Landscape Design System Based on Virtual Reality

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Abstract
City Park landscape design can be divided into two parts including city park green space system planning, landscape spatial planning and specific space design, it is a way of thinking and solutions dealing with the relationship between artificial and natural environment. This thesis taking virtual reality design of city park landscape design as a starting point based on augmented reality by visual computing of virtual reality of landscape design system. Aiming at the problem that the applications of the augmented reality technology in various fields are mainly dominated by the functions of browsing and displaying, lack of the interaction with users, this article studies the key technology of the augmented reality based on visual calculation. The transfer matrixes among the coordinate systems are determined through the mark points on the two already known images, which achieves the virtual-real registration of AR system. Secondly, the method of virtual-real synthesis display is designed in the environment of OpenGL, through which the images of virtual objects and real scenes are displayed in the same window. Finally, this article sums up the interactive operation functions supplied for users into the three aspects of the interaction with the real world, the interaction with the virtual object and the interaction with the history, and designs a kind of method of utilizing relevant parameters of virtual-real synthesis to store and call out the virtual-real synthesis effect in real scene, and the living examples verify the effectiveness of the method.
Key Words: VIRTUAL REALITY, LANDSCAPE DESIGN, VIRTUAL COMPUTING

1. Introduction

Along with the rapid development of computer technology, the virtual reality technology on the background of realistic work and life get fully developed. The so-called virtual reality [1-2] (VR for short) is to utilize computer to generate a kind of lifelike virtual environment of watching, listening, strength, touching and moving and other feelings, to let users “immerse” into such environment through various sensing equipment and make users have the feeling of being personally on the scene, which is widely used in the scientific research, design, teaching, entertainment, movie and television and many other fields. As an emerging research field, the augmented reality technology is attracting the attention of people increasingly due to its huge advantages and application potentials.

The virtual environment in virtual reality system is generated through utilizing 3D modeling display of computer, as the display quality of scenes is limited by the modeling quality and the computing speed of computer, it has the considerable difference with the real scenes, may loss much detailed information that not easy to omit when they are observed directly by human eyes, which limits the observation and sensory ability [3] of users for the real world. In order to overcome these problems, the augmented reality (AR for short) technology [4,5] appears, to accurately overlap the virtual scenes or system prompt information generated by computer and display into the real scenes in real time, and thus realize the “augment” for the real world, it can also greatly increase the sensory ability of users for the real world.

The research on this field at domestic is still in its initial stage [6], and there are more researches on algorithms, the applications on the augmented reality technology mainly directs at indoor environment, for example the display system of model houses [7], the display system of underground pipe network and so on, these systems are all adopted with the augmented reality technology to provide the function of browsing and displaying to users in indoor environment. However, these systems lack of necessary interaction between users and system, in order to expand the application scope of the augmented reality, people begin to turn their attention to the development of the augmented reality application outdoors. Meanwhile, in order to apply the augmented reality technology in the design field, people long for the breakthrough of the interaction technique of the augmented reality much more.

The current development of landscape design theory broke through the level of simple landscape aesthetics—from the systematic construction of overall urban parks to the design of specific garden chair, the application of the harmonious human theory, all of them reflected the development and breakthroughs in landscape design theory. How to use virtual reality technology to fulfil the idea of landscape design? Therefore, comprehensively understanding the concept of the augmented reality and thoroughly researching the key technology involved in realizing the augmented reality system mainly include camcorder calibration, the virtual-real registration, the virtual-real synthesis display technology and the storage of the virtual-real synthesis effect, on this basis, a set of AR landscape design system based on vision is explored and developed, and the feasibility of the augmented reality system is demonstrated according to practice.

2. Principle of landscape design

The basic principle of the park landscape design should include the following aspects:

1) Holistic principles embodied both between departments or groups involved in the construction of the park. It has also been reflected in the operation of the whole process of fine park, and also reflected in the landscape design and completion effect. Limited by thesis topic, author in this thesis relates only to the environment as a whole on the shape environment. All combinations of the overall shape environment should be supported by people's imagination, in line with human behavior.

