

Research on the space architecture based on Fractal Theory

Jing-Ming LI

School of Architecture and Urban Planning,
Guangzhou University, Guangzhou, 510006, China
Ljmarchi@163.com

Abstract. This article describes four space architecture models with pictures based on Fractal Theory, and tries to sum up the advantages and disadvantages of the four basic space architecture models which can produce artificial gravity. Based on Fractal Theory, the author also puts forward to expanding the space architecture with powerful Cellular structures. The Conclusion of this research is that the use of honeycomb structures and four basic models can create lots of fantastic space architecture which provides artificial gravity. Therefore, this paper will have a profound impact on the development of space architecture.

1. Introduction

Building houses in the vast universe and expand the territory of mankind has always been our dream. In this paper, the space architecture is defined as a huge man-made structure in the universe.

The prototype of the space architecture are running on Earth's orbit or some Lagrange point in the solar system now. They are satellites and space stations. For example, the “International Space Station” is running on Earth's geosynchronous orbit, the “Solar and Heliospheric Observatory” is running on the Lagrange point 1, and the “Wilkinson Microwave Anisotropy Probe” is running on the Lagrange point 2. There are also many examples that are not listed here due to limited space. But most of them are unable to produce artificial gravity, so it is very important to study the space architecture which can produce artificial gravity, and it can provide a suitable living environment for human beings.

Space architecture is dealing with the most extreme environments^[1]. Space architecture can not only run on the planetary orbit or Lagrange point in order, but also travel in the vast universe.

According to the speed of the spacecraft in the early twenty-first Century, if we accelerate the space architecture, we can make it possible for us to reach Alpha Centauri in universe for several generations, the Alpha Centauri is the closest star system which is 4.24 light-years from the solar system. When we get there in the future, we may settle on a new planet and start a wonderful new life.

Therefore, the space architecture have extremely broad application prospect.

2. Four basic models of space architecture

The author believes that space architecture can be divided into the following four basic models. Each has its advantages and disadvantages. And then based on the fractal theory, we can derive more complex models from these basic models. Actually, the four models which can generate artificial gravity are funnel model, ring model, cylinder model and sphere model.

2.1. Funnel model

Funnel model is a relatively simple model of space architecture. It revolves around the core of the funnel, it can be rotated clockwise or counterclockwise at a certain angular velocity. The funnel model



of space architecture have some advantages: Construction principle is relatively simple, and the curvature of the inner surface of the funnel bottom is not so large.

And the funnel model of space architecture has some disadvantages: First of all, the space utilization ratio of the atmosphere above the bottom of funnel is low. Second, if we want to get to the other side of the funnel from the bottom of funnel, we need to take a variable speed elevator and it will take a long time. Last but not least, the tensile stress in the core of the funnel model is relatively large. Therefore, it is necessary to take the reinforcement measures at the core of the funnel.

The bottom area of the funnel model is actually a circular truncated cone. When building funnel model, the bending degree of the inner surface of the funnel bottom area can be changed, so the Vector of gravity acceleration g would be perpendicular to the ground. So this method can stabilize the buildings on the inner surface of the funnel, and people living above will not be dizzy. Therefore, human interaction with technology has been a central characteristic of space architecture^[2].

Based on the basic fractal theory, three funnel models can be derived from the basic funnel model, they are the windmill funnel model, the nested funnel model and the coaxial funnel model.

Different funnel models have different characteristics and different application value.

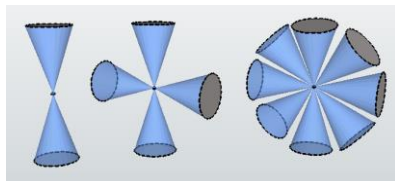


Figure 1. Windmill funnel

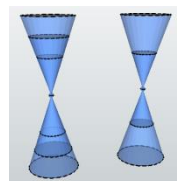


Figure 2. Nested funnel

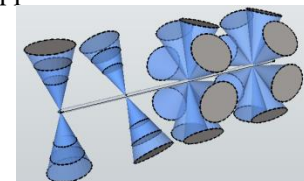


Figure 3. Coaxial funnel

2.1.1. Windmill funnel model. Let's start with the windmill funnel model. This model is formed by rotating the basic funnel model around the funnel core, and a plurality of funnels with the same core and the same rotation direction can be formed. It looks like a big windmill on the farm.

