Multifunctional Space Transformation Design in Multidimensional Interior Design Based on Citespace Knowledge Mapping

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Abstract In this paper, based on Citespace software and knowledge graph theory and method, a knowledge graph construction algorithm and word frequency detection algorithm for multifunctional space transformation design are proposed. In the knowledge graph construction algorithm, based on the theory of co-citation analysis and path-finding network algorithm, the TF-IDF weighting algorithm is used to extract the clustering labels, and the intermediary centrality algorithm is used to determine the key points in the graph network. And in the word frequency detection algorithm, bulk information detection algorithm is used to detect the highlighted words in the published literature. In the knowledge graph analysis of multifunctional space conversion design, the number of literature issued during 2014-2023 shows a fluctuating trend of first increase and then decrease, and the research is mainly concentrated in the discipline of building science and engineering, with the number of literature being 326 articles. The research institution Nanjing Forestry University has the highest number of publications, 62, while Kunming University of Science and Technology is the structure with the highest centrality, with a centrality of 0.2. The key with the highest frequency of occurrence in the literature is interior design, up to 286 times, while the highest intermediary centrality is spatial design (0.72). Above all, this paper has important impetus for the innovation of the multi-functional space transformation design in the technology and method.

Index Terms citespace, knowledge graph,TF-IDF, co-citation analysis, pathfinding network algorithm

I. Introduction

As the urban population continues to expand, the demand for housing increases exponentially, leading to heightened urban living space pressures and subsequently, a persistent rise in urban housing prices [1, 2]. Among these demands, the living room represents a fundamental and rigid requirement for modern urban youth. Concurrently, there is a growing diversification in people's preferences for residential functional spaces, with small and medium-sized houses not merely reflecting a reduction in living area but also embodying a novel lifestyle choice [3, 4].

Dwellings serve not only as the fulfillment of people's fundamental living requirements but also encompass a multitude of diverse functions, including living, leisure, and home office activities [5, 6]. Consequently, within the constraints of limited space, the realization of a harmonious coexistence among these various functional spaces necessitates the adoption of an effective design approach, namely, "variability." Flexibility and adaptability must be inherent in the design of residential functional spaces to facilitate functional transformations, thereby accommodating the evolving needs of families across different time periods [7, 8].

In the past, designers of interior functional spaces adhered to conventional thinking, with most individuals perceiving architectural spaces and interior design as limited to fixed functions and areas [9]. However, with the advancements in science and technology, the landscape of indoor spaces has diversified, and factors influencing people's sense of well-being have shifted from material and technological conditions to lifestyle changes and shifts in mindset. Consequently, as we strive for diverse living modes, ensuring that residential spaces possess a broader range of adaptability has emerged as a novel challenge for residential design [10].

Over the past 40 years of reform and opening up, China's urbanization process has accelerated, leading to an increasingly acute contradiction between land resources and population growth. To address the growing demand for housing and alleviate the housing crisis, the concept of small houses has emerged. Despite their smaller footprint compared to larger dwellings, small houses must cater to the diverse and rich needs of their inhabitants. Consequently, achieving a harmonious coexistence of multiple functions within limited

Wang : Multifunctional Space Transformation Design in Multidimensional Interior Design Based on Citespace Knowledge Mapping

ARCHIVES DES SCIENCES
A Multidisciplinary Journal

spaces has garnered significant attention [11]. Magdalena C. has incorporated environmentally sustainable principles into interior design, ensuring that residential spaces not only meet human needs but also contribute to environmental sustainability [12]. Furthermore, Itami, H. et al. explored the cognitive differences between interior design professionals and non-professionals regarding residential living. Their findings revealed that non-professionals tend to use emotional language in their representations, whereas professionals prioritize interior structure and detail perspectives. However, both groups shared similar viewpoints at the aesthetic value and cognitive structure levels [13]. In another study, Sanni Siltanen introduced a modular, real-time, scaled-down pipeline for interior design applications. This approach offers more realistic simulations of interior scenes under various lighting conditions, surpassing traditional methods [14]. Additionally, Christoph et al. delved into the visual effects of texture on object surfaces, explaining how texture can distort the perception of spatial extent. They highlighted the potential applications of this phenomenon, known as visual interference of texture, in interior design [15].

