Construction and Evolutionary Analysis of the Knowledge Graph in the Theory of Architectural Space Narrative

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Abstract The theory of spatial narrative enhances the connotation of architectural design and broadens the interaction between architecture and its users. Drawing upon a literature review of relevant keywords related to "architectural space narrative" from the China National Knowledge Infrastructure (CNKI) over the past two decades, alongside an analysis and content identification of high-frequency keywords, clustering, timelines, and other knowledge graphs generated by CiteSpace, this study summarizes the evolution path of spatial narrative theory. This approach offers diverse perspectives for examining emerging trends and key issues within spatial narrative research.

Keywords Architectural space narrative, CiteSpace, Knowledge graph, Evolutionary analysis
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The theory of architectural space narrative incorporates narratological approaches into architectural design and research, highlighting the function of space as a narrative medium that communicates stories, culture, and emotions through spatial design. The integration and progression of time, culture, and stories render architectural space a multidimensional narrative entity, serving not merely as an assemblage of materials but also as a carrier for cultural connotations and emotional value.

Le Corbusier introduced the concept of the "architectural promenade", positing that architectural design parallels the process of film editing. By manipulating time, space, and narrative structure within a work, architecture directs the experiencer's interaction and perception of the building. In *Montage and Architecture*, Eisenstein similarly likened architecture to a sequence of shots, asserting that both architecture and film are art forms that communicate emotions and meanings through the orchestration of time and space. Bernard Tschumi examines architectural narrative through a montage approach and identifies three fundamental architectural elements: "movement, space, and event". In *Red is Not a Color*, it is argued that architecture requires events to impart its essence. Additionally, the book *The Violence of Architecture* highlights the influential role of time in shaping space. These concepts are exemplified in La Villette Park, where Tschumi established a "marker" pattern of architectural space through the spatial arrangement of points, lines, and surfaces, thereby creating a field that facilitates events. Koolhaas posits that both architects and film editors intentionally construct spatial sequences. In the designs of the Seattle Central Library and the CCTV building, parallel narratives and non-linear editing of functional elements are employed to represent the complexity of urban life[1].

"Narrative" closely associates architecture with the art of film. While film conveys images through a temporal sequence, architecture offers an experience through a spatial sequence. From the narrative elements embedded in historical buildings, to the deliberate organization of spatial sequences and experiences in modernist architecture, and further to the exploration of complex cultural connotations and emotional expressions in contemporary architecture, the narrative of architectural space has consistently permeated architectural development and has become a fundamental element for comprehending and shaping architectural space.

Currently, the extensive volume of academic materials not only encompasses a wealth of knowledge but also presents challenges in organizing and comprehending the academic context. To address this, CiteSpace software was employed to analyze relevant academic literature on architectural space narrative from the past 20 years[2]. This approach aimed to identify the key nodes in the current developmental stage of the theory and to trace the dynamic evolution of research hotspots.

1 Trend analysis of CNKI publication volume

Focusing on the keyword of "architectural space narrative", relevant bibliographic data were retrieved from the China National Knowledge Infrastructure (CNKI) database. Following data cleaning, textual information, including keywords and abstracts, was extracted. This information was subsequently analyzed using CiteSpace software to generate a knowledge graph. The CNKI database search yielded a total of 250 publications, encompassing academic journals, dissertations, and books. Regarding the temporal distribution, the publication volume has generally exhibited an upward trend since 2006 (Fig.1).

The period can be divided into two stages, using the year 2014 as the dividing point.

The period from 2006 to 2014 was characterized by gradual exploration and development. Long Diyong[3] proposed a spatial shift in narratology research, advocating a transition from the traditional focus on the temporal dimension to an approach that emphasizes the spatial dimension. This shift offers a theoretical foundation and methodological framework for the narrative of architectural space, highlighting the central role of space in narrative construction and encouraging architects to reconsider spatial design from a narrative perspective. Zhou Rong[4] examined how contemporary Chinese architecture can adopt a composed narrative approach within architectural practice amid the contexts of globalization and marketization. Through an analysis of the Courtyard on the Canal Bank project, Zhou sought to explore new concepts of living, thereby providing a practical model for the academic community to investigate architectural space narratives. Lu Shaoming[5] conducted an analysis of the inherent elemental attributes, spatial structures, construction strategies, and cultural significance of

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architectural narratives through case studies and interdisciplinary research. This study elucidates the logic and literary qualities inherent in architectural space narratives, thereby reinforcing the central role of spatial narrative in the formation of material structures and the conveyance of profound semantic content. The paper contributes to the theoretical framework of architectural narratology and offers novel perspectives and methodologies for fostering architects' innovative thinking and practical skills.

