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A Study on the Application of Spatial Directionality in Buildings

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I. Overview

Five-dimensional space is a new concept of space which is to study the relationship between human being and natural (or architectural) space. People feel the space mainly from the visual sense while the condition of visual sense is the visible light. People feel the space not only from the various interfaces which constitute the space, but also from the space filled with visible photons ----- visible light. The wavelength range of the visible spectrum that most people's eyes can feel is 400 to 700 nm (nm) and the minimum brightness B_{min} is 3.1831×10^{-5} Nituo (nt), (which is equal to produce the luminous intensity of a candle at one square meter area along the normal direction, i.e: 1.0 nt = 1.0 cd /㎡) [1-2]. If the minimum brightness of visible light is less than B_{min}, the illumination produced by it is not sensible. Thus, people cannot feel the existence of that space. Einstein raised the theory of space and time---- Four-dimensional space[3] in the early twentieth century, which mainly studied the physical space. The five-dimensional space is primarily about the organic relationship between human being and architecture (space). It is real natural, logical and objective. Five-dimensional space is composed of three-dimensional space (ie, geometric space), time and visible light (five parameters). It has the characteristics of logicality, directionality, stability, continuity, limitation, variability and artistry. Five-dimensional space, human being, three-dimensional space, the relationship between visible light and time are shown in Fig.1. The purpose of studying five-dimensional space is to create suitable architectural art space for people to live and enjoy their life.

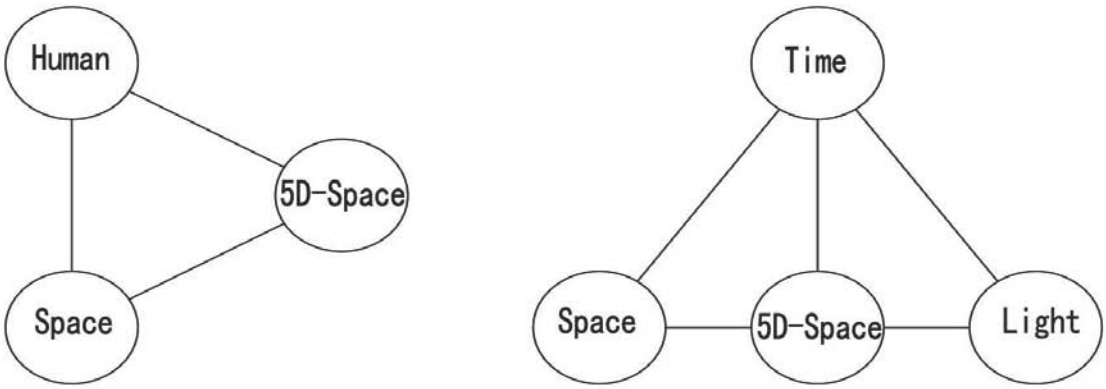

Fig.1: The relationship between human being and space

Bruno Zevi stated in “Theory of Architectural Space ”[4] (p. 34): "If the cubism confirms that the building is four-dimensional, then our current way to show the space is already perfect. But we further asserted that the building has more space dimensions than the four-dimensions. "

The famous architect Le Corbusier[5] mentioned in the book that: "The architecture is a

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refined, correct and excellent treatment for a variety of objects in the sunshine. Our eyes are born to watch the image in a light. Cube, cone, sphere, cylinder, pyramid and so on are the main body mainly expressed by the light. These images are clear, tactile and not vague. For this reason, they can be called a beautiful image, the most beautiful image. Everyone has agreed to this view, whether he is a child, a savage, or a metaphysician. This is the essence of formative art".

Polish architect M Devarovsky mentioned in the book "Sunshine and Architecture" [6]: "Any sculptor will not allow buyers to transform their creation of sculpture. But when the sunshine creates a contingency of artistic effect, changes the modeling expression of the art works, and often reduce their artistic values to a large extent, no sculptor can protest against this. Light condition change will cause various light and shadow combination effect on sculptures. So it is better to consider the effects of light beforehand in the design than to let a skewed image appear accidentally.

All of the above theories on building space are from well-known architects although they did not mention the theory of five-dimensional space. But their arguments mentioned both the time and the light and its relation with three-dimensional space constituting artistic space.

