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Research and Innovative Application of Biomimetic Tessellation Principles

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Abstract: Biomimetic tessellation is the combination of biomimetic and tessellation principles. This paper conducted an in-depth study on those theory. First, the author introduced biomimetic pangolin scales and biomimetic aggregates fruit, and conducted a target study on their animal and plant morphology by using the biomimetic tessellation principle. Second, according to the advantages obtained, the author chooses a suitable building case and makes innovate application of two biomimetic tessellation principle to test its rationality. The conclusion shows that the two biomimetic tessellation principles can greatly improve the building in the aspects of shading, comfort, flexibility, stability, economy, etc., which provides ideas and directions for future research.

1. Introduction

The term “Biomimetic Tessellation” mostly appears in the field of mechanical engineering, often used to generate novel mechanical engineering parts, and the descriptions about “Biomimetic Tessellation” can be found in a number of invention patents, but those descriptions are one-sided, and do not really discuss “Biomimetic Tessellation” as a design principle. In the paper *Form Follows Function (Mathematical Function)—the Generation of Architectural Form Based on the Simulation of Biological Cells' Mosaic Morphological Laws by Using Digital Tools* [1], Dr Ning Li used digital technology to simulate cellular mosaic and applied it to the field of architecture, describing how the cellular mosaic morphological law is applied to biomimetic buildings. In *Digital Diagram from BIO-Form for Architectural Design* [2] written by Professor Weiguo Xu, a variety of biomorphs related to mosaics are mentioned and applied to architectural design after simulating these biomorphs using digitalization. Therefore, through the theoretical and practical experience of the previous authors, this paper proposes the biomimetic tessellation principles. Afterwards, this paper will digitally illustrate and analyse the advantages of two type of biomimetic tessellation principles. Finally, the reconstruction results are innovatively applied to existing architectural cases, and will help us to prospect the future development of the biomimetic tessellation principles.

2. Study on Animal and Plant Morphology of Biomimetic Tessellation Principles

2.1. The Tessellation of Biomimetic Pangolin Scales

2.1.1. Analysis of Pangolin Scales Morphology

The scales on the pangolin's body overlap each other, and each inch of its skin is protected by multiple scales, this kind of arrangement can better protect the pangolin's body. At the same time, these hard scales are combined with its flexible skin, thus significantly increasing the efficiency of excavation[3].

When the pangolin needs to expel the excavated soil from the burrow, its scales open almost perpendicular to the skin, while the body moves backwards, it using the scales to “shovel” the soil out of the burrow. This kind of scale structure and arrangement provides the pangolin with efficient, flexible and precise movement, and thus has important biomimetic significance.

2.1.2. The Advantages of Biomimetic Pangolin Scales

The arrangement of biomimetic pangolin scales has a strong puncture resistance, and in *Pangolin-Inspired Stretchable, Microwave-Invisible Metascale*, Changxian Wang tested the puncture resistance of pangolin scales and found that with the same material, the experimental group using pangolin scale arrangement has obvious puncture resistance[4]. (Con-II is the group using pangolin scale arrangement)

Pangolin scales are highly flexible, and the angle of opening and closing of pangolin scales is significantly different when the pangolin digging and drilling, in order to match the habits of the pangolin. Biomimetic pangolin scales also have such properties, when the procedure for generating bionic pangolin scales is adjusted, the parameter of the distance from each scale’s centre point to the interference curve is associated with the rotation angle of the scales.

2.2. The Tessellation of Biomimetic Aggregates Fruit

2.2.1. Analysis of Aggregates Fruit Morphology

Aggregates fruit or etaerio is a fruit that develops from the merger of several ovaries that were separated in a single flower. Common examples are strawberries, anise, lotus flowers, etc.

When the receptacle to which the fruit is attached is approximately flat, such as the morphology of the lotus, the fruit is distributed more uniformly on the receptacle, and the curved shape formed by each fruit is approximately the same. When the receptacle is irregularly curved, the fruits are distributed disorderly on the receptacle surface, but the shape of the curved surface formed by each fruit on the receptacle surface is similar.

2.2.2. The Advantages of Biomimetic Aggregates Fruit

The core advantages of the biomimetic aggregates fruit tessellation is the ability to uniformly subdivide arbitrary surfaces, with the subdivided shapes defaulting to hexagons, but being able to be changed to other shapes depending on the needs of the researcher. The algorithm can also be applied to the generation of two-dimensional planes as well as three-dimensional forms. Because of its ability to uniformly subdivide surfaces, the algorithm can be applied to the design of building facades, making the structural elements of the building facade more consistent and easier to work with later. In addition, this algorithm can make building facade more aesthetically pleasing and in harmony with their surroundings. Also, this algorithm is more efficient than traditional manual modelling methods.