The period from 2014 to 2022 was characterized by rapid growth. Following 2022, a slight decline was observed, indicating that this research area has gradually transitioned into a mature and stable phase of development. Li Xinggang et al.[6] illustrated, through the design and construction of the Shangqiu Museum, how the historical and cultural characteristics of a city can be integrated into the spatial layout and formal language of buildings, thereby creating a miniature urban model. This case provides a compelling example of the synthesis of historical context with contemporary architectural practice in the study of architectural space narrative. It underscores the pivotal role of architectural space narrative in bridging the past and present, the city and architecture, as well as enhancing the viewer's experiential engagement. Lu Shaoming[7] further elucidated the importance of spatial narrative design in preserving cultural information, bridging cultural divides, and fostering local cultural identity, thereby offering a theoretical framework for the comprehension and application of spatial narrative design.

2 CiteSpace knowledge graph analysis

CiteSpace is a significant academic tool used to analyze the development context and emerging trends within research fields. Utilizing CNKI as the data source, multiple topic searches were conducted on "architectural space narrative", "architectural montage", and "film architecture". The literature search covered the period from 2004 to 2024, yielding 563 valid journal articles. Through software-based analysis, this study presents the research hotspots, frontiers, developmental and evolutionary trends of architectural space narrative over the specified timeframe, as well as the interrelationships among various hotspots.

2.1 Keyword co-occurrence and betweenness centrality

The software identified 293 high-frequency keywords to collaboratively construct a knowledge graph, illustrating the co-occurrence relationships among these keywords. In this graph, the size of each node corresponds to the frequency of the keyword's occurrence, while the edges between nodes represent the intensity of their co-occurrence. By applying a threshold, 396 statistically significant connections were selected, resulting in the formation of a co-occurrence network graph (Fig.2).

Betweenness centrality is a crucial indicator for assessing the significance of nodes within a network, as it quantifies the frequency with which a node appears on all shortest paths. Nodes exhibiting high betweenness centrality serve as bridges within the network and exert a substantial influence on information flow. The values of betweenness centrality range from 0 to 1, with higher values indicating greater centrality of the node. In CiteSpace, nodes exhibiting betweenness centrality values greater than 0.1 are typically considered key nodes, signifying their critical role within the network. The betweenness centrality of a keyword serves as an indicator that quantifies its function as a communication bridge within the knowledge network, reflecting its connectivity and influence in the respective research domain. As shown in Table 1, the betweenness centrality value of the keyword "architecture" is 0.43, indicating its central role in the associated research topics. Subsequently, the keywords "experience", "narrative thinking", and "montage" have extensive connections with other significant keywords.

2.2 Timeline and trends of hot keywords

The timeline graph illustrates keyword clusters across different time periods, highlighting shifts in research focus. The analysis indicates that keywords such as "montage", "film" and "architecture" emerged in 2005. Since 2012, "spatial narrative" has emerged as a sustained research hotspot. In recent years, increased attention has been directed toward "landscape design", "industrial heritage", and "traditional village" within their respective clusters (Fig.3). Furthermore, the structure of the temporal network reveals the interconnections and mutual influences among various topics, reflecting the dynamic nature of interdisciplinary research.

2.3 Main clustering and keyword analysis

The Q value (Modularity) represents the significance of the cluster structure. It is generally accepted that a Q value exceeding 0.3 indicates a remarkable cluster structure. Higher Q values correspond to improved modularity of the clustering outcome, implying that nodes within the same cluster are more densely connected. The S value (Silhouette) serves as an indicator for evaluating the validity of clustering by quantifying the similarity of each node to its own cluster as well as its dissimilarity with other clusters. It is widely accepted that an S value exceeding 0.5 suggests that the clustering is reasonable, while an S value above 0.7 indicates that the clustering is convincing. An S value approaching 1 signifies an excellent clustering effect, characterized by high similarity among nodes within the same cluster and low similarity with nodes in other clusters. The analysis revealed that Q=0.835 5 and S=0.952 1, demonstrating that the clustering structure is both significant and reasonable. Fig.4 illustrates the relationships and structures among the various research topics (clusters).