2) Local principle should run through the whole process of park landscape design compilation, local territorial contains not only natural factors, but also includes local cultural characteristics.

3) Sustainable ecological principles, not rigid pursuit of sustainable ecological principles, it should be noted that human nature is the characteristic of the city's comprehensive park landscape, design should combine the natural ecology while showing the creation of man. Traditional evaluation of the botanical garden landscape, "extraordinary as if done by the spirits", "although it’s done by the people, just like the nature make it" both reflects the creative aspects of human.

3. Overall design of system

3.1 System overview

This article applies the augmented reality technology to the landscape design field, through AR technology, to integrate the design object with the image information of a certain point of sight in real world, and show and feed back the object information visually to designers, and make designers carry out the visualized assessment for the designing scheme more effectively. The objective finally to be achieved is to utilize visual C++ and OpenGL to develop the AR software that can integrate the images in true environment with the three-dimensional geometrical modeling generated by computer, and apply it to the landscape design field. This software will provide the nonprogrammable user interface to users, and the users only need to utilize the mouse and keyboard to provide relevant information required for the integration of the images of true environment and the geometric model generated by computer in the window supplied by software according to system prompt, the system will automatically finish the integration of the images of true environment and the geometric model generated by computer, and show the effect picture of integration to users, the users can also modify the synthetic effect as required; finally, the users can also save the satisfying effect for looking up and browsing in the future.

3.2 Working process of system

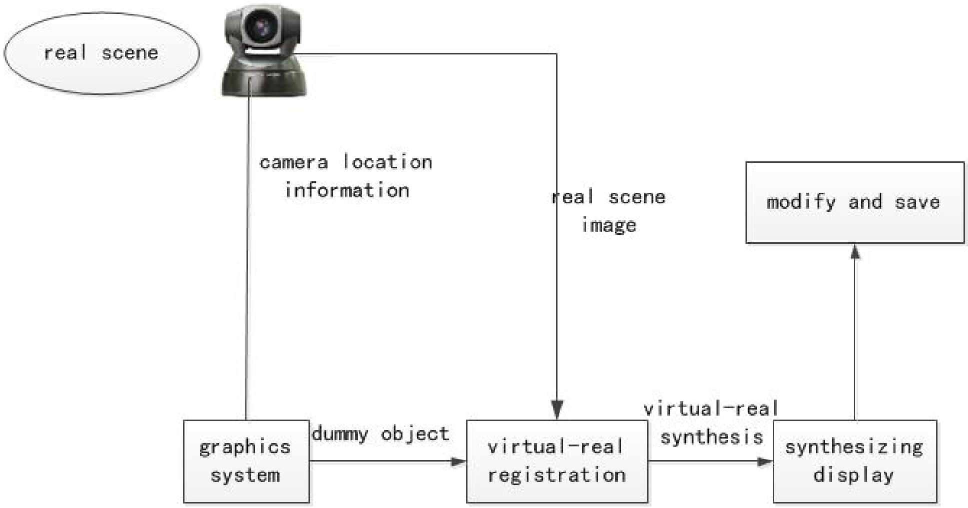

Figure 1. Working process of system

AR is a typical inter-discipline, its research scope is very wide, which involves various fields, such as, signal processing, computer graphic and image processing, human-computer interface and psychology, mobile computing, computer networks, distributed computation, information acquisition and information visualization, and the design of new type of displayer and sensor. Although AR system does not need to display the complete scene, it needs to analyze plenty of locator data and scene information to guarantee the virtual object generated by computer to be accurately located in real scenes; therefore, the working process of the system in this article is as shown in figure 1.

4. Detailed design of system

4.1 Camera calibration

The system needs carrying out calibration during the process of initialization to acquire the internal parameter and external parameter of camera. The data of the virtual-real registration algorithm are directly derived from the image information of camera, and the entire registration algorithm is based on the projection principle of camera, if the internal and external parameters of camera are not accurate, the entire registration model will generate serious error or even cannot be registered normally. Based on the above consideration, in order to realize the virtual-real registration accurately, the calibration for the internal and external parameters of camera must be carried out.