In fact, by expanding the bottom of the windmill funnel model, the bottom of the windmill funnel model can be connected together, and it can eventually evolved into a round ring space architecture.

2.1.2. Nested funnel model. This model actually inserts a smaller circular truncated cone in the atmosphere of the basic funnel model, and it also looks like a small funnel nested in another big funnel. In comparison with other technology-assisted models, the advantage of this model is also apparent: it can solve the problem of low utilization rate of the upper atmosphere in the basic funnel model.

When the nested funnel model revolves around the core, the angular velocity is constant. Therefore, the gravitational acceleration is related to the radius of the funnel model, the small funnel model has a relatively small radius of rotation, so the acceleration of gravity is relatively low. This can adapt to the different needs of different people. We can do different kinds of scientific research on it and plant different plants that will greatly promote the study of Biotechnology and genetic engineering.

As we can see, space architecture enables the continuum from 1-G to other gravity regimes^[3].

2.1.3. Coaxial funnel model. We continue to study the coaxial funnel model based on Fractal Theory, this model has a transverse axis that connects several basic funnel models together. The radius and the angular velocity of each basic model can be different, so they can produce different gravity acceleration. The advantage of this model is that it can provide transportation services inside the horizontal axis, and it is beneficial to the transportation of people and goods between different funnel.

2.2. Ring model

Ring model is a well known model. It has been widely used in various types of science fiction and famous film. It also looks like a bicycle wheel. All kinds of tensile core tube can be regarded as the spokes of the bicycle wheels, so people seem to be living in the inner parts of the bicycle tires. When the ring rotates, the giant spokes bear strong tensile stress, and different buildings can built on the inner surface of the bottom area of the ring. Based on the basic fractal theory, four ring model can be

derived from the basic ring model, they are the contact rotating ring model, the nested ring model, the coaxial ring model and the mixed ring model. Different ring models have different characteristics.

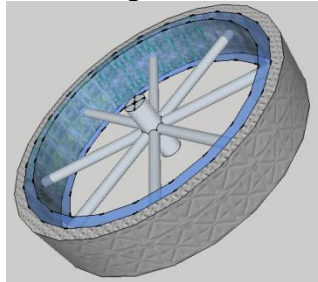


Figure 4. Basic ring



Figure 5. Contact rotating ring

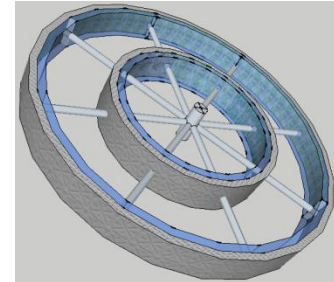


Figure 6. Nested ring

2.2.1. Contact rotating ring model. Let's start with the contact rotating ring model, through different combinations, these rings can be rotated in different directions. The advantage is that it is easy to control the gravitational acceleration of all rings, but the disadvantage is that the transportation between the ring and the ring is difficult to achieve, because the direction of rotation is not the same. In order to solve this problem, the author believes that we can set the jet transport device at the bottom of the ring at regular intervals, and jet the spaceship to another ring at the right time through the airlock module. The author believes that the use of jet pipe is also an ideal method.

2.2.2. Nested ring model. This model can be seen as a small ring model nested in a large basic ring model. It looks like a lot of concentric circles nested together. In this wonderful model, the angular velocity is constant, and the gravitational acceleration is also related to the radius of the ring model. Furthermore, in the field of the transportation, it is possible to use the variable speed elevator in the tensile core tube structure as the modes of transportation between the big ring and the small ring.

This model plays a very important role, it can be used for different people to adapt to different gravity acceleration. For example, if some people from Earth are going to Mars, they can live in a smaller ring with a gravitational acceleration of 4.36 meters per second squared. When they get used to this acceleration of gravity, they can go to Mars with confidence. In addition, some of the ring with relatively low gravity acceleration, can also be used for industrial or biological engineering research.

