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Research on the Integration Application of 3D Modeling and Computer Vision Technology in City Brand Image Innovation

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Abstract The application of digital projection technology provides new possibilities for the landscape light show to display the city brand image, and the combination of dynamic light show and three-dimensional modeling and other technologies has become an innovative direction for the design of light shows with urban characteristics. This paper analyzes the role of landscape light show in the development of urban aesthetics and the creation of urban cultural image, in the interpretation of the digital landscape, virtual landscape in the development of the role of urban cultural pulse construction, based on the design of the digital landscape production process about the light show. Analyze the beam energy distribution as well as the projection accuracy of the digital lighting landscape stereoscopic projection system designed in this paper. Select city permanent residents, tourists and other city light show perception evaluation survey, analyze the role of city light show in building the city brand image. After the public watched the city's characteristic light show, the six aspects of the city's overall image, city image promotion, economic image, residents' image, cultural image, and governmental image were significantly different from the perceptual evaluation before watching, which indicates that the city light show can effectively enhance the city's brand image, and it can be used as a way to promote the city's brand image.

Index Terms three-dimensional modeling, digital landscape, virtual landscape, stereoscopic projection, urban light show

I. Introduction

In the 1960s, Kevin Lynch, the famous American urban planning and design theorist, first put forward the concept of "city image" [1]. With the introduction of corporate image design and the proposal of city image strategy, people began to combine corporate brand and city image, from the perspective of city brand image to carry out research on the city [2]. Kevin Lane Keller, a professor at Duke University in the United States, argues in A City Can Be Branded that the power of city branding is to make people know and understand a certain area and naturally associate an image and association with the existence of this city [3]-[5]. City visual image is the carrier of city branding, and considering city brand image construction from the perspective of visual design, i.e., using visual images to convey the cultural connotation of the city, is a more intuitive, cross-linguistic way of communicating the world [6]-[8]. In the era of homogenization of city styles, based on the excavation and enhancement of the city's cultural connotations, shaping the city's personalized brand visual image with the help of visual carriers has become an important part of the city branding strategy [9]-[11].

City brand image is an important way for tourists and investors to recognize a city [12]. In today's increasingly fierce competition between cities, a city with a good and unique brand image can often attract more attention and resources, thus occupying a favorable position in the competition, which makes the brand image design crucial for the development of a city [13]-[15]. 3D modeling and computer vision technologies are gradually becoming core tools for urban planning, cultural and tourism promotion, and digital marketing. Combining these two technologies and applying them to the innovative design of urban brand image can not only improve the precision and interactivity of urban visual expression, but also help to shape a high-quality urban image and create favorable conditions for the construction and development of the city [16]-[18].

This paper tries to interpret the city brand image design in terms of city characteristics and other aspects, proposes landscape lighting (light show), and analyzes its role in enhancing the city aesthetics and city cultural image. Analyze the application of three-dimensional modeling in urban digital landscape, and expound the importance of digital landscape and virtual landscape for the construction of urban cultural pulse. Design the production process of landscape light show, analyze the distribution of light bands in the landscape three-dimensional model. The digital light landscape stereoscopic projection system designed in this paper is compared with the multifocal plane projection system, the target dome projection system, and the LIDAR imaging system to conduct projection simulation tests and compare the projection accuracy of each projection system. Investigate the residents' perceived evaluation of the city light show in displaying the city's brand image.

II. Digital projection design in city brand identity

II. A. City brand image

Definition of city brand: a city brand is the same as a company's product, and a geographic location or a certain spatial area can also be a brand. Therefore, if you want to create a city brand image, you need to integrate the city brand with the city image [19].

Although city brand is similar to city image, it is two different concepts.

City brand is the city builder to refine and integrate the characteristics of the city, a blend of history, culture, humanities, geography and industry, these differentiated elements are the core concept of the city to the public.

The city image is the reflection of the objective things of the city in the mind of the public, who will recall the memory of the city image and form the general cognition of the city because of the city characteristics. The city's geographic factors, cultural features, and humanistic feelings shown in the integration process can enhance the city's brand recognition to a certain extent.

II. B. Interpretation of city brand image design

II. B. 1) Tapping into urban characteristics

Cities can be recognized and read by people, and the sources of imagery are “personality and characteristics”, “structure and association”, and “imagery and meaning”. In other words, city image is the relative memory of the majority of residents. The city brand is the elements and symbols that can represent the whole city, which are summarized and abstracted from it, and the two complement each other, so the breakthroughs of the city characteristics are explored based on the three aspects mentioned above.

II. B. 2) Innovative design process

After generalizing, summarizing and extracting the city's “personality and characteristics”, “structure and associations”, and “imagery and implications”, the representative elements are then applied to the construction of the city brand. The representative elements are then applied to the construction of the city brand.

Based on the above hierarchical analysis of the city, the following is a three-step process of city brand design.

(1) Positioning and defining the style and temperament of the city. Before designing a city brand, it is necessary to position the city in terms of economy, environment, humanities, policies, etc., define the style of the city, and find the general sense of the city.

(2) Find the core imagery. If integrating city image is a process of collecting and searching, then searching for the core imagery of the city is a process of sifting and extracting.

(3) Reconstructing city imagery. The communication of city brand image cannot be separated from the condensation of visual symbols, and the process of reconstructing city imagery is actually to transform the refined core imagery into abstract symbols, and in this process, it is necessary to consider the characteristics of the city from various aspects to reflect the differences between cities.