The images collected by camera is imported into computer in the form of standard television signals, and converted into the digital image through the special digital-to-analogue conversion board in computer. Every piece of digital image is MxN array in computer, the numerical value of every element (named as pixel) in line M and column N is the luminance of the image point (or named as gray level, in case of color image, the luminance of pixel on the image will be represented by the luminance of three colors, i.e. red, green and blue). The rectangular coordinate system $\{u,v\}$ is defined on image; the coordinates $\{u,v\}$ of every pixel are respectively the column number and the line number of such pixel in the array. Therefore, $\{u,v\}$ is the coordinates of image coordinate system with the unit of pixel. As $\{u,v\}$ only represents the column number and the line number of such pixel in the array, does not show the location of such pixel in the image by using the physical unit, therefore, the image coordinate system represented by physical unit (such as, mm) needs to be established, such coordinate system takes a certain point O in the image as the origin, x axis and y axis respectively parallel to u axis and v axis, as shown in Diagram 2. In the coordinate system $\{x,y\}$, the origin O_l is defined at the intersection point of the optical axis of camera and the image plane, such point generally located at the center of the image, but due to the reason of being produced by camera, there will be deviation, if the coordinates of O_l is $\{u_0,v_0\}$ in the coordinate system $\{u,v\}$, and the physical dimensions of every pixel on the direction of x axis and y axis, the coordinates of any pixel in the image under two coordinate systems have the relationship as follows:

$$u = \frac{x}{dx} + u_0 \qquad v = \frac{y}{dy} + v_0 \tag{1}$$

By using the homogeneous coordinates and matrix form, the above formula is represented as follows:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{dx} & 0 & u_0 \\ 0 & \frac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{2}$$

The inverse relation can be written as:

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

As camera can be placed at any position in the environment, the reference coordinate system in the environment is also selected to describe the location of camera and use it to describe the location of any object in the environment; such coordinate system is named as the world coordinate system, which comprises of the axes X_w, Y_w, Z_w. The relationship between the coordinate system of camera and the world coordinate system can be described by using the rotation matrix R and the translation vector T.

Therefore, if the homogeneous coordinates of a certain point P in the space are $(X_w, Y_w, Z_w, 1)^T$, $(X_c, Y_c, Z_c, 1)^T$ under the world coordinate system and the coordinate system of camera, the following relationship exists:

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R & T \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} = M_1 \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} \tag{4}$$

4.2 Ideal imaging model of camera

In the computer graphics and computer vision, the pinhole camera model is generally used to simulate the projection changes from three-dimensional scene to two-dimensional observation plane. The position of image formation of any spatial point P on the image can be represented approximately by using the pinhole model, that is, the projection position p of any point P on the image is the intersection point of the connection line between the optic centers O and P and the image plane. Such relationship is also named as the central projection or perspective projection. The relational expressions derived from the proportional relation are as follows:

$$x = \frac{fX_c}{Z_c} \qquad y = \frac{fY_c}{Z_c} \tag{5}$$

The above mentioned perspective projection relationship is represented by homogeneous coordinates and matrix representation:

$$Z_c \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} \tag{6}$$

And the relationship of P point coordinates and the coordinates $\{u, v\}$ of its projection point represented by the world coordinate system is obtained:

$$Z_c \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \frac{1}{dx} & 0 & u_0 \\ 0 & \frac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & T \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} \alpha_x & 0 & u_0 & 0 \\ 0 & \alpha_y & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & T \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} = M_1 M_2 X_W = M X_W$$

(7)

The calibration object of the already known three-dimensional coordinates is utilized to carry out the experiment of the camera calibration of linear model, in which there are 3D coordinates of the calibration object and its corresponding ZD image coordinate value, through utilizing the method of the camera calibration of linear model, the entire matrix form of the camera calibration can be solved:

$$\begin{bmatrix} 44.837536 & 29.805575 & -5.520180 & 94.522692 \\ 2.516073 & 42.249540 & 40.778468 & 337.877106 \\ -0.000688 & 0.064917 & -0.010312 & 1.000 \end{bmatrix} \tag{8}$$

4.3 The virtual-real registration of augmented reality based on vision

The substance of the virtual-real registration technology is the 3D--3D image registration between the three-dimensional virtual image generated by computer and the real image filmed by camera, and is to find the corresponding relation corresponding to the same position point of the space in two images.

