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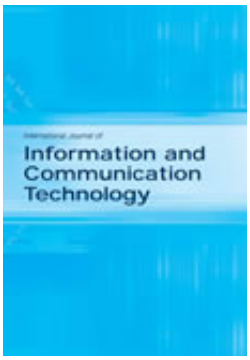

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The application of geometric form in architectural interior environment design

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Abstract: In the traditional interior design realm, limitations in conveying spatial concepts led to the emergence of virtual reality (VR) and artificial intelligence (AI) integration. These technologies aim to offer enhanced user experiences and meet personalised demands by simulating indoor environments. The contemporary approach emphasises a harmonious blend of art and science to streamline design processes, aiming for efficiency. However, despite efforts to simplify and automate design, reliance on specialised designers persists, elongating design cycles and increasing costs. Presently, manual furniture selection involves a cumbersome process, impacting design outcomes and elevating building expenses. This paper explores geometric and mathematical optimisation strategies for interior environmental design in buildings, aiming to address inefficiencies in design and bridge the gap between professional expectations and user preferences.

Keywords: geometric form; architectural design; indoor environment; spatial planning.

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Biographical notes: Nan Yin studied in the Jilin College of the Arts from 1999 to 2003 and obtained his Bachelor's degree in 2003. Since 2006, he has been a teacher of Environmental Design in the Jilin Institute of Architecture and Technology, and has published more than ten papers in Chinese journals.

1 Introduction

Domestic leaders in the field of interior design include Autodesk in the USA, Kusile in China, etc. Their internal design software is easy to use, greatly reducing the working time of designers, so that ordinary users can experience the fun of interior design, and better convey the ideas of users. Users to fill in the room, can make use of interior space planning software for 3D reconstruction, only need to be replaced in the database to drag or household items, can effectively complete interior space planning and correction, in 3D environment, experience to the design and manufacture of the virtual indoor, can see everything is true (Fitria et al., 2021; Bai, 2019).

The heavy workload, complex design and strong professionalism of the interior design of buildings restrict the development of the network interior design industry to the direction of data, high efficiency and personalisation. Therefore, the development of an intelligent design system is of great practical significance and significance for solving these problems and promoting its better and more rapid development. In addition, it also has important application and theoretical significance for computer animation, games, military simulation, circuit layout and other aspects.

At present, the interior space design software developed by using geometric form has been more users to join the interior design, so as to achieve the goal of 3D effect preview. Aiming at the characteristics of high professionalism, high cost and high labour participation rate of interior space design on the Internet, this paper proposes an intelligent building scheme based on hybrid recommendation mode. This method has a certain application prospect in computer animation, military simulation, circuit design, etc. (Passy, 1970; Stathacopoulos and Barry, 1974).

The development of geometry is an ever-changing process, which can obtain the user's preferences according to the user's activities and activity characteristics, and make suggestions suitable for the user. In this paper, according to the characteristics of the proposed intelligent system based on hybrid recommendation mode, the main geometric morphology methods are summarised:

A review of the application of geometric forms in the field of architecture and interior design reveals that a great deal of research has been carried out by scholars at home and abroad. For example, Wang et al. explored the influence of specific geometric forms on spatial perception, and Reichert et al. applied variable geometric forms based on parametric design. The current research on the application of geometric forms mainly focuses on a small range of internal spaces with specific forms. However, on the whole, there is a lack of systematic research on the scientific application of geometric forms. Unlike Wang et al.'s study on the influence of geometric forms on spatial perception, this study found that geometric forms mainly affect the connectivity of interior spaces by changing the spatial movement and functional zoning. This may be due to the fact that Wang et al. used a more idealised experimental scenario, whereas the real building interiors in this study are influenced by more complex factors. This provides an opportunity to expand the analytical perspectives for subsequent studies. The core idea of geometric morphological algorithm is to construct the user's feature vector or project's feature vector based on the objective to be learned, and then provide the user with the information to be related according to the similarity between the information features to be expressed. After introducing the implicit Markov model, Li et al. combined it with the probabilistic model and CB method, and adopted the implicit Markov model to select the user model, so as to achieve the suggestion to the customer. Adnan et al. proposed a new fuzzy news recommendation system, which integrates fuzzy reasoning into content-based geometric form method to evaluate current news reports. Aiming at the traditional network environment, this paper establishes a fast and efficient object-oriented query method, establishes a general model for new products facing potential customers, and solves the traditional 'cold start' problem. Cold start problems include 'cold start' and 'cold start', that is, there is no reason to offer any advice to a new customer in a new user or project. Liu identifies individual differences between different musical creations based on users' preferences, and compares random algorithms, genetic algorithms and genetic algorithms to come up with suggestions suitable for music. By associating the semantics of new items with old items, Fan et al. construct a weighted labelled directed graph by

