

## Research on Nonlinear Thinking of Landscape Architecture Design based on Computer-aided Parametric Model

Hongxiu Liu\*, Jingjing Jiao and Nuo Zhang

North China University of Science and Technology, Tangshan 063000, China

\*lhxt2008@126.com

### Abstract

*With the development of information technology, computer technology has been fully penetrated into every field of life, the computer technology in architectural design also developed from aided design to parametric design. In this paper, the authors analyze the application of parametric design in nonlinear landscape architecture, and realize the dynamic simulation of nonlinear design. By using 3D digital technology, the engineer can simulate the real information of the nonlinear building; and this technology is an important technical support for the construction of complex structures. The results show that in the face of the construction of the complex structure building, the nonlinear shape building is not only dependent on the computer software technology, but also depends on the computer aided manufacturing technology.*

**Keywords:** *Parametric design, nonlinear architecture, architectural design, computer simulation*

### 1. Introduction

The whole twentieth Century is the rapid development of the construction period; the important reason is the continuous renewal and progress of science and technology. Large scale industrial production and advanced construction technology have made the rapid development of the city [1]. However, a single planning model, over reliance on the construction of technology, resulting in the same city, the loss of regional characteristics, the formation of a large-scale global urban construction group. In our country in recent years, with economic development is faced with the problem more severe. China's undisputed become every year in the world largest national new construction, every year a new area of 20 million square meters, use 40% of the world cement, steel. On the other hand, in twenty-first Century, with the development of global technology, especially information technology, there are many new buildings around the world. They rely on the construction of excellent technology, exaggerated form, and the traditional aesthetic. These buildings although unconventional, unique personality, but is eventually destroyed the local urban space and cultural attributes, destroyed the original venue site sequence, lost some of the social value and cultural connotation [2]. Since the middle of the 20th century, nonlinear science as a nonlinear theory to study the common phenomenon of emerging scientific rise, it is beyond the category of dynamics and thermodynamics, already with sociology, with ecological up, and even for the development of guidance architecture. Nonlinear science initiates the universal law of human society and nature.

In the context of Chinese architecture, ecology, green, sustainable architecture has become popular keywords. New technologies and new materials have been used in the construction of new form, but in essence, the same phenomenon has not been changed. Architectural creation is still based on the traditional linear creative thinking [3-4]. And in the current developed countries and regions, nonlinear scientific guidance of architectural design has become a new field of architectural design to open up new areas. Many famous architects are trying to break the inertia of the original architectural creation, and turn the

field of vision to the new thinking and new method of nonlinear science. Nonlinear theoretical results have been widely spread in the fields of science, technology, culture, society and so on. It has penetrated into the building space systems which are closely related to human beings. In the past thirty years, the tendency of the convergence of urban architecture in China has become more and more obvious, and has a linear growth trend. New technologies and new materials have been used in the construction of new forms, but in essence, the same phenomenon has not been changed.

Landscape architecture as a kind of architectural structure is a new type of construction strategy for the relationship between the environment and the environment. Contemporary landscape architecture on the one hand to promote integration with the surrounding environment, the new location techniques at present more and more attention has been paid to, but this part of the building did not reach landscape architecture by proper design expected, inconsistent form and function, and even use the defects, the reason is lack of related research on the urban environment and the people behavior patterns and vision and strategies [5]. On the other hand, the complex morphology of the contemporary landscape architecture often make it must design with unique way of generation, the nonlinear science and especially is closely related to the contemporary digital generation and parametric technology, how to take appropriate technical design strategy the design read consistent, has become a topic worthy of study [6]. Now domestic landscape architecture examples often one-way linear thinking in design, although some examples shows more unique and varied shape effect, but is still not out of the traditional design methods and ways of thinking, are not out of the traditional technology and system support, in the form of often and landscape architectural value orientation of the original contrary. By the nonlinear science derived nonlinear thinking will exceed linear science of human thought control, make the architectural subject to construct a new form and structure system of the building to new concepts and strategies, in order to adapt to the changing contemporary habitat requirements. On the nonlinear theory to guide the advanced design idea and construction rules of the understanding and reference, is conducive to grasp the domestic architects of this kind of building form, change the buildings lack of details to consider and the technical problem of evasive.

