

# Dynamic Uncertainty: Exploring the Spatial Order of Future Digital Architecture

#### Yuxin Zhao

ImaginationLancaster, Lancaster University, Bailrigg, LA1 4YW, United Kingdom

Abstract: The spatial order of architecture has been significantly impacted by digital architectural design and production, creating a dynamic uncertainty. This study aims to explore digital architecture from the perspective of spatial order, discussing the antidote/poison effect caused by digital technologies in architectural practice and the cultural digital changes in digital architectures. The study selected four digital architecture cases, including the (W)rapper at Los Angeles by Eric Owen Moss, Beijing Daxing International Airport by Zaha Hadid, 3D Print Niaokan Bridge by Xu Weiguo, and World Internet Conference Center by Yuan Feng. This study is hypothesising that the future special order of digital architectures will be a dynamic and balanced new spatial order. This new order includes the symbiosis of a human-machine and virtual-real hierarchy; the interactive co-existence between nature, humanity and technology; and the creative multi-immersive sharing of parametric information, built-environment resources and cultural artistic information. The evolution of spatial order of future digital architecture will be discussed in connection with the idea of the metaverse. The value of this work is its ability to inspire a broader examination of the new order of digital architectural space.

Key words: Spatial superimposition, digital technology's antidote & poison effect, the spatial order of digital architectures, alteration of spatial order.

## 1. Introduction

The traditional spatial order has been changed by digital technology, altering the dynamic effects of inside architectural space and outside environmental space. The driving force behind the development of architecture has always been technological upheavals [1]. Digital technology is a driving factor in modifying the spatial order of architecture, as well as alternations in conventional architectural connections and shapes. The interesting point is that digital technology has a dual nature, having both an antidote effect and a poison effect. As recorded in Gu Xuewen's interview with the French philosopher Bernard Stiegler, when asked about the influence of the technology on humanity, Stiegler says: "Technology is the antidote and the poison of humanity. Humans need to be wary of the heightened development of technology. Humans need to develop a new technical culture to deal with the new technological era." [2].

Meanwhile, digital technology had probably become a poison, producing a poisonous impact. For example, some of the new technological buildings are aimlessly seeking unique shapes, unusual functions and distinctive designs with the assistance of digital technologies. As a result, the interior functions of these buildings are in conflict with the rules, the structure of these buildings is in chaos, and their architectural forms and spatial order are in a state of "disorder" [3]. The newly digital architectures become part of the original environment and natural space, creating а superimposition of old and new space layout that changes the order of numerous spatial combinations.

This study's objective is to assist in understanding the orderliness and aesthetic effects of spatial order during the dynamic uncertainty stage, and strives to identify potential new orders for the development of digital architectural spaces in the future.

**Corresponding author:** Yuxin Zhao, PhD, research fields: urban design and future city.

## 1.1 Digital Architecture

The term "digital architecture" which first appeared in the middle of the 1990s, is the result of the impact of architectural construction becoming involved in digital technology. It is also a basic notion that has arisen as a consequence of the fast growth of digital technology and the global popularity and reach of AI. Digital architecture has been used to refer to buildings that feature digital technologies, with no delineation until now, but it is a product of the collision between digital technology and architecture, which applies to a spatial structure created using digital methods [4]. Digital architecture is a product of the profound integration of new-generation information technology with advanced manufacturing concepts, and includes the entire cycle and whole elements of the architectural construction industry [5]. It is a crucial engine for enhancing construction levels and building quality, as well as for accelerating the transformation and upgrading of the architecture industry [5]. There are several definitions of digital architecture at this point, however in this research, the researcher believes that digital architecture is the process of architectural digitisation, and that "algorithmic architecture" is same as "digital architecture".