defining the meaning relationship of the definitions, and give a classification and recommendation model for new items (Kirschen et al., 2018; Olivier et al., 2019; Rubio-Martín et al., 2015).

Based on the characteristics of objects, CB recommendation algorithm does not have the problem of "cold start" or the bias of popularity. Therefore, the method has high interpretability.

CF is a common user-based, project-based, pattern-based geometric form method for Coin this basis, CF's recommendation algorithm is based on the user's historical preference to provide appropriate services for the recommended customers. In this process, users' preferences are not required, only the characteristics of the project itself are taken into account. CF recommendation is a typical machine learning method, which uses the historical data of the participants as training samples to establish a network model to describe the recommendation relationship between the participants, and uses the optimal method to determine the parameters of the model, and then obtains the appropriate recommendation value according to the method. Renin L4 constructed a new news feature vector by vector space pattern (VSM) and TF-IDF method, and applied Bisecting k-means clustering algorithm to classify the feature vectors. In order to improve the recommendation accuracy of CF recommendation system, Ju et al. improved Pearson's collaborative screening method, and optimised the conventional geometric shape method by analysing user contour, item characteristics and user behaviour. Due to the rapid increase of sample, due to the rare data, results in the decrease of the suggestions on the user's quality. Nassarl et al. have established a new model for multi-criteria collaborative filtering based on in-depth study, which takes advantage of the characteristics of users and engineers and introduces it into hierarchical and hierarchical networks.

The method does not require accurate modelling of the experimental objects, nor does it require the attributes of the objects to be accepted by the machine. Moreover, the geometric morphology method is not affected by the involved domain, so it is suitable for most cases. But CF method on the basis of the history of the target preferences, so both new users and new plan, will appear a new problem, therefore, to promote efficiency of the method and the target of the number of historical data and the accuracy are closely related. In addition, in the rapidly increasing number of research targets, the recommendation accuracy problem caused by using sparse matrix should not be underestimated (Kuznetsova et al., 2017; Wu and Li, 1992; Hu et al., 2021; Gradziński, 2017). This study explicitly addresses the application and challenges of geometric forms in architectural interior design. This study is of great significance because the rational use of geometric forms can optimise the function of space and enhance the user experience. However, in the process of applying geometric forms, designers are faced with the gap between theory and practice, and are unable to realise the scientific application of geometric forms. Therefore, in-depth exploration of the application of geometric forms in interior design is urgently needed to promote the development of this field. The current challenges faced by in-house design software and designers stand out. In order to realise scientific and personalised interior design, there is an urgent need to combine advanced technological tools to enhance user experience. In this study, we propose to construct an intelligent interior design scheme through geometric and mathematical optimisation strategies. Collaborative filtering methods and convolutional neural networks will play an important role.

2 Research methods

The goal of this study is to bridge the gap between current theory and practical application by empirically analysing the effects of geometric forms on the functionality of interior spaces. This is in line with the problem of inconsistency between the theoretical study of geometric forms and the practical application challenges raised in the literature. Based on the geometry of the interior design platform, for housing matching and family planning advice of carried on the thorough discussion, finally formed a system of intelligent design. Because this section covers a lot of filial piety animal and basic knowledge of the neural network, this chapter will therefore individual technology principle of list. Establish an image feature vector library, so as to achieve the image similarity measure between, and through a project-based collaborative filtering method and a geometry method based on the content to construct a hybrid recommend pattern matching (Schiller and Evans, 1998). Collaborative filtering methods are used to construct the basic pairing suggestion model through historical pairing data. Convolutional neural networks are used to extract the features of furniture images and build corresponding feature vector libraries. The synergistic utilisation of these two technical tools helps to improve the accuracy of intelligent interior design solutions.