Clustering utilizes the Log-Likelihood Ratio (LLR) algorithm, a statistical technique grounded in the log-likelihood ratio, to identify cluster structures within the literature network and to extract keywords or phrases that characterize each cluster. The number following each cluster label denotes the LLR value, whereas the value in parentheses indicates the p-value associated with that LLR value. In Table 2, the term "spatial narrative" (39.46, 1.0E-4) has a very high LLR value of 39.46, indicating that it is a highly significant representative label within

Table 1 Top 10 keywords (sorted by betweenness centrality)

No.	Keyword	Frequency	Betweenness centrality	Year
1	Architecture	37	0.43	2005
2	Experience	11	0.38	2007
3	Narrative thinking	4	0.28	2007
4	Nontage	51	0.28	2005
5	Spatial narrative	92	0.27	2012
6	Museum	10	0.20	2006
7	Film	35	0.20	2005
8	Narrative	23	0.16	2006
9	Narratology	14	0.15	2012
10	Space	25	0.14	2010

the corresponding cluster. The small *p*-value (1.0E-4, 0.000 1) confirms the statistical significance of this LLR value. Similarly, landscape design (12.69, 0.001) has an LLR value of 12.69, which denotes it as another important label within its respective cluster. The *p*-value of 0.001 indicates that the LLR is statistically significant, suggesting a strong association between "landscape design" and the observed clustering. Cluster analysis enables the identification of multi-theme co-occurrence phenomena within architectural space narratives, as well as the interrelationships and influences among various research topics.

2.4 Keyword burst analysis

Fig.5 presents the citation bursts of 23 keywords in academic literature from 2004 to 2024. The term "spatial narrative" had an exceptionally high burst intensity of 18.28 between 2021 and 2024, signifying its prominence as a highly popular research area. "Landscape design and industrial heritage" had significant bursts from 2022 to 2024, with intensities of 3.23 and 2.56, respectively, indicating rapid growth in scholarly interest within these fields. The keyword "architectural space" had a relatively high burst intensity of 3.28 from 2017 to 2021, reflecting considerable academic attention during this timeframe. Additionally, "science fiction films" had a sudden burst from 2016 to 2020, likely associated with the increased popularity of science fiction films or heightened academic discourse during that period.

The chart indicates that the terms "image", "editing" and "narrative" appeared during an earlier period. In contrast, "spatial narrative", "landscape design" and "industrial heritage" have emerged more recently, suggesting potential new research trends or areas of interest.

3 Phases in the evolution of architectural space narrative

In the early 20th century, Dr. Long Diyong[8] proposed the concept of spatial narrative and applied it across multiple disciplines, including philosophy, sociology, geography, and design. The essence of narratology lies in constructing meaning through narrative, and spatial narrative expands upon this concept within the realm of spatial design, highlighting the communication of stories through the organization of spatial elements.

By identifying relevant literature and focusing on the key nodes in the development course of the theory of architectural space

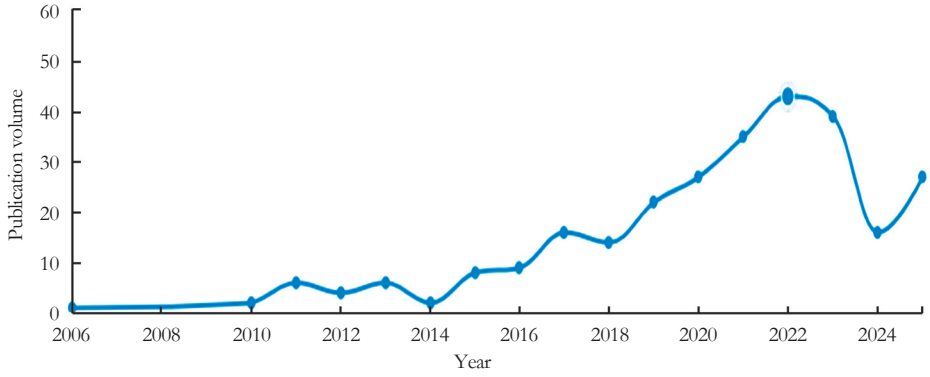


Fig.1 Publication trends for the keyword "architectural space narrative" from 2006 to 2024