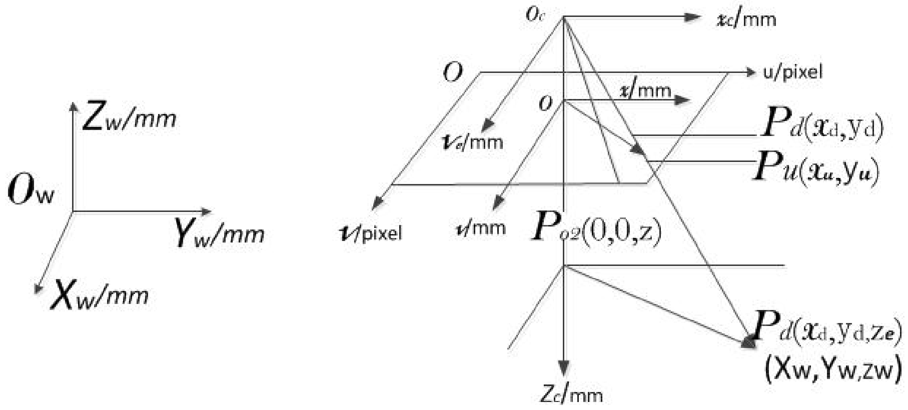

Figure 2. Four coordinate systems involved in virtual-real registration

The key to complete the correct registration of virtual image lies in precisely confirming the projection coordinates of each point in the virtual object model on the scene image, the image registration is the mapping and converting between space coordinates systems substantially, this process involves four coordinate systems: the object coordinate system (space coordinates system of virtual model), the coordinate system of camera, the image coordinate system and the world coordinate system (space coordinates system of real scenes), as shown in Diagram 2; therefore, the key is to unify the coordinates under different coordinate systems through coordinate transformation.

The virtual-real registration is actually to require confirming the transformation relation between different space coordinates systems in image, only by confirming the transformational relations among each coordinates system, the all-dimensional registration of the virtual object generated by computer and the real scenes around users can be achieved. In the following, the process of solving these matrixes through the method of virtual-real registration on the basis of visual calculation that adopted in this subject is provided, mainly including the selection of mark point, the positioning of mark point, the coordinate system conversion and other steps, through these steps, the virtual-real registration system of the augmented reality based on vision will be established preliminarily.

(1) The selection of mark point: the augmented reality system realized in this article adopts the mark point registration method based on vision, therefore, the selection and positioning of mark point will produce a certain influence on the accuracy of the virtual-real registration.

(2) The positioning of mark point: the binocular stereoscopic vision position finder constituted by two cameras A and B is used for the positioning of the mark, the cameras A and B observe a certain point $P(X_w, Y_w, Z_w)$ in the space at the same time, the image points of P on the cameras A and B are respectively p1 and p2, the calculation of the three-dimensional location of the spatial point needs two sets of cameras to observe at the same time and calculated from two pieces of two-dimensional images at least. This is also the fundamental principle of utilizing the stereoscopic vision positioning method to acquire the coordinates of the three-dimensional point in space.