Nowadays, living space is becoming increasingly valuable, particularly in metropolises such as Beijing, New York, and London. Consequently, there is a significant demand for intelligent convertible spaces that can offer multiple functionalities. Sun, Y. attempted to incorporate artificial intelligence algorithms into the design and layout of interior spaces, thereby enhancing the investment-to-output ratio in the interior design process [16]. Li, H. emphasized the concept of interior design as a seamless blend of emotion and mood, and further explored the selection of soft furnishing materials for coastal residential constructions, providing novel insights into the development and optimization of interior design [17]. Fan, Y. proposed a stochastic general equilibrium framework grounded in the notion of sticky house price dynamics. An analysis within this framework revealed that intertemporal and liquidity constraints significantly impact the dynamics of real estate markets [18]. Weinthal, L. drew an analogy between the architectural structures of buildings and the structure of human clothing, suggesting that this comparison offers a unique perspective for comprehending and optimizing interior design [19].

To conduct a knowledge mapping analysis of multifunctional spatial transformation design within the context of multidimensional interior design, this paper introduces the construction algorithm and word frequency detection algorithm specifically tailored for multifunctional spatial transformation design knowledge mapping. In the knowledge graph construction algorithm, we employ the co-reference analysis theory and path-finding network algorithm as foundational frameworks. Leveraging the spectral clustering algorithm, we generate clusters based on the connectivity between nodes, enabling the clustering of sample spaces of any class and achieving a globally optimal solution within the convergence domain. To extract cluster labels, we utilize the TF-IDF weighting algorithm. Furthermore, the centrality measurement algorithm

is employed to ascertain the grouping structure within the knowledge graph network. In the word frequency detection algorithm, we select the two-stage information burst detection method and devise a burst word weight index to capture the dynamic fluctuations in the frequency characteristics of the terminology. This index highlights the hotspot high-frequency words that are most representative of the subject's temporal relevance. Finally, utilizing Citespace software in conjunction with the knowledge map construction and word frequency detection algorithms proposed herein, we conduct a comprehensive knowledge map analysis focusing on both the quantity of literature and the disciplinary classification, centered around the key phrase "multifunctional space conversion design."

II. Citespace Software

Citespace software, a Java-based multi-perspective information visualization tool, was initially developed in 2004. Since its inception, the software has experienced rapid development, with the developers dedicating themselves to promoting and applying the Citespace series visualization software globally. They have consistently updated the software versions to enhance its functionality and capabilities. From its humble beginnings, Citespace has evolved into the latest iteration, CitespaceV, and with the continuous deepening of research and the broadening of scientific inquiry, it is expected that future versions of Citespace will introduce even more powerful features.

Citespace boasts distinctive features, serving as a software tool utilized within scientific literature to identify and visually represent scientific trends and dynamics. It is capable of elucidating research hotspots and disciplinary structures within the content under investigation. Furthermore, it organizes the research history and trends of individual scholars within a specific research field, elucidating the trajectory of disciplinary development and the evolution of disciplinary knowledge. Additionally, Citespace quantifies the frequency and intimacy of collaborations between authors and scientific research institutions, providing insights into the interconnectedness of the research community. The integration of bibliometrics and geographic maps, facilitated by platforms such as Google, further enhances the tool's capabilities. In summary, Citespace not only counts the frequency of collaborations but also reveals the research foundation, frontiers, and future development trends of a given research field.