II. B. 3) Multi-perspective expression of design forms

The design form of city brand image is to visualize and express the logo system, color system, lighting system, advertisement system, square image, road image, building image, etc. through the above excavation and induction methods. It includes VIS, main visual, public facilities, mascot and other forms, integrating the external image and internal temperament of the city to form a complete set of standardized visual image of the city brand. It not only demonstrates the cultural characteristics of the city so that the public can perceive the relevant city culture, but also strengthens the unique city image characteristics, transforms the city visual image into a brand image in different ways, and then creates a sustainable city image.

II. C. The Role of Light Shows in Urban Aesthetics and Cultural Image

(1) Spatial aesthetic design and light and shadow art combination

Landscape lighting (the main emphasis here is on the light show) combines the art of light and shadow with spatial aesthetics, injecting a unique artistic expression into the urban night scene. As an important carrier of landscape lighting, urban landmark buildings realize the night image of buildings through precise light projection and façade design. For example, the “Little Barbarian Waist” of Guangzhou Tower adopts a dynamically changing lighting scheme, in which the lights present different color combinations and dynamic effects with the passage of time or the change of festival themes, which not only enhances the recognition of the building, but also highlights the sense of science and technology and innovative vitality of the city. The high degree of compatibility between the lights and the building structure makes the tower look like a work of art in the night sky, leading the design direction of the landmark night scene.

(2) Color and emotional expression

The use of lighting color can not only strengthen the spatial atmosphere, but also enhance the artistic infectivity of the night scene through emotional expression. In festival scenes, the lighting is usually dominated by warm colors such as red and gold, and the unique atmosphere of the festival is created through the detailed design of buildings, squares and landscape elements. For example, the New Year's light show on the Bund in Shanghai has created a strong festive atmosphere through the gradient of light colors, the superposition of dynamic effects and collaboration with the Bund complex, and the light and dark rhythms and dynamic changes have also added artistic tension to meet the needs of the festival scene on the atmosphere of the rendering.

(3) Lighting expression of regional culture

In the enhancement of the city's cultural image, landscape lighting often expresses regional cultural connotations through the light, color, brightness and form to show the unique cultural qualities. Night lighting design of historical and cultural heritage often through the warm light color and low brightness lighting techniques, highlighting the sense of gravity and cultural value of historical buildings.

Lighting art in the performance of regional characteristics, often need to combine the city's traditional symbols and cultural elements, for the landscape into a unique artistic characteristics. For example, Lijiang Ancient City night lighting through the soft light design highlights the delicate contours of traditional architecture, and combined with the Naxi cultural symbols for lighting embellishments, so that the ancient city night scenery is not only visually attractive, but also become an important carrier of cultural dissemination.

(4) The driving role of culture and tourism economy

Landscape lighting plays an important role in promoting the development of culture and tourism economy, the characteristics of the night scene has become an important factor in attracting tourists, and directly promote the prosperity of the city night economy. For example, the lighting landscape of Hongyadong in Chongqing presents a strong visual impact at night through rich color combinations and hierarchical lighting design, which makes the traditional hanging buildings cluster. Lighting design not only highlights the depth of space and the three-dimensional structure of the building complex, but also combines the commercial business to create the landscape as a night-time economic center integrating ornamental and experiential, bringing significant economic benefits to the surrounding commercial districts and cultural and tourism industries.

(5) The integration of modern technology and cultural heritage

The application of modern technology for landscape lighting to express the city's cultural image provides new possibilities, the combination of dynamic light show and digital technology has become an innovative direction of lighting design. For example, Shanghai Huangpu River light show uses holographic projection and dynamic lighting technology to show the development history and cultural story of the city in an artistic way. The light show visualizes the origin, inheritance and change of sea culture to the audience through rich dynamic effects, which not only realizes the deep integration of technology and culture, but also enhances the visual shock of the city at night.

II. D.3D modeling in urban digital landscapes

“Digital landscape” is a new type of landscape field that uses computer technology, image and media technology, optoelectronic control technology and a series of related technologies, collects text, image, sound, light, etc., and uses various interactive behaviors to form a landscape space. Examined from the perspective of landscape, “digital landscape” is a collection of landscape design and digital technology, which is divided into three categories: landscape information acquisition technology, analysis and evaluation technology and simulation visualization technology [20], [21].

Nowadays, the wave of globalization and urbanization makes cities converge in form, structure and function, and cities of different cultures and countries are becoming more and more alike in this wave, which makes citizens living in cities gradually lose their sense of belonging. Under this background, the importance of the humanistic significance of the cityscape itself is rising, designers and planners try their best to bring the unique identity symbols to the city, on the basis of protecting the cultural symbols of the city itself, stimulate and create the characteristics of the city through various means, including the application of new technologies, and upgrade the appearance, humanity and functions of the city in various aspects.

In the current era, the need for “speed” makes cities lack the time to stop, think and scrutinize in planning and construction. Because of this, the culture of the city is gradually lost, and the city life becomes hard and monotonous. Urban culture should be full of vitality, from which you can see the history, humanities and other information, and let the public experience this urban culture to produce a sense of yearning.

Virtual landscape gives designers a high degree of creative freedom, which is the basis of virtual landscape for the construction of urban culture. It is not only to provide beautiful scenes for the city, but more importantly, to build a cultural and artistic atmosphere for the city in line with the original flavor of the city. Virtual landscape deepens the real world through the virtual world, thus giving users emotional experience and philosophical thinking [22].