Digital architecture has three main characteristics: digitised, interactive and intellectualisation. 1). "Digitised" refers to the process of digitising the whole process, including all aspects and participants, by deconstructing and modelling entities and physical actions and building digital models that are mapped into entities. It includes digital design, digital manufacturing, digital construction, digital operation and maintenance, and digital participants. 2). "Interactive" refers to the ubiquitous connecting real-time and online of HCPS (information physical system) based on "people, things, and objects" between the virtual building and the physical building, appearing in the form of a "digital twin" and generating a fusion mechanism of virtualreal mapping and real-time interaction. HCSPCS is an acronym for "high-capacity, high-performance computing system". 3). "Intellectualisation" is a growing process that is data-driven and generates intelligent algorithms. In other words, the virtual building and the physical building can perceive, adapt, and predict based on big data and intelligent algorithms, and then rely on and optimise each other to become an "artificial intelligence" with comprehensive perception, analysis, and cognition, scientific decision-making, precise execution, and selfevolution, to realise the optimisation of resources in the process of closed-loop automatic data flow [6].

#### 1.2 Space of Digital Architecture

In the early days, people separated architectural areas from natural environments with certain material constructions [7]. The function of architecture is to form a space; it also serves to enclose a space, and social activity is contained inside this space. The creation of architectural space is the result of human activities in the realm of social production. It has committed to the theory presented in The Production of Space: "(social) space is a product (of society)" [8], and the combination of architectural space creates the fundamental shape of urban space. The city is a location that has been formed and constructed by social activities during a particular historical time [8]. Iterations of urban spatial patterns are always evolving in response to the shifting phases of human history, and the changes in spatial forms will trigger a change in the spatial order of the city. The advent of digital architecture as a form has resulted in the merging of digital technology with architecture, which has produced digital structures in the space. These digital architectures not only speed up the automated processing of building information, but they also enable architects to directly drive and manage the deployment of both natural resources and spatial information in reality via intelligence technology. The space of digital architecture mentioned in this study relates to architectural spaces that have digital architectural characteristics.

### 1.3 Space Order

Spatial order is the state that spatial patterns present at a specific time [9]. Spatial order characteristics exist at multiple spatial scales, are hierarchical in nature, present spatial heterogeneity and spatial complexity with changes in spatial scale; meanwhile, spatial order exhibits distinct levels of non-uniformity and complexity at different spatial scales [10]. Order is the concept concealed behind things; it incorporates the aesthetics in space and surroundings via implicit methods and organises the shape of space with various representations [11], such as architectural symmetry, stratification, spacing, and density. Lefebvre [8] argues that "space is a social form; the space of order is hidden in the order of space ... Space is neither 'subject' nor 'object', but a social reality." Thus, it is a collection of relations and forms [8]. The house or building started out as a way to protect people from risk; it creates a relationship between humans and their built environment, which forms distinct periods of relatively stable order. As technology advances, it alters the structure of physical space, ushering in a new spatialtechnological order with cultural transformations.

#### 1.4 Previously Organising Principles of Diverse Orders

Through variances in size, shape, and layout, architectural spaces produce order for their internal channels and nodes, and the organising principles of diverse orders directly lead to vastly varied forms of spatial arrangement [12]. Digital architecture allows the integration of design and construction with the use of intelligence and digital tools, resulting in the creation of creative digital architectural spaces that defy the conventional principles of architectural organisation and spatial order while simultaneously developing a new order. This is accomplished via the process of generating digital architectural spaces. This research explores the spatial order of digital architecture and illustrates that the advent of digitalisation will usher in a new architectural period that is rich with significance.

"Digital architecture" refers to the digital technical creation of architectural space that exists now, as well as Lefebvre's criticism of technological utopia and the quiet violence of architectural ideology, where technological utopia could produce the risk of technological reliance. It is the violent silence that destroys the original space order. Only by constraining danger and chaos can people construct a spatial order, in which nature, spirit, and society are united, symbiotic, and harmoniously intertwined. As Peng [7] claims, the spatial trinity of "functional, aesthetic, and structural" which refers to organic and cohesive architectural space, will be reinterpreted and improved by VR (virtual reality), AR (augmented reality), MR (mixed reality), and XR (extended reality). In the last four years (2019-2022), architects and urban designers have explored multiple aspects in the theory and practice of digital architecture and architectural space, which are shown below.