## **2. Parametric Design and Construction Technology Platform**

The parametric design and construction of the technical platform here mainly refers to the computer software technology and digital construction technology. Computer software technology, in particular, refers to the operating software that can translate and input parameters. Of course, here is not to introduce the software itself, but a brief analysis and summary of how they are used to carry out parametric design, as well as in the design process to reflect the basic characteristics [7]. At present, parametric design and operation of the software can be divided into two categories. The first is specially developed with parametric operation interface design software, such as digital Project, generative components, rivet *etc.* The second is through a variety of three-dimensional software itself comes with a scripting language to carry out the parameter coding, such as Rhino Script based on rhino software, based on the MEL language Maya software. Although the use of different syntax, but the two are the software it comes with built-in language. In addition, this chapter also through examples briefly illustrates the basic characteristics of building information model (BIM), describes the various integrated construction project related information and engineering data model, detailed digital expression of project information, is also a kind of application in the design, construction, management and other aspects of integrated digital method.

## 2.1. Parametric Design Software

As a technical tool, parametric design software must possess the ability to simulate and construct nonlinear dynamic systems. This is in addition to the characteristics of the system to solve the problem of the system, but also depends on the software itself has the ability to simulate. In the software implementation of this nonlinear dynamic simulation are the influence parameters corresponding to the variable value control, again through the software's built-in function, dynamic input is used to deal with design factors of uncertainty changes, as shown in Figure 1. In addition, we can use some advanced computing techniques, such as random function, recursive algorithm, to simulate the complexity of the real world. The operation idea of software is that the core logic of nonlinear parametric design is completely unified. The core of the GC software is to store the feature tree in the file. The feature tree represents the connection between the process and the parameters of the model. The complex relationship between these characteristic trees can be used to describe the architecture of the system. Moreover, these operations are reversible and can satisfy the solution from the beginning to the end [8]. In addition, the emerging software Grasshopper specifically developed for the Rhino is able to represent the development trend of this kind of software with parametric interface type. The operation interface of Grasshopper is completely graphical and object-oriented, and it can show the influence model between parameters with the very intuitive parameter relation diagram. The user can modify the association mechanism between parameters directly in the parameter memory of these similar devices, as shown in Figure 2.