III. Algorithm for Building a Knowledge Map of Multifunctional Space Conversion Designs

Literature analysis mapping is grounded in the theoretical framework of co-citation analysis and pathfinding network algorithms. Through the systematic collection and rigorous analysis of research literature within a specific field, this approach enables us to identify research hotspots, core scholars, and seminal works, while also elucidating the internal structure of the discipline. Furthermore, the subsequent application of a series of visualization maps facilitates the analysis of the

Wang : Multifunctional Space Transformation Design in Multidimensional Interior Design Based on Citespace Knowledge Mapping

ARCHIVES DES SCIENCES
A Multidisciplinary Journal

dynamic mechanisms underlying scientific frontiers and their evolutionary trajectories.

This study employs the theory of co-citation analysis and pathfinding network algorithm as the foundational framework for its research endeavors. Subsequently, the theoretical basis underpinning the experimental process of this paper is elaborated upon in the following sections.

A. Principle of citation analysis

Citation analysis constitutes a quantitative methodology that utilizes computational and mathematical techniques to dissect the intricate knowledge network formed by citations and citation relationships among scholarly works. This approach enables the identification of quantitative features of literature, the delineation of disciplinary structures, and the exploration of the internal evolution of knowledge within a given field.

Citation analysis includes citation analysis and co-citation analysis. Citation analysis is the analysis of the knowledge flow contained in a large number of collected citations, focusing on whether the literature is cited, when it is cited and the direction of citation. Co-citation analysis refers to the relationship between two documents by recording the number of times they have been cited by other documents at the same time. For example, if we calculate the relationship between documents A, B, and C, co-citation analysis is to record the situation in which documents A and B are cited by document C at the same time, and the higher the citation frequency is, the closer the relationship is, and the more similar the disciplinary backgrounds or research contents of A and B are.

B. Clustering principle basis

Co-citation analysis employs a spectral clustering algorithm to form clusters, leveraging the connectivity relationships among nodes. This method has the capability to partition the sample space of arbitrary classes, and within a specified convergence domain, it aims to achieve a globally optimal clustering solution.

The generation of cluster labels involves the delimitation and interpretation of co-citation (co-occurrence) clusters, and the standard approach is based on the set of words extracted from the set of citation documents (or co-occurrence documents) clustered from the co-cited literature, and each cluster is represented by its highest ranked feature word. The use of TF*IDF weighting algorithm to extract cluster labels is the mainstream of research, the larger the TF*IDF value (weighted value), the more important the subject word is, the higher the degree of characterization of the clusters, and the weights of the TF*IDF of the words are calculated as follows:

$$TF \times IDF = \text{Word Frequency } (TF)$$
$$\times \text{ Inverse Document Frequency } (IDF). \quad (1)$$

Word Frequency (TF)

$$= \frac{\text{The number of occurrences of a word in a document}}{\text{Total number of words in the document}}. \quad (2)$$

Inverse Document Frequency (IDF)

$$= \log\left(\frac{\text{Total number of documents in the corpus}}{\text{Number of documents containing the word} + 1}\right). \quad (3)$$

It is further stated that spectral clustering algorithms are devised based on connectivity relationships. Specifically, the process of quantifying the strength of connectivity among nodes in the knowledge graph (i.e., the edges of the graph) essentially involves normalizing the co-occurrence or co-reference matrices. Moreover, three distinct methods exist for calculating this connectivity strength.

Clip angle cosine algorithm is,

$$\text{Cosine}\,(C_{ij}, S_i, S_j) = \frac{c_{ij}}{\sqrt{S_i S_j}}. \quad (4)$$

Jaccard's algorithm is,

$$\text{Jaccard}\,(C_{ij}, S_i, S_j) = \frac{C_{ij}}{S_i + S_j - C_{ij}}. \quad (5)$$

Dice algorithm is,

$$\text{Dice}\,(C_{ij}, S_i, S_j) = \frac{2C_{ij}}{S_i + S_j}. \quad (6)$$

The values of the linkage strengths obtained after normalization are all between 0 and 1, where C_{ij} is the number of co-occurrences (co-citations) of node i and node j, S_i is the frequency of node i occurrences (citations), and S_j is the frequency of node j occurrences (citations).