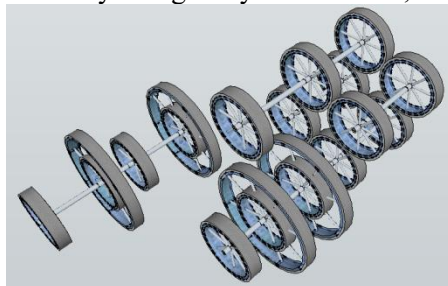


Figure 7. Coaxial ring model

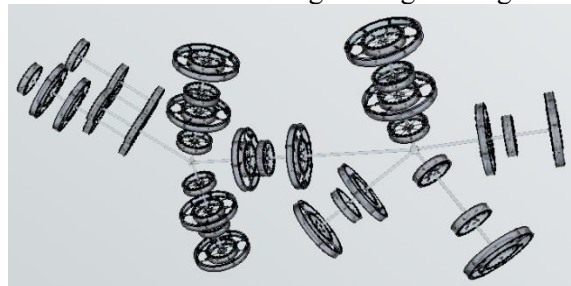


Figure 8. Mixed rotating ring model

2.2.3. Coaxial ring model. We continue to study the coaxial ring model. This ring model can insert a plurality of rings including some nested rings, which have different radius and different angular velocity on a transverse axis, so different rings can simulate different gravity acceleration environment.

2.2.4. Mixed ring model. In fact, the three ring models described above can be cleverly combined with each other, which can be developed into a mega space city group. We can even set the intelligent mechanical bearing device at the end of the horizontal axis and change the direction of other axes to a certain extent, which can also form a more wonderful space city group. And then, we can install the jet engine in some right places of the space architecture so that we can carry out distant interstellar travel.

But for those mega space city group which are stationary relative to the nearby Planets and natural satellites in the universe. It is important to control the overall barycenter of the space city at the Lagrange point. Otherwise, it will take a lot of energy to control the mega space city group back to the Lagrange point, so it is also important to install some jet engines on the surface of some space architecture to make sure that the mega space city group run on the Lagrange orbit smoothly.

2.3. Cylinder model

Cylinder model is also a well known model. It appears in many science fiction computer games and movies. In fact, this model is based on the expansion of the ring model, and it also rotates around a horizontal axis to produce artificial gravity, looking like a lot of bicycle wheels stacked together. The advantage of this model is that it is convenient to extend the model along the axis of rotation, and the two bottoms of the cylinder can be sealed by high strength translucent material, so that the inside of the cylinder is filled with the atmosphere for human survival, thus forming a closed systems^[4].

Based on the basic fractal theory, three cylinder models can be derived from the basic cylinder model. They are the contact rotating cylinder model, the nested cylinder model and the coaxial cylinder model, different cylinder models have different applications and characteristics.

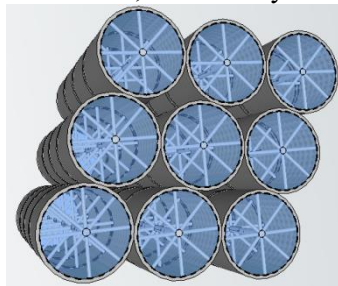


Figure 9. Contact rotating cylinder

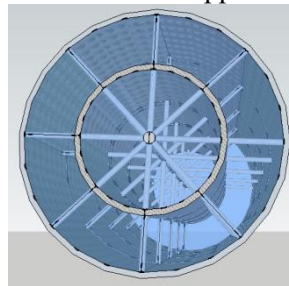


Figure 10. Nested cylinder

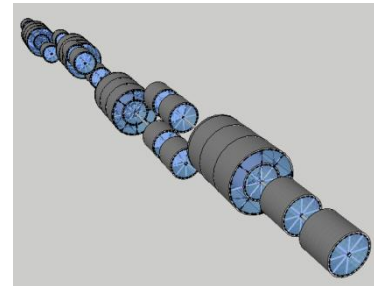


Figure 11. Coaxial cylinder

2.3.1. Contact rotating cylinder model. Let's start with the contact rotating cylinder model. This model is made up of many basic cylinder models, and these cylinder models can be rotated in different directions. This kind of model is similar to the ring model at some degree, it also has the problem of transportation. Similarly, it can be solved by the airlock module in the bottom of the cylinder, if we use the jet boat, the goods and people can be transported rapidly from one cylinder to the other cylinder through the airlock module. Of course, the jet pipe device can also be considered.