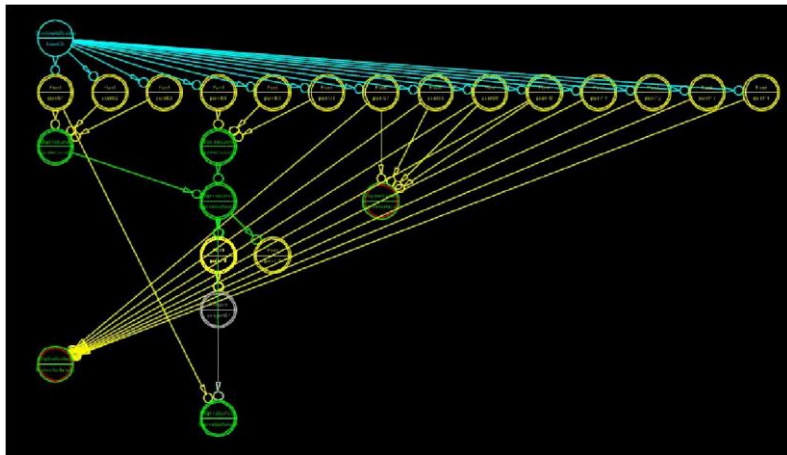


Figure 1. Characteristic Tree in GC

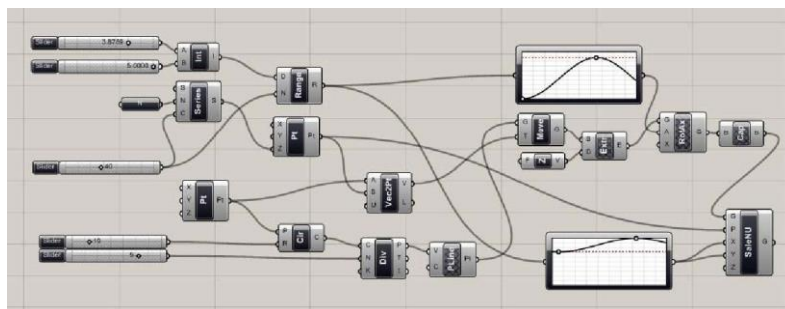


Figure 2. Organizational Structure in Grasshopper

## 2.2. Building Information Model

The emphasis of parametric design software and script technology is on the input and translation of parameters, and the building information model is the design process directly related to the expected construction and processing. Building information modeling (building information modeling) to three-dimensional digital technology based, integrated construction project all relevant information and engineering data model, which supports the construction of integrated management environment, can make the construction project in the whole process significantly improve efficiency and reduce risk. Building information model is to simulate the real information of buildings by digital information, and it is a component of the real world used to build buildings. Not only the geometric description of the visual information, but also contains a large number of non-geometric information, such as the construction of components of the material, weight, price. Even some software can do the whole process of the end of the construction cycle, including the construction process and operation process.

Building information model is now being more and more experts, applied to a wide variety of buildings. Building information model provide virtual building model, for the team to design and construction of the construction between transfer and sharing data, can be in various stages of adding their professional information, update, track changes, and to maintain the common digital model, can effectively reduce the process in between providing and receiving the information leakage. The development of building information model is an important technical support for parametric design in the face of complex form construction. But there are few outstanding examples of the combination of building information model and complex shape construction.

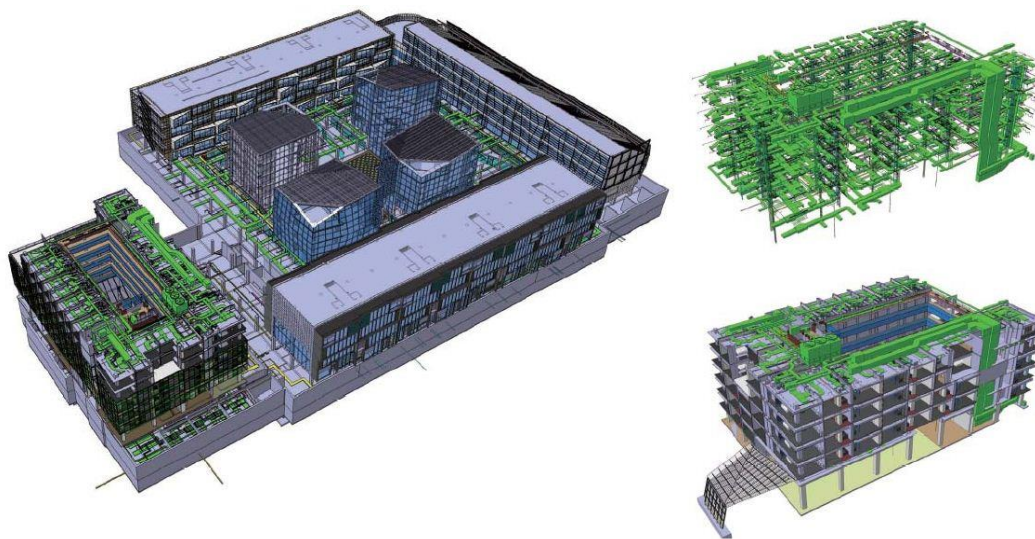


Figure 3. Building Projects Using Project Digital

## 3. Characteristics of Nonlinear Architectural Form

### 3.1. Architectural Form

The technique of artificial terrain will be regarded as the terrain to carry out the operation, rather than the traditional sense of the building. Through the roof shape or the whole building a terrain simulation, is constructed in the Cartesian grid and is the embodiment of the traditional geometric order. The artificial terrain is a kind of non-linear architectural style, which makes the rules and uncertainties, thus breaking the rigid rules of the rational order. The simulation of the nonlinear shape is closer to the natural state.