It is assumed that the camera calibration has been completed; their projection matrixes are respectively MI and M2, the following matrix equations are established according to the camera model:

$$w_1\begin{bmatrix}u_1\\v_1\\1\end{bmatrix}=M_1\times\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}=\begin{bmatrix}m_{11}^1 & m_{12}^1 & m_{13}^1 & m_{14}^1\\ m_{21}^1 & m_{22}^1 & m_{23}^1 & m_{24}^1\\ m_{31}^1 & m_{32}^1 & m_{33}^1 & m_{34}^1\end{bmatrix}\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}$$

$$w_2\begin{bmatrix}u_2\\v_2\\1\end{bmatrix}=M_2\times\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix}=\begin{bmatrix}m_{11}^2 & m_{12}^2 & m_{13}^2 & m_{14}^2\\ m_{21}^2 & m_{22}^2 & m_{23}^2 & m_{24}^2\\ m_{31}^2 & m_{32}^2 & m_{33}^2 & m_{34}^2\end{bmatrix}\begin{bmatrix}X_w\\Y_w\\Z_w\\1\end{bmatrix} \quad (9)$$

Four linear equations about X_w、Y_w、Z_w are obtained:

$$\left(u_1m_{31}^1-m_{11}^1\right)X_w+\left(u_1m_{32}^1-m_{12}^1\right)Y_w+\left(u_1m_{33}^1-m_{13}^1\right)Z_w=m_{14}^1-u_1m_{34}^1$$
$$\left(v_1m_{31}^1-m_{21}^1\right)X_w+\left(v_1m_{32}^1-m_{22}^1\right)Y_w+\left(v_1m_{33}^1-m_{23}^1\right)Z_w=m_{24}^1-v_1m_{34}^1$$
$$\left(u_2m_{31}^2-m_{11}^2\right)X_w+\left(u_2m_{32}^2-m_{12}^2\right)Y_w+\left(u_2m_{33}^2-m_{13}^2\right)Z_w=m_{14}^2-u_2m_{34}^2$$
$$\left(v_2m_{31}^2-m_{21}^2\right)X_w+\left(v_2m_{32}^2-m_{22}^2\right)Y_w+\left(v_2m_{33}^2-m_{23}^2\right)Z_w=m_{24}^2-v_2m_{34}^2$$
(10)

(3) Coordinate transformation of virtual-real registration: it is known from the study in the previous section that to realize the technology of virtual-real registration needs approximate three coordinate conversion link as follows:

1) Coordinate conversion from world coordinate system to camera coordinate system: it is to decide the relative position and direction between the real scene and the camera. In the AR System, the tracking system is responsible for observation point and angle of the real scene, which is conversion between the camera and the real scene.

2) The coordinate conversion from camera coordinate system to image coordinate system: it is to get the coordinate conversion from the camera to ZD image plane. To get the conversion, first of all, we need to calibrate the camera. The task of the calibration to get internal parameter of the camera, in the general application of AR, the camera's internal parameter includes: the focal length of the lens and the width, height and aspect ratio of the sensor's pixel. After that, the coordinate conversion from the 3D scene to ZD imaging plane will be realized based on the principle of the image from the camera's perspective.

3) The coordinate conversion from body coordinate system to world coordinate system: it is to decide the position and orientation in a 3D Euclidean space of the virtual object from the real scene. The conversion can be expressed as

$$\begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} = A \begin{bmatrix} x_0 \\ y_0 \\ z_0 \\ 1 \end{bmatrix} \quad (11)$$

Seen from the above equation, once the coordinate transformation matrix-N is given, each point of the virtual object may be individually corresponding to the image plane to realize the overlay of virtual-real. It can thus be seen, the purpose virtual-real registration is to clarify the conversion between various coordinate systems. In the above-mentioned three technical links, how to realize the real-time detection to the conversion from real-space coordinate system to observation space coordinate system is the most important link of virtual-real registration, which is also a difficulty for study on AR System at present stage. Through the analysis of the previous algorithm, we will decide the conversion from the real-space coordinate system to the camera coordinate system and to the ZD image coordinate system to get internal parameters and external parameters of the camera. Based on these parameters, the registration of each 3D scene point in the real-space coordinate system will be realized in ZD scene image, which implements a virtual-real registration.