1.4.1 Collaborative Design Methods

The design methods of digital architecture should backtrack to a structured technical strategy with consideration of the discipline's origins [14]. Designers employ digital and computational techniques to construct a "scalable algorithmic model of smart architecture" in the digital architecture's design process, which established a cognition between architecture design and AI. The algorithmic model introduced the new thinking and a valuable cycle with upgrades, which surpasses the logical limitation of the human mindset, in the space of probability for shaping the future of architecture [14]. Xu [15] highlights four technologies impacting architectural design from virtual to reality. The first is VR and AR, which make the building of complicated forms easier; the second is artificial intelligence, whereby design tools of artificial intelligence may replace architects; the third is interactive technology, which pursues the genie loci by creating the interaction in architecture, people, and the environment, while giving people a personalised sense of belonging; the last is 3D printing, which supports the

constructed evolution of buildings, such as creating curved surfaces of architectures.

1.4.2 Intelligent Construction Evolution

The designer team led by Xu Weiguo [15] made significant advancements in the application of smart manufacturing and 3D printing materials into architectural practice. These advancements included the creation of a 3D concrete printing-based housing system as well as a robotic arm mobile platform that is suited for architectural printing and is used in building construction [16]. Yuan Feng's designer team [17] explored the paradigm update of human-machine hybrid architectural creation and twin co-creation, by defining a new subject under human-machine cooperation, suggesting a new mentality of intelligent enhanced design and evolution, and reconstructing the sense of humanism in the post-humanist age, where human-machine co-creation is unavoidable [18].

1.4.3 Digital Transposition

Digitisation has changed the way residents and stakeholders live, work, cooperate, and communicate. Scholars have done useful research on how digital technology affects urban space and how people's lives and work change because of it. The related ideas and concepts of digital transposition are extracted from their results as follows: Digitalisation refers to a sociotechnical method of adopting digitising techniques to improve social and institutional contexts [19]. Ansong and Boateng [20] define digital transposition as "the creative use of digital technologies (social, mobile, analytics, IoT, platforms, and ecosystems)" to tackle long-standing issues. As Kaplan and Haenlein [21] claimed, digital transformation has the potential to result in disruptive innovation, the development of value networks, and new markets. The objective of digital transformation is to induce major change by combining information, computer, and communication technologies [22]. According to a recent interdisciplinary assessment, there are three distinct phases of digital transformation: digitisation, digitalisation, and digital transformation [23].

# 1.4.4 Theoretical Practice

Wei Likai's [24] team discusses the positive significance of artificial intelligence intervention for architectural digital history from a future perspective. Based on the popular understanding of "digital being" of society, Zhang [25] claims that the combination of the virtual and reality becomes prevalent in architectural design and research in the digital age. He provides an emotional orientation for discussing in depth the origin of digital architecture theory. Xu [16] claims that architecture as a spatial carrier of robots would face the potential need for intelligent innovation and upgrading. By sequentially exploring the logic of incorporating perception, behaviour, and social capabilities in future architecture, Liu et al. [26] mentioned a new architectural design theory that is proposed to be highly integrative of robot- and human-living environments. Huang and Wang [13] argue that diverse creative freeform building approaches have merged morphology, geometry, structure, and manufacturing as an extension of architects' design thinking and a wide cognitive framework during the last two decades.

Based on the current literature reviews, there are very few results directly focusing on the "spatial order of digital architecture", but some that are partly related with digital architecture or spatial order. The four aspects summarised above could not be separated; there is crossover and permeation between the different aspects, with no clear boundaries in the mixture. The broad digitalisation of architectural space generates a multi-dimensional mixing of theories, practices, time, space, society, culture, and art. Constructs as organisms are constantly impacted by the technical and cultural environments in which they are found as well as by the physical sensations and existential meanings of those who create and live in them. As a result, they are compelled to be in constant, dynamic change [27]. The traditional architecture order has been changed, and this study will explore the new order with its numerous aspects, and will look for a new order with technoculture in digital architectural space.