Meisel fossil pit tourist information center design, by the German design agencies to complete the entire design needs to be integrated with the history of the earth's crust, science and technology, as well as the origin of the building itself and many other factors. The appearance of Meisel fossil pit Tourist Information Center building design concept comes from the oil shale rocks form. With the turning of the retaining wall to the pit and gradually increasing the change and change, the whole shape of the climax in the cantilever viewing platform, as Figure 4.



**Figure 4. Messer Fossil Pit Tourist Information Center**

WEAVA Busan opera house design is not a mountain building, and its shape and mountain terrain to obtain the method of isomorphism is worth learning from. Design will be far away from the image of the Gubong into the mountains, through the use of soft line texture, that is, the level of the plateau like strips, designed to make the natural site into a harmonious environment and urban form. In addition, the design is also integrated into the twisted between the bands, thereby forming a strategic opening. Finally the overall image and Gubong mountain mutual echo, as one of the contributing factors in the development of the city, as shown in figure 5.



**Figure 5. The Busan Opera Program Yamagata Texture**

Cities with vertical characteristics tend to give a visual impact, while the level of urban emphasis on human body perception of the city. Therefore, the level of architecture is more concerned with the emphasis on the physical life of the world, which requires the landscape and urban design should be concerned about the city's living space in the building. Contemporary landscape architecture has spread of obvious level feature, as in the urban middle berth carpets, huge buildings in the horizontal extension of the facade form repeatedly weakened until it disappears, only extending to the roof and floor. The

traditional performance function of the building has been cancelled, and it is necessary to have a thorough understanding of the architecture. While the horizontal extension of the landscape architecture and the huge scale, so that it can respond to the city environment, the appropriate way to disappear in the urban environment, the formation of fuzzy boundaries. Elevation can even shrink to a side, directly from the ground up. For example, the new Brooklyn botanical garden visitor center, designed by the New York architectural firm, is shown in Figure 6.



**Figure 6. Brooklyn Botanical Garden Visitor Center**

Interface extension strategy is generally applicable to try to emphasize the interior urbanization characteristic of landscape architecture, it features more close to the early mat building prototypes, only pay more attention to the external environment in the vertical direction how to enter inside the building, in the external, physical construction still has clear boundary but the form and the material attribute has been weakened or even disappeared to integration with the surrounding urban environment or natural environment; the most important landscape characteristic not only in the relationship between the ground and the roof, in the interior of the building, interior space mainly emphasizes can penetrate and are connected to each other, forming a tight binding model. And the building internal circulation woven into the urban streamline network, the city in a variety of flow into the inside of the building, and in which the guide, diversion, in order to realize the building became a part of the urban infrastructure. South Korea's Seoul Memorial Park, as show in Figure 7, Building foundation underground, the slope from the bottom of the road is to maintain the shape of the original terrain, while with the decline of the roof echoes.



**Figure 7. Seoul Memorial Park**

### 3.2. Architectural Interface under Nonlinear Influence

By chaos theory and nonlinear science, contemporary landscape architecture usually exhibits a nonlinear form, interface morphology and environment harmony is to accommodate the many people's behavior, will eventually architecture, the natural environment and melting together to form a complex system of association. Hadid is one of the most famous innovative architects in the world, and she always has the shape of dynamic structure. Its works, often with the wedge and its tilt and deformation to shape the shape of the dynamic, quite a sense of weightlessness in the form of composition, full of dynamic composition. Redscrew Lake Club, as shown in Figure 8, the tilt and dislocation form to construct the linear momentum. For the architectural expression nervous, fast character, a plurality of overlapping, in the long and thin sharp concrete slab welcome to the site in the avenue, then building along the road and low and long to go on an extension, but is not a single cube lateral continuation, but three similar acute triangle side by side overlap together, and has to the acute vertex flow direction is dynamic and strong. The interior of the building is not orthogonal space; all the walls are tilted and implies a certain overlapping relationship, external support concrete slab of the tilt of a group of steel column reinforced the momentum.