The unique and sustainable development of culture is the goal of urban culture construction. Virtual landscape has both cultural and aesthetic significance for the city, and it is a medium for generating unique urban culture and good aesthetics. Designers should strive to obtain the humanistic information in the real world and apply it to the construction of virtual landscape, so as to form a unique virtual landscape model and theoretical framework of urban culture, and thus generate an urban culture with uniqueness, continuity, adaptability and modernization.

III. Digital landscape production process and realization for light shows

With the development of cities, at present, many traditional public landscapes cannot be integrated with the environment, and traditional materials and forms can no longer meet the needs of cities. Therefore, the combination of lighting and landscape has become a new trend with stronger interactivity and artistry.

As a visual object, the landscape based on lighting makes full use of light and shadow, reality and reality, and is more attractive in terms of expression and final presentation.

III. A. Binocular Stereo Measurement System

In visual imagery applications, the purpose of constructing a geometric imaging model of a camera and solving for its model parameters is to be able to accurately correlate object points in the field of view air with object points in the image. The main objective is to obtain the inner and outer parameter matrices of the camera, i.e., to solve the projection matrix P thereby improving the accuracy of the image. This process involves transformation of several coordinate systems for example, world coordinate system, camera coordinate system and image coordinates. Approximate approximation through mathematical modeling methods is thus applied to computer vision tasks such as depth recovery and 3D reconstruction. In short, the calibration of internal and external camera parameters is based on the imaging geometry model to serve various vision applications.

In the pinhole imaging model, a three-dimensional scene is projected onto a two-dimensional plane through a pinhole to form an inverted image. The pixel coordinate system and the image coordinate system are shown in Fig. 1, XO_1Y is called the image coordinate system and UO_0V is called the pixel coordinate system, and the relationship between them can be described by the following equation.

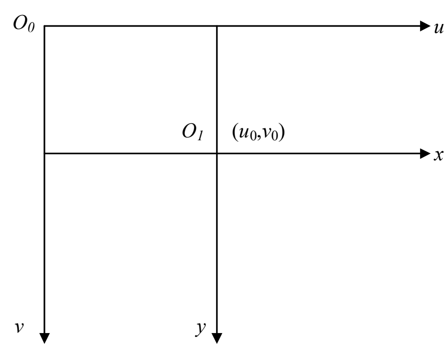

Figure 1: Pixel coordinate system and image coordinate system

$$u = \frac{x}{dx} + u_0 \tag{1}$$

$$v = \frac{y}{dy} + v_0 \tag{2}$$

where O_1 is the camera optical center, and dx and dy denote the physical dimensions of the pixel, using the matrix form instead as follows:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{dx} & 0 & u_0 \\ 0 & \frac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{3}$$

The positional relationship between the camera coordinate system $O_c - X_c Y_c Z_c$ and the camera imaging coordinate system $O-XY$ is shown in Figure 2.

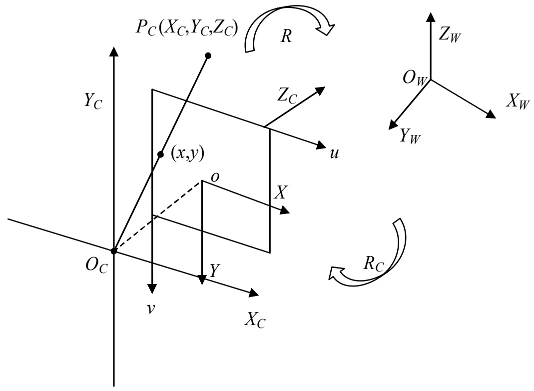

Figure 2: Like plane, camera and world coordinate system

In the figure, $O_c - X_c Y_c Z_c$ is the camera coordinate system, where O_c is the optical center of the camera. At the same time, the X and Y axes of the image plane coordinate system are parallel to the X_c and Y_c axes, respectively. According to the similarity relationship of triangles, we can get the correspondence between a point P_c in the camera coordinate system and a point (x, y) in the image plane coordinate system:

$$x = f \frac{X_c}{Z_c} \tag{4}$$

$$y = f \frac{Y_c}{Z_c} \tag{5}$$

where f represents the focal length in the camera model and Z is the object distance. By this projection relation equation, any point in the 3D space is projected onto the camera imaging plane and its corresponding point coordinates on the imaging plane are obtained. The relationship is obtained as follows:

$$z \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ z_c \\ 1 \end{bmatrix} \tag{6}$$

In the camera mapping model, in order to easily get the spatial position of the camera, the camera pose is usually represented by the world coordinate system. Where F_W and F_c denote the world coordinate system and camera coordinate system respectively. The points $P_{Wi}(X_{Wi}, Y_{Wi}, Z_{Wi})$ in the world coordinate system, $i = (1, 2, 3, \cdots, n)$ where n denotes the total number of mid-points under the world coordinate system, and $P_{Ci}(X_{Ci}, Y_{Ci}, Z_{Ci})$ is the camera coordinate expressed by F_W. It has the following relation:

$$P_{Wi} = RP_{Ci} + T \tag{7}$$

The rotation matrix R and the translation vector T represent the position of the camera in the world coordinate system. At the same time an observation point $P_W(X_W, Y_W, Z_W)$ in the world coordinate system is transformed to the camera coordinate system as:

$$P_{Ci} = R_c P_{Wi} + T_c \tag{8}$$

For subsequent convenience the matrix form is used to express as:

$$\begin{bmatrix} x_c \\ y_c \\ z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R_c & T_c \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} \tag{9}$$

