Frontier Science, University of Electronic Science and Technology of China, Chengdu 610054, China
[b] School of Engineering, University of British Columbia Okanagan, 3333 University Way, Kelowna V1V 1V7, BC, Canada
[c] School of Computer and Information Science, Southwest University, Chongqing 400715, China

ARTICLE INFO

*Keywords:*
Strategy analysis
Z-number
Evolutionary games
Reliability

ABSTRACT

Evolutionary games with the fuzzy set are attracting growing interest. While among previous studies, the role of the reliability of knowledge in such an infrastructure is still virgin and may become a fascinating issue. Z-number is combined with “restriction” and “reliability”, which is an efficient framework to simulate the thinking of human. In this paper, the stable strategies analysis based on the utility of Z-number in the evolutionary games is proposed, which can simulate the procedure of human's competition and cooperation more authentically and more flexibly. Some numerical examples and an application are used to illustrate the effectiveness of the proposed methodology. Results show that total utility of Z-number can be used as an index to extend the classical evolutionary games into ones linguistic-based, which is applicable in the real applications since the payoff matrix is always determined by the knowledge of human using uncertain information, e.g., (outcome of the next year, about fifty thousand dollars, likely).

© 2017 Elsevier Inc. All rights reserved.

## 1. Introduction

Game theory [1] has been applied in lots of applications, such as economics [2], sociology [3], and computer science and logic [4], biology [5], etc. In recent decades of years, after Smith and Price [6] proposed the new fundamental insight from frequency-dependent selection within biology, evolutionary game theory has got great attentions, e.g., comprehensive review on coevolutionary mechanics [7], evolutionary dynamics of group interactions [8], spatial reciprocity influence in evolutionary cooperation game [9], infection control of coupled disease from the perspective of complex networks [10], evolutionary puzzle of cooperation [11], and some other related applications of evolutionary game based, i.e., statistical physics of human cooperation [12], phase transitions in models of human cooperation [13], statistical physics of vaccination [14], etc.

In the real application, for the complexity and uncertainty of the real world, knowledge or opinions are always expressed as a fuzzy linguistic variable, some efforts have been made to predict the evolutionary outcome using fuzzy techniques [15,16]. Limited work has been done in the area of discussing the role of reliability of uncertain information in such an

* Corresponding author at: Institute of Fundamental and Frontier Science, University of Electronic Science and Technology of China, Chengdu, 610054, China.

*E-mail address:* dengentropy@uestc.edu.cn (Y. Deng).

https://doi.org/10.1016/j.amc.2017.12.006
0096-3003/© 2017 Elsevier Inc. All rights reserved.

infrastructure, which is still virgin and may become a fascinating issue. For example, the decision maker wants to obtain the outcome of the next year considering the influence of the competitors, he evaluates an uncertain result, e.g., the outcome of next is about fifty thousand dollars and it is likely. The classical methods including the classical fuzzy method cannot deal with this scenario. Z-number is combined with “restriction” and “reliability”, which is an efficient framework to simulate the thinking of human. It can be formulated as a Z-number, i.e., (about fifty thousand dollars, likely) for the example. In this paper, we extend the crisp payoff matrix into one Z-number based, and a method of analyzing evolutionary stable strategy (ESS) based on the total utility of Z-number is proposed. The proposed frame can degenerate into classical ESS when the information is extremely reliable. At the same time, the proposed method can disclose that the mixed ESS profit decreases with the increasing constraint uncertainty of the information in spite that the ESS is unchangeable. This is consistent with the real situation since the expected profit always decreases with the increasing of the uncertainty. Some simple numerical examples are used to illustrate the effectiveness of the proposed method. In this paper, we employed the Hawk–Dove model to illustrate the basic process of the evolutionary game framework.

The paper is organized as follows. The preliminaries fuzzy sets, Z-number, total utility of Z-number and Hawk–Dove game and evolutionarily stable strategy (ESS) are briefly introduced in Section 2. Section 3 proposed the method of stable strategies analysis based on the utility of Z-number in the evolutionary game. In addition, relation of uncertainty and mixed ESS profit based on total utility of Z-number are discussed in Section 3. Some numerical examples are used to illustrate the effectiveness of the proposed frame in Section 4. Application in avoiding a price war considering the information reliability is discussed in Section 5. At last, this paper is concluded in Section 6.

## 2. Preliminaries

In this section, some preliminaries are briefly introduced.

### *2.1. Fuzzy sets*

In 1965, the notion of fuzzy sets was firstly introduced by Zadeh [17], providing a natural way of dealing with problems in which the source of imprecision is the absence of sharply defined criteria of class membership. The fuzzy set theory can be used in a wide range of applications, such as fuzzy multi-criteria decision making in marine transshipment container port selection [18], fuzzy evaluation of airline service quality [19], uncertain measure in evidence theory [20], physarum-inspired model in user equilibrium traffic assignment problem [21], multiple criteria decision making [22–24], multi-objectives tracking [25], unsteady aerodynamics effects in cycloidal rotor [26], investigation in parallel processing strategies [27], multiple nested event pattern queries [28], study of similarity of complex networks [29], supplier selection [30], human reliability analysis [31,32], forecasting time series [33], risk analysis [34–36], investigation of fuzzy similarity measure for intuitionistic fuzzy sets [37], failure mode and effects analysis [38], location selection of facility [39]. A brief introduction of Fuzzy sets are given as follows.

**Definition 2.1.** A fuzzy set A defined on a universe X is denoted as:

$$A = \{\langle x, \mu_A(x)\rangle | x \in X\},$$

where $\mu_A$: $X \to [0, 1]$ is the membership function of A. The membership value $\mu_A(x)$ describes the degree of belongingness of $x \in X$ in A.

The triangular fuzzy number can be defined as follows.

**Definition 2.2.** A triangular fuzzy number $\widetilde{A}$ can be defined by a triplet $(a_1, a_2, a_3)$ , where the membership can be determined as follows

A triangular fuzzy number $\widetilde{A} = (a_1, a_2, a_3)$ can be shown in Fig. 1.

$$\mu_{\widetilde{A}}(x) = \begin{cases} 0, & x \in (-\infty, a_1) \\ \dfrac{x - a_1}{a_2 - a_1}, & x \in [a_1, a_2] \\ \dfrac{c - x}{a_3 - a_2}, & x \in [a_2, a_3] \\ 0, & x \in (a_3, +\infty) \end{cases} \quad (1)$$

Similarly, the trapezoidal fuzzy number can be defined as follows:

**Definition 2.3.** A trapezoidal fuzzy number $\widetilde{A}$ can be defined by a quadruplet $(a_1, a_2, a_3, a_4)$ , where the membership can be determined as follows

Download English Version:

https://daneshyari.com/en/article/8901216

Download Persian Version:

https://daneshyari.com/article/8901216

Daneshyari.com