IETI Transactions on Business and Management Sciences, 2016, Volume 1, Issue 1, 47-55.
http://www.ieti.net/tc
An International Open Access Journal

Evaluation of the application of BIM technology based on PCA - Q Clustering Algorithm and Choquet Integral

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Keywords: PCA-Q Clustering; Choquet integral ; BIM Technology.

Abstract: For the development of the construction industry, the construction of data era is approaching, BIM (building information model) with the actual needs of the construction industry has been widely used as a building information clan system software, different software for the practical application of different maturity, through the expert scoring method for the application of BIM technology maturity index mark, establish the evaluation index system, using PCA - Q clustering algorithm for the evaluation index system of classification, comprehensive evaluation in combination with the Choquet integral on the classification of evaluation index system, to achieve a reasonable assessment of the application of BIM technology maturity index. To lay a foundation for the future development of BIM Technology in various fields of construction, at the same time provides direction for the comprehensive application of BIM technology.

0 Preface

Since China entered the twenty-first Century, the rapid development of economic construction, with the increasing progress of economy, the construction industry chain has been a huge influence, building the application of information technology has also been a good development, BIM technology is a cutting-edge technology of global construction of information technology in our country, the promotion of the development of.BIM technology has attracted much attention and has been applied in the actual construction project with his family thought, but the BIM technical information structure is huge, there is no guarantee that all software can be applied to practical engineering, the application of BIM technology maturity evaluation is conducive to the development of BIM technology and improvement, can make more practical application of BIM technology direct, strengthen the promotion of BIM technology, indirectly provides the direction for the development of BIM technology.

1 Overview of application of BIM Technology

Under the trend of global economic society, industrialization, industrialization, the increasingly close relationship between the information and information factors become economic and social development is one of the important factors.BIM technology architecture exhibition industry, information technology, as the core will become increasingly comprehensive development to adapt to the needs of the actual engineering, the engineering project in BIM Technology of collaborative management more convenient and efficiency, the management of.BIM technology will be closely integrated project specific technical level and management level, the combination of tools and techniques to project whole life cycle management, reasonable and effective control of engineering project in the various stages of the operation, to ensure smooth operation of each project.

2 Classification of PCA application maturity evaluation index based on Q - BIM clustering algorithm

By the experts on the BIM technology application maturity evaluation index system for scoring, each index is composed of 10 factors, the table is as follows: 1:

From table 1 shows, each level indicator is viewed as a 10 dimensional vector, a total of 18 10 dimensional vector consisting of high-dimensional data sets, in order to ensure the rationality of the data classification, principal component analysis method and Q type clustering combination method, the screened reasonable data group to the overall response number according to the characteristics. The method through the PCA of indicators for dimensionality reduction, low dimensional embedding data expressed as data manifold linear smoothing function combination, Q type clustering algorithm was then used to reduce the dimension of the data set, cluster analysis was conducted, and the index system of reasonable classification.

1）Standardized processing of raw data[2-5]

When the principal component analysis is carried out, the dimension of the index is often different, so the influence of the dimension should be eliminated before the principal component is calculated[6-8].Standardization of raw data transform are as follows:

$$x_{ij}^{*}=\frac{x_{ij}-\overline{x}_j}{s_j} \qquad i=1,2,...,n;\ j=1,2,...,p \tag{1}$$

Among: $\overline{x}_j=\frac{1}{n}\sum_{i=1}^{n}x_{ij}$ ， $s_j^2=\frac{1}{n-1}\sum_{i=1}^{n}(x_{ij}-\overline{x}_j)^2$

Table 1 BIM application maturity evaluation index score

index	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10
Data completeness and availability	85	80	82	85	82	83	82	81	85	86
Data mutual	86	84	80	90	83	82	84	82	83	84
Conflict detection capability	85	83	82	90	84	81	83	80	80	80
information content	84	84	84	91	81	80	80	82	83	85
Support professional	82	85	83	93	82	81	82	80	82	83
Spatial localization ability	80	83	84	85	84	85	83	81	90	90
Hardware capability	90	85	83	83	85	82	80	0	0	0
Timeliness of information transmission	95	87	82	84	81	85	81	84	80	82
Access control	90	83	81	86	81	87	83	82	80	0
Change management and Application	88	82	87	82	84	80	86	81	83	85
life cycle	80	80	84	0	83	83	81	0	0	0
Business information flow	84	80	85	85	83	82	82	81	84	86
Basic equipment	86	0	84	0	83	81	81	0	0	0
Human resource management	84	83	85	82	84	82	80	82	80	81
Product based, service oriented	89	84	83	82	84	81	83	82	80	82
Contract system	84	85	83	80	83	0	0	0	0	0
Regulation	83	84	81	81	84	0	0	0	0	0
Reserve forces	85	82	80	82	81	0	0	0	0	0

2）Computing covariance matrix

$$\Sigma = \left(s_{ij} \right) p \times p \text{,among}$$

$$s_{ij} = \frac{1}{n-1}\sum_{k=1}^{n}(x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j) \quad i,\ j = 1,2,\ldots,\ p \qquad (2)$$

3）Find the eigenvalues of the covariance matrix λ_i Characteristic vectors after orthogonal variation a_i