R_c and T_c are the transformation relations from the world coordinate system to the camera coordinate system for the set of spatial observation points. Therefore, the mutual transformation relations (R, T) and (R_c, T_c) of the camera coordinate system in any space can be transformed using the above equation. I.e:

$$R_c = R^T \tag{10}$$

$$T_c = -R^T T \tag{11}$$

In summary the relationship between any point $P_W(X_W, Y_W, Z_W)$ in the world coordinate system and its projected pixel point coordinates $P(u, v, 1)$ in the image plane can be expressed as:

$$Z_c \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & u_0 & 0 \\ 0 & f_y & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R_c & T_c \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} = AM \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} \tag{12}$$

A is the inner calibration matrix, which consists of parameters f_x, f_x, u_0, v_0, and M is the outer calibration matrix, which describes the camera position. The above case is the model under ideal conditions, so the aberration problem in practical use needs to be considered. That is, the expression of the relationship between the actual pixel coordinates (u_s, v_s) and the ideal pixel coordinates (u_0, v_0) is as follows:

$$\begin{cases} r^2 = [(u_s - u)d_x]^2 + [(v_s - v)d_y]^2 \\ u = u_s(1 + k_1 r^2 + k_2 r^4) \\ v = v_s(1 + k_1 r^2 + k_2 r^4) \end{cases} \tag{13}$$

In a nutshell the process of camera calibration is the process of solving for the internal and external parameters and k_1, k_2, M_1, M_2 to ensure that the camera is able to accurately capture and reproduce real world image information.

III. B. Modeling

Study of digital lighting landscape tower of the cylindrical three-dimensional model design of how each strip of light is distributed, it is intended that the model can be viewed from different angles of the light belt are uniformly distributed, as well as to make the six circles of light belt composed of three-dimensional animation on the digital landscape tower can be uniformly presented.

Production of small model data: small model of a total of eight circles of light belt, each length of 1.2m, each circle on the light belt from 360 ° front view are uniformly distributed, the outermost circle of 12-sided diameter of 0.6m, the outermost circle on the very edge.

The arrangement of light strips from the innermost circle to the outermost circle is 3 in the first circle, 3 in the second circle, 3 in the third circle, 10 in the fourth circle, 15 in the fifth circle and 22 in the sixth circle, totaling 56.

Ⅰ Mapping from arcs to line segments

In order to determine how each light strip is distributed in the 3D model design of the landscape tower, it is necessary to realize the conversion of the cylindrical three-dimensional model to a plane graphic. Therefore, according to the basic parameters of the solid model, the distribution of the 3D model parameters is calculated by arc-to-line segment mapping.

The specific calculation process of the distribution of line segments and light bands in each circle in the model is as follows:

(1) Sixth circle: The 1/4 circle arc of the sixth circle is divided into 6 arc segments, and the lights on these 6 arc segments are mapped to 6 line segments on the X axis. The number of lights on each arc is equal to the number of lights on the corresponding line segment. The placement rate of the lamps on the circle is denoted by X6, and thus the length Length of each arc can be expressed as:

$$Length = R \times \beta \tag{14}$$

where R denotes the radius of the circle and β denotes the angle corresponding to the arc. Eq:

$$\begin{aligned} \beta_6 &= \alpha_6 \\ \beta_5 &= \alpha_5 - \alpha_6 \\ \beta_4 &= \alpha_4 - \alpha_5 \\ \beta_3 &= \alpha_3 - \alpha_4 \\ \beta_2 &= \alpha_2 - \alpha_3 \\ \beta_1 &= \alpha_1 - \alpha_2 \end{aligned} \tag{15}$$

where the angle corresponding to the $i\left(i=1,2,3,4,5,6\right)$ segment arc can be calculated by the following equation:

$$\begin{aligned} &\cos(\alpha_i) = (i/6R)/R \Rightarrow \alpha_i = \arccos(i/6) \\ &\cos(\alpha_1) = 0 \Rightarrow \alpha_1 = \arccos(0) \end{aligned} \tag{16}$$

The relative value B_6 of the length of each arc of the angle corresponding to each arc of the sixth circle can be expressed as:

$$B_6 = \beta / \beta_1 \tag{17}$$

From equation (14), it can be seen that the length of each arc is linearly related to the angle corresponding to the arc, and thus the relative value of β is also the relative value of the Length of each arc, and the ratio of the number of lamps on each arc. Therefore, the number of lights on each arc of the sixth circle D_6 can be expressed as:

$$D_6 = B_6 \times X_6 \tag{18}$$

where X6 denotes the rate of lamp placement on the circle. So we can get the expression for the number of lights on the sixth circle on the line segment $i\left(i=1,2,3,4,5,6\right)$ as:

$$D_{6\_i} = B_{6\_i} \times X_6 \tag{19}$$

According to the above formula you can get the parameters of each line segment on the sixth circle as well as the calculation results of the rate and number of lamps placed.

(2) Fifth Circle: The 1/4 arc of the fifth circle is divided into 5 arc segments. The lights on these 5 arc segments are mapped to the 5 line segments on the X axis. By using the previously described method of calculating the number of lights on the sixth circle, the number of lights on the fifth circle on the line segment $i\left(i=1,2,3,4,5\right)$ can be obtained by the equation shown below:

$$D_{5\_i} = B_{5\_i} \times X_5 \tag{20}$$

Calculations of the parameters of the line segments on the fifth circle as well as the rate and number of lamp placements can be obtained.