C. Centrality Measurement Algorithm

The centrality of a node is a metric employed to quantify the importance of a specific node within a network. It is defined as the proportion of shortest paths in the network that traverse through a given node relative to the total number of shortest paths connecting any two points in the network. Nodes with high median centrality tend to reside on paths that bridge distinct clusters, and this principle is frequently leveraged to identify group clustering patterns within networks.

The purpose of the mediated centrality algorithm is to identify key points in the graph network, i.e., nodes with high mediated centrality. Assuming that there are two clusters centered on node a and node b, node p on the path connecting these two clusters i.e., characterizes the transition from a to b. We refer to point p as the critical or inflection point, i.e., the node with higher centrality. The mediated centrality of a node is calculated as:

$$BC_i = \sum_{s \neq i \neq t} \frac{n_{st}^i}{g_{st}}, \quad (7)$$

where g_{st} is the number of shortest paths from node s to node t and n_{st}^i is the number of shortest paths passing through node i out of the g_{st} shortest paths from node s to node t.

Wang : Multifunctional Space Transformation Design in Multidimensional Interior Design Based on Citespace Knowledge Mapping

ARCHIVES DES SCIENCES
A Multidisciplinary Journal

D. Graph pruning basis

Co-induced networks often exhibit a large number of intricate connections. To enhance the clarity and conciseness of the network's main structure, the number of connections can be appropriately reduced. Two pruning methods are employed: the minimum spanning tree algorithm and the path-finding network algorithm. The minimum spanning tree algorithm aims to construct a spanning tree that includes all vertices and has the smallest sum of weights through the original graph G. This method offers the advantages of simple operation and fast results. The path-finding network algorithm, based on the principle of triangular inequality in the neighboring network, selects significant relationships to simplify the network and highlight its important structural features. It has the advantage of completeness (unique solution) and will not change the number of nodes in the graph network, but will greatly reduce the number of connecting lines in the graph. The following is a detailed description of the principal processes of these two pruning algorithms.

The first, the minimum spanning tree algorithm.

Minimum Spanning Tree means that in a network graph $G = (V, E)$, any vertices $u, v \in V$, $w(u, v)$ denote the weights of the edges $(u, v) \in E$, and if there exists a generating subgraph $T = (V, TE)$, $TE \subseteq E$ and T is loop-free such that the sum of the weights of all the edges of T is $w(T) = \sum_{(u, v \in TE)} w(u, v)$ minimized, then T is the minimum spanning tree of G. MST includes Kruskal's algorithm (the additive edge method) and Prim's algorithm (the additive point method).

The second, warp-seeking network algorithm.

The pathfinding network algorithm determines the deletion of a given connection based on the principle of triangular inequality, i.e., the length of a single connected path cannot exceed the length of multiple other connected paths. The structure of the warp-seeking network is mainly determined by the parameters r and q, and r is the length of the connected paths of the network nodes measured based on the Minkowski distance. When $r = 1$, the distance is the sum of the distances between two points. When $r = 2$, the distance measure is the common Euclidean distance. When $r \to \infty$, the path is the maximum distance in its component connections. When given a metric space, the triangular inequality relation is defined as $w_{ij} \leq \left(\sum_k w_{n_k n_{k+1}}^r \right)^{1/r}$, where w_{ij} denotes the link distance between node i and node j. $w_{n_k n_{k+1}}$ denotes the link distance between nodes n_k and n_{k+1}, $k = 1, 2, 3, \ldots, m$. In particular, the alternative path between i and j will pass through all nodes $(n_1, n_2, n_3, \ldots, n_k)$ when $i = n_1$, $j = n_k$, each intermediate connection belongs to the network. If w_{ij} is larger than the alternative path distance, then the direct path between i and j violates the condition of inequality, at which point the link between i and j is removed.

A q triangle derived from Minkowski's calculus satisfies the principle of $1/r$ triangular inequality if and only if all possible path weights in a network are less than or equal to the parameter q. The value of q can take any integer between the interval $[2, N - 1]$ where N denotes the number of nodes in the network. The network pathfinding algorithm reaches its maximum tailoring capacity when $r \to \infty$ and $q = N - 1$.