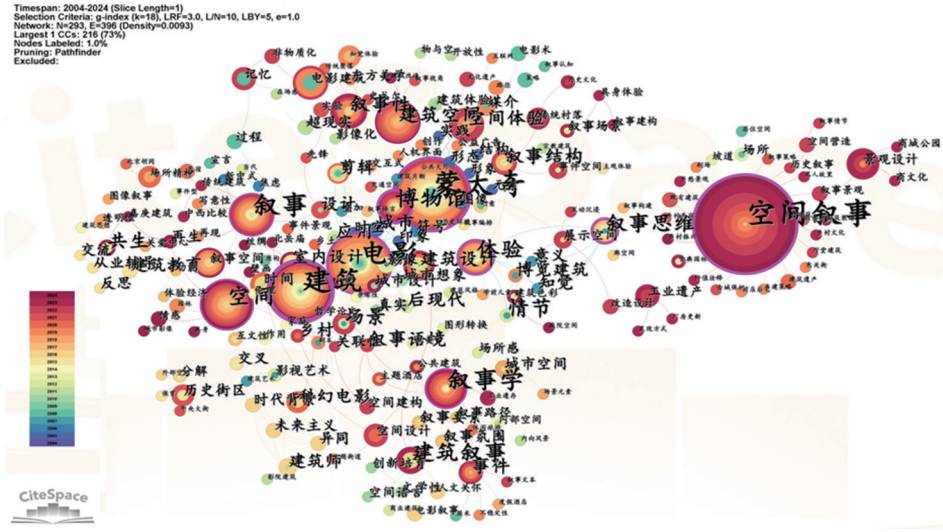
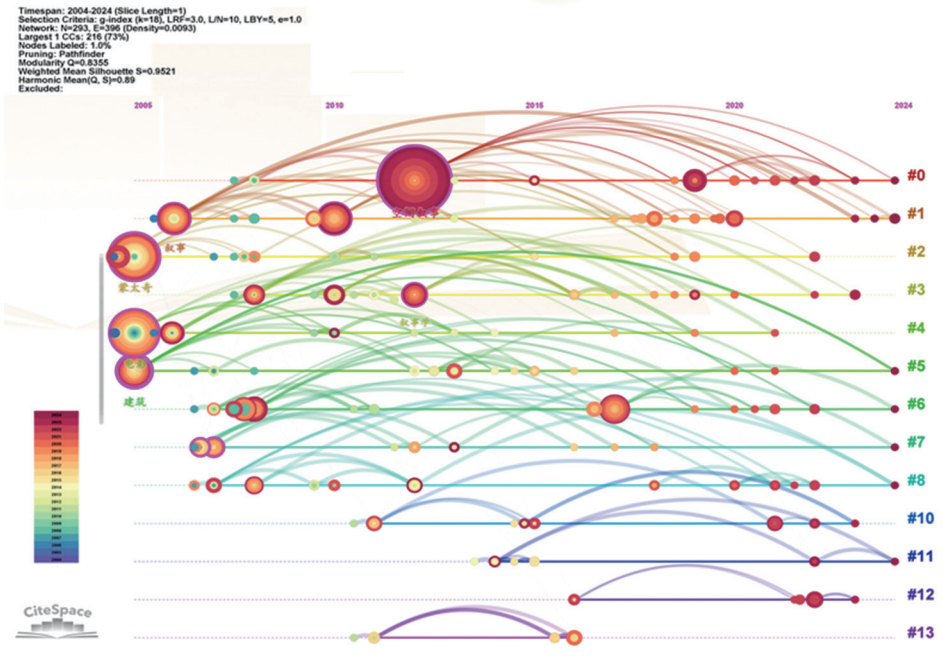


Fig.2 Keyword co-occurrence network graph



Note: #0. Spatial narrative; #1. Narrative; #2. Nontage; #3. Architectural narrative; #4. Museum; #5. Architecture; #6. Narratology; #7. Plot; #8. Scene; #10. Narrative construction; #11. Symbiosis; #12. Industrial heritage; #13. Historical context.