# 2. Research Method

This research adopts a qualitative methodology by using a case study approach to collect data from previous literatures. An effort is made to acquire knowledge of digital architectural and spatial order by extracting ideas from relevant literatures from 2017 to 2022. To address the integration of digital architecture practice and frictions in the spatial order, data were collected using case studies from specific cases. The terms and knowledge from the literature were coded with categories, then cross-checked within the findings from the case analysis.

When searching the keyword of "spatial order of architecture" on the CNKI (China National Knowledge Infrastructure) database for Chinese literatures, and both English literatures, until 2022, there are only 11 academic papers that are closely related to the topic, which shows that relevant research is lacking in quality and quantity. The following terms are associated with the spatial order of architectures: orderliness, regularity, organisation, unity, completeness, plasticity, diversity, continuity, hierarchy, adaptability, polysemy, difference, commonality, coexistence, morphology, topology, integration, transparency, orderly organisation, cultural

 Table 1
 Related key words in papers from 2017 to 2022.

arrangement. When searching the keyword "digital architecture", there are 244 closely related papers, and when searching the keyword "spatial order", there are 204 closely related papers, as show in Table 1 (made by author).

As Table 1 shows, the number of papers peaked at 49 for the key words "digital architecture" in 2019, and 48 for the key words "spatial order" in the same year. This raises some interesting questions. The influence of the pandemic that started in 2019 and other unknown factors may have sidetracked the interest of the researchers involved. From the analysis of the literature on "spatial order in architecture", the author devised a research strategy of "digital architecture + spatial order", correlating digital architecture with spatial order, and exploring the spatial order of digital architecture. Searching for "spatial order of digital architecture" yielded 0 articles from 2000 to the present, which means that "spatial order in digital architecture" is a research topic with a degree of originality. Based on the objective of this research, the author chose four prominent digital architecture works in the worldwide context, to do case studies and investigate the changes in the spatial order of digital architecture.





Fig. 1 Photo of (W)rapper of Eric Owen Moss.



Fig. 2 Photo of Beijing Daxing International Airport.

## 3. Case Studies

(W)rapper of Eric Owen Moss (Fig. 1<sup>1</sup>) is a tower in downtown Los Angeles that has no columns and no beams, which is full of clashes of forms and elevations that appear to be colliding, breaking, deforming, superimposing, bending, splitting, melting and exploding, as if out of control. All these architectural features cannot be relegated to any one methodology of design. Crossing the building's four elevations are ribbons of curved steel tubing. The only producers who can create these corners are in Shenzhen, China, and in Munich, Germany, where they combine many plates to create a solid with the required strength. China manufactures the ribbons, which are the most intricate steel components, for locations as far away as LA and been slowed down by activities such as drawing or building a model in the traditional manner. "The project's design concept and conceptual approach are still derived from my hand drawings. However, the computer rapidly takes over and becomes a fantastic editing tool." [28]. Eric Owen Moss's architectural work replaces the traditional way of making buildings by using the convenience and speed of digital technology. This makes it possible to build buildings that are global, shared, and built at the same time. The buildings appearance style also created a new perspective that provides unlimited possibilities for further architectural development.

Through parametric design, the airport project in Beijing (Fig.  $2^2$ ) is a conjugated and harmonised leaflike structure, with the singularity of the structure at its centre. It combines traditional culture with modern design, the inspiration was a variant of the ancient Chinese phoenix, an auspicious symbol with a particular aesthetic identity that produces a regional aesthetic spatial order. Through multicultural sharing of information, the worldwide sharing of construction materials and fabrication processes, and the tendency to utilise computers and digital tools to assist architects' designs are illustrations of the "antidote effects" of digital technologies. It can be seen from this case, that while digital intelligent design and construction alters the norms of traditional architectures, it does not totally replace the architect's job, but stays at the assistant level.

