Development of an Immersive VR Display System for 3D Digital Art

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Abstract

In this paper, a new 3D digital art and an immersive VR display system are presented. A 3D drawing interface and a real time object modeling, which is using auto 3D strokes, are implemented for 3D digital art. One 3D stroke makes some part of the object in one movement. This 3D modeling method has an advantage in representing complex objects quickly. 2D mouse interface is not appropriate for this kind of 3D stroke modeling task, so 3D virtual environment system with 3D wand interface is realized in this study. And an infrared camera-tracking device is used. Since the user viewpoint and wand are tracked, the user can see different screen display at various points of view and interact with objects directly.

Keywords--**VR, Camera Tracking, 3D Digital Art**

1. Introduction

Recently more attention is paid to digital art which is combined with art and engineering. Digital art is art forms such as sculpture, painting, installation art etc completed through digital media. The biggest characteristic of digital art is that the spectators do not just observe but really cohere with the work. What is more, artists make work together with the spectators. This kind of work is called 'interactive art'. For this reason digital art is not for just a few spectators but more for the masses and active spectators. In other words the artist is no longer only a producer but also a curator.

Among this form, 3D digital art combined with the immerse VR display system stands out since it simultaneously maximizes the users visual immersion and can produce interactive action with the work in various ways.

Projection type immerse VR display system has various display devices and the display system is not solely used by itself, but requires development of a combined system needing related display tools according to the fitting application program and equipment. Also all of the currently used immerse VR display system is combined with a tracking device which tracks down the users location, but for artists to work in the system or spectators to interact with the work, wireless tracking is required for free movement for the user and the space occupied by the system must be ideal.

2. Research on 3D Digital Art

2.1. CavePainting

CavePainting[1](Figure 1) realized by Cave™ is a system that allows drawing in 3D space with input tools similar to real art tools such as 2D brushes and paint pots. Not only engineers construct the system and utilize it but also actual artists like Daniel Keefe used the CavePainting system for creative work.

Figure 1 Cave Painting

2.2 ConFIGURING the CAVE

ConFIGURING the CAVE[2] is a digital art work realized in the CAVE, and is constructed by the subject of body and outer space. In the center of the CAVE stands a 5 ft multi-joint wooden doll. Spectators can freely adjust the wooden doll's position, and this position is calibrated by a mechanic tracking device. Every time a participant adjusts the wooden doll's position, the data is delivered to the server and the visual of CAVE changes.

2.3 Haptic Painting through 3D VR Brushes

This system allows the user to paint oil paintings on the desktop using a haptic device (PHANToM)[3]. Using the haptic device as a brush, the user can perceive a feeling that the brush is touching the canvas, hence feel like painting a real oil painting. Furthermore, painting through a computer is convenient that modification is easier than real painting. Through the palette on the monitor the user can choose the size and shape of brush and paint color, and also mix colors. But being realized on the desktop, a weak point is that the immersion lacks a bit.

2.4 Hiding Spaces

Hiding Spaces[4] is a work that realizes the ambiguity of an abstract painting on the 3D space of the CAVE. On the screen of CAVE, 2D background and 3D object coexists.

The movement of a user wearing position tracking 3D glasses enables the user to continuously see new 3D abstract paintings on his every step. The artist purposely realizes this kind of ambiguous visual expression on CAVE, and by connecting the user's movement to the visual, attempts to bring up the same interest as when someone looks at an abstract painting.

3. Development of an Immersive VR Display System for 3D Digital Art

3.1 Development of a Dual Display System

By fixing the projection plane to a certain position and changing the visual by adjusting the viewpoint nearer or further, the Window Projection Model can project more flexibly than the Camera Model. This method creates an immersive VR display system navigation-like effect. The core benefit of the Window Projection[5] is that the point of view and placement of the projection plane is flexible. For implementation, we need to use the *glFrustum*( ) projection function provided at OpenGL and have the ability to find the 4 Clipping volume values for left, right, bottom, and up according to the change of viewpoint. Thus, if the user moves from the center of the screen frame by the size of d, e, f (Figure 2), the screen parameters can be evaluated as in equation (1).

$$\left(-\frac{(a-2d)}{2(c-e)},\frac{(a+2d)}{2(c-e)},\frac{(b-2f)}{2(c-e)},-\frac{(b+2f)}{2(c-e)}\right) \qquad (1)$$

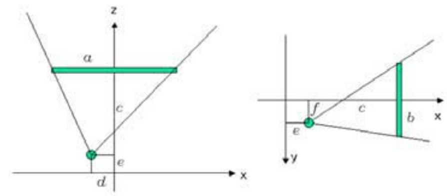

Figure 2 Window projection model

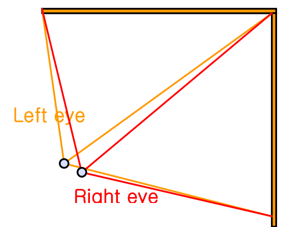