Bruno Zevi mentioned the idea of buildings with more spaces than the four-dimensional space. Le Corbusier proposed the relationship between light, the eyes of man and the objects (spaces) of various shapes. And he identified it as the essence of the formative art phenomenon. The Polish architect Mdevalovsky proposed the relationship between art and the sunshine. These arguments are similar to the five-dimensional space concept raised by the author. In other words, although the author raised the new concept of five-dimensional space in April 6, 2001 for the first time, people have similar understanding of the five-dimensional space long time ago.

II. The Logicality of Space

According to the theory of five-dimensional space, the relationship between human being and natural space or architecture is a five-dimensional space. First of all, let's discuss the logicality of five-dimensional space. It is believed that the logical space must be a five-dimensional space and a logical space must be a natural space; Non-logical space is certainly not a five-dimensional space. That is to say: five-dimensional space is a visual space but visual space is not necessarily a five-dimensional space. For example, the space inside the mirror is a visual space but it is not a five-dimensional space. People's feeling on the real space of nature is an objective reality. The phenomena that occur in a five-dimensional space system are logical and cannot be replicated, eg: Seen from a train window, the space outside the window is dynamic.

When people stay in a room, they feel the space is static because all the interfaces of the room are static. The various interfaces outside the window on a running train are changing all the time while the interfaces in a room do not change with the time. Another example is that people's feeling is different when they stand in front of a small building model and a real building with the same shape. This phenomenon, i.e: the change of spatial parameters directly changed the spatial state and form, is the characteristic of five-dimensional space logicality. On the contrary, a space without logicality must be non-five-dimensional space. Movie or television can be understood as a four-dimensional relationship because they get visual effect on a plane via changeable patterns by the light and time. It is non-stereoscopic but with three-dimensional sense and without depth dimension. A photo can be understood as a three-dimensional space, i.e: a static graphic or image formed by planar two-dimensional graphic and light.

In addition, two abstract spatial concepts are presented here: one is two-dimensional space, i.e: When a person (suppose a blindman) hears a description of a music or language on a space, he will feel he is in that space. In the story (see Supplementary Material 1) of Boya Yu and Ziqi Zhong [7], Boya Yu's music play of the mountains and rivers made Ziqi Zhong feel the existence of that space. Such space feeling has only two parameters: time and sound. It can be called two-dimensional space. The other is one-dimensional space, i.e: the space that a person feels in his sleep. It sometimes has mountains and rivers, rivers and lakes, pavilions, bridges and others. This space is called dream space, which has only one parameter---time. All spaces discussed here, from one-dimensional to four-dimensional, are not directional. Only five-dimensional space has directionality.

III. The Spatial Directionality

The spatial directionality discussed here is limited to those in natural space or architectural space for human being to recognize the east, west, south, north (or front, rear, left, right). It does not involve the directionality of "up" (or "down"), as well as the identification of directionality in universal space. Since the gravitation always points to the center of the earth, no matter where a person stays and/or whether the space a person stays has any visible light, he can easily recognize upward or downward directionality by his own sense of gravity. The five-dimensional space directionality is based on the light and reference system. The so-called reference system is similar to the reference space [8], which can be understood as a reference object, such as: the urban survey coordinate system widely used in architectural engineering design.

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Regarding the spatial directionality, let's study the following occasions: First, in a cloudy day or dark night, when people (take a windowless car) come to a new street in a new city. If they do not watch road sign(with road name and direction) and also do not watch compass, people will lose their way; Second, some people living in an old city for a long time may lose their direction if the old city is re-planned and re-constructed since all roads and buildings are changed; Third, people will lose their sense of direction when they drive to an underground (three level) parking area and meet an emergency power outage---all lighting equipment do not work plus people did not bring any lighting tools with them.

The three reasons for people lose their sense of direction for above three occasions: First, sky and the sun for people to identify the direction are clouded, plus people are not familiar with surrounding roads and buildings. Hence, the reference system for identifying the direction was not established; Second, the reference system for identifying the direction is changed. The reference objects with original memory (buildings and roads) were changed. The reference system to distinguish the direction is different from the original position; Third, all visible lights are lost in underground parking area. People are unable to identify the direction of the space.