(3) Fourth circle: 1/4 arc of the fourth circle is divided into 4 arc segments. The same equation can be obtained as shown below:

$$D_{4\_i} = B_{4\_i} \times X_4 \tag{21}$$

The parameter values of each line segment of the fourth circle as well as the calculation results of the rate and number of lamp placements can be obtained.

(4) Third circle: 1/4 arc of the third circle is divided into 3 arc segments. The same equation can be obtained as shown below:

$$D_{3\_i} = B_{3\_i} \times X_3 \tag{22}$$

(5) Second circle: 1/4 arc of the second circle, divided into 2 arcs. The same equation can be obtained as shown below:

$$D_{2\_i} = B_{2\_i} \times X_2 \tag{23}$$

(6) First circle: 1/4 arc of the first circle with only 1 arc. The same equation can be obtained as shown below:

$$D_{1\_1} = B_{1\_1} \times X_1 \tag{24}$$

The values of the parameters of each line segment as well as the rate and number of lamp placements are obtained for the third, second and first circles.

II System of equations for the distribution of lights on the line segments

The system of equations for the number of lights on the line segments is as follows:

(1) Total number of lights on line segment 1:

$$D1 = \sum_{i=1}^{6} D_{i\_1} = \sum_{i=1}^{6} B_{i\_1} \times X_i \tag{25}$$

(2) Total number of line 2 lights:

$$D2 = \sum_{i=2}^{6} D_{i\_2} = \sum_{i=2}^{6} B_{i\_2} \times X_i \tag{26}$$

(3) Total number of line 3 lights:

$$D3 = \sum_{i=3}^{6} D_{i\_3} = \sum_{i=3}^{6} B_{i\_3} \times X_i \tag{27}$$

(4) Total number of line 4 lights:

$$D4 = \sum_{i=4}^{6} D_{i\_4} = \sum_{i=4}^{6} B_{i\_4} \times X_i \tag{28}$$

(5) Total number of line 5 lights:

$$D5 = \sum_{i=5}^{6} D_{i\_5} = \sum_{i=5}^{6} B_{i\_5} \times X_i \tag{29}$$

(6) Total number of line segment 6 lights:

$$D6 = D_{6\_6} = B_{6\_6} \times X6 \tag{30}$$

III Solution of the set of equations

According to the requirement, it is known that the total number of lights on each line segment is equal and the overall total number of lights includes the number of all lights on the 6 line segments in the 4 sectors, thus the number of lights on each line segment is equal to 1/24 of the total number of lights.

So, the solution for the placement rate X_i can be obtained as:

$$\begin{aligned}
&X_6 = Total\ number\ of\ lights / 24 / B_{6_6} \\
&X_5 = (Total\ number\ of\ lights / 24 - B_{6_5} \times X_6) / B_{5_5} \\
&X_4 = (Total\ number\ of\ lights / 24 - B_{5_4} \times X_5 + B_{6_4} \times X_6) / B_{4_4} \\
&X_3 = (Total\ number\ of\ lights / 24 - B_{4_3} \\
&\quad \times X_4 + B_{5_3} \times X_5 + B_{6_3} \times X_6) / B_{3_3} \\
&X_2 = (Total\ number\ of\ lights / 24 - B_{3_2} \times X_3 \\
&\quad + B_{4_2} \times X_4 + B_{5_2} \times X_5 + B_{6_2} \times X_6) / B_{2_2} \\
&X_1 = Total\ number\ of\ lights / 24 - (X_2 + X_3 + X_4 + X_5 + X_6)
\end{aligned} \tag{31}$$

Ⅳ Distribution of lights on circles

After obtaining the placement rate X_i, the number of lights on each circle can be calculated. Since each circle has 4 sectors as mentioned above, the number of lights D_i on the $i\left(i = 1,2,3,4,5,6\right)$ circle can be expressed as:

$$D_i = 4 \times \sum_{j=1}^{i} D_{i\_j} \tag{32}$$

Use the integer function round to round the number of lights on each circle to get the integer of the number of lights on each circle. From an aesthetic point of view, choose an integer with a convention close to the above result.

IV. City light shows and city brand image creation

IV. A. Digital Lighting Landscape Stereo Projection Effect

In order to verify the practicality of the digital landscape stereoscopic projection system designed in this paper, this system is compared and tested with the multifocal planar projection system, target dome projection system, and LIDAR imaging system in the simulation experiment for projection effect comparison.

The imaging system selected for this experiment is Daheng camera, this camera has a faster imaging speed and meets the requirements of three-dimensional imaging, the lens model is M0814-MP2, the specific parameters are: camera resolution 1920*1024, frame rate 40fps, pixel size 6.0 μm ×6.0 μm , and spectral color black and white. The lens has a C connector for operation, a focal length of 10mm, an operating distance of 0.2m-1.0m, and an aperture of F1.6-F20C.

In addition, the choice of HD-720P model projector, with small and portable features such as brightness is 2500 lumens, uniformity up to 90%, the working luminous flux is 60lm, very suitable for this paper. The laser is selected as red, green and blue color laser, the specific parameters are shown in Table 1.