2.1 Geometry related mathematical concepts in the application of interior design

In the geometry method, based on the calculation of similarity. After the recommended mode established a foundation, we have adopted a new recommendation algorithm to improve the model, this process should consider the similarity of the project, the following simply describes some commonly used methods.

$$\begin{aligned} d(x, y) &= \sqrt{\sum (x_i - y_i)^2} \\ sim(x, y) &= \frac{1}{1 + d(x, y)} \end{aligned} \tag{1}$$

As is the point of two dimensional vector space, type is in the distance, continental distance away from the absolute distance is, the smaller the value, the greater the similarity, x, yn2.1d (x, y)x, ysim (x, y). Due to the vector data size may exist between the order of magnitude of other differences, so before using Euclidean distance metric, for data normalisation process. When the low dimension and vector data to measure the size of the more important, the better result of Euclidean distance. This article selects Euclidean distance as the image similarity measure in this paper.

$$p(x, y) = \frac{\sum x_i y_i - n\overline{xy}}{(n-1)s_x s_y} = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n\sum x_i^2 - \left(\sum x_i\right)^2}\sqrt{n\sum y_i^2 - \left(\sum y_i\right)^2}} \tag{2}$$

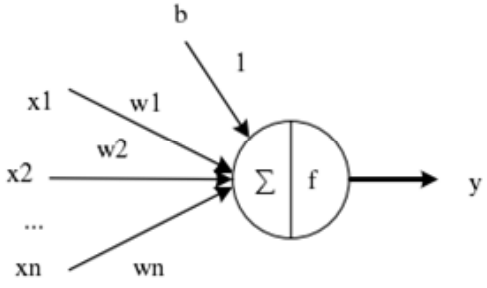
Pearson correlation coefficient reflects the tightness between two interval variables, the values. [–1, +1] s_x, s_y is the sample standard deviation x, y.

$$T(x, y) = \frac{x \cdot y}{\|x\|^2 * \|y\|^2} = \frac{\sum x_i y_i}{\sqrt{\sum x_i^2}\sqrt{\sum y_i^2}} \tag{3}$$

Such as cosine similarity is referring to the cosine of the Angle between two vectors, the difference vector in the direction that is often used to offset the higher dimensional Euclidean distance.

For two equal lengths of string, by replacing operation makes the two strings are equal the required minimum replacement number, the number of times is the hamming distance of two strings. In Figure 1 string with hamming distance is 2 AB. When the image as the research object, through the hash algorithm to image perception mapping for equal length of string, the hamming distance between the two images from the smaller, shows that the higher the measure of the similarity between items (Peng and Liu, 2021; Gavrilova and Rokne, 2003).

Figure 1 The geometry in the construction of interior design model of the Euclidean distance method



As shown in Figure 1, Jaccard similarity is used to compare the differences between finite sample in the sample, its calculation, and for the target object, Jaccard similarity It is to point to in the dataset and the intersection of proportion in the with and set in between the values, the value, the greater the similarity is higher, ABJ(A, B)ABAB[0, 1]. In particular, when all is empty, has a value of 1, A, BJ(A, B). This measure is applicable to the binary data, in this paper, inspired by the Jaccard similarity, to realise the calculation of degree of match between household items.

$$J(A, B) = \frac{|A \cap B|}{|A \cup B|} \tag{4}$$

2.2 Based on the indoor environment of habitant geometry design

Based on the user, according to the history of user preference information, search for similar users, realise to users recommend other similar items. In the table, the user further away from, so recommend to users like items.