Fig.3 Timeline graph of keywords

Table 2 Primary keywords for clustering

No.	Cluster	Label (LLR)	Sihouette	Mean (year)	Size
1	Spatial narrative	Spatial narrative (39.46, 1.0E-4); landscape design (12.69, 0.001); montage (8.01, 0.005); film (6.57, 0.05); architecture (6.57, 0.05)	1	2019	30
2	Narrative	Narrative (30.09, 1.0E-4); space (23.28, 1.0E-4); transparency (8.71, 0.005); spatial narrative (8.27, 0.005); time (5.13, 0.05)	0.941	2016	27
3	Montage	Montage (23.13, 1.0E-4); spatial experience (16.81, 1.0E-4); media (13.11, 0.001); cinematography (8.71, 0.005); architectural experience (8.71, 0.005)	0.987	2010	24
4	Architectural narrative	Architectural narrative (21.75, 1.0E-4); narrative element (10.78, 0.005); narrative atmosphere (10.78, 0.005); humanistic care (10.78, 0.005); film narrative (10.78, 0.005)	0.941	2014	21
5	Museum	Museum (21.69, 1.0E-4); film (17.26, 1.0E-4); architectural design (8.6, 0.005); cross-media (8.6, 0.005); postmodernism (8.6, 0.005)	0.979	2010	21
6	Architecture	Architecture (14.77, 0.001); historical district (9.59, 0.005); film and television art (9.22, 0.005); reorganization (9.22, 0.005); decomposition (9.22, 0.005)	0.996	2015	20

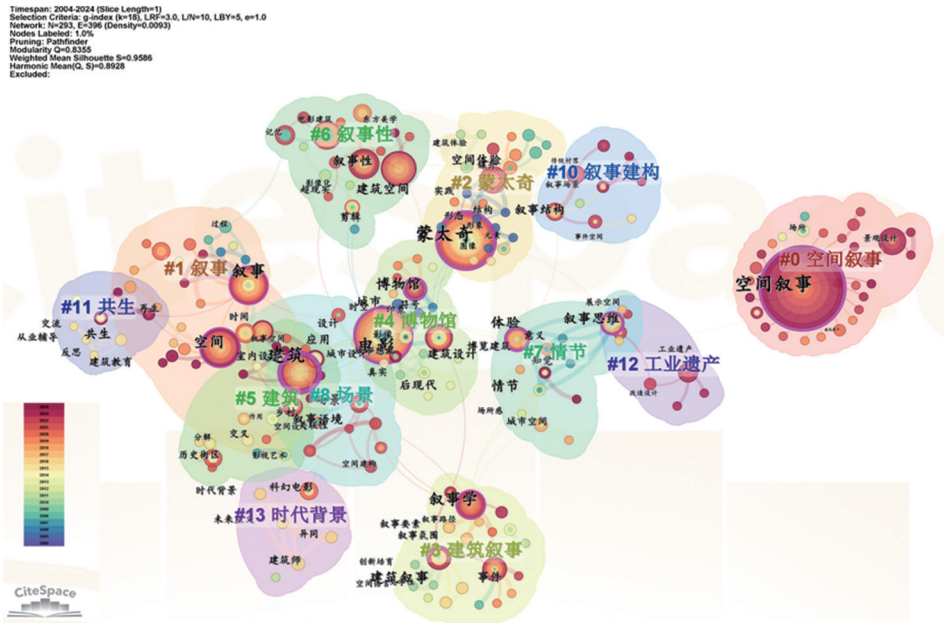


Fig.4 Keyword clustering

Keywords	Year	Strength	Begin	End
Image	2005	1.33	2005	2013
Editing	2007	1.35	2007	2011
Architectural experience	2010	1.28	2010	2011
Narrative	2006	1.53	2011	2013
Architect	2011	1.38	2011	2016
Experience	2007	2.03	2012	2018
Value	2012	1.55	2012	2015
Interior design	2012	1.24	2012	2016
Architecture	2005	2.31	2014	2017
Montage	2005	1.60	2014	2016
Narrative space	2008	1.88	2015	2019
Space	2010	2.36	2016	2017
Science fiction film	2016	1.28	2016	2020
Architectural space	2017	3.28	2017	2021
Film	2005	2.86	2017	2020
Perceptual experience	2017	1.89	2017	2019
Genius loci	2018	1.81	2018	2020
Narratology	2012	1.36	2019	2021
Spatial design	2020	2.24	2020	2022
Spatial narrative	2012	18.28	2021	2024
Traditional village	2021	1.78	2021	2024
Landscape design	2019	3.23	2022	2024
Industrial heritage	2022	2.56	2022	2024