In this case, utilising digital communication and information transmission across different cultural and national boundaries, the engineering and manufacturing were made feasible by a common digital language for sketching, detailing, and production. This is made possible by shared technologies, which also provide the architects with access to technological assets internationally.

<sup>&</sup>lt;sup>1</sup> Photo of (W)rapper of Eric Owen Moss, 2019. Accessed 12 December 2022. https://www.archdaily.cn/cn/tag/eric-owen-moss.

<sup>&</sup>lt;sup>2</sup> Interior Photo of Beijing Daxing International Airport, 2019. Accessed 31 December 2022. https://www.zcool.com.cn/work /ZNTMwMjkxMzI=.html.



Fig. 3 Photo of the 3D Niaokan Bridge.



Fig. 4 Photo of the World International Conference Center.

Digital manufacturing makes it possible to quickly produce and research a variety of solutions. As Moss mentioned: "In the past, the process would have Beijing Daxing International Airport by Zaha Hadid is known for its innovative use of unconventional construction techniques and new materials". Parametric design is the characteristic of the digital spatial representation of this case, which breaks with the style of appearance of traditional layered interlacing, spatial curling, and increasingly intricate features, Zaha's building creates more agitated but organised motions with a pulsating perceptual power [29]. At the same time, her ideas disrupt the conventional forms of architecture by blurring the lines between roof and facade to give the building a fluid, modern, integrated, sculptural aspect. As digital technology pervades the realm of architecture, architects can play more freely with the rules of order, introducing chaotic methods such as tilting and crossing, dislocation and distortion into building design and construction, resulting in

subversive, paradoxical, and uncomfortable constructions. This unorthodox ordered building hides a dynamic order under its rebellious exterior, exhibiting the beauty of a specific order. For example, architectural design technology with digital generates complex, multidimensional, and other dynamic shapes that constitute a new component of architecture and may establish a new aesthetic order. Spatial order affects and governs architecture's structure, organisation and way of being, and is the principle and logic of its creation. The beauty of architecture exists in order, and the aesthetic in digital architecture subverts the aesthetic order of traditional architecture, which implies the construction of a new aesthetic order in the space.

The 3D Print Niaokan Bridge (Fig. 3<sup>3</sup>) by Xu Weiguo earned the "Technology Use Award" at the ROB&ARCH (International Robotic Construction Conference) in 2018. It constructed the world's biggest concrete 3D printed pedestrian bridge in Baoshan, Shanghai, using its self-developed robot arm 3D printing concrete technology, which saves material, labour, time, and money in the building process [30].

As an intelligent construction technology, 3D print permits not only the production of conventional building shapes, but also a range of rich organic architectural forms, allowing tradition and modernity to coexist. 3D concrete printing building technologies and systems are not simply a tool for production, but a new method of production that will result in the formation of a new social organisation. Xu [31] asserts, on the basis of the intelligent integration of digital building design and construction, that "AI design tools may replace architects". This opinion contradicts Eric Owen Moss's idea that "the intelligent technology is an excellent tool for designers". As AI grows and penetrates deeply into the area of architecture, the future of digital architecture may alter the architect's identity, altering what architecture means to people and

<sup>&</sup>lt;sup>3</sup> Photo of the 3D Niaokan Bridge, 2019. Accessed 31 December 2022. https://www.rd.tsinghua.edu.cn/info/1054/149 2.htm.

the human-machine synergy. Eric Owen Moss believes that people may utilise digital tools to produce architecture, but that these techniques do not guarantee the traditional meaning of architecture. The meaning of architecture comes from other things, such as culture and the way designers think about things [32]. The World International Conference Center by Yuan Feng's team (Figs. 4<sup>4</sup> and 5<sup>5</sup>) located in Wuzhen, won the top prize at the 2022 AIA (American Institute of Architects) International Design Awards for the Wuzhen Internet Light Expo Centre [33]. Wuzhen is a historic town with cultural features in the Jiangnan area of China, and the development of a mega-expo centre of tens of thousands of square metres presented a formidable task (Fig. 4), balancing the harmony between the scale of the traditional and modern buildings with the need to establish a new architectural order of the times. The design of the new venue for this case takes into account the continuation of spatial and functional integration with the current venues, as well the future orderliness of the overall built as environment, with the interaction between tradition and modernity, technology and culture serving as the focal point of the overlaid spatial order of the site.