As shown in Table 1, a CF algorithm based on projects similar to the former, the participation of relevant data without user, based on subject characteristics information of the project itself, only through the similarity relationship between projects and project recommend prediction. In the table, according to the historical preference information, be

fond of user preference items, so the projects and project is similar, it is proposed that the preference items may also be user preferences.

Table 1 The CF recommendation algorithm based on the user 1

User/items	*The project A*	*Project B*	*Item C*	*Project D*
User A	✓	-	✓	Recommended
User B	-	✓	-	-
User C	✓	-	✓	✓

Table 2 Watch the CF recommendation algorithm

User/items	*Project A*	*Project B*	*Item C*
The user A	✓	-	✓
User B	✓	✓	✓
User C	✓	-	Push the deposit

Unlike CF algorithm, based on the content (the content-based, CB) recommendation algorithm relies on the internal characteristics of the object of study, in building a good object feature vector, by the degree of similarity between feature vector is recommended for users. On this basis, puts forward a new geometry method based on the content of the project, its calculation process is complex, the efficiency is low. For CB operations, recommended by a convolution of the neural network-based method was proposed to extract image family project of and by PCA to further compression, so that the CB recommended speed (Table 2).

$$\begin{aligned} z^l &= w^{l-1}a^{l-1} + b^{l-1} \\ a^l &= f(z^{l-1}) \\ y_{w,b}(x) &= f(w^T x + b) \end{aligned} \tag{5}$$

Among them, said input, according to the current network layers, is the linear and the current layer, is through the activation function of nonlinear transformation after the result, is the offset of the current layer, said the weight, xlzabw.

Just by the way to spread to build neural network model is not enough, in addition to from the input layer to output layer prior to operation, also need by the output layer to input layer back propagation algorithm. Back propagation is a supervised training mode, to reverse transfer network, the output of the error network parameters correction and the training of the network model.

The back propagation algorithm steps:

According to the data input and the current parameters and calculate each layer and, computation formula is as follows, wbza:

$$\begin{aligned} z^l &= w^{l-1}a^{l-1} + b^{l-1} \\ a^l &= f(z^l) \end{aligned} \tag{6}$$

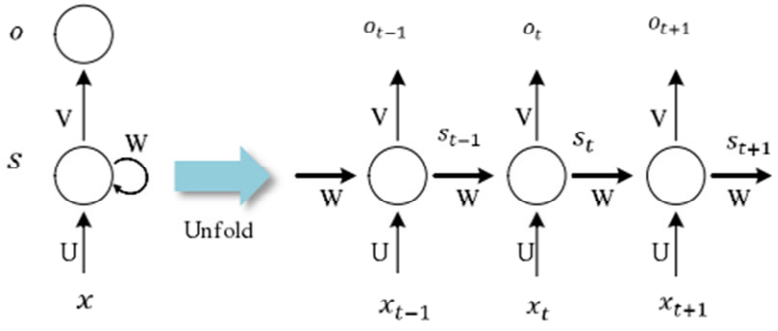
Error value, the formula for computing the output layer is as follows:

$$\delta^L = \left|y - a^L\right| * \sigma(z^L) \tag{7}$$

2.3 Value is calculated for each layer of the error

Convolution computation methods, from the most basic figure pixel array extract image feature, and when the higher the degree of hierarchical image, its structure is more complex. Convolution method not only can be used in the original image data, and can be the basis of the original image using convolution properties. With graphic method according to pixel convolution method, shown in Figure 2.

Figure 2 The geometry of convolution layer associated with building design (see online version for colours)



The picture using a matrix slip on the pixel grid, then with the product of the resulting image data calculation, get the information of the next level. In this, because considering the simple narrative, without considering the thickness of the convolution, and USES is 224 * 224 * 3D graphics, as a result, the convolution operation is a three-dimensional convolution, its calculation method is similar to a one-dimensional convolution, so not say here.

In some sequence, two-way RNN can well preserved better data. In this method, we put the layout problem is decomposed into multi-level, its type is related to the segments of the function in front of, is also associated with the back of the segments of function, therefore, has a two-way memory ability of RNN is more applicable to the design proposal of this paper.