Covariance matrix m Characteristic value of a feature vector $\lambda_1 \geq \lambda_2 \geq \lambda_3 \ldots \lambda_m > 0$,Just before m Variance values corresponding to the principal components.， λ_i Corresponding unit feature vector a_i Principal component F_i On the coefficient of the original variable,The original variableNo. i Principal component score F_i by:

$$F_i = a_i X \qquad (3)$$

Variance (information) contribution rate of principal component is used to reflect the size of information, α_i by：

$$\alpha_i = \lambda_i / \sum_{i=1}^{m}\lambda_i \qquad (4)$$

4）Select principal component

Finally to select a few main components,That is $F_1, F_2, \ldots\ldots, F_m$ in m Is determined by the variance (information) cumulative contribution rate $G(m)$ To determine.

$$G(m) = \sum_{i=1}^{m}\lambda_i / \sum_{k=1}^{p}\lambda_k \qquad (5)$$

When the principal component is worth the cumulative contribution rate of more than 85%, it can be found that the performance of the initial variables can be reflected by the information.

5）Calculate principal component load

Principal component loading is a reflection of the principal component scores F_i with Initial variable X_j The close degree,Initial variable $X_j(j=1,2,\ldots,\ p)$ In each main score $F_i(i=1,2,\ldots,\ m)$ Load in $l_{ij}(i=1,2,\ldots,\ m;\ j=1,2,\ldots,\ p)$:

$$l(Z_i,X_j)=\sqrt{\lambda_i}a_{ij}(i=1,2,\mathrm{L}\ ,m;j=1,2,\mathrm{L}\ ,p) \tag{6}$$

6）Principal component score

Calculate sample in m Score on a principal component:

$$F_i=a_{1i}X_1+a_{2i}X_2+\ldots+a_{pi}X_p \quad i\ =\ 1,2,\ldots,\ m \tag{7}$$

Solving model:

Using Matlab programming, the 8 main components, the cumulative contribution rate reached 91.22%, can be clearly seen as the main component of the filter has a strong representative and reasonable.

Table 2 principal component analysis

Principal component category	Characteristic value	Individual contribution rate	Cumulative contribution rate
Data completeness and availability	54.445	54.445	54.445
Conflict detection capability	7.407	7.407	61.852
information content	6.182	6.182	68.034
Hardware capability	6.041	6.041	74.075
Timeliness of information transmission	5.351	5.351	78.425
Change management system	4.645	4.645	83.070
Business information flow	4.416	4.416	87.487
Product based service	3.732	3.732	91.219

By using the Q clustering algorithm to classify the principal components, the specific steps are as follows:

1）set up $\Omega=\{w_1, w_2, w_3, ...w_{12}\}$,Calculate the distance between 8 sample points d_{ij} ,Record as a matrix $D=(d_{ij})_{n\times n}$, $d(x,y)=[\sum_{k=1}^{p}|x_k-y_k|^2]^{\frac{1}{2}}$;

2） The preparation of 8 kinds of data, each class contains only one sample point, all kinds of platform height is 0;

3）The nearest two class is a new class, and the distance between the two classes is the height of the platform;

4）Calculate the distance between the new class and other types of values, if the class number is equal to 1, the transfer step (5), not equal to 1 when the return to the step (3);

5）Determines the number and class of classes.

Table 3 results of cluster analysis

principal component	Data abundance and reliability	Conflict detection capability	information content	Hardware capability	Real-time information transmission	Change management	operation flow	Products and services
category	1	2	2	1	1	2	2	1

3 Evaluation of principal component index by Choquet fuzzy integral

Combined with BIM technology application maturity index, index factors, the main factor as a fuzzy aggregation operator, using Choquet fuzzy integral,Its definition is as follows:Set a finite setY=$\{y_1, y_2, y_3, ...y_{n-1}, y_n\}$,the function is defined as the Y (x) discrete function, and the function value is $\{y(x_1), y(x_2), y(x_3).....y(x_{n-1}), y(x_n)\}$,The assumption function y (x) is monotone increasing,That is $y(x_1)\le y(x_2)\le y(x_3).....y(x_{n-1})\le y(x_n)$,Then define[11]Y (x) in the X on the fuzzy measure of the Choquet fuzzy integral:

$\int_X \mu(x)d\rho=\sum_{i=1}^{n}\rho(A_i)[y(x_i)-y(x_{i-1}]$,integral form： $y(x_0)=0$, $A_i=\{x_i, x_{i+1}, ..., x_n\}$ (10)

Choquet is an extension of weighted average operator.

The above fuzzy integral can be used to sort the dominant elements in order to get the final BIM technology application maturity sort, and the application effect of BIM technology to complete the comprehensive evaluation. Sort results are shown in table 4:

Table 4 main component index sort results

principal component	category	sort
Data abundance and reliability	1	3
Conflict detection capability	2	2
information content	2	4
Hardware capability	1	6
Real-time information transmission	1	1
Change management	2	5
operation flow	2	7
Products and services	1	8

4 Conclusion

This paper introduces the concept of BIM technology application, reference to the United States on the application of BIM technology maturity standards[12],In accordance with the principle of scientific rationality grading on the application of BIM Technology Maturity, and gives the application of BIM Technology mature degree index system, according to the expert's score, using PCA-Q type clustering algorithms for data processing, classification, combination of Choquet fuzzy integral derived the principal component (indicators) sort, direct reflect the maturity of the application of BIM Technology gap, for the future development of the technology and application of Bim and provide convenience.

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