Table 1: Laser parameter

Index	Parameter
Wavelength	600nm
Spot form	Near
Power	18mW
Power stability	1.9%
Divergence Angle	>1mrad

In this paper, the energy distribution of the method, the multifocal plane projection system, the target dome projection system, and the LIDAR imaging system are used to measure the quality of the laser beams of the four systems by the following beam uniformity evaluation index:

$$E\left(E_{f'}\right) = \sum_{E_{i'} = E_p}^{E_{f'}} \frac{E_{i'} N_{pix}, E_{i'}}{E_L} \tag{33}$$

In the formula, E is the fraction of energy, E_p is the peak energy, E_i is the threshold energy, E_L is the total beam energy, and $N_{pix}, E_{i'}$ describes the number of pixels relative to E_i .

The results of the laser energy tests for the four methods are shown in Figure 3. The beam energy distribution of the three existing methods is uneven, and the energy produced by the system decreases over time. The highest energy of the multifocal plane projection system, the target dome projection system, and the LiDAR imaging system are 96mJ, 97mJ, and 103mJ, respectively. The lowest energy is 70mJ, 72mJ, and 86mJ, respectively.

While the system designed in this paper beam energy is always distributed evenly, producing a beam energy of up to 106mJ and a minimum of about 102mJ. This is because the method in this paper uses a laser beam expanding mirror, the beam passes through the lens, generating a new beam waist and divergence angle, keeping the laser energy unchanged, and distributing it uniformly during the imaging process.

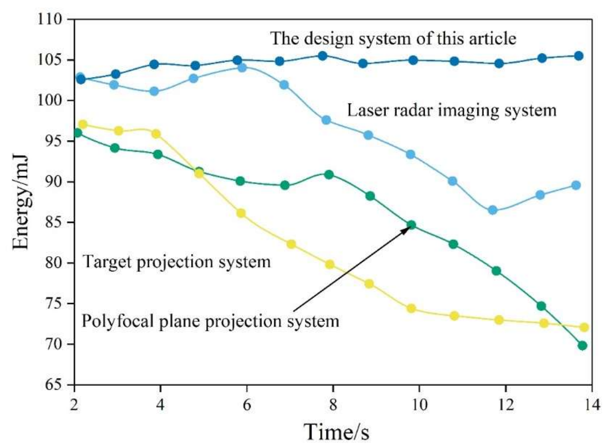

Figure 3: Laser beam energy distribution

The accuracy of projection of the same stereo image is compared using different systems. The accuracy of projection is the best indicator to check the actual performance of different systems.

The comparison of the accuracy of image edge feature extraction is shown in Fig. 4. The highest imaging accuracies of the multifocal plane projection system, target dome projection system, and LiDAR imaging system are 87%, 82%, and 78% in that order. The imaging accuracy of the multifocal plane projection system is 77% to 87%, and the imaging accuracy of the target dome projection system is 65% to 82%. The imaging accuracy of the LiDAR imaging system is in the range of 68% to 78%.

The imaging accuracy of the proposed system in this paper is always more than 90%, with the highest accuracy of 94% and the lowest of 87%, which can prove that the system in this paper has higher imaging accuracy and better practical application.

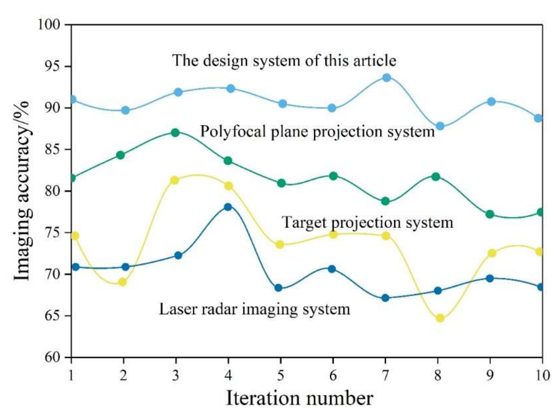

Figure 4: Image edge feature extraction accuracy contrast

IV. B. Light Show and City Brand Image

In order to test the differences in potential tourists' perceptions of Shenzhen's city brand image through the Shenzhen Civic Center light show and the dimensional measurement of city brand personality, this paper plans to use a mixed research method of qualitative and quantitative questionnaire surveys of a proposed experimental design.

The source of textual information for this web-based text analysis is the user web reviews of Dianping.com, which is the world's first independent third-party consumer review website and tops the list of essential tools for life.

The pre-test questionnaire was carried out with the help of online research tools, with the questionnaire preparation function of the Questionnaire Star platform, and the wide coverage of popular social media, the snowball sampling method was adopted, and the link was shared with friends through WeChat, QQ and other software to provide some proposed respondents who could participate in the questionnaire survey.

The distribution of the questionnaire lasted for 8 days, from December 20, 2023 to December 28, 2023, and the selected respondents included three groups: local permanent residents of Shenzhen, foreign tourists who had visited Shenzhen, and potential tourists who had not visited Shenzhen. The inclusion of local residents in the target group of survey respondents is based on the data analysis of the light show crowd collected by the data platform, which shows that the participants of the light show in the central area of Shenzhen, which is a one-night tourism and ornamental activity, mainly include two types of local residents and tourists from neighboring provinces and municipalities, and a part of the participants of the nighttime tourism activities are also local residents.

The pre-test questionnaire issued a total of 500 copies, excluding 21 copies of the unfinished answer sheet, the current recovery of the effective sample data for 479 copies, the recovery rate of the questionnaire is 95.8%, and then through manual screening to put forward the invalid questionnaires do not meet the questionnaire requirements, the remaining 458 copies of the effective questionnaire, questionnaire effective rate of 91.6%.