In order to conceptualise and build the centre in Wuzhen, the "traditional characteristic" and the "Zeitgeist" served as the starting point. The fusion of Zeitgeist and the culture of construction is the key point of creation [33], and the completion of the project entails the construction logic and formal logic of the new productivity of the creative process, as well as the cultural reconstruction of the digital humanities period. This case in Wuzhen is not only a new architectural space, but also a constructive experiment in the context of post-humanistic philosophical thinking [34]. It is a mapping of technology and culture, a reconfiguration of the architect's identity, a revolution of the architectural business, and a paradigm shift in architectural discourse. The interweaving of traditional and contemporary architectural spaces in Wuzhen provides a complex variety order, where regional, traditional, and modern architectural characteristics are naturally merged, and where single and multiple orders tend to be organically harmonised. The combination of the traditional community culture of the historical town and the Zeitgeist in the digital architectural space creates a new techno-culture, heralding the technocultural transformation of the spatial order.

Internet technology, one of the technical cornerstones of digital architecture, has been repeatedly updated to the third generation and is regarded as a metaverse [35]. The combination of the metaverse and the encompassing VR, AR, MR, and XR with architecture and civil engineering [36], upgrades the technological applications of digital architecture. Multiple environmental data sets from the natural and social spheres are parametrised into computer tools, computationally produced, and then 3D printed into an integrated algorithmic architecture. These various technologies are driven and constrained bv computational programming, which has an algorithmic order. The spatial superimposition of the algorithmic architecture itself, added to the superimposition of older places, results in the production of an intricate spatial order that contains both old order and new order simultaneously. Order requires complexity for its manifestation, and complexity requires order for its



Fig. 5 Photo of architectures in the World International Conference Center.

<sup>&</sup>lt;sup>4</sup> Photo of the World International Conference Center, 2021. Accessed 31 December 2022. http://www.archcollege.com/a rchcollege/2021/11/50161.html.

<sup>&</sup>lt;sup>5</sup> Photo of the World International Conference Center, 2021. Accessed 31 December 2022. http://www.archcollege.com/a rchcollege/2021/11/50161.html.

comprehension [37]. In an effort to understand the future spatial order of digital architecture, the interpretation of these four cases investigates the cohabitation of the complexity of "order/disorder" and the organic unity of "single/multiple order" in space.

#### 4. Conclusions

If "dynamic space with order" is the architect's goal for architectural design and construction, then the development of a sustainable place that fits into the natural order may be the direction for the production of a digital architectural spatial order. Natural and social environmental data are input into the design parameters, resulting in an algorithmic architecture that most closely resembles the natural and social spatial orders. The traditional rules of the spatial order of architecture are broken and subverted by digital architecture. However, the new digital architecture is placed in the built environment and natural ecosystem, where spatial superimpositions penetrate, rub, restrict, and converse with one other towards integration, reflecting order's regularity. The construction of a new spatial order for digital architecture necessitates time to settle and identify with the process.

Spatial order can be discovered in digital architectures through the above literature and case studies: digital architecture both breaks and inherits the old architectural spatial order; the digital architecture has a binding and aesthetic in the order; it changes the relationship between digital technology and human, frees up labour for a while, makes building in the highly efficient way, and this order is controlled and bound by human digital symbiotic order; multiple intelligent manufacturing technologies establish a combined order as digital technology penetrates deeply into the area of architecture, such as technological theory and humanistic theory, tradition order and modernity order; it uses computer technologies and the IoT (Internet of Things) to communicate parameters, and share resources, to establish an sharing order. Meta-universe space will also develop the embryonic digital

architectural spatial order features of symbiosis, communion, sharing, and the blending of reality and imagination. "Symbiosis" will demonstrate complex hierarchies, logical levels of algorithms, and hierarchies of human consciousness and social classes; "combined" will demonstrate cross-border, bionic, simulation, unrestricted interaction with reality and reality conversion; and "sharing" will demonstrate the sharing of a fully perceptual immersive experience, the sharing of immersive space. The result of the virtual evolution of the metaverse space can be projected onto the real space, and the symbiosis, commensality, and sharing of virtual and real space form a new technological culture, laying the groundwork for the future digital architectural space to establish a new order of dynamic equilibrium and foster its innovative development.

