Knowledge-Based Systems xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Knowledge-Based Systems

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

A dynamical consensus method based on exit–delegation mechanism for large group emergency decision making

Xuan-hua Xu, Xiang-yu Zhong *, Xiao-hong Chen, Yan-ju Zhou

School of Business, Central South University, Changsha, Hunan, China

ARTICLE INFO

Article history:
Received 8 October 2014
Received in revised form 7 June 2015
Accepted 8 June 2015
Available online xxxx

Keywords:
Decision making
Consensus
Exit–delegation mechanism
Large group

ABSTRACT

Aiming at the lower consensus and the urgency of large group emergency decision making, a dynamical consensus method based on an exit–delegation mechanism is proposed and investigated. Firstly, the method is initiated by transferring a large group into small groups via the preference clustering method. Then, the consistency and consensus measures are calculated and two different criteria are used to guide the consensus reaching process. In addition, considering the urgency of emergency decision making, an exit–delegation mechanism is introduced to deal with clusters. When the consistency/consensus level is low, the proximity index of each cluster is computed. For the cluster whose proximity degree is lower than the threshold, it is advised to exit the decision-making process and a delegation mechanism is employed to reserve his influence by giving trust weights to other clusters. Meantime, a feedback mechanism is developed to give advice to clusters whose preferences should be subject to change, and to obtain a solution which satisfies the consistency and consensus criteria simultaneously. Finally, a case is taken to verify the rationality and feasibility of the method.

1. Introduction

Recent years witnessed the frequent occurrence of many unconventional emergency events, such as earthquake and hurricane, which tend to trigger a series of unexpected catastrophic consequences [1]. When such devastating emergencies occur, emergency decision can play a crucial role in mitigating their potential effects. Usually, an emergency decision has two distinct features. First, an emergency decision must often be made in a short period of time. Second, these decisions may potentially give rise to serious effects. In many cases, a wrong decision may even result in fatal consequences [2]. Thus, it is of vital importance to make a correct decision to handle emergency events within the shortest period of time. Previously, plenty of studies have been conducted on emergency decision making [1–6].

In the process of emergency decision making, due to the complexity of emergency events themselves and their personal factors, decision-making experts often find it hard to give order value or utility value to alternatives directly, but feel a relatively easier job to make judgments on the merits of alternatives by intercomparison. Thus, during emergency decision making, experts can give their evaluation on alternatives through preference relations, aggregate individual preference relation into collective preference relation and finally select or rank alternatives according to the collective preference relation. There are three commonly used preference relations: fuzzy preference relations [7–19], multiplicative preference relations [20–22] and linguistic preference relations [18,23–31]. Among the three preference relations mentioned above, fuzzy preference relations is most widely used because of its utility and ease of use. Therefore, in this paper, the fuzzy preference relations will be adopted to represent the preferences of decision-making experts.

As emergency decision making usually has three constraints: timeliness, finiteness of information and decision load [1], more experts are required to participate in the decision-making process. When the number of experts involved outnumbers 11, it is defined as a large decision-making group [32]. Generally speaking, decision-making experts vary in knowledge structure, self-interest and growth background, thus the emergence of preference conflict is inevitable. In order to ensure the effectiveness of emergency decision making, it is imperative to construct a consensus process to reduce and remove preference conflict prior to decision making; otherwise, it may further worsen the damage caused by emergency events.

Currently, plenty of methods can be found in previous literatures to model the consensus process during group decision-making [14,23–26,28,33–40]. These methods identify

* Corresponding author. Tel.: +86 15200906082.
E-mail address: zhongxiangyucsu@163.com (X.-y. Zhong).

http://dx.doi.org/10.1016/j.knosys.2015.06.006
0950-7051/© 2015 Published by Elsevier B.V.

preference values given by experts that contribute less to reaching a high consensus state, and then provide them with particular preference values to reach a higher consensus state. The above methods, however, are aimed at the conventional decision making. Compared with the conventional one, emergency decision making is characterized by more experts involved that result in a lower consensus degree, and short decision-making time that prevent the consensus process from costing too much time. So it is necessary to put forward a new method to solve these two issues. Perez et al. [41,42] proposed a new consensus approach to establish a dynamic decision framework by allowing the change of the alternatives that constitute the set of solution alternatives; Alonso et al. [43] put forward a delegation method to solve the dynamic of Wikipedia users in the decision-making process. Inspired by these literatures, we proposed to advice the expert who contribute the least to reaching a high consensus state to exit the decision-making process, and to reserve his/her influence through the delegation mechanism.

In accordance with the lower consensus among experts and the urgency of emergency events, a dynamical consensus method is proposed in this paper. Firstly, experts are clustered by preference and each cluster produced is considered as a decision unit. Then, for the cluster whose proximity degree with collective preference relation is lower than the consensus threshold under some circumstances, it is advised to exit the decision-making process, wherein a delegation mechanism is proposed to reserve his influence. At the same time, a feedback mechanism is brought up to increase the consensus level by advising some clusters to change their preference relations. Thus, the consensus degree will be increased in a shortest period of time through the dynamical consensus method.

