Modeling and Discovery of Emergent Chance for Decision Making

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Keywords: Emergent Chance, Decision Making, Analytic Hierarchy Process, Grey Relational Model

Abstract: This paper presents a modeling procedure of discovering emergent chance for decision making based on Analytic Hierarchy Process (AHP) and Grey Relational Analysis (GRA). Firstly, the influencing factors of the chances are obtained from domain experts, and then calculate the weights of these influencing factors. Secondly, we use the grey relational model to grade possible chances in decision making process. Finally, we consider that the chance with the highest grade is most likely to emerge in the future.

Introduction

Chance discovery, proposed by Ohsawa in 2000, is a human-computer interaction process to detect rare but important chances for decision making. A chance in chance discovery means to understand an unnoticed event or situation which can be uncertain but significant for making a decision (Ohsawa & McBurney, 2003). KeyGraph is a text mining visualization tool with the KeyGraph algorithm (Ohsawa, Benson & Yachida, 1998) to assist the process of chance discovery. That is, KeyGraph can recognize and display relations between events and event clusters in a document. In the last few years, chance discovery has been widely applied in various research areas, especially in business.

However, the methods presently known in chance discovery are mainly based on qualitative analysis to visualize the data structure and to discover the potential future scenario (Hong, 2009). Actually, we human beings are good at qualitative data and weak in quantitative data (Matsumura, 2003). Sometimes it is very hard for humans to discover a chance directly from some possible chances only depending on their experiences. As a result, the chance that they discover is probably not a real chance. Therefore, quantitative analysis methods to discover chances for making decision still need to be solved expectantly.

Analytic Hierarchy Process (AHP), developed by Saaty (1980), is a multiple criteria decision-making tool which has been used in almost all the applications related with decision-making (Vaidya & Kumar, 2006). However, Ho (2008) provided the conclusion that the integrated AHPs are better than the stand-alone AHP, and assisted decision makers for decision making by using the integrated AHPs effectively. The tools commonly integrated with the AHP include mathematical programming, quality function deployment (QFD), meta-heuristics, SWOT analysis, and data envelopment analysis (DEA). AHP can be easily integrated with other techniques, and therefore in this paper we will use it to calculate the weights of factors influencing emerging chance.

There are a lot of limitations in using traditional statistic methods. Thus the grey system theory, proposed by Deng (1982), has been widely applied in various fields for dealing with uncertain, poor, and incomplete information. Grey relational analysis (GRA), as a part of grey system theory, is an effective quantitative analysis for solving the complicated interrelationships among factors in developing dynamic process. Kung et al. (2007) applied Grey Relational Analysis and Grey Decision-Making to evaluate the relationship between company attributes and its financial performance. Kuo et al. (2008) presented the efficiency of GRA for solving multiple attribute decision making (MADM) problems by two cases study.

In this paper, we firstly present a method to calculate the weight of each factor influencing emergent chances by AHP, and then use the grey relational model to grade possible chances in decision making process. Finally, we consider that the chance with the highest grade is most likely to emerge in the future.

Research Methodology and Modeling Procedure

The weight of each factor influencing emergent chance. According to the problems that they want to solve, decision makers fully communicate with one another and exchange ideas. Finally, they reach consensus and find out major factors influencing emerging chances which are not measured directly only depending on human's qualitative analysis. The influencing factors are indicated as (F_1, F_2, . . . , F_n).

Although decision makers may not be able to identify the weight values w_i of influencing factors, they can make paired comparison between them. Therefore, the weight of each factor influencing emerging chance is determined by a series of paired comparisons. That is, decision makers only make value judgments in the matrix F.

$$F = \begin{bmatrix} \frac{F_1}{F_1} & \frac{F_1}{F_2} & \cdots & \frac{F_1}{F_n} \\ \frac{F_2}{F_1} & \frac{F_2}{F_2} & \cdots & \frac{F_2}{F_n} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{F_n}{F_1} & \frac{F_n}{F_2} & \cdots & \frac{F_n}{F_n} \end{bmatrix}$$

Then decision makers get together to make paired comparison between these influencing factors obtained. The value of each comparison should be referred to a 1-9 numerical rating scale shown in Table 1 (Saaty, 2006). For example, if the value for influencing factor F_1 compared to another influencing factor F_2 is F_{12}, then the value for influencing factor F_2 compared with F_1 is F_{21}= 1/ F_{12}. Thus the times N of paired comparison for a set of n influencing factors is $N = n\ (n\text{-}1)/2$.