## References

- [1] Pitchnikova, G. A., and Antyfeev, A. V. 2019. "The Four Factors Influencing Media Architecture." *IOP International Conference on Construction Architecture and Technosphere Safety* 687: 055026.
- [2] Gu, X. W. 2018. "Technology Is the Antidote and Poison: Interviewing Bernard Stiegler." China Writer Web. Accessed December 31, 2022. http://www.chinawriter.co m.cn/n1/2018/0427/c405057-29953400.html.
- [3] Kong, L. M., and Yao, Q. F. 2020. "Construction of Architectural Space Order under the Evolution of the Grid System." *South Architecture* 5: 84-9.
- [4] Zhou, J., and Yu, J. 2017. "The Collision of Digital Technology and Architectural Space: The Development of Digital Architectural Art Applications." *Art Tasting*14: 175-6.
- [5] China Academy of Information and Communication Research. 2022. "White Paper on Digital Building Development." CAICT. Accessed December 21, 2022. http://www.caict.ac.cn/kxyj/qwfb/bps/202203/P02022033 0512284345397.pdf.
- [6] Liu, G. 2017. "Digital Transformation Produce the Evolution of Industry." *China Engineering Consulting* 12: 58-61.
- [7] Peng, Y. G. 2008. Theory of Architectural Space Combination. Beijing: China Construction Industry Press.
- [8] Lefebvre, H. (trans.). 2021. *The Production of Space*. Beijing: The Commercial Press.
- [9] Meng, B., Deng, W., and Peng, L. 2019. "Understanding of Space and Optimization of China Territory Space

Functional Based on Geography." *Ecological Economy* 35. (9): 170-6.

- [10] Li, H., and Reynolds, J. F. 1995. "On Definition and Quantification of Heterogeneity." Oikos 73 (2): 280-4.
- [11] Zhang, X. F. 2018. "Discussion on the Formation of Architectural Form Based on the 'Theory of Beauty in Relations': Taking Museum Buildings as an Example." *Nan Chang University Academic* 12: 1-79.
- [12] Hu, J. 2017. "The Alternative Description of Spatial Order: The Evolution and Innovation of 'Conception Space'." *Hua Zhong Architecture* 35 (8): 12-6.
- [13] Huang, W. X., and Wang, L. Y. 2022. "Digital Architecture Design and Research: A Broad Spatial Cognition." *World Architecture* 11:64-67.
- [14] Li, B., Zhang, J. S., Ludger, H., and Guo, Z. F. 2019."Analyzing the Black Box of Design with Algorithm Model." *The Architect* 41 (1): 94-9.
- [15] Xu, W. G. 2020. "A Vision for Digital Architecture." Contemporary Architecture 1 (2): 20-2.
- [16] Xu, W. G. 2022. "From Digital Building Design to Intelligent Construction Practices." Architecture Technology 53 (10): 1418-20.
- [17] Yuan, F., Zhou, J. J., and Yan, C. 2019. "Cyborg Craftsmanship: A Human-Machine Collaboration Future in Architecture." *Architectural Journal* 66 (4): 1-8.
- [18] Yuan, F., Xu, X. H., and Li, K. K. 2022. "Rethinking the Architectural Digital Future in the Age of Anthropocene." *Architectural Journal* 69 (9): 12-8.
- [19] Seth, H., Talwar, S., Bhatia, A., Saxena, A., and Dhir, A. 2020. "Consumer Resistance and Inertia of Retail Investors: Development of the Resistance Adoption Inertia Continuance (RAIC) Framework." *Journal of Retailing and Consumer Services* 55 (July): 1-14.
- [20] Ansong, E., and Boateng, R. 2019. "Surviving in the Digital Era-Business Models of Digital Enterprises in a Developing Economy." *Digital Policy, Regulation and Governance* 21 (2): 164-78.
- [21] Kaplan, A., and Haenlein, M. 2019. "Digital Transformation and Disruption: On Big Data, Blockchain, Artificial Intelligence, and Other Things." *Business Horizons* 62 (6): 679-832.
- [22] Vial, G. 2019. "Understanding Digital Transformation: A Review and a Research Agenda." *The Journal of Strategic Information Systems* 28 (2): 118-44.
- [23] Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., and Haenlein, M. 2021. "Digital Transformation: A Multidisciplinary Reflection and Research Agenda." *Journal of Business Research* 122 (Jan): 889-901.