On the Earth, the directionality of the five-dimensional space discussed by the author is relative. It is relative to the earth's terrain, features and the sun, moon and stars that people can see, and the Earth's north and southpole magnetic field that people cannot see. The directionality of the five-dimensional space is based on a certain reference system. If people stay at a corner of the universe or space where they cannot see the sun, stars and the moon, also can not feel the gravity of the Earth or other planets, people won't distinguish the directionality of surrounding space. The north-south direction of the earth is mainly determined by the Earth's magnetic field, such as: the compass is an equipment invented by the ancestor of the Chinese people according to the Earth's magnetic field to know the direction.

There are three prerequisites for the author to discuss the directionality of the five-dimensional space: one is to discuss the relationship between human being and natural (or architectural) space; Second is visible light; Third is reference system. That is to say, light is the necessary condition of five-dimensional space with directionality while the reference system is the sufficient condition of five-dimensional space with directionality. If different shapes of buildings can be used as a reference system but without any light, people cannot identify the direction. On the contrary, If only the light is available but without reference system, it is also unable for people to distinguish the direction of space. For example, it is difficult for a person to identify the East, West, South, North direction on the vast sea or the vast grasslands if he does not have the compass, the sun, the moon and the Big Dipper.

Why is light a necessary condition for the five-dimensional space with directionality? This is because the ordinary light seen by the human eye has two important characteristics: one is that light does not change direction in the same medium (the Fermat principle) [9] and radiates at a straight line(With the exception of Einstein's theory of light bending) [10]); Second, the speed of light is very fast. The speed of light in air or space is 299,838.882 (km / s) ≦300,000 (km / s) [11]. Therefore, light is a necessary condition for the directionality of space. If the light is not a straight line, people may be wrong on the direction of the space. And if the light transmission speed is not 300,000 km per second, but 30m per second or less. Then the speed of the car on the road must not exceed 30m per second, otherwise the moving car will collide with the object or car ahead. When the car's speed is 30m per second, the driver can only see the object within 30 meters in front of him and cannot see farther ahead, which means the driver goes ahead of the light. It is not difficult to understand this assumption since the visibility is only 50m or 100m when the car is driving in a heavy fog. In this case, the driver cannot drive the car too fast and the traffic department will set a speed limit on the expressway. If the visibility is too low due to heavy fog, the traffic department will close the expressway. Similarly in the waterway, the event of fog will generally stop the sailing of ships to prevent collision accident.

Thus, when the relationship between human being and space is discussed, only five-dimensional space has the characteristics of directionality. Visible light is a necessary condition while reference system is a sufficient condition for distinguishing the directionality of space. Only when these two conditions exist, people can distinguish the directionality of space.

IV. Application of Spatial Directionality

The spatial directionality can be divided into: (1) directional space; (2) non-directional space. The directional space can be divided into: (a) Identifiable directional space; (b) Difficult identifiable directional space; (c) Directional space with target; (d) Azimuth directional space. Directional space with target refers to people can find their goal (or destination, Such as Beijing) relying on the surrounding terrain, features and topography and other reference systems when they go to some place(such as Beijing, China) from a location (such as Shanghai, China). The layout of Sun Yat-sen Mausoleum, Nanjing, Jiangsu, China is a good example with obvious target directionality. The mausoleum building locates at the high point of the base and thus people can see it in a very far distance. See Fig.2.