To recover the scale w using the following equation:

$$Fw = nw \tag{1}$$

$$\begin{bmatrix} \frac{F_1}{F_1} & \frac{F_1}{F_2} & \cdots & \frac{F_1}{F_n} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \frac{F_n}{F_1} & \frac{F_n}{F_2} & \cdots & \frac{F_n}{F_n} \end{bmatrix} \begin{bmatrix} w_1 \\ \cdots \\ \cdots \\ \cdots \\ w_n \end{bmatrix} = n \begin{bmatrix} w_1 \\ \cdots \\ \cdots \\ \cdots \\ w_n \end{bmatrix}$$

This is a system of homogeneous linear equations. In order to recover the scale w from the matrix of ratios F, we must solve the eigenvalue problem $Fw = nw$ or $(F - nI)\ w = 0$. It has a nontrivial solution if and only if the determinant of $F - nI$ vanishes ($F - nI = 0$), that is, n is an eigenvalue of matrix F. Thus we calculate w as the largest eigenvector λ_{max} of the matrix F, that is,

$$Fw = \lambda_{\max} w \tag{2}$$

The matrix F is not only reciprocal, but also consistent. Thus the comparison of decision makers should be consistent in terms of the following equation:

$$(Fi / Fj)\ (Fj / Fk) = Fi / Fk \tag{3}$$

But decision makers cannot keep the consistent completely when making paired comparison. We should measure the inconsistency within a set of influencing factors through a consistency index (CI), given by

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{4}$$

Consistency ratio (CR) is a measure of how a given matrix compares to a purely random matrix in terms of their consistency indices. Accordingly, Saaty (2006) defined the consistency ratio as:

$$CR = \frac{CI}{RI} \tag{5}$$

Table 2 provides the random index (*RI*) values obtained from a set of simulations corresponding to different matrices size. A value of the consistency ratio *CR* <= 0.1 is considered acceptable. That is, if the value of *CR* is a larger than 0.1, decision makers have to adjust their determinations properly until the value of *CR* is in the specified operating range.

Table 1 The numerical rating scale of influencing factors paired comparison

Paired comparison value of influencing factors	Identification standard of relation between Fi and Fj in Matrix F
1	*Fi* and *Fj* is equally important
3	*Fi* is slightly important than *Fj*
5	*Fi* is strongly more important than *Fj*
7	*Fi* is very strongly more important than *Fj*
9	*Fi* is extremely more important than *Fj*
2, 4, 6, 8	intermediate values of two adjacent comparison above

Table 2 Random index for corresponding matrix size

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Grey relational grade of factors influencing chances. 1) Factors standardization processing: grey relation generating. Because of each factor measured by different units, this step is to translate the performance of influencing factors into a comparability sequence. If the value of influencing factor is the higher the better, normalized result can be expressed as

$$x_{ij} = \frac{X_{ij} - \min_j X_{ij}}{\max_j X_{ij} - \min_j X_{ij}} \tag{6}$$

If the value of influencing factor is the lower the better, normalized result can be expressed as

$$x_{ij} = \frac{X_{ij} - \max_j X_{ij}}{\min_j X_{ij} - \max_j X_{ij}} \tag{7}$$

where x_{ij} is the value of influencing factor *j* of chance *i*.

2) The calculation of grey relational coefficient and grey relational grade. The grey relational coefficient is used for determining the relationship how close the ideal chance is to the practical possible chances proposed by decision makers. That is, we can calculate grey relation coefficient of each comparative chance series to reference standard chance series separately.

$$\xi_{ij} = \frac{\min_i \min_j \left| x_{0j} - x_{ij} \right| + \zeta \max_i \max_j \left| x_{0j} - x_{ij} \right|}{\left| x_{0j} - x_{ij} \right| + \zeta \max_i \max_j \left| x_{0j} - x_{ij} \right|} \tag{8}$$

for i = 1,2 ,…,m   j = 1,2,…,n

where ξ_{ij} is the grey relational coefficient between x_{ij} and x_{0j}, and x_{0j} is the ideal chance series for the *jth* influencing factor. ζ is the distinguishing coefficient $\zeta \in (0,1)$, the purpose of which is to expand or compress the range of the grey relational coefficient.