2.3.2. Nested cylinder model. In this model, the angular velocity is constant, and the magnitude of gravitational acceleration is also related to the radius of the cylinder model. Furthermore, in the field of the transportation, it is also possible to use the variable speed elevator in the tensile core tube structure between the big cylinder and the small cylinder or other cylinders.

We can also set up high-speed bullet trains in the interior of the transverse axis that we can achieve the goal of horizontal transportation in the cylinder, because this area is basically zero gravity. We can even create a vacuum tube in the horizontal axis, and the bullet train can run at high speed. This will be a revolution in interstellar transportation, and a milestone in the transportation industry.

2.3.3. Coaxial cylinder model. We continue to study the coaxial cylinder model. This cylinder model can insert a plurality of cylinders including some nested cylinder models with different radius and different angular velocity on a transverse axis, so that different cylinders can simulate different gravity acceleration and different space environment. It can help us to carry out various scientific researches.

The outer surface of cylinder can also be installed industrial-scale space solar power platforms^[5].

2.4. Sphere model

Sphere model is a relatively popular model in recent years. The inner surface of the sphere shell can generate enough artificial gravity by rotating around the core of the sphere. Of course, there are many

tensile core tube structures looks like the bicycle spokes which are extended from the core of the sphere to the inner surface of the sphere shell. The shell of the sphere can be very strong and looks like a “Dead Star” in famous sci-fi movie called Star Wars. Therefore, this model can withstand a variety of weapons and even the impact of fragments or meteorites in a remarkable way. So we can see that the biggest advantage of this model is the high security and defense performance.

But there is a serious problem with this sphere model, when the sphere rotates around the core in a certain direction, the acceleration of gravity on inner surface of the shell is not exactly the same, and the magnitude of gravitational acceleration on inner surface of the sphere shell is zero near the spherical poles. Therefore, the author thinks that different gravity acceleration can be used to create different agricultural or industrial areas. These areas can be used for different scientific experiments.

In addition, most parts of the shell of the sphere are basically sealed, so we need to solve the lighting problem of inner surface of the spherical shell. Some people suggested setting up an artificial sun that using controlled nuclear fusion technology at the core of the sphere, and it can also solve the energy problem; Others suggested that the rotation shaft can be set up with a light guide system, which allows the light to be introduced into the interior of the sphere, which is also a very wonderful idea.

Similarly, the sphere model can evolve into three specific sphere models, which are the contact rotating sphere model, the nested sphere model and the Dyson Sphere model.

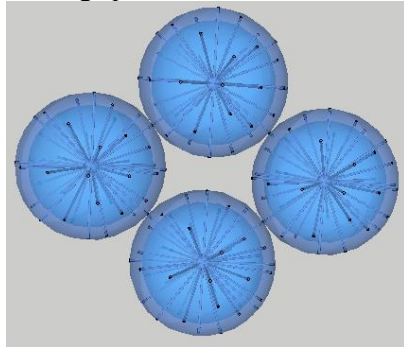


Figure 12. Contact rotating sphere

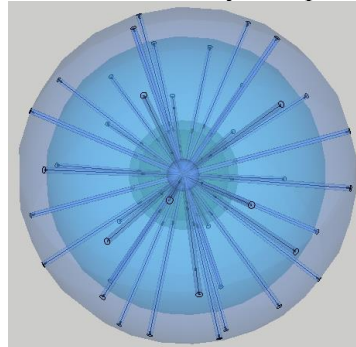


Figure 13. Nested sphere

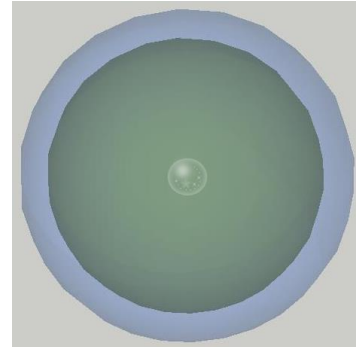


Figure 14. Dyson sphere

2.4.1. Contact rotating sphere model. Let's start with the contact rotating sphere model. The principle of this model is similar to the contact rotating ring model and the contact rotating cylinder model. The biggest problem is also the transportation between the sphere and the other sphere, we can also set up the airlock module regularly in the sphere shell to solve this problem skillfully.