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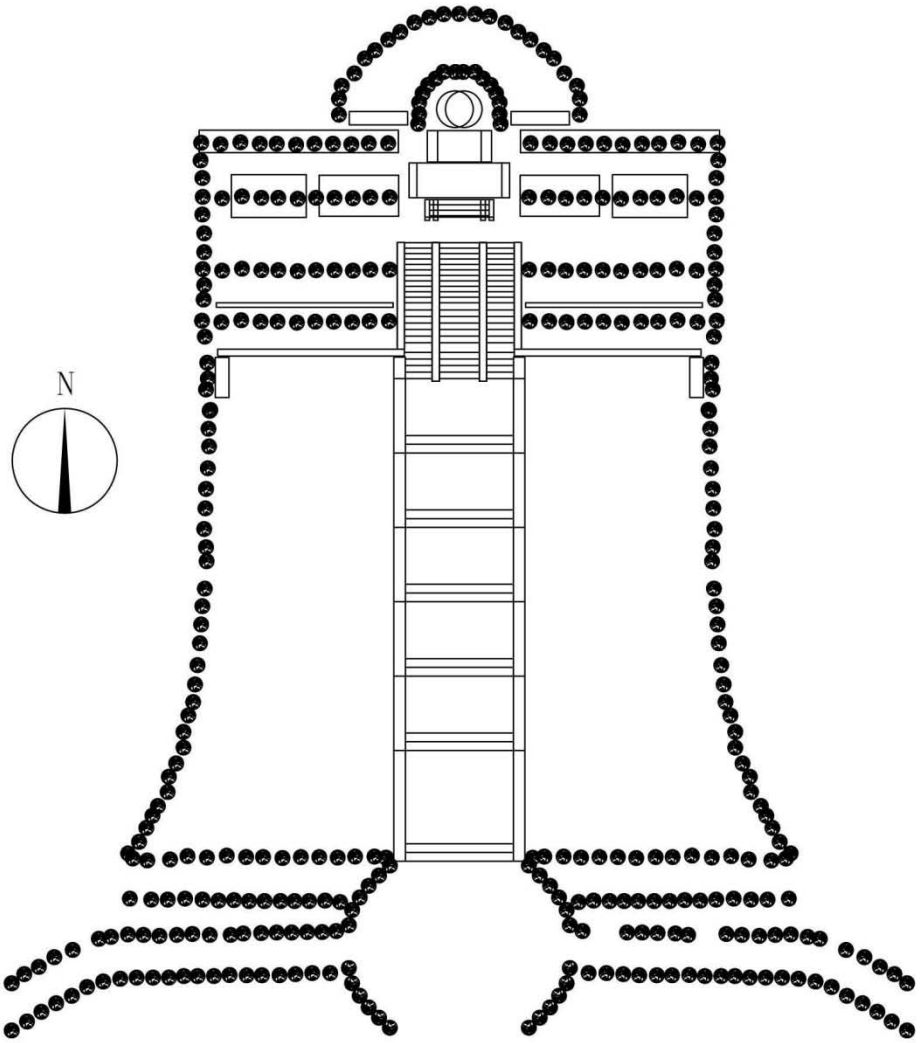

Fig. 2: Schematic diagram of the Sun Yat-sen Mausoleum in Nanjing, China

Oriented directionality refers to that people at a place (or in a space) can identify the East, West, South, North without needing a compass by means of the surrounding buildings, roads and other reference system, such as: road (and buildings) layout in Beijing and Xi'an city, which are basically aligned in a parallel and crossing way of east, west, south, north. The directionality of this urban layout is so obvious that people can easily identify the East, West, South, North whether they are at any road in Beijing or Xi'an city. It belongs to the identifiable directionality space, as shown in Fig.3 and Fig.4.

