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Analysis of Multilevel Risk Measurement Algorithm of Software Projects Based on Grey Variable Weight Clustering Model

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Abstract

The development process of the software system is influenced by multi factors, thus the risk control of software projects is of vital importance. Targeting at the features including multi-factor, multilayer, fuzziness and uncertainty during the process of risk assessment of software projects, this paper analyzed the risk measurement of software projects and proposed a multilevel risk measurement algorithm of software projects based on grey variable weight clustering model. This algorithm firstly analyzed the influencing factors of the risk control of software projects, establishing a multilevel risk measurement system for software projects; next, establishing the whitenization weight functions of different measurement indexes and different measurement grades of software projects risks respectively on the basis of the grey system theory, and under the condition of considering the degree of importance of the indexes of different levels, the corresponding risk measurement algorithm of software projects based on grey variable weight clustering model was established; then the paper presented the detailed execution steps of this algorithm and discussed the detailed process to achieve the algorithm. Finally, the algorithm was verified through the case study.

***Keywords**: software projects; risk measure; grey variable weight clustering model; multilevel measure system; fuzzy algorithm*

1. Introduction

Software projects risks mean the losses and harms to the development process of the software projects or software system product during the process of developing the software system, for the process is influenced by many links of design and development of the software system. Especially for the development of the large-scale and complex software system, since different links of designing are influenced by the uncertain factors like the internal management conditions, the external environment, the abilities of technology development, the execution of the system, the software products themselves and so on, the risk control of the software projects is particularly important. Consequently, experts and scholars of different fields analyzed and studied the risk control algorithm for software projects with different methodologies and models from all kinds of perspectives. However, there are still some deficiencies in the present studies, especially in the matter of processing the fuzzy and uncertain factors in the risk control of software projects; for instance, some methods overemphasized the subjective aspects while neglected the objective aspects, and some methods emphasizing the qualitative analysis ignored the quantitative analysis. Therefore, this paper introduced the grey system theory into the risk control of software projects,

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processed the uncertain factors in the risk control of software projects from the perspective of the grey clustering analysis method, and further put forward a multilevel risk measurement algorithm of software projects based on grey variable weight clustering model.

2. Multilevel risk Measurement System for Software Projects

In the viewpoint of the author of this paper, the development of a large-scale and complex software system should give consideration to the possible risks of different sides in the process of developing the software projects, and the risk measurement of software projects of these risk factors of could be quantified; in other words, the software projects risks could be classified by a unified standard, to decide the levels of the risks of the software projects to be developed. Therefore, in order to analyze the software projects risks roundly and completely, this paper discussed the whole lifecycle process of the software development from the perspectives of software demand, management, technology development, market, project implementation, software developers and so on, and thus established a multilevel risk measurement system for software projects. The detailed structure and content of the system are listed in table 1.

Table 1. Multilevel Risk Measurement System for Software Projects

System layer	Primary index	Secondary index
multilevel risk measurement system for software projects S	Demand risk of software projects P_1	Accuracy of demand analysis p_{11}
		Flexibility of customer demand p_{12}
		Cognition of demand p_{13}
	Management risk of software projects P_2	Project management experience p_{21}
		Standardization of quality management p_{22}
		Team cooperation p_{23}
		Management skills of the project manager p_{24}
	Technological risk of software projects P_3	Development environment of software and hardware p_{31}
		Design and realization of software system p_{32}
		Upgrading and maintenance of software system p_{33}
		Design method of software system p_{34}
	Implementation	Project progress

	risk of software projects P_4	planning p_{41}
		Scale of software system p_{42}
		Security of software system p_{43}
		Reliability of software system p_{44}
	Market risk of software projects P_5	Cost controllability p_{51}
		Commercial market viability p_{52}
		Availability of funding p_{53}
	Personnel risk of software projects P_6	Technological capacity of software developers p_{61}
		Planning of employee training p_{62}
		Personnel consistency p_{63}
		Personnel coordination p_{64}

3. A Multilevel Risk Measurement Algorithm of Software Projects Based on Grey Variable Weight Clustering Model

3.1. Data Normalization of Risk Measurement of Software Projects

It could be seen from the forms of the measurement indexes in Table 1 that some indexes are fuzzy indexes which need qualitative description while some indexes are quantity value indexes which need quantitative description. To unifying the measurement standards of the qualitative and quantitative measurement indexes, the measurement indexes of different forms need normalization processing.