IV. Multi-Functional Spatial Transformation Design Word Frequency Detection Algorithm

The salient word detection algorithm is used to study words that exhibit a different frequency growth rate than usual, as these words can reveal hotspots and trends in the field more instantaneously. Traditionally, word frequency analysis is based on the frequency at a single point in time, which can only reveal hotspots but not dynamically indicate trend changes. The change rate of word frequency over time for a single word can better describe the evolution of local hotspots in the field. Although localized and subtle changes may not typically attract the attention of scholars, short-term subtle changes are an indispensable part of the development of the research field. Even if they may not meet the threshold requirement for word frequency, they exhibit a high growth rate and strong potential for future development. Figuratively speaking, these words accumulate more "energy" and possess unparalleled effectiveness and dynamism in revealing the direction of research themes within a target field. Therefore, despite their lower frequency, they hold significant dynamic intelligence value.

The principle of the algorithm is fundamentally based on probabilistic modeling of the frequency of occurrence of a topic word within a text stream over a short time period, serving as a method to identify the salient word. In the context of salient word detection, our objective is to pinpoint the salient word and determine its corresponding salient period.

Based on the characteristics of the data to be detected, bursting algorithms can be categorized into two types: continuous information bursting detection and batch information bursting detection. Batch information refers to data that appears in groups, such as thesis collections or journal papers. Furthermore, according to the number of burst states, the algorithms can be classified into two-stage and multi-stage burst algorithms.

Based on the aforementioned description, this paper employs the batch information detection algorithm to identify burst words within published literature. Furthermore, since the objective of utilizing this algorithm in this study is solely to obtain the probability of word frequency for words within a short, specific time period, rather than for hierarchical analysis, the two-stage information burst detection algorithm has been selected for this paper.

The algorithm of burst word detection for batch information is designed as follows:

First, there is n batch of data available, of which batch t has a total of d_t documents, of which r_t contain the target topic. Definition:

$$R = \sum_{t=1}^{n} r_t. \tag{8}$$

That is, R is the number of all documents in the target domain

Wang : Multifunctional Space Transformation Design in Multidimensional Interior Design Based on Citespace Knowledge Mapping

ARCHIVES DES SCIENCES
A Multidisciplinary Journal

data that contain the target topic:

$$D = \sum_{t=1}^{n} d_t. \tag{9}$$

D is the sum of the number of all documents in the target domain.

The probability machine is of the form $B_{s,\gamma}^{k}$, defined where k reveals the hierarchical structure of word bursts, and the level difference between multiple states can be expressed by this parameter, and the value of k can be determined from above as 2, s is known as the scale parameter, which is used for the degree of state discrimination in the probability machine, and the magnitude of s responds to the magnitude of the difference between the states, which is a reflection of the intense degree of bursting states, and the s takes the value of based on the entire batch of data selected from the number of years, according to the Kleinberg (2003), the literature of this paper takes the value of the span of 1998-2015, s should take the value of 10, γ is the cost parameter of changing between different states, the default value is 1.

Let q be the state variable, i.e., a state is q_i $(i > 0)$, the corresponding topic's proportion of the total literature is p_i, and p_0 is the base state. Where:

$$p_0 = \frac{R}{D}. \tag{10}$$

$$p_i = p_0 s \, (p_i \le 1). \tag{11}$$

Assume that the sequence of state flow occurrences is:

$$q = (q_{i1}, q_{i2} \ldots \ldots q_{in}). \tag{12}$$

According to the definition of the previous formula, q_{in} means that the state in batch n data is q_i. In state q_i, the frequency of a topic in the batch text stream obeys a quadratic polynomial distribution with probability p, which is expressed by the formula $\binom{d_t}{r_t} p_i^{r_t} (1 - p_i)^{d_t - r_t}$, and according to the previous setup, the Bayesian conditional equation for constructing the sequence of topic occurrences of the batch data stream, i.e., the probabilistic machine is still in the cost of being in the state q while being in the batch t data, is:

$$\sigma(i, r_t, d_t) = -\ln \binom{d_t}{r_t} p_i^{r_t} (1 - p_i)^{d_t - r_t}. \tag{13}$$