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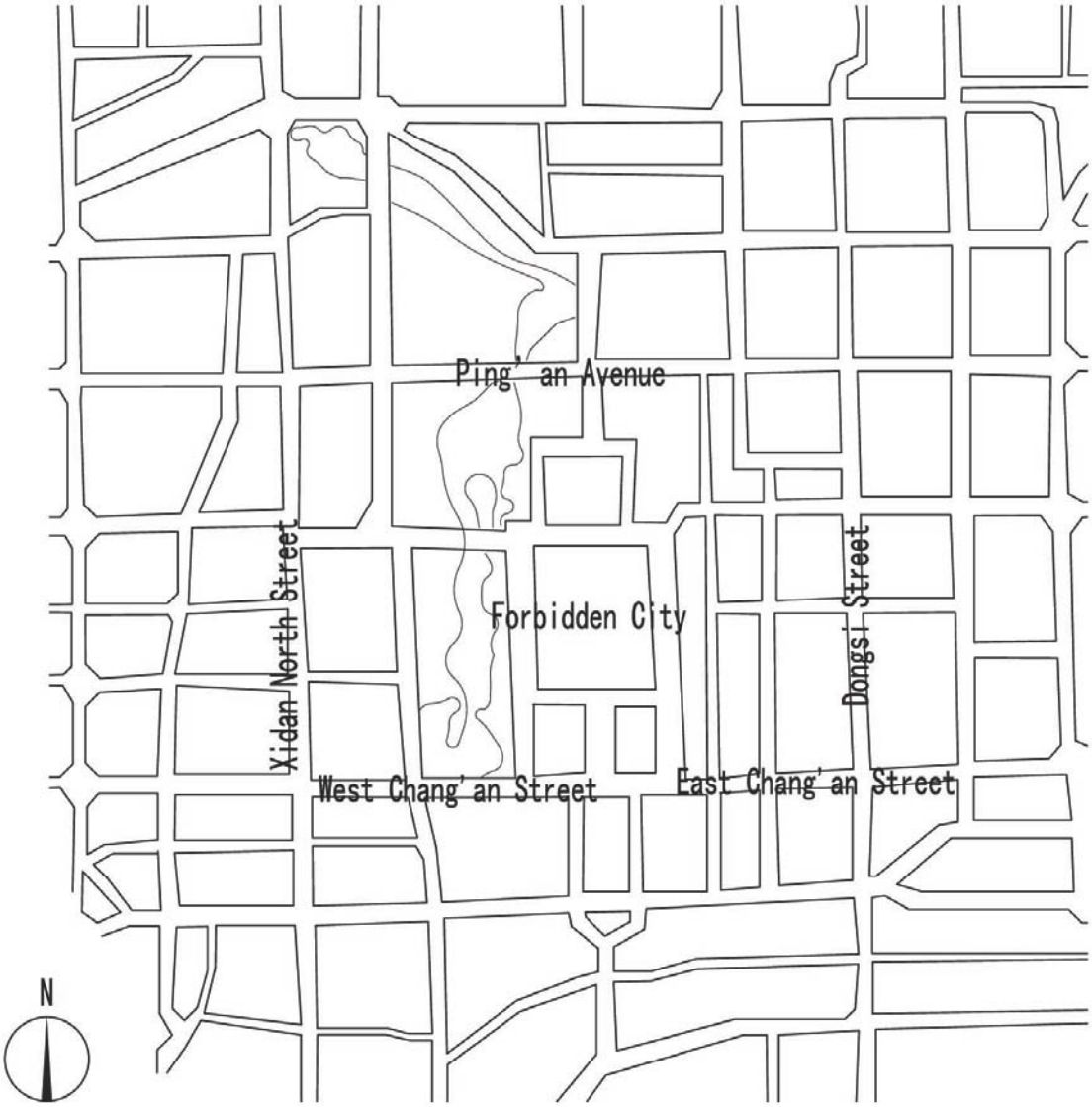