4.4 Composite Display of Virtual-real Image

It use OpenGL to construct virtual information, including 3D objects, images, text, etc.. The construction of 3D objects is particularly complex, including virtual object's viewpoint control, lighting, scene change etc., meanwhile, it takes a series of image processing such as material definition, processing of lighting, transparency and fusion, texture mapping and atomization to achieve a sense of reality presented by the virtual object in a real-world environment.

OpenGL is designed to generate a two-dimensional image of 3D virtual scene, since the two-dimensional image can only be achieved on the screen. The process from a 3D scene to a two-dimensional image is acted like taking a picture with a camera, which usually needs the following steps:

(1) Place the camera on a tripod and make it aim the at 3D scene which is equivalent to the position of the adjusting viewpoint in OpenGL, i.e., the viewpoint conversion.

(2) Place the 3D object in an appropriate position of the scene, which is equivalent to the model transformation in OpenGL, i.e., perform rotation, translation and scaling to the model.

(3) Select the camera Lens and make it focused and make 3D object projected on a two-dimensional film, which is equivalent to be in OpenGL.

The process is the projective transformation of OpenGL. There are ways to project in OpenGL, i.e., orthographic projection and perspective projection. To make objects appear with appropriate position, size and orientation, it must be performed through the projection. Projective transformation essentially defines a view frustum which may display content on a screen, if only drawing a 3D scene in the real body. During the orthographic projection, it is a cuboid’s view frustum, of which the position does not affect the orthographic projection, that is, the object or the scene's geometric property after the orthographic projection will remain the same, such as the size, surface and the angle between two surfaces of the object; it is generally a pyramid like view frustum, and the perspective projection is consistent with the daily habit of observation of natural object which appears smaller if away from the viewpoint.

(4) Develop the film, which decides the size of two-dimensional photo. The process is equivalent to the viewport transformation (we can define a rectangle in the screen window, called a viewport in which the graph through the view frustum is displayed) in OpenGL. It also sets the scope and size of the scene displayed on the screen.

4.5 Park landscape detailed design

(1) City park landscape content elements

According to the characteristics of city park at the present stage, it is generally believed to have the following content and elements: terrain, hard landscape, soft landscape, water, and other architectural pieces.

(2) City park landscape creation method

The traditional gardening methods are: scenic focal point, obstructive scenery, interval scene, frame scene, and scenery-borrowing and other practices including the three aspects which are landscape conception, landscape form, and landscape layout, these three aspects are unified and indivisible as a whole.

Landscape conception should be reflected through landscape form and landscape layout. Landscape layout closely related to landscape form. On the one hand, landscape shape is figurative landscape layout, landscape layout must rely on landscape form for embodiment, landscape layout determines landscape shape; On the other hand, landscape layout focus on specific space organizations and arrangements, landscape form slightly heavier than the form and features, form is the results of layouts, and also is the starting point of layout. These three aspects in turn contains a complicated political, economic and cultural factors.

5. Test and evaluation

Interaction with the real world mainly refers to that the user can specify the main 3D information it want to get in the real scene, which is usually the 3D coordinate where the virtual object is placed. It is also specified by the user. When displaying virtual object the Augmented Reality System based on label I is dependent on the label. Once it is identified by the system, it will be difficult to change the position, attitude or type of the virtual object. Using computer vision methods succeeds in getting rid of Augmented Reality System's dependency on the label I. So the user can achieve the editing of the virtual object by the operation of the menu, mouse or keyboard. Figure 3 is used to achieve two pictures of the virtual-real registration.