The algorithm has important applications for the fields of building skin generation and artwork modelling.

3. Innovative Applications of the Biomimetic Tessellation Principle

3.1. Biomimetic Pangolin Scale Tessellation in Architecture

3.1.1. Application to External Surfaces of Building

We modifying the building skin of the ARC-River Cultural Pavilion to demonstrate the application of biomimetic pangolin scales. (Figure 1)

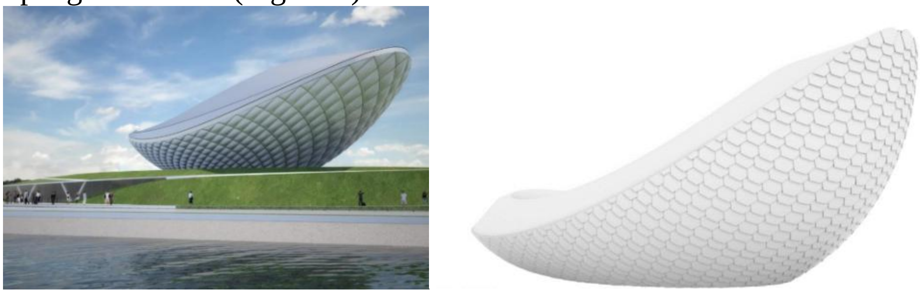

Figure 1: ARC-River Cultural Pavilion before and after application.

When biomimetic pangolin scales applied to building skins, it provides a new pattern for building skins and offer strong puncture resistance. Biomimetic pangolin scales are also flexible when applied to building skins, allowing the angle of the biomimetic scales to be adjusted as required. In strong sunlight, the biomimetic scales can also provide good shading effect, thus improving the brightness and comfort of the building interior. In addition, biomimetic scales can effectively reduce the maintenance costs of a building because the building materials used in biomimetic scales have good corrosion resistance. This is especially obvious in humid and extreme weather conditions, biomimetic scales can well protect the appearance of the building, so that the building will remain beautiful for a long time. In conclusion, the application of biomimetic pangolin scales in building skins has a positive significance in terms of improving building performance, improving the building environment and reducing maintenance costs.

3.1.2. Application to Internal Surfaces of Building

Biomimetic pangolin scales can also be applied to the interior space of the building. This paper takes the interior space design of a grand theatre as an example to show the application of biomimetic pangolin scales in the internal surfaces of the building. (Figure 2)

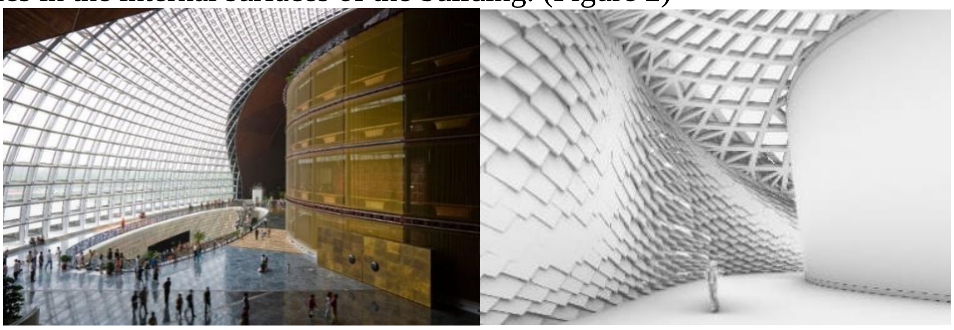

Figure 2: A grand theatre before and after application.

In the design of interior space, biomimetic pangolin scales can well meet the demand for the shape of the heterotypic wall, and biomimetic pangolin scales can also imitate the opening and closing characteristics of the pangolin scales, which can bring a combination of real and virtual feelings for the creation of interior space. Its application in the interior space greatly enhances the interest and dynamism of the space, and also makes the transition between spaces more natural. In addition, biomimetic pangolin scales can not only beautify the shape, but also bring a new light effect to the interior space with its optical properties. Overall, the inlay of biomimetic pangolin scales provides more options and possibilities for the design of interior spaces, making them more diverse.