Deep two-way RNN consists of two aspects: one is the previously hidden layer transfer message, contains the pros and cons of the message.

3 The result analysis

3.1 geometry optimisation in architectural interior design

Through the study of 846 different types of home decoration schemes, including five different types of furniture, a total of 1,240 furniture products, including 190 TV cabinets, 418 beds, 257 bedside tables, and 201 wardrobe. 600 samples were randomly selected as training samples, and 300 samples were selected from 712 samples on the basis of 246 samples to test the correctness of the samples. In the following table, each family item can be expressed as (TVark_14, BED_149, BED_12, DresSER_1, and Wardrobe_1). Each family item is expressed as ‘tympanum’, where ‘type’ is the item type name and ‘num’ is the item type number. Therefore, each combination can be

expressed as a five-membered combination, with 0 representing that there is no corresponding family item in the combination. 0 means that there is no bed table among the five elements of the plan, and a recommendation needs to be made to a house of type wardrobe, and then a Ton recommendation is obtained based on the recommendation result.

The design idea of this scheme is easy to implement, without taking into account the characteristics of 3D residential project itself, and the calculation speed is fast. However, the collaborative filtering method mainly relies on the past matching data, and if there is no history of matching, it will be regarded as 0. In addition, if a new product is developed in the interior design software, there will be a 'cold' problem because there is no historical matching data. In this 'database', if there is a new house model, then the suggestion is groundless, and there will be no new homes.

CB geometry method is based on the user's own attribute characteristics are recommended, because it only rely on the user's own data for recommendation, so there will be no deviation and the popularity of the project could start problem, and has higher interpretability. However, in the intelligent home space modelling, there are some problems, such as difficult to extract characteristics, complex calculation process and low efficiency. At present, there are four main feature extraction methods: statistics-based feature extraction, topological relation feature extraction, geometric structure feature extraction and projective feature extraction. By comparing different feature extraction techniques, it is found that it is very difficult to apply 3D modelling technology to feature extraction compared with text and image. Moreover, due to the existence of a large number of data storage forms in 3D modelling, this technology is difficult to effectively extract features.

According to the above VGG-16 feature extraction of the image, the feature vector of each image is 4096D vector, its main goal is according to the similarity of the same type of house, find previously corresponding item Num, in order to estimate the zero value of match, the sparse portfolio model more intense, raise the promotion of the recommended model accuracy. In the 4096-dimensional vector, the similarity calculation workload is very big, so as to greatly reduce the time of the operation. The dimensionality of the above eigenvectors is reduced by using PCA method, which keeps good eigenvalues and greatly speeds up the computation speed. CA is a common method of dimensionality reduction. In order to dimensionally reduce a one-dimensional feature vector, a single bit orthogonal basis must be selected to map the feature information of the original image to the new coordinate system. In order to make each dimension contain more information, the covariance of each dimension is 0, indicating the uncorrelation of the two dimensions. When transforming the attribute data of the original image into the new coordinate system, the variance value is maximised, so as to obtain better performance. CA linearises a series of data with linear relationship and decompositions it into a series of different linearly independent datasets, so that the main features can be extracted from these data effectively. The key of PCA algorithm is to use the correlation between vectors in the eigenmatrix to keep the uncorrelated parts, so that it can better reflect the validity of the image and simplify the calculation results. The specific steps of the algorithm are as follows:

1 Here, the total number of examples of various family activities is 1,000, and the image feature vector constructed by VGG-16 convolutional neural network can be

reduced from 1,000 4096-dimension vectors to dimension, that is, one 4096-dimension vector represents the feature vector of the first image.

2 Each column represents a kind of feature quantity, and the average of each element in each column divided by the average of the attributes in this column is 0 average, so as to simplify the operation of covariance.

3 Solve the covariance matrix of the eigenvector matrix.

4 Perform operations on the eigenvalues and eigenvectors of the covariance matrix, where the next formula is the eigenvalues and normalise them.