The perceived structure system of Shenzhen city brand image to be constructed in this paper consists of three dimensions, namely, innovation factor, practicality factor and innocence factor, of which the innovation factor consists of six brand personality descriptive items, the practicality factor consists of six brand personality descriptive items, and the innocence factor consists of four brand personality descriptive items.

The descriptive analysis of the relevant categorical characteristics of the respondents is shown in Table 2.

According to the table of descriptive analysis statistics, it can be seen that among the overall respondents, the proportion of the number of permanent residents of Shenzhen, the proportion of the number of people who have visited Shenzhen, and the proportion of the number of people who have not visited Shenzhen are 31.66%, 46.51%, and 21.83%, respectively. The number of people who had seen other similar light shows was 290, accounting for 63.32%.

Table 2: Descriptive analysis of the characteristics of the interviewees

Item	Number	Proportion/%
Shenzhen permanent resident (more than half a year in deep residence)	145	31.66
Visit shenzhen, but not permanent residents.	213	46.51
I have not visited Shenzhen.	100	21.83
Southerner	99	21.62
Northerner	256	55.90
I've seen other lights	290	63.32
I haven't seen any other light shows	168	36.68

Using mathematical statistical analysis software to test the comparative differences of the recovered samples, with the help of paired-sample t-test, we analyze the differences in the mean values of the respondents' perceptions of the six aspects of the city brand image of Shenzhen as well as the overall image of Shenzhen before and after the viewing of the light show in the samples, to test whether there is a significant difference between the mean values of the paired variables before and after the two times of the same indicator about the city brand image and to summarized in the following table.

The paired-sample t-test of city brand image is shown in Table 3 (N=458).

According to the statistical results, it can be seen that for the seven items of the city brand image of Shenzhen, a total of seven groups of paired data with differences between before and after were generated, among which six groups of paired data all showed significant differences ($p<0.01$).

Sorted according to the size of the t-value, they were Shenzhen's overall image (0.020), city image promotion (0.017), economic image (0.014), residents' image (0.005), cultural image (0.001), and government image (0.000). One group of paired data showed a $p>0.05$ degree of variability, and it was the ecological image of Shenzhen, which had an increase in the mean value of scoring before and after, but did not reach a significant level.

Table 3: The city brand image matching sample T test

Item	Pairing (average)		Mean difference	t	p
	Pair 1	Pair 2	(Pair 2-Pair 1)		
Ecological image	4.251	4.231	-0.02	1.265	0.288
Economic image	4.621	4.568	-0.053	-2.659	0.014**
Cultural image	3.895	4.123	0.228	7.253	0.001**
Government image	4.124	4.325	0.201	4.517	0.000**
Resident image	3.965	4.117	0.152	4.890	0.005**
Urban brand image promotion	4.152	4.433	0.281	8.857	0.017**
Overall image	4.236	4.389	0.153	5.723	0.020**

Using mathematical statistical analysis software to test the comparative differences of the recovered samples, by analyzing the differences in the mean values of the respondents' perceptions of the city brand personality of Shenzhen caused before and after watching the light show in the samples, to test whether there is a significant difference between the mean values of the perceptual scoring before and after the two times of the same index of the relevant questions in the questionnaire, and to summarize it into the following table.

The paired-sample t-test for city brand personality (N=458) is shown in Table 4.

The mean value of Shenzhen city brand image can be obtained, after watching the light show in Shenzhen city center area, according to the mean value can be obtained that the top rankings are fashion, technology, openness, enthusiasm, and efficiency.

The before and after comparison of fashion shows a significant increase in the mean value at the $p<0.05$ level, and the difference in the mean value is 0.157 ($t=5.633$, $p=0.001$), and the mean value of fashion has a significant perceptual improvement after watching it.

Table 4: The city brand image matching sample t test

What do you think of the image of shenzhen city brand?	Pairing (average)		Mean difference	t	p
	Pair 1	Pair 2	Pair 2- Pair 1		
Fashion	4.365	4.522	0.157	5.633	0.001**
Vigour	4.412	4.476	0.064	2.615	0.002*
Youth	4.475	4.473	-0.002	1.020	0.596
Technology	4.434	4.529	0.095	3.245	0.001**
Imagination	4.229	4.368	0.139	5.078	0.000**
Intelligence	4.416	4.445	0.029	1.142	0.235
Contemporary	4.475	4.492	0.017	0.756	0.332
Joyfulness	3.895	4.157	0.262	7.005	0.000**
Friendliness	4.208	4.373	0.165	3.213	0.001**
Charm	4.266	4.369	0.103	3.798	0.000**
Open	4.525	4.536	0.011	0.095	0.925
Inclusiveness	4.396	4.412	0.016	0.825	0.412
Advance	4.458	4.453	-0.005	0.426	0.704
Cultural poverty	3.125	3.112	-0.013	3.256	0.000**
Make public	4.142	4.366	0.224	6.879	0.000**
Enthusiasm	4.199	4.505	0.306	6.525	0.000**
Optimism	4.214	4.372	0.158	3.018	0.002**
Freedom	4.239	4.335	0.096	3.459	0.001**
Efficiency	4.458	4.523	0.065	3.251	0.024**

V. Conclusion

This paper creates a city light show by utilizing digital projection technology, and takes the light show with city characteristics as one of the city brand image promotion designs. By investigating the public's view of the city light show, the role of the city light show in shaping the city brand image is analyzed.