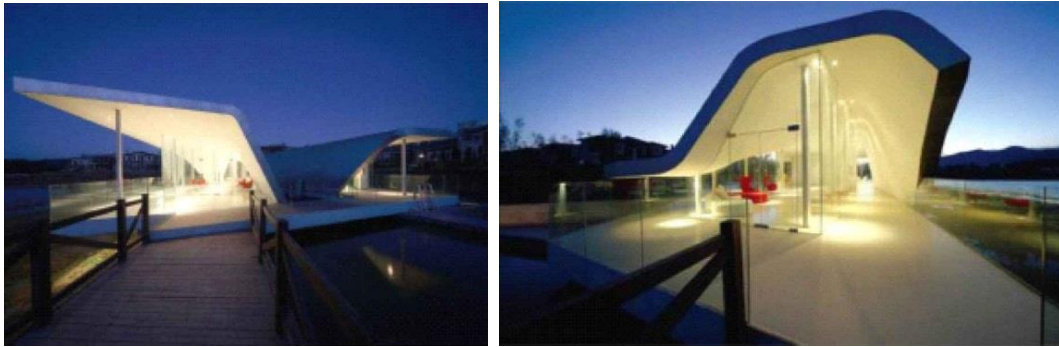


Figure 8. Redscrew Lake Club Dynamic Form

## 4. Nonlinear Architectural Design Method

### 4.1. Pre- Design

Build a nonlinear open design thinking is we in Deconstruction closed frame of landscape architecture linear thinking when necessary, architects in landscape architectural design process need to project the preliminary plan, the progress of the project, construction completed an overall grasp and the late stages of each service, the internal structure of the building system become open and external environment and the system exchange material, energy and information. Landscape architecture to meet the requirements of living and working at the same time, we, the external physical environment, social environment, natural environment of site interaction, itself is a kind of open structure; architects in the design of landscape architecture, space, form and construction should emphasize the architecture, human and environment interaction of the Trinity. The basic characteristics of the internal mechanism of architecture are the closure and the rigidity of the system. There is a lack of dynamic generation of genes in the system, which leads to the speed of scientific development. The use of nonlinear science to guide the contemporary landscape architecture is to combine with the complexity of scientific results, deconstruction of the original landscape architecture framework, to eliminate the lag factor, and thus promote the development of landscape architecture. In

the specific design methods, open system pay more attention to the establishment of the overall thinking, dynamic generation model, and by virtue of the model to the external conditions for the system of perception, obtain and process information, so as to establish the design strategy and work plan. Nonlinear guidance of landscape architecture is a dynamic system, in the operation of the system is always in the volatility can be maintained in the overall coordination. This ensures that the internal model of the landscape architecture, which is a nonlinear guidance, is the basic concept and the design strategy, which can give a reasonable response in the face of complex external conditions.

Architecture and urban environment, human behavior and ecological environment of the relationship more closely, so they think of such a complex external environment must be a complex process, such as geometric graphic and digital quantization, MVRDV's digital city as shown in Figure 9