Fig. 3: Map of Beijing (Partial), China

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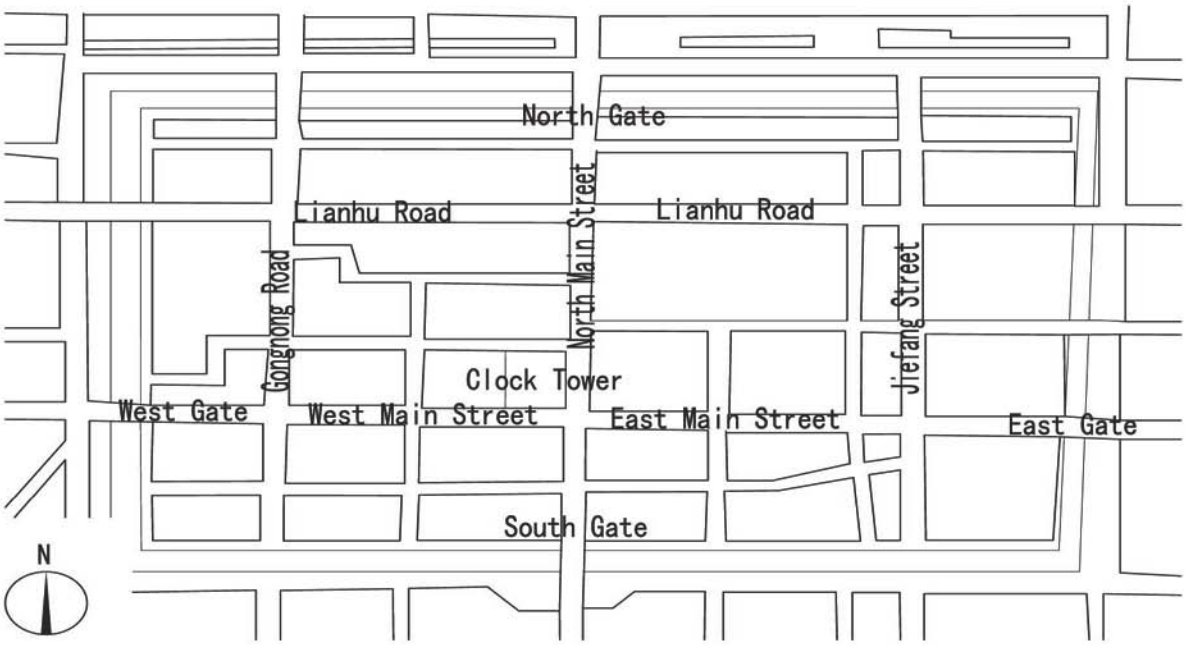

Fig. 4: Map of Xi'an (Partial), China

Another example is Shanghai, China. Some roads are in acute angle-shaped layout with north-south axis while some vertical and horizontal roads are not orthogonal. The oriented directionality of this kind of urban space is not obvious, or, difficult to identify the direction. People are easy to get lost in such an urban space, as shown in Fig.5.