- [24] Wei, L. K. 2020. "Engineering Brain: Metaverse for Future Engineering AI in Civil Engineering." Architectural Journal 67 (1): 2-18.
- [25] Zhang, R. S. 2022. "Exploring the Theoretical Origins of Digital Architecture from the Perspective of Emotional Attachment: Cases of Three Pioneering Digital Architecture Theorist." *New Architecture* 3 (5): 106-11.
- [26] Liu, J., Liu, X. C., and Xu, W. G. 2022. "Sensing, Knowing, Connecting: Architecture in the Area of Intelligent Robots." *Contemporary Architecture* 3 (6): 14-8.
- [27] Yan, C., and Yuan, F. 2020. "A Post-humanist Tectonics: Technological and Cultural Reflections in Digital Fabrication." *Times Architecture* 37 (3): 6-11.
- [28] Xie, R. G. 2019. "Eric Owen Moss: As an Architect, I Provide Design, I Have Something to Give and Give Users A New Perspective to Perceive the World." Zhihu Zhuanlan. Accessed December 30, 2022. https://zhuanlan.zhihu.com/p/69432668.
- [29] Zhu, Y. L. 2021. "The Non-objective New Order: Analysis on the Evolution of Suprematism from Art to Architecture from the Perspective of Architectural Aesthetics." *Urbanism and Architecture* 18 (10): 136-40.
- [30] Tsinghua News. 2022. "The Fantastic Project of the 3D Print Bridge." Tsinghua News. Accessed December 31, 2022. https://www.rd.tsinghua.edu.cn/info/1054/1492.htm.
- [31] Xu, W. G. 2020. "Digital Architecture: From Imagination to Reality." *Housing and Real Estate* 26 (14): 10-7.
- [32] Xu, W. G. 2012. "Balance between Theory and Practice, Conflict between Character and Convention: Dialogue between Eric Owen Moss and Xu Wei Guo." Urban Environment Design 9 (10): 112-3.
- [33] Tongji News. 2022. "The Award of World Internet Conference Center in Wuzhen." Tongji News. Accessed December 31, 2022. https://news.tongji.edu.cn/info/1003/ 82476.htm.
- [34] CMGJ. 2019. "The Design of World Internet Conference Center in Wuzhen." CMGJ. Accessed December 31, 2022. https://www.archiposition.com/items/4fd298bad6.
- [35] Yuan, F., Zhang, L. M., and Ma, H. S. 2020. "Generation, Simulation, Optimization and Construction Practicing Human-Machine Collaborative Tectonics in Wuzhen Internet Expo Center." *Architectural Journal* 67 (8): 5-11.
- [36] Cheng, S. Q. 2022. "The Production of Space and Justice of Space in Metaverse: Taking the 'Virtual City' as an Example." *Hebei Academic Journal* 42 (5): 16-9.
- [37] Shi, M. L., Peng, J. G., and Tang, F. H. 2010. "The Aesthetic Value of Order and the Aesthetic Pursuit of Contemporary Architecture." *Journal of Architecture* 57 (4): 16-9.