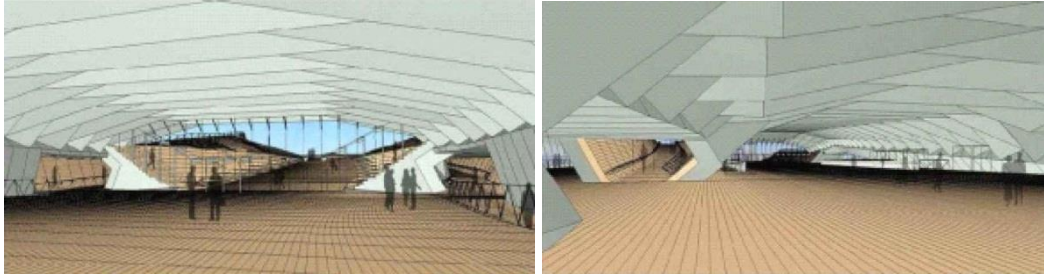


**Figure 9. Reflection on the High Density City of MVRDV**

#### **4.2. Computer Simulation Technology**

Interdisciplinary research has become an important means and method of scientific research since the seventies of last century. The chaos theory of nonlinear science, fractal geometry, and so on, is the results of the study of interdisciplinary research. In the scientific community, the development of nonlinear science and complexity science is much more rapid than in the past. Interdisciplinary research and collaborative design in the construction sector has long existed, but the development is relatively slow. Proposed by Sullivan, Wright organic architecture thoughts of architecture and biological combined together; Frank Gehry is integrated the art, shipbuilding, aircraft production process and powerful computer operation ability, and to achieve the design and manufacturing collaborative operation and remote network technology, thus creating the famous "Bilbao" architectural phenomenon. Obtained at the early stage of the design concept and fuzzy modeling basis, if the lack of computer modeling and shaping the basic condition, it will seriously affect the concept of the final implementation, the process including deepening design in technical cooperation and later production of the production methods and so on, many tend to in design of complex nonlinear form of architects are the frontier in the field, they use computer technology of the method is also applicable in the landscape architecture design.





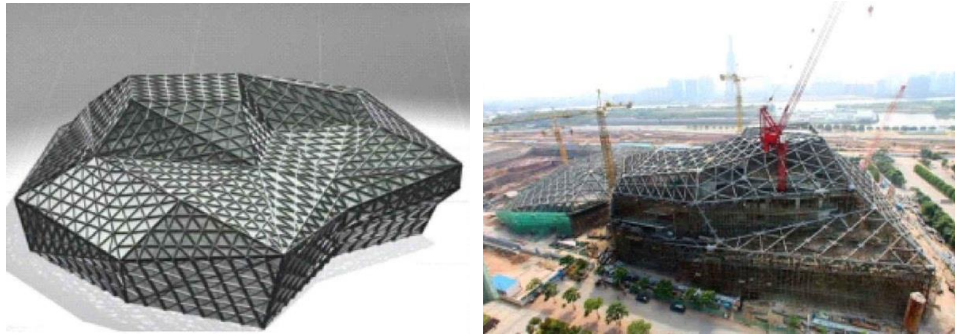
**Figure 10. Yokohama International Terminal Computer Model Screenshot**

At the beginning of the concept, a typical operation flow for the design of nonlinear configuration can be summarized as:

- 1) according to the concept (sketch) to produce a large number of physical model to deliberate;
- 2) with 3D laser scanner and the selected form physical model of digital, some architects at this stage will use computers to filter and interpret before collection of various environmental parameters, building under the influence of various environmental variables, building form even generated architectural form;
- 3) using computer virtual model is shaping up, most of the current building is building the parametric model, the change of various kinds of design condition should be the model of adjustments and changes of the overall, but also conducive to generate a variety of possible forms, than the choice for architects. This stage is mostly alternate design computer modeling and model entities.

#### **4.3. Design Control and Adaptability**

The development trend of building architecture designers were asked to use a more overall, nonlinear and relevant ways of thinking and design strategies to see problems, deal with architectural complexity problem in the process of evolution, and to establish the mechanism of complex adaptive system. At the same time, in the design of the early concept design phase, but also to consider the long-term relevance of the design of the design. The basic principle of the nonlinear landscape architecture design is the principle of adaptive design. Adaptive design not only expresses the adaptation to the natural environment, but also covers the adaptability to the social environment. According to the nature of the design, it is necessary to choose a suitable environment for their survival, and the construction itself is to adapt to the existence of the environment. When the building is determined to exist, the landscape architecture must work hard to adapt to the environment, and to make a positive response to the current various constraints such as cost, technology, labor and so on. In the era of information network, adaptive design tends to be more complex, especially the rapid development of computer technology achievements have been applied to architectural design to, architects need to broader knowledge and wisdom to understand the spirit of the times in architectural creation.