V. Knowledge Mapping Analysis of Multifunctional Space Conversion Designs

For the multifunctional spatial transition design in multidimensional interior design, this paper selects 'multifunctional spatial transition design' as the subject term. It relies on the Citespace software to search for literature information on related research conducted during the period of 2014-2023, resulting in a total of 427 pieces of literature. Subsequently, these are analyzed by combining the knowledge mapping algorithms and word frequency detection method proposed in this paper. Utilizing the knowledge graph-related algorithm and word frequency detection method presented herein, a knowledge graph analysis is carried out.
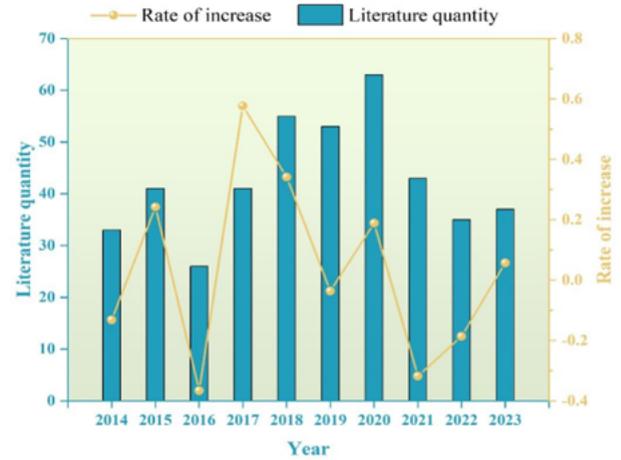

Figure 1: Quantity of literature

A. Quantitative analysis of the literature

The results of the annual distribution of the number of literature studied in this paper over the last ten years are presented in Figure 1. As can be seen from Figure 1, the amount of literature issued on multifunctional space conversion design during the period of 2014-2020 exhibited an upward trend, increasing from 26 articles in 2014 to a maximum value of 63 articles in 2020, marking an increase of more than two times. Subsequently, a slight decline was observed, but the trend remained stable overall. This indicates that, with the continuous development of the design industry, research related to multifunctional space conversion design is receiving increasing attention. However, from 2020 onwards, the number of research documents related to multifunctional space conversion design has shown a decreasing trend, with decreases of 31.75% and 18.61% in 2021 and 2022 respectively. This suggests that research in this field is beginning to enter a development bottleneck stage, with the growth rate slowing down.

B. Analysis of the disciplinary classification of the literature

The statistical data on the discipline classification of published literature related to multifunctional space conversion design are presented in Table 1. Currently, research on multifunctional space conversion design is primarily concentrated in the discipline of architectural science and engineering, accounting for 76.35% of the literature classification, with a total of 326 articles, significantly more than other disciplines. The second highest percentage of disciplines in the literature classification is Fine Arts, Calligraphy, Sculpture, and Photography, but this only accounts for 8.67%, with a total of 37 articles. The remaining disciplines of vocational education, higher education, and computer software and applications have less than 5% of the literature, with each having fewer than 20 articles. Overall, multifunctional space conversion design has become a research theme of common interest across multiple disciplines.

Wang : Multifunctional Space Transformation Design in Multidimensional Interior Design Based on Citespace Knowledge Mapping

ARCHIVES DES SCIENCES
A Multidisciplinary Journal

Subject category	Literature quantity	Literature ratio
Building science and engineering	326	76.35%
Art calligraphy sculpture and photography	37	8.67%
Vocational education	20	4.68%
Higher education	12	2.81%
Computer software and computer applications	10	2.34%
Light industrial industry	6	1.41%
Education theory and education management	6	1.41%
Industrial economy	5	1.17%
Automation technology	3	0.70%
General service	2	0.47%