If the measurement index i belongs to the qualitative description, this paper described it in the form of fuzzy membership degree, namely, its quantity value is:

$$v_i = f(x_i), 0 \le f(x_i) \le 1 \tag{1}$$

Where $f(x_i)$ means membership function of the measurement index i.

If the measurement index i belongs to the quantitative description, and when it is the measure index which gets better as it gets bigger, its normalized quantity value v_i is:

$$v_i = \frac{x_i - \min_{i \subset \Omega}(x_i)}{\max_{i \subset \Omega}(x_i) - \min_{i \subset \Omega}(x_i)} \tag{2}$$

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The x_i in above formula is the initial data of the measurement index i, the $\max\limits_{i \subset \Omega}(x_i)$ is the maximum threshold in the domain, and the $\min\limits_{i \subset \Omega}(x_i)$ is the minimum threshold in the domain.

When i is the the measurement index which gets better as it gets smaller, its normalized quantity value v_i is:

$$v_i = \frac{\max\limits_{i \subset \Omega}(x_i) - x_i}{\max\limits_{i \subset \Omega}(x_i) - \min\limits_{i \subset \Omega}(x_i)} \tag{3}$$

3.2. The Whitenization Weight Functions of the Risk Measurement of Software Projects

In order to conduct the risk measurement of software projects effectively, the definite weighted functions of the risk measurement of software projects need to be established. Supposing the risk measurement of software projects are divided into M ranks, the levels l of the risk measurement of software projects includes N measurement indexes.

When the measurement index i belongs to the rank j of the risk measurement of software projects and conforms to the form of the typical measurement whitenization weight function which is shown in figure 1:

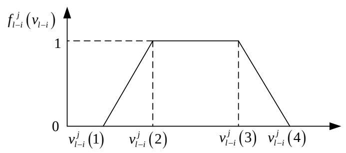

Figure 1. Typical Measurement Whitenization Weight Function

Then the model of the whitenization weight function $f_{l-i}^{j}(v_{l-i})$ is:

$$f_{l-i}^{j}(v_{l-i}) = \begin{cases} \dfrac{v_{l-i} - v_{l-i}^{j}(1)}{v_{l-i}^{j}(2) - v_{l-i}^{j}(1)} & v_{l-i} \in \left[v_{l-i}^{j}(1),\ v_{l-i}^{j}(2)\right] \\ 1 & v_{l-i} \in \left[v_{l-i}^{j}(2),\ v_{l-i}^{j}(3)\right] \\ \dfrac{v_{l-i}^{j}(4) - v_{l-i}}{v_{l-i}^{j}(4) - v_{l-i}^{j}(3)} & v_{l-i} \in \left[v_{l-i}^{j}(3),\ v_{l-i}^{j}(4)\right] \\ 0 & v_{l-i} \notin \left[v_{l-i}^{j}(1),\ v_{l-i}^{j}(4)\right] \end{cases} \tag{4}$$

When the measurement index i belongs to the rank j of the risk measurement of software projects and conforms to the form of the lower limit measurement whitenization weight function which is shown in figure 2:

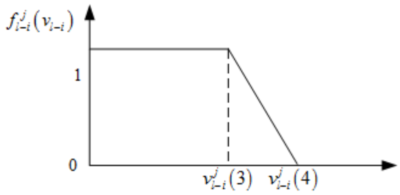

Figure 2. Lower Limit Measurement Whitenization Weight Function

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Then the model of the whitenization weight function $f_{l-i}^{j}(v_{l-i})$ is:

$$f_{l-i}^{j}(v_{l-i})=\begin{cases}1 & v_{l-i}\in\left[0,\ v_{l-i}^{j}(3)\right]\\ \dfrac{v_{l-i}^{j}(4)-v_{l-i}}{v_{l-i}^{j}(4)-v_{l-i}^{j}(3)} & v_{l-i}\in\left[v_{l-i}^{j}(3),\ v_{l-i}^{j}(4)\right]\\ 0 & v_{l-i}\notin\left[0,\ v_{l-i}^{j}(4)\right]\end{cases} \tag{5}$$