Eigenvectors corresponding to eigenvalues, and the eigenvectors are normalised:

$$A_{cov}x = \alpha x \tag{8}$$

Traversing the original match ability recommendation matrix, for the row home item and the first home item, if the two items are of different classes and the value of their match ability) is 0, the match ability data need to be filled with prediction, DcolDm(type$1_{num1\ 1}$, type$2_{num\ 2}$). In the similarity table built in the first step, the matching degree data missing from the home item is retrieved respectively. The calculation method of predicted match ability is shown in formula below:

$$\begin{aligned} &Dm\left(\text{type } 1_{num\,1}, \text{type } 2_{num\,2}\right) = D[row, col] \\ &D[row, col] = Dm_{new} \\ &= \begin{cases} \left(\dfrac{1}{2*i}\sum_{i}\left(Dm1*sim_1 + Dm2*\text{sim } m_2\right)\right), & 0 < i \le \text{sim Num} \\ 0, & i = 0 \end{cases} \end{aligned}$$

where represents home items similar to type 1, and represents items similar to Type$sim_{type\ 1,}$ $1_{num\ 1}$, $sim_{type\ 2}$, $2_{num\ 2}$.

Home item, represents the similarity between SimType1, type and type respectively, sim1, sim2, $1_{num\ 1}$, $sim_{type\ 2}$, $2_{num\ 2}$.

Among the top household items in degree ranking, the missing collocation data should be predicted by counting the items with collocation data, and then updated after obtaining the new collocation data of type and type:

$$\begin{aligned} Dm1 &= Dm\left(\text{type } 1_{num\,11}, sim_{type\ 2}\right) \\ Dm2 &= Dm\left(\text{sim }_{type\,11}, type_{num\ 2}\right) \\ \text{sim } 1 &= \text{sim}\left(\text{type } 1_{num\,1}, sim_{type\ 1}\right) \\ \text{sim } 2 &= \text{sim}\left(\text{type } 2_{num\,2}, sim_{type\ 2}\right) \end{aligned} \tag{9}$$

Based on the parameters selected in the above experiments, pan is set to 128, sternum is set to 2, sinus is set to 4, and a mixed CF recommendation mode based on content recommendation is established. After the top > 20, the traditional geometry method has reached the saturated state, but it is improving, we recommend precision because this kind of method of recommended matrix model is a very rare, so cannot use in the history matching, nor for the increase of household products, However, our algorithm adopts the text-based geometry method, which can effectively solve this problem. As can be seen

from the chart, when Ton = 20, the accuracy of the suggestion is more than 80%, which can solve various problems in family life very well.

4 Conclusions

On this basis, combined with a practical interior space planning system, this paper discusses the matching geometric form method and optimisation method based on home environment. In the first category, the CF method based on engineering is used to construct the basic matching suggestion pattern, the convolutional neural network is used to extract the characteristics of the image, and the corresponding feature vector library is built. The second category is the digital processing of data in the picture, then use a text hidden methods to extract the vector intersection between, then using two different LSTM construct different partitions and the layout of the different modes. Experiments show that the proposed intelligent design methods can well adapt to the actual matching and layout of indoor space, and are beneficial to practical applications and scientific research. It has been found that different types of geometric forms, such as linear and curved forms, can enhance or weaken the connectivity and functional zoning of indoor spaces by changing the visualisation of the space and the line of movement of human beings. For example, the application of curvilinear forms can form a dynamic effect with stronger mobility and enhance the interconnection between areas. This provides a theoretical basis for the scientific and targeted application of geometric forms. Through to the surface of the furniture, the use of VGG 16 convolution neural network to the plane of texture analysis, and calculated by applying the method of Euclidean distance similarity between two images, thus achieved the similarity between the measurement mode. This study analyses the influence of geometric forms on the function of interior space by empirical means, bridges the gap between theory and application, and contributes to the scientific and customised application of geometric forms. This provides a reference for the selection and optimisation of geometric forms in building interior design. This study is mainly based on sample analysis, with limited research scenarios and scope. This may affect the generalisability of the findings. In the future, the robustness of the conclusions can be further improved through large sample validation.

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