Table 1: The classification of the subject of literature

Rank	Name of organization	Frequency	Intermediate center
1	NanjingForestry University	62	0.18
2	Central South University of Ucience and Technology	50	0.12
3	Kunming University of Science and Technology	44	0.2
4	Hunan Arts and CraftsVocational College	42	0.07
5	Southwest Jiaotong University	38	0.04
6	Dalian University of Technology	32	0.02
7	Shenyang Construction University	27	0.1
8	Northeast Forestry University	26	0.09
9	Nanchang University	24	0
10	Suzhou University	17	0
11	Hebei University	12	0
12	Wuhan University of Technology	10	0.02
13	Jilin Academy of Arts	8	0
14	Hunan Normal University	7	0.03
15	Jiangnan University	6	0.06
16	Inner Mongolia Normal University	5	0
17	Jilin Construction University	5	0
18	Hefei University of Technology	4	0
19	Qingdao University	4	0
20	Shenyang Normal University	4	0.07

Table 2: Research institutions and centers

C. Analysis of research institutions and centers

The institutional analysis of Multifunctional Space Conversion Design research from 2014 to 2023 aids in understanding the geographic distribution of this field and the collaboration among institutions. The research institutions that have published literature related to multifunctional spatial conversion design are sorted by the number of publications, as shown in Table 2. From the table, it can be observed that the top 5 high-yield institutions for multifunctional space conversion design research during 2014-2023 are Nanjing Forestry University (62 articles), Central South University of Forestry and Technology (50 articles), Kunming University of Science and Technology (44 articles), Hunan Institute of Arts and Crafts Vocational College (42 articles), and Southwest Jiaotong University (38 articles). These highly productive institutions constitute the main research force in the field of multifunctional space conversion design research from 2014 to 2023.

On this basis, this study also analyzes the research institutions with an intermediary centrality of 0.1 or above. The analysis reveals that Nanjing Forestry University (0.18), Central South University of Forestry and Technology (0.12), Kunming University of Science and Technology (0.2), and Shenyang University of Architecture (0.1) occupy more significant positions in the field of multifunctional spatial conversion design research. Notably, Kunming University of Science and Technology exhibits the highest intermediary centrality, indicating its status as the most authoritative research institution in the field of multifunctional space conversion design during the period from 2014 to 2023.

Rank	High frequency keywords		Central keywords	
	Keyword	Frequency	Keyword	Intermediate center
1	Interior design	286	Space design	0.72
2	Space design	254	Spatial transformation	0.48
3	Spatial transformation	146	Interior design	0.4
4	Color space conversion	143	Indoor	0.38
5	Architectural interior design	174	Indoor color	0.36
6	Interior design art	128	Interior design performance chart	0.35
7	Interior design performance chart	112	Color space conversion	0.35
8	Color space transformation	97	Modern interior design	0.33
9	Indoor ecology	88	Color space transformation	0.33
10	Interior layout	79	Interior design art	0.31
11	Color space conversion	68	Indoor environment	0.29
12	Indoor lighting	51	Interior design education	0.28
13	Interior design education	45	design philosophy	0.28
14	Residential design	40	Building space	0.27
15	Conversion parameter	38	Artistic designing	0.24

Table 3: Hot keyword

D. Research hot keyword analysis

Table 3 presents the statistics of high-frequency and centrality words in the research field of multifunctional space transformation design for the period 2014-2023. As can be observed from the table, the top ten keywords with the highest frequency of occurrence in the research literature during this period are: interior design, space design, space transformation, color space transformation, architectural interior design, interior design art, interior design presentation, interior ecology, and interior furnishings. Notably, the keyword 'interior design' has the highest frequency of 286 occurrences, followed by 'space design' with 254 occurrences. Furthermore, the top ten keywords with the highest mediated centrality in the literature during the period 2014-2023 are: space design, space transformation, interior design, interior, interior color, interior design representation, color space transformation, modern interior design, and interior design art. Among these, the three keywords with the highest mediated centrality are space design (0.72), space transformation (0.48), and color space transformation (0.38).