When the measurement index *i* belongs to the rank *j* of the risk measurement of software projects and conforms to the form of the upper limit measurement whitenization weight function which is shown in figure 3:

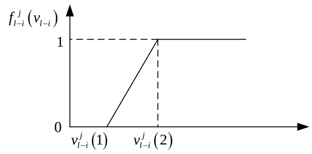

Figure 3. Upper Limit Measurement Whitenization Weight Function

Then the model of the whitenization weight function $f_{l-i}^{j}(v_{l-i})$ is:

$$f_{l-i}^{j}(v_{l-i})=\begin{cases}1 & v_{l-i}\ge v_{l-i}^{j}(2)\\ \dfrac{v_{l-i}-v_{l-i}^{j}(1)}{v_{l-i}^{j}(2)-v_{l-i}^{j}(1)} & v_{l-i}\in\left[v_{l-i}^{j}(1),\ v_{l-i}^{j}(2)\right]\\ 0 & v_{l-i}\in\left[0,\ v_{l-i}^{j}(1),\right]\end{cases} \tag{6}$$

When the measurement index *i* belongs to the rank *j* of the risk measurement of software projects and conforms to the form of the moderate measurement whitenization weight function which is shown in figure 4:

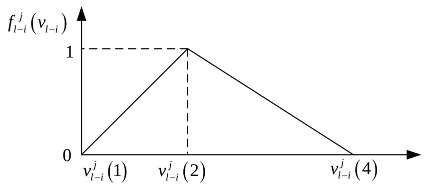

Figure 4. Moderate Measurement Whitenization Weight Function

Then the model of the whitenization weight function $f_{l-i}^{j}(v_{l-i})$ is:

$$f_{l-i}^{j}(v_{l-i})=\begin{cases}\dfrac{v_{l-i}-v_{l-i}^{j}(1)}{v_{l-i}^{j}(2)-v_{l-i}^{j}(1)} & v_{l-i}\in\left[v_{l-i}^{j}(1),\ v_{l-i}^{j}(2)\right]\\ 0 & v_{l-i}\notin\left[v_{l-i}^{j}(1),\ v_{l-i}^{j}(4)\right]\\ \dfrac{v_{l-i}^{j}(4)-v_{l-i}}{v_{l-i}^{j}(4)-v_{l-i}^{j}(2)} & v_{l-i}\in\left[v_{l-i}^{j}(2),\ v_{l-i}^{j}(4)\right]\end{cases} \tag{7}$$

3.3. Analysis of Multilevel Risk Measurement of Software Projects based on Variable Weight Clustering

During risk measurement of software projects, measurement indexes can have different influences upon different measurement ranks, that is, measurement indexes may have different degrees of significance at different measurement ranks. Hence, it needs to obtain sublevel measurement indexes' weight. If the measurement index *i* belongs to rank *j* of risk measurement of software projects and conforms to typical whitenization weight function's structure, then

$$g_{l-i}^{j} = \frac{1}{2}\left(v_{l-i}^{j}(2) + v_{l-i}^{j}(3)\right) \tag{8}$$

If the measurement index i belongs to rank j of risk measurement of software projects and conforms to moderate measurement whitenization weight function's and upper limit measurement whitenization weight function's structures, then

$$g_{l-i}^{j} = v_{l-i}^{j}(2) \tag{9}$$

If the measurement index i belongs to rank j of risk measurement of software projects and conforms to lower limit measurement whitenization weight function's structure, then

$$g_{l-i}^{j} = v_{l-i}^{j}(3) \tag{10}$$

Thereout, measurement index i belongs to rank j of risk measurement of software projects, and its weight w_{l-i}^{j} is:

$$w_{l-i}^{j} = g_{l-i}^{j} / \sum_{i=1}^{M} g_{l-i}^{j} \tag{11}$$

Then, all sublevel measurement indexes on l floor belong to rank j of risk measurement of software projects, and its clustering coefficient κ_l^j is:

$$\kappa_l^j = \sum_{i=1}^{N}\left(w_{l-i}^{j} * f_{l-i}^{j}\left(v_{l-i}\right)\right) \tag{12}$$