Digital landscape stereoscopic projection system beam energy in the projection process always maintains a balanced distribution of beam energy up to 107mJ, the lowest not more than 102mJ, than the multifocal plane projection system, target dome projection system, LIDAR imaging system can maintain the highest precision.

Projection effect is better, three-dimensional imaging is more intuitive, can be applied to the actual landscape projection.

By investigating the public's evaluation of the city light show, the data show that the public's city brand image keywords of fashion, vitality, technology, imagination, intelligence, contemporary, joy, friendliness, charm, openness, inclusiveness, openness, enthusiasm, optimism, freedom, and efficiency have been perceived to be enhanced after watching the city light show. This suggests that city light shows designed with digital technology can be considered as an effective way to promote a city's brand image.

References

[1] Peláez, J. M. L. (2018). Kevin Lynch: The image of the city. Proyecto, Progreso, Arquitectura, (19), 154-155.

[2] Černikovaitė, M., & Karazijienė, Ž. (2020). City brand image formation by urban heritage initiatives. Management: Journal of Contemporary Management Issues, 25(Special issue), 29-42.

[3] Do-Heon, K. (2018). The effects of city brand image on city brand recognition and city loyalty. The Journal of Industrial Distribution & Business, 9(3), 69-79.

[4] Sepe, M., & Pitt, M. (2017). Urban branding and place as a quality product: innovations in the urban experience. Journal of facilities management, 15(1), 2-14.

[5] Zhang, S., Shi, B., Xu, Y., & Wang, T. (2025). The Impact of Government Policy and City Image on Beverage Brands: Brand Innovation, Urban Culture, and Brand Loyalty. Journal of Relationship Marketing, 1-39.

[6] Wu, Y., & Shen, M. (2021, April). The design of city brand visual image recognition system. In 2021 IEEE Asia-Pacific Conference on Image Processing, Electronics and Computers (IPEC) (pp. 938-941). IEEE.

[7] Rezvanpour, N., & Bayat, A. (2017). Determining effective urban design factors within the branding strategy due to brand city spaces and evaluating city spaces by comparing them to the presented factors. A case study of ChaharBagh Avn, Isfahan, Iran. Energy Procedia, 115, 6-17.

[8] Cao, J. (2023, October). Study on Strategies of Promoting Urban Brand Image by Public Benefit Using WeMedia. In 2023 International Conference on Culture-Oriented Science and Technology (CoST) (pp. 353-356). IEEE.

[9] Lalehpour, M., & Amirhosseini, P. (2020). Analysis of the Position of Urban Brand Components Case Study: Maragheh City. Sustainable city, 3(2), 63-76.

[10] Pompe, A. (2019). DESIGNING THE IMAGE AND THE PERCEPTION OF THE CITY AND ITS'BRAND: THE IMPORTANCE AND IMPACT OF QUALITATIVE URBANISTIC ELEMENTS. Advances in Business-Related Scientific Research Journal, 10(2).

[11] Vanolo, A. (2008). The image of the creative city: Some reflections on urban branding in Turin. Cities, 25(6), 370-382.

[12] Li, Y., Hsü, P., Hao, G., Sun, K., & Wang, Y. (2021). City brand image building and its impact on the psychological capital of new entrepreneurs following cultural construction. Frontiers in Psychology, 12, 717303.

[13] Matlovičová, K., Tirpáková, E., & Mocák, P. (2019). City brand image: Semiotic perspective a case study of Prague. Folia Geographica, 61(1), 120.

[14] Cao, J. (2024). The influential factors on brand image–a case study on city image. In Exploring the Financial Landscape in the Digital Age (pp. 69-75). CRC Press.

[15] You, S., Christofi, K., Tsappi, E., & Papageorgiou, G. (2024). Developing a Framework for City Brand-Image Promotion via Social Media Communication. In FEMIB (pp. 60-68).

[16] Liu, S. (2025). Research on Morphological Innovation in City Brand Image Based on Computer Graphics Technology. J. COMBIN. MATH. COMBIN. COMPUT, 127, 2833-2856.

[17] Zhao, W., & Seokhyun, L. (2024). Determines factors of cultural city brand equity: from the perspective of a city's integration with residents. Journal of Asian Architecture and Building Engineering, 1-20.

[18] Wang, H., & Liu, Y. (2023). Stone carving design of urban public landscape based on three-dimensional modeling. In Structural Engineering and Industrial Architecture (pp. 332-339). CRC Press.

[19] Munawer Syed,Yusuf A. Aina & Tan Yigitcanlar. (2024). Smart and Sustainable Doha? From Urban Brand Identity to Factual Veracity. Urban Science,8(4),241-241.

[20] Emerald Dilworth,Emmanouil Tranos & Daniel J. Lawson. (2025). Assessing geographic polarisation in Britain's digital landscape through stable dynamic embedding of spatial web data. EPJ Data Science,14(1),19-19.

[21] Junrong Hu & Jingjie Yan. (2025). Research on Urban Ancient Street Planning and Design Based on Digital Landscape Technology: A Case Study of Rulinli Ancient Street. Academic Journal of Humanities & Social Sciences,8(1).

[22] Jones Phil Ian & Osborne Tess. (2020). Analysing virtual landscapes using postmemory. Social & Cultural Geography,21(2),186-206.