3.2. Biomimetic Aggregates Fruit Tessellation in Architecture

3.2.1. Application to External Surfaces of Building

The roof of the Hilltop Gallery designed by dEEP Architects has been selected for reconstruction, and the building's roof is able to better demonstrate the application of the biomimetic aggregates fruit tessellation algorithm to irregular surfaces due to its rich morphological variations. (Figure 3)

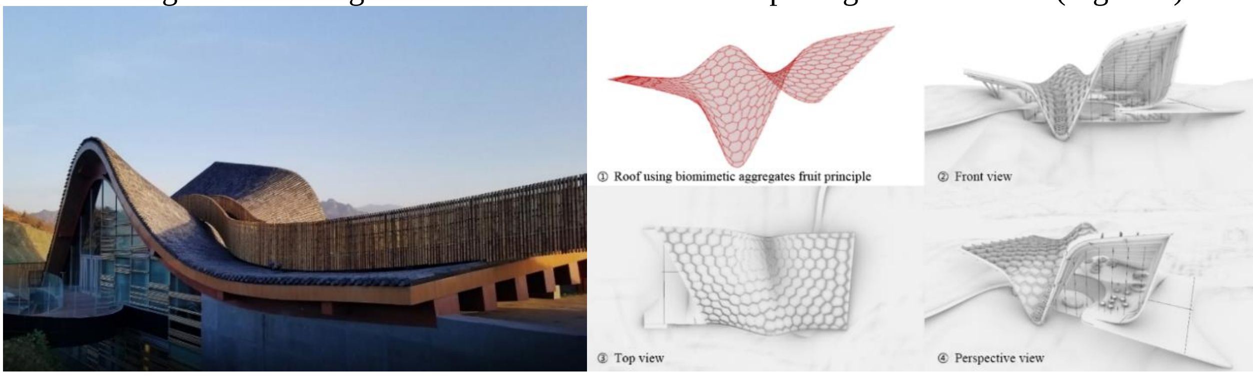

Figure 3: The roof of the Hilltop Gallery before and after application

The results of the application of the biomimetic aggregates fruit tessellation principle on an irregular roof, fully demonstrated that the principle has the advantages of being able to uniformly subdivide the curved surface of the roof, being able to adjusting the number of subdivisions according to the needs of use, being able to modularise the design of irregular roof, having a strong integrative character, and being able to harmonise with the natural environment.

3.2.2. Application to Building Forms

The biomimetic aggregates fruit tessellation principle can also be directly applied to the generation of building forms. In this paper, the Serpentine Pavilion which designed by BIG is selected for research, with the purpose of exploring a new type of Serpentine Pavilion generation method by combining the biomimetic aggregates fruit tessellation algorithm. (Figure 4)

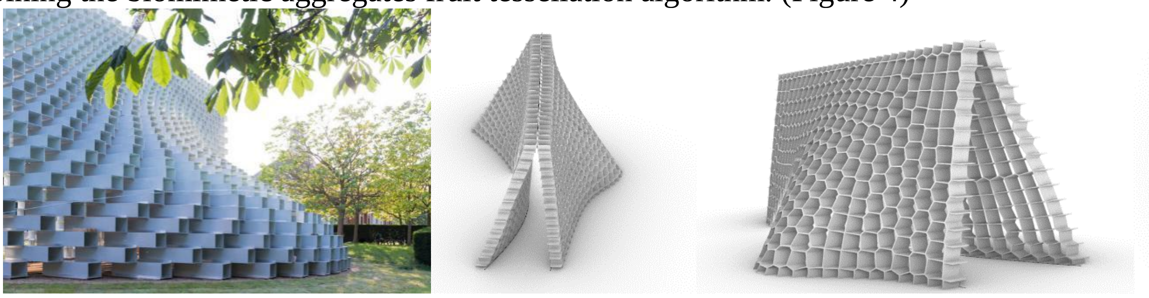

Figure 4: Serpentine Pavilion designed by BIG.

The new Serpentine Pavilion generated with the biomimetic aggregates fruit tessellation algorithm, simplifies the shaping process to a certain extent and allows the architect to see the shaped building in the fastest way possible. At the same time, thanks to the parametric involvement, it is possible to make numerical adjustments at various points in the shaping process to change the final model. Not only that, the core of the biomimetic aggregates fruit tessellation algorithm is to get a uniform distribution of discrete points, when the discrete points are uniformly distributed on the surface, the tessellation patterns can be controlled by human beings, it can be a square, rhombus irregular shapes and so on, which enriches the architectural form to a certain extent.

4. Conclusions

Through the study of existing architectural case which using biomimetic tessellation principle, found that the principle in the application of architectures, has a variety of characteristics. In the future, with the growing demand for environmentally friendly buildings, biomimetic tessellation is expected to become an important design tool. For example, through the biomimetic tessellation principle, buildings can be better adapted to different climatic and environmental conditions, improving the energy efficiency and environmental sustainability. In conclusion, the bionic mosaic principle will have a wide range of applications and development prospects in the future architectural design.

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