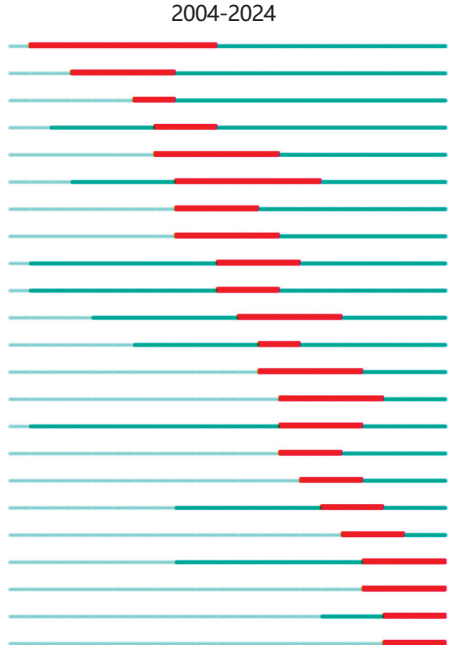


Fig.5 Top 23 keywords with the strongest citation bursts

narrative, its evolutionary process can be delineated into three distinct stages (Table 3).

4 Conclusions and prospects

The theory of architectural space narrative, shaped by literary criticism and related disciplines in the late 20th century, has progressively evolved into a systematic theoretical framework. Utilizing CiteSpace software, this study constructed a knowledge graph to illustrate the network structure underlying the theory's development. Analysis of the literature reveals that research priorities have shifted over time: initially concentrating on theoretical construction, subsequently expanding to the practical application of architectural design, and more recently exploring diverse emerging areas, including digitalization and sustainability narratives.

CiteSpace software has facilitated the transformation of extensive literature data into an intuitive knowledge graph within research contexts, thereby elucidating the academic landscape and offering a perspective for investigating the theory of architectural space narrative. Nevertheless, regarding the data samples, the study exclusively utilized data retrieved from the CNKI database. Due to limitations such as retrieval strategies, database access permissions, and the dispersion of interdisciplinary literature, certain key materials from specific fields, emerging research directions, or non-academic sources may have been omitted. This limitation consequently results in an incomplete representation of the comprehensive theoretical framework within the knowledge graph. Furthermore, various parameter combinations exert nuanced effects on the outcomes, complicating the determination of an optimal configuration. With the rapid advancement of big data technologies, it is anticipated that more intelligent parameter optimization methods will be developed, thereby further improving the accuracy and depth of knowledge graphs.

Table 3 Three development stages of the theory of architectural space narrative

Phase	Time	Key event	Main features
Early budding stage	The 1960s and 1970s	Roland Barthes published *Elements of Semiology*, introducing a semiotic framework for analyzing the transmission of meaning in architectural elements[9-10]; Christian Norberg-Schulz authored *Genius Loci*: *Towards a Phenomenology of Architecture*, highlighting the intrinsic relationship between architectural space and the significance of human existence[11-12].	These studies began to transcend the constraints of traditional architectural research by incorporating semiotic and phenomenological perspectives, emphasizing that architectural space is not merely a physical entity but also serves as a narrative medium embodying history, culture, and emotions.
Development stage	The 1980s and 1990s	Long Diyong published *Spatial Narratology*, systematically integrating spatial dimensions into the narratological research framework[13]; Frank Owen Gehry designed the Guggenheim Museum Bilbao, demonstrating the applicability of spatial narrative theory through deconstructivist modeling and spatial sequencing[11].	The theory of space narratology has swiftly emerged as a significant guidance for innovation in architectural design; numerous practical cases, including the Guggenheim Museum Bilbao, have demonstrated the theory's effectiveness in real-world applications.
Mature stage	From the early 21st century to the present	Interdisciplinary research has become standard practice, with fields such as sociology, psychology, and cultural studies being thoroughly integrated; the utilization of digital technologies, including virtual reality (VR) and augmented reality (AR), in the narrative design of architectural spaces is increasingly prevalent.	The ongoing advancement of both theoretical and practical approaches has propelled the narrative of architectural space into a mature and flourishing phase; enabled by digital technologies, including VR and AR, this progression transcends the constraints of physical space, facilitating the creation of immersive narrative experiences.

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