If the weight the measurement index on l floor corresponds to is w_l, all risk measurement indexes on l floor belong to rank j of risk measurement of software projects, and its clustering coefficient κ^j is:

$$\kappa^j = \sum_{l=1}^{S}\left(w_l * \kappa_l^j\right) \tag{13}$$

If there is

$$\kappa^o = \max_{1\le j\le M}\left(\kappa^j\right) = \kappa^k, 1 \le k \le M \tag{14}$$

Then it suggests that the software projects in developing plan corresponds to the risk rank k.

3.4. Implementing Steps of Multilevel Risk Measurement Algorithm of Software Projects

In summary, implementing steps of a multilevel risk measurement algorithm of software projects based on grey variable weight clustering model are elaborated below:

Step 1 Adhering to principles of scientificalness, objectiveness and effectiveness, determine risk measurement indexes of software projects, and based on this establish multilevel risk measurement system of software projects.

Step 2 According to the method of normalizing data of risk measurement of software projects discussed in 3.1, standardize the measurement data using formulas (1) – (3) and obtain the corresponding quantity value of measurement.

Step 3 Determine the divisions of risk measurement of software projects. Based on the method of constructing whitenization weight function of risk measurement of software projects discussed in 3.2, construct whitenization weight functions of different measurement indexes according to formulas (4) – (7).

Step 4 Obtain clustering coefficients of all sub-measurement indexes when they belong to different ranks of risk measurement of software projects according to formulas (8) – (12).

Step 5 Use formula (13) to obtain clustering coefficients of risk measurement indexes of all levels when they belong to different ranks of different risk measurement of software projects and conduct analysis of multilevel risk measurement of software projects based upon variable weight clustering.

Step 6 Obtain the corresponding risks ranks of software projects in developing plan using formula (14).

Step 7 End the algorithm.

4. Case Analysis

This paper, taking a large-scale commercial information software that is listed in a software developing company's plan as an example, has analyzed and verified the project's risk measurement of the large-scale commercial information software through the model and algorithm proposed in this paper. On the basis of market-based research, after consulting experts in this filed, this paper divides the project's risk measurement of large-scale commercial information software into five ranks, that is, *A* representing relatively small, *B* small, *C* general, *D* big, *E* relatively big. According to the construction model of whitenization weight function of risk measurement of software projects mentioned in this paper, whitenization weight functions of the five risk measurement ranks can be established, that is,

$$f_i^A(v_i)=\begin{cases}1 & v_i\in[0,0.4]\\ \frac{0.5\text{-}v_i}{0.1} & v_i\in[0.4,0.5]\\ 0 & v_i\notin[0,0.5]\end{cases} \tag{15}$$

$$f_i^B(v_i)=\begin{cases}\frac{v_i\text{-}0.4}{0.1} & v_{l-i}\in[0.4,0.5]\\ 0 & v_{l-i}\notin[0.4,0.6]\\ \frac{0.6\text{-}v_i}{0.1} & v_{l-i}\in[0.5,0.6]\end{cases} \tag{16}$$

$$f_i^C(v_i)=\begin{cases}\frac{v_i\text{-}0.5}{0.1} & v_{l-i}\in[0.5,0.6]\\ 0 & v_{l-i}\notin[0.5,0.7]\\ \frac{0.7\text{-}v_i}{0.1} & v_{l-i}\in[0.6,0.7]\end{cases} \tag{17}$$

$$f_i^D(v_i)=\begin{cases}\frac{v_i\text{-}0.6}{0.1} & v_{l-i}\in[0.6,0.7]\\ 0 & v_{l-i}\notin[0.6,0.8]\\ \frac{0.8\text{-}v_i}{0.1} & v_{l-i}\in[0.7,0.8]\end{cases} \tag{18}$$

$$f_i^E(v_i)=\begin{cases}1 & v_i\geq 0.8\\ \frac{v_i\text{-}0.7}{0.1} & v_i\in[0.7,0.8]\\ 0 & v_i\in[0,0.7,]\end{cases} \tag{19}$$

Normalized analysis data of original measurement can be obtained through qualitative description and transformation or fuzzy membership. Under the framework of the established multilevel risk measurement system of software projects, this paper got grey clustering coefficients of different measurement indexes. The results are shown in table 2.