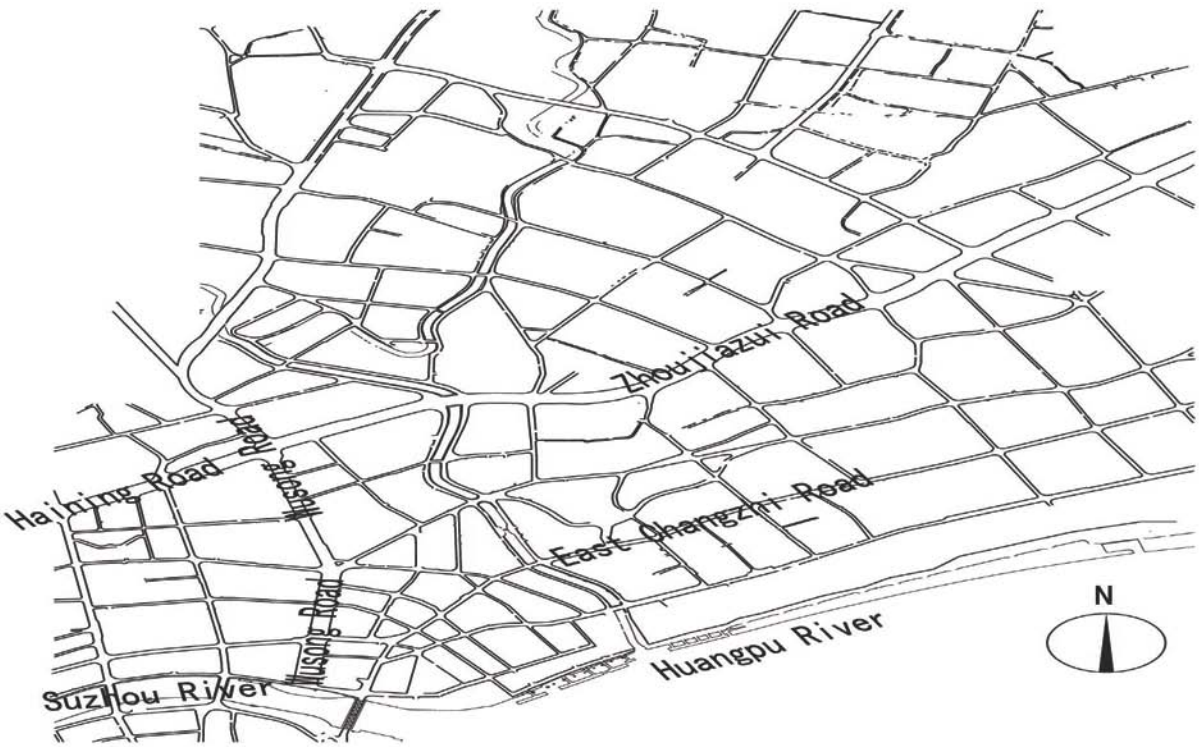

Fig. 5: Map of Shanghai (Partial), China

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In the vast sea or prairie, people cannot identify the direction and orientation without the help of the Big Dipper and compass. This type of space can be called non-directional space. In architectural and landscape design, the architect can create some non-directional space, such as: the maze of buildings and the maze of plants in gardens. They are examples of non-directional spaces. Architects can use this principle to design mazes with various fun. In the landscape design, the spatial target directionality can guide visitors to enjoy the rich and colorful art space in accordance with the intention of the designer. The directionality of space is widely used in architectural design, mainly in the art of indoor and outdoor space. The space will be ever-changing and colorful in the role of light, showing the charm of art.

V. Concluding Remarks

To sum up, the directionality of five-dimensional space is based on people, space, visible light and the reference system. The directionality of space can be divided into three categories: one is directional space or identifiable directional space; The second is the space which is difficult to identify the direction; Third is the space without directionality. A proper use on the spatial directionality in architectural design can get a better art space and facilitate the use to identify the direction.

In addition to the directionality of the five-dimensional space discussed above, there are also geometric, topological, and digital spaces, and Einstein's four-dimensional space----time and space theory. The fundamental difference between the above spaces and the five-dimensional space is: The first one is to study the spaces with mathematics, physics methods, while the five-dimensional space we discussed here is a study of the relationship between human being and space based on the feeling of art and experiences. The main points of this new concept are: The object is three-dimensional and the space is five-dimensional. If we can discuss the existence of five-dimensional space from the view of Physics, it will be a larger and new topic.

VI. Acknowledgments

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Appendix 1: Boya Yu And Ziqi Zhong's Story

Boya Yu and Ziqi Zhong's story took place in the Spring and Autumn Period in the ancient China. In the Chu State, there was a man named Boya Yu, who was proficient in music temperament and had superb skill in playing *qin*(A musical instrument), a musical instrument. But he always felt that he could not vividly present his feelings for various things with his performance. When his teacher knew about this, he took Boya to the Penglai Island on the East China Sea, asking him to enjoy the natural scenery and listen to the sound of the ocean. Boya saw the surging waves beating the coast and flying seabirds crying, which filled his ears with harmonious and pleasant music of the nature. He was so impressed that he began to play his *qin*(A musical instrument). The sound of the music followed his feelings and the beauty of nature entered the sound of his musical instrument. But no one could understand his music. He felt very lonely and isolated, and was very unhappy.

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One night, Boya took a boat trip. Facing the breeze and seeing the moonlight, he indulged in deep thoughts, and began to play his *qin* (A musical instrument). The melodious sound of music was carried far away, when suddenly he felt someone was listening to his music. He saw a woodman standing on the shore, so he asked the woodman on board, and played music to demonstrate the beauty of the high mountains. The woodman said: "solemn and mighty, just like the Taishan Mountain rising into the sky." When he played music to present the surging waves, the woodman said, “broad and vast, just like the boundless sea!” Boya said excitedly: “I have found an understanding friend.” This woodman was Ziqi Zhong. Later Ziqi Zhong died, and when Boya Yu got the news, he played a last melody in front of Ziqi Zhong’s tomb and then broke all the strings of his *qin*(A musical instrument). He never played again.

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Highlights

1. The relationship between human being and space is a five-dimensional space composed of three-dimensional space, time and visible light.
2. The five-dimensional space owns logic, directional and artistic characteristics.
3. Two key elements to identify the spatial directionality: reference system and visible light.
4. Visible light is necessary condition while reference system is sufficient condition to identify the direction of space.
5. The application of spatial directionality principle in the engineering design can increase the interest and recognizability of the architectural space.

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