E. Analysis of the results of the distribution of the number of keyword postings

The top four high-frequency keywords identified in the previous section—spatial design, interior design, color-space conversion, and spatial conversion—are selected as the focal keywords for this study. To further illustrate the prominence of these keywords in multifunctional space conversion design, this study conducted an analysis of their posting distribution, as presented in Table 4. Specifically, spatial design and interior design emerge as the leading keywords in space conversion design research, with respective posting frequencies of 254 and 286 articles from 2014 to 2023. Conversely, color-space conversion and spatial conversion occupy the second tier, each having been posted in 143 and 146 articles, respectively. The keyword volume of spatial design peaked in 2014 and 2018, with 30 postings each year, while interior design reached its maximum in 2014 with 38 postings. Notably, the two keywords of color-space conversion and spatial conversion exhibited their highest posting frequencies in 2021 and 2022, respectively, with 22 and 17 postings. Evidently, spatial design, interior design, color-space conversion, and spatial conversion constitute the most prolific keywords in the research of multifunctional space conversion design, and the overall

Wang : Multifunctional Space Transformation Design in Multidimensional Interior Design Based on Citespace Knowledge Mapping

ARCHIVES DES SCIENCES
A Multidisciplinary Journal

Year	Space design	interior design	Spatial transformation	Color space conversion
2014	40	48	9	12
2015	36	32	7	11
2016	37	30	14	16
2017	32	36	22	12
2018	40	43	20	9
2019	38	40	18	25
2020	34	42	8	13
2021	35	43	22	16
2022	30	35	10	17
2023	32	37	13	15

Table 4: The number of keyword published

number of articles published between 2014 and 2023 has maintained a relatively steady trend.

VI. Conclusion

Utilizing the theory and methodology of CiteSpace software and knowledge mapping, this paper presents a construction of the knowledge map and a word frequency detection algorithm tailored for multifunctional space transformation design. It provides a foundation for analyzing the knowledge map of multifunctional space transformation design.

The study draws the following conclusions:

1) Regarding the literature count, the number of publications on multifunctional space conversion design exhibited an upward trend from 2014 to 2020, peaking at 63 articles in 2020. However, since 2020, the literature related to multifunctional space conversion design has shown a decreasing trend, with a decline of 31.75% in 2021 and 18.61% in 2022. In 2023, there was a slight resurgence in growth, with an increase of 5.71%. Overall, the research on multifunctional space conversion design has entered a bottleneck stage, and the growth rate has decelerated.

2) In the analysis of research institutions and their centrality, Nanjing Forestry University emerges as the institution with the highest number of publications from 2014 to 2023, recording a total of 62 publications. Conversely, Kunming University of Science and Technology stands out as the research institution with the highest intermediary centrality of 0.2, making it the most authoritative research institution within the field during the same period.

3) In terms of the disciplinary classification of literature related to multifunctional space conversion design research, the research is primarily concentrated in the discipline of architectural science and engineering, accounting for 76.35% of the total literature, with a count of 326 publications, which is significantly higher than that of other disciplines. The proportion of literature in the remaining nine disciplines does not exceed 5%. Overall, research on multifunctional space conversion design is dominated by the disciplinary direction of architectural science and engineering, while also being related to a number of other disciplinary fields.

4) During the period from 2014 to 2023, the keyword 'interior design' had the highest frequency of occurrence, reaching up to 286 times. In terms of mediated centrality, the three hottest words with the highest mediated centrality were 'spatial design' (0.72), 'spatial transformation' (0.48), and 'color spatial transformation' (0.38).

5) In the analysis of the number of articles published for the research hot keywords, 'space design' and 'interior design' emerged as the top-ranked keywords in the field of space conversion design research. Specifically, 'space design' was associated with 254 articles, while 'interior design' appeared in 286 articles during the period from 2014 to 2023. On the other hand, 'color space conversion' and 'space conversion' belonged to the second tier, with 143 and 146 articles respectively. Overall, the volume of articles related to hot keywords maintained a relatively steady trend of development.

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