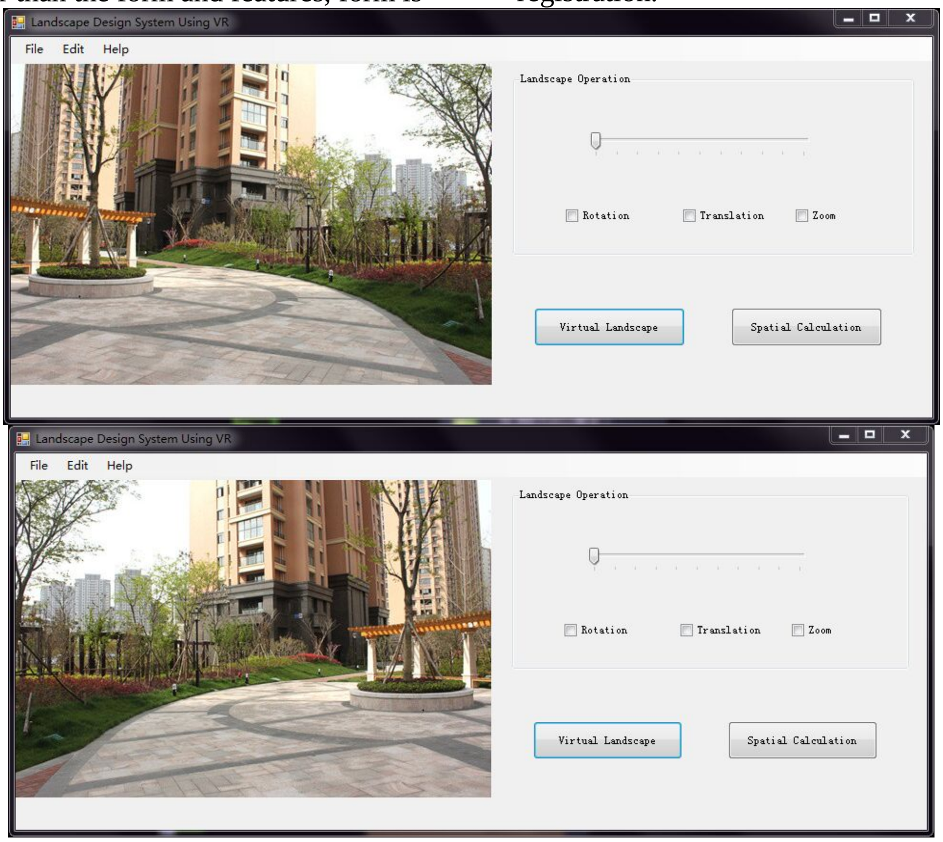

Figure 3. Two images of virtual-real registration

By mark point information input, the transformation matrix information like Figure 4 is available.

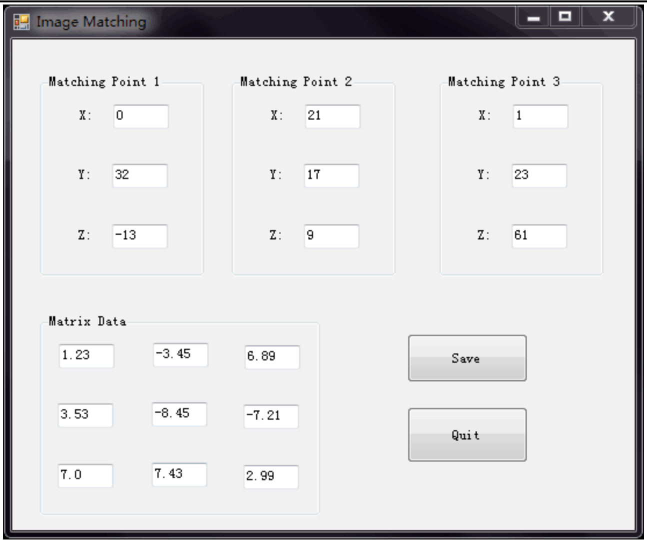

Figure 4. The transformation matrix information

After the virtual-real registration and virtual-real synthesis the system will supply the effect to the user as shown in Figure 5.

Figure 5. Display of virtual-real synthesis effect

6. Conclusions

This paper establishes the basic principles of garden landscape design, it applies the augmented reality technology to landscape design, through the combination of virtual reality and landscape design, which does beneficial research and exploration on camera calibration based on computer vision and virtual-real registration, and achieves an initial prototype system which is an initial design for outdoor Augmented Reality System. The living examples verify the effectiveness of the method.

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