**Figure 11. Construction of Parametric Control**

In the face of the construction of the complex structure of the current building, the powerful computing and processing ability of the computer has greatly enhanced the processing ability of this kind of building construction problem. The nonlinear shape building is not only dependent on the computer software technology, but also depends on the computer aided manufacturing technology (CAM). And with the help of computer numerical control (CNC machine tools), nonstandard architectural form can be split into irregular parts, parts can be in the form determined by the computer through the operation of division and determine the connections between each other. Then through the software input computer numerical control machine tool, directly processes the components, and then to the field assembly molding.

## **5. Conclusions**

Contemporary landscape architecture blurs the artificial and natural, the boundary between architecture and landscape, gradually formed a new strategy to design writing architecture and the relationship between the venues, and began to enter the mainstream of architectural creation vision. This researches both for landscape architecture, and is urban design and other disciplines have very positive meaning. The development of nonlinear science and it in the architecture of translation has become increasingly subject to the approval and support of the field of architecture, to chaos theory intervention on behalf of the nonlinear science broke the previous traditional architecture of linear thinking, leading architects in a systematic thinking way to deal with construction project internal, and the environment, and relationship or contradiction between social, emphasizing a overall, complex, open, related to the construction of thinking mode.

On the other hand, the nonlinear science to other disciplines and even the active penetration of architecture, making it to the chaos theory as the representative of the nonlinear thinking is gradually accepted by the people. Contemporary landscape architecture is often presented in complex and varied forms, and new challenges to the traditional architectural design methods, computer modeling technology, structure, materials, construction and so on are presented. And these are the traditional linear architectural thinking cannot be solved. The translation of the architecture and the development of the contemporary landscape architecture have become the needs of the times. This article will pay attention to the contemporary landscape architecture on the complicated and changeable tendency, traces the historical reason, theoretical and practical basis of the non-linear science and combined with the research, for its unique value orientation, the generation process, design method and parametric computer technology for data review.

## Acknowledgements

This paper is supported by Social Science Fund Project of Hebei province: "Performance evaluation of industrial heritage regeneration design based on Fuzzy Comprehensive Evaluation -- a case study of Tangshan". (HB15YS027)

## References

- [1] R. E. Skelton and F. Fraternali, "Minimum mass design of tensegrity bridges with parametric architecture and multiscale complexity", *Mechanics Research Communications*, vol. 58, (2014), pp. 124-132.
- [2] S. Yasmin and I. Said, "Knowledge Integration between Planning and Landscape Architecture in Contributing to a Better Open Space", *Proceeding Social and Behavioral Sciences*, vol. 170, (2015), pp. 545-556.
- [3] P. Tassinari and D. Torreggiani, "The FarmBuiLD model (farm building landscape design): First definition of parametric tools", *Journal of Cultural Heritage*, vol. 12, (2011), pp. 485-493.
- [4] I. A. Kapetanakis and D. Kolokotsa, "Parametric analysis and assessment of the photovoltaics' landscape integration: Technical and legal aspects", *Renewable Energy*, vol. 67, (2014), pp. 207-214.
- [5] W. Suyoto and A. Indraprastha, "Parametric Approach as a Tool for Decision-making in Planning and Design Process. Case study: Office Tower in Kebayoran Lama", *Proceeding Social and Behavioral Sciences*, vol. 184, (2015), pp. 328-337.
- [6] B. Jankowski, "Functional Assessment of BIM Methodology Based on Implementation in Design and Construction Company", *Proceeding Engineering*, vol. 111, (2015), pp. 351-355.
- [7] C. Tagliaferro and M. Boeri, "Stated preference methods and landscape ecology indicators: An example of transdisciplinarity in landscape economic valuation", *Ecological Economics*, vol. 27, (2016), pp. 11-22.
- [8] J. Choi, "Structural and parametric design of fuzzy inference systems using hierarchical fair competition-based parallel genetic algorithms and information granulation", *International Journal of Approximate Reasoning*, vol. 49, (2008), pp. 631-648.