2.4.2. Nested sphere model. In this model, a small spherical shell is nested into a large spherical shell, and different spherical shell can generate different magnitude of gravity acceleration. The biggest advantage of this model is that it has a stronger defense performance, and can set many lines of defense against different attacks. For the internal lighting of these spheres, the author believes that light guide system and lots of light guide outlets can be placed inside the nested spheres.

2.4.3. Dyson Sphere model. We continue to study the Dyson Sphere model. In fact, the purpose of this model is to remove all the inner tensile core tube of the sphere, and only the sphere shell left.

Dyson Sphere is thought to be the best space city to absorb star energy, because it can absorb the light from the stars like the sun quite adequately. But it still needs to set jet engines on its surface regularly and make sure that the Dyson Sphere can revolve around the star steadily by making appropriate adjustments. In the future, Dyson Sphere will be one of the ultimate symbol of space technology, and it will represent the highest level of human industrial development to some extent.

3. Extension pattern based on Fractal Theory

The author believes that the expansion of the space architecture can use the cellular structure which is a kind of prefabricated high strength composite structure. The strength and stiffness are better than

most other structures, so it has a very good geometric properties. The cellular structure can be also used in the industrial mass production. In the construction of space architecture, the honeycomb structure is also available for the assembly of components. With the rapid development of space manipulator and laser fusion device in the future, the construction speed can be greatly accelerated.

Honeycomb structure also has the advantage of high security and high efficiency. The damage of one or more of the honeycomb structure does not have a serious impact on other honeycomb structures in the space architecture. Honeycomb structure can also prevent the spread of disasters such as fires, floods and toxic gases by using double deck door which are placed in the honeycomb structure.

Therefore, the skeleton of the space architecture is actually a honeycomb structure assembled one after another. By allowing the different positions of the honeycomb structure to slightly change the angle and length, the structure of space architecture can be able to bend gradually. Eventually, the entire space architecture will bend distinctly, thus forming a ring, cylinder or spherical structure.

In addition, the honeycomb structure can also form a three-dimensional block and transportation systems in the space architecture, so that people can implement effective management between blocks. Not only can we build all kinds of small buildings on the inner surface of the space architecture, but also build more underground commercial or industrial blocks in the interior of the shell of space architecture. In this way, we can maximize the utilization of the universe.

Finally, through force analysis and analog computation of structural reinforcement by computer, the honeycomb structure in the space architecture is also easy to disassemble so that the small honeycomb structure can be transformed into a large honeycomb structure for different uses.

4. Conclusion

Based on the fractal theory, this paper not only probes into four kinds of space architecture, but also discusses how to expand the space architecture with the honeycomb model. These theory not only help us to maximize the use of resources in the universe, but also provide reference for marine buildings and underground buildings on Earth. All models in the picture above were built by myself so that everybody can understand them easily. The author hope that people with lofty ideals can continue to carry out a more deep study of this area and make a greater contribution to the space enterprise.

References

- [1] Vernoosfaderani, Mahsa Taheran (International Space University, France) .2011.Space architecture for sustainable living on earth[C]. *62nd International Astronautical Congress 2011*, IAC 2011, 2011: 9791-9796.
- [2] Peldszus, Regina (European Space Agency) ;Silva-Martinez, Jackelynnne; Imhof, Barbara. 2014.Contemporary human technology interaction issues in space architecture - A position paper [C]. *65th International Astronautical Congress 2014: Our World Needs Space*, IAC 2014, 2014: 9791-9796.
- [3] Cohen, Marc M (Marc M. Cohen Architect P.C. - Astrotecture) . 2012.The continuum of space architecture: From Earth to orbit[C]. *42nd International Conference on Environmental Systems 2012*, ICES 2012.
- [4] Martinez, Vera (Technical University Darmstadt, Germany) .2007.Architecture for space habitats. Role of architectural design in planning artificial environment for long time manned space missions[J]. *Acta Astronautica*, 2007, (60): 588-593.
- [5] Sherwood, Brent (JPL,USA) .2012.Space architecture for industrial-scale space solar power[C]. *42nd International Conference on Environmental Systems 2012*, ICES 2012.