After calculating the grey relational coefficient, the grey relational grade can be calculated by

$$\Gamma(X_0, X_i) = \sum_{j=1}^{n} w_j \xi_{ij} \quad (9)$$

for i=1,2,..m

where $\Gamma(X_0, X_i)$ is the grey relational grade between X_0 and X_i, which represents the degree of correlation between the reference chance series and comparative chance series. Here, w_j is the weight of influencing factor depending on judgments of decision makers, and can be obtained in previous step A.

The reference chance series X_{0j} stands for the best ideal event or scenario for decision making, thus if a comparative chance series gets the highest grey relational grade with reference chance series, which means the comparative chance series is most similar to the reference chance series. Accordingly, it's considered that the comparative chance series which has the highest grey relational grade should be the best choice for decision makers.

The Modeling Procedure of Discovering Emergent Chance. Figure 1 shows the modeling procedure of discovering emergent chance based on analytic hierarchy process and grey relational analysis.

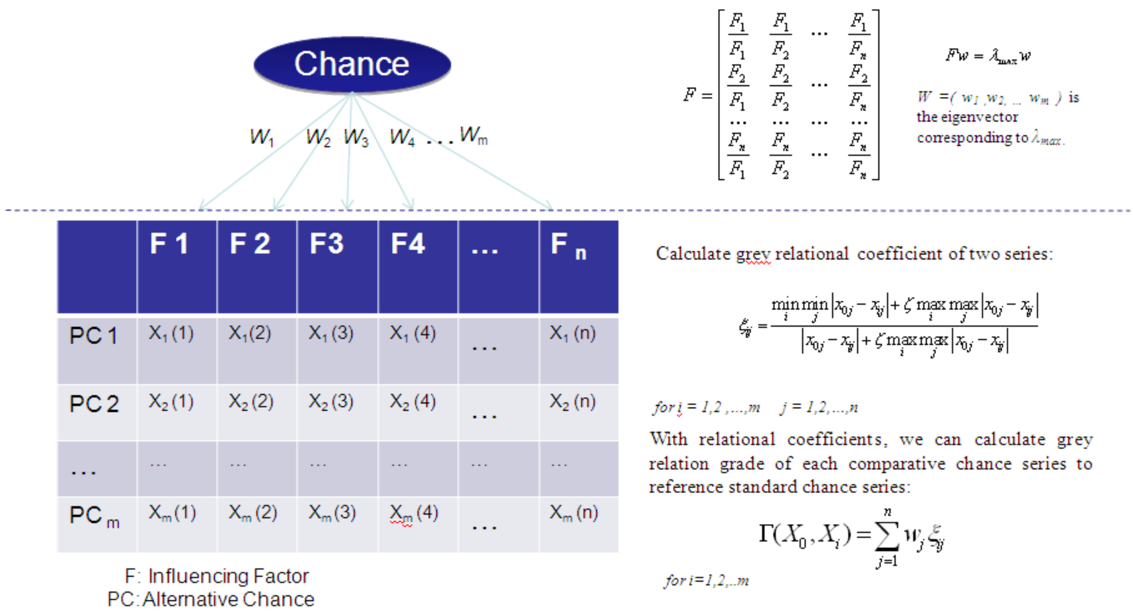

Figure 1. The Modeling Procedure of Discovering Emergent Chance Based on Analytic Hierarchy Process (AHP) and Grey Relational Analysis (GRA)

Conclusion

An emerging chance usually cannot be well determined directly by qualitative analysis of human, because chance could emerge when factors influencing the chance are up to some threshold respectively. Nevertheless, we human being can use some ways to determine the factors influencing chances. Ohsawa (2008) proposed innovation game as a workplace for human sensing values in design and market. Innovation game can be applied in this research to sense the influencing factors of chances.

In this paper, we propose a method to analyze and obtain the influencing factors of possible chances. Based on the influencing factors, we compare possible emerging chances with reference chance which is considered to be the best chance emerging in the future. The grey relational grade represents the correlation degree between possible chance and reference chance. The chance which has the biggest grey relational grade will be most likely to emerge in the future. Therefore, we design an effective method to discover emerging chance for decision making, and directed a case study to validate the effectiveness (Wang et al., 2010). This method can also be well applied in competitor analysis for decision making in the future.

Acknowledgment
The author was supported through the Global COE Program "Global Center of Excellence for Mechanical Systems Innovation," by the Ministry of Education, Culture, Sport, Science and Technology.

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