Table 2. Grey Clustering Coefficients of Second Degree Risk Measurement Index

Primary index	secondary index	Ranks of Risk Measurement					Data of Risk Measurement
		A	B	C	D	E	
		$w_i^A = 0.133$	$w_i^B = 0.167$	$w_i^C = 0.200$	$w_i^D = 0.233$	$w_i^E = 0.267$	
P_1 $w_1 = 0.10$	p_{11}	0	0.75	0.25	0	0	0.525
	p_{12}	0.80	0.20	0	0	0	0.420
	p_{13}	0.75	0.25	0	0	0	0.425
P_2 $w_2 = 0.15$	p_{21}	0	0	0.50	0.50	0	0.650
	p_{22}	0	1.00	0	0	0	0.500
	p_{23}	1.00	0	0	0	0	0.350
	p_{24}	1.00	0	0	0	0	0.350
P_3 $w_3 = 0.25$	p_{31}	1.00	0	0	0	0	0.225
	p_{32}	1.00	0	0	0	0	0.225
	p_{33}	0.50	0.50	0	0	0	0.450
	p_{34}	0.50	0.50	0	0	0	0.450
P_4 $w_4 = 0.25$	p_{41}	0	0	0.75	0.25	0	0.625
	p_{42}	0	0	1.00	0	0	0.600
	p_{43}	0	0	0	0.50	0.50	0.750
	p_{44}	0.50	0.50	0	0	0	0.450
P_5 $w_5 = 0.10$	p_{51}	0	0	0	0	1.00	0.850
	p_{52}	0	0	0.50	0.50	0	0.650
	p_{53}	0	0.50	0.50	0	0	0.550
P_6 $w_6 = 0.15$	p_{61}	1.00	0	0	0	0	0.300
	p_{62}	0.50	0.50	0	0	0	0.450
	p_{63}	1.00	0	0	0	0	0.400
	p_{64}	1.00	0	0	0	0	0.400

Based upon the algorithm model of grey clustering coefficient of multilevel risk measurement, grey clustering coefficients of the first degree risk measurement index as well as the integrated grey clustering coefficients of software projects when they were at different risk measurement ranks could be obtained, which are shown in table 3.

Table 3. Ranks of Risk Measurement of Primary index

Primary index	Ranks of Risk Measurement				
	A	*B*	*C*	*D*	*E*
P_1	0.0206	0.0200	0.0050	0	0
P_2	0.266	0.167	0.100	0.117	0
P_3	0.399	0.167	0	0	0
P_4	0.067	0.084	0.350	0.175	0.134
P_5	0	0.084	0.200	0.117	0.267
P_6	0.466	0.084	0	0	0
Integrated Clustering Coefficients	0.433	0.309	0.173	0.073	0.060

From the discriminant model of integrated grey clustering coefficient of risk measurement of software projects, the large-scale commercial information software in developing plan has the systematical developing risk at *A* level, that is to say, the software project has small risks, which corresponds with the market effect achieved after the software system was put into practice. This proves the effectiveness and feasibility of multilevel risk measurement algorithm of software projects based on grey variable weight clustering model when faced with large-scale and complicated software projects.

5. Conclusions

This paper analyzed and studied on the problem of risk measurement during developing large-scale and complicated software system and proposed a multilevel risk measurement algorithm of software projects based on grey variable weight clustering model. Standing upon existing analysis of risk measurement of software projects, this paper established an improved multilevel risk measurement system of software projects, and furthermore, based on constructing whitenization weight functions of different risk measurement ranks, obtained grey clustering coefficients between software projects and different risk measurement ranks, whose value could indicate what ranks software projects' risks stood at. Since the algorithm takes the differentiations of different measurement indexes' significance towards different measurement ranks, the reliability of this algorithm has been improved. Meanwhile, the algorithm employs grey system theory to construct model, which makes its physical meaning clear and calculation simple.

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