At the same time, these consensus methods have considered not only consensus measures, but also consistency measures [14,20,28,36,44]. Obviously, consistent information is more appropriate or important than that containing contradictions. If we secure consensus first and then consistency, consensus would be destroyed for the sake of individual consistency and the final solution obtained might not be acceptable to decision-making experts [36,44]. Clearly, it is preferable that the set of experts should reach a high individual consistency level and group consensus before the application of the selection process. Therefore, the consensus method presented in this paper considers both consistency and consensus measures simultaneously.

This paper is set out as follows. Section 2 deals with the preliminaries necessary to develop the consensus method. In Section 3, the dynamical consensus method for large group emergency decision making is presented. Section 4 introduces the system construction to apply the method proposed in this paper to practice. Section 5 incites an example to illustrate the application of the consensus method. Finally, a conclusion is drawn in Section 6.

2. Preliminaries

In this section, the tools necessary to design the consensus method will be briefly presented, that is, the concept of fuzzy preference relation, the preference clustering method for large-group members and consistency measures.

2.1. Fuzzy preference relation

In the process of large group emergency decision making, let set $X = \{x_1, x_2, \ldots, x_n\}\,(n \geqslant 2)$ represent the alternatives and $E = \{e_1, e_2, \ldots, e_m\}\,(m \geqslant 11)$ the decision-making expert group. Experts evaluate each alternatives and give their corresponding fuzzy preference relations.

Definition 2.1. The fuzzy preference relation P on a set of alternatives X is a fuzzy set on the product set $X \times X$, characterized by a membership function $\mu_p : X \times X \to [0, 1]$.

When the cardinality of X is small, the preference relation can be conveniently represented by the $n \times n$ matrix $P = (p_{ij})$, in which $p_{ij} = \mu_p(x_i, x_j)\,(\forall i, j \in \{1, 2, \ldots, n\})$ is interpreted as the preference degree of alternative x_i over x_j. $p_{ij} = 0.5$ indicates the indifference between x_i and $x_j (x_i \sim x_j)$, $p_{ij} = 1$ indicates that x_i is absolutely preferred to x_j, and $p_{ij} > 0.5$ indicates that x_i is preferred to $x_j (x_i \succ x_j)$. Based on the above interpretation, $p_{ii} = 0.5$ can be obtained. Meanwhile, the preference relation is assumed as complementary, that is, $p_{ij} + p_{ji} = 1$, verifying $i, j \in \{1, 2, \ldots, n\}$.

2.2. Preference clustering method for large-group members

Emergency decision making often involves a large group. Thus, in order to simplify the decision-making process, experts are clustered first by preference to transform into small-group decision making. Firstly, the fuzzy preference relations $P_{n \times n}$ is transformed into n^2 dimensional preference vector V. Then, experts are clustered into K clusters $(1 \leqslant K \leqslant m)$ by means of preference clustering method [45]. The specific steps are as below:

Step 1: Transform the fuzzy preference relations $P_{n \times n}$ of all experts into n^2 dimensional preference vector V and construct a preference set U comprising all preference vectors. Then, all the vectors of the set U are sorted randomly and signed with $1 \sim m$. Meanwhile, let T be a temporary set.

Step 2: Initialize $k = 1$ as the number of clusters and $i = 1$ as the sequence number of vector. Also, the threshold γ is determined according to practical situation.

Step 3: Select the preference vector V^i sequentially from the set U and allocate them to the cluster C^k. And then remove the vector from the set U and let the number of members in cluster C^k be $n_k = 1$.

Step 4: Linearly combine preference vectors in the cluster C^k to obtain Y, which is as follows:

$$Y = \frac{\sum_{i=1}^{n_k} V^i}{n_k}. \tag{1}$$

Step 5: Select the preference vector $V^i\,(i = i + 1)$ sequentially from the set U if U is not null; otherwise, go to Step 7.

Step 6: Compute the gather degree of Y and V^i

$$r_i(Y, V^i) = \frac{Y \cdot (V^i)^T}{||Y|| \cdot ||V^i||}. \tag{2}$$

Allocate the preference vector V^i to the cluster C^k, remove it from the set U and let $n_k = n_k + 1$ if $r_i(Y, V^i) \geqslant \gamma$; otherwise, remove it from the set U and allocate it to the temporary set T. Then go to Step 4.

Step 7: If T is not null, let $U = T$, $T = NULL$ and $k = k + 1$ respectively and go to Step 3; otherwise, go to Step 8.

Step 8: Record the results of clustering. Let K be the number of clusters in the group, n_k the number of members in cluster $C^k\,(k = 1, 2, \ldots K)$ and $\sum_{k=1}^{K} n_k = m$.

The clustering criterion is the gather degree between two vectors. The threshold γ should be identified before clustering, which is used to determine whether the preference vector V_i of the decision member e_i can enter the cluster C^k or not. A smaller value of the threshold γ makes it easier for the preference vector V_i of the

Please cite this article in press as: X.-h. Xu et al., A dynamical consensus method based on exit–delegation mechanism for large group emergency decision making, Knowl. Based Syst. (2015), http://dx.doi.org/10.1016/j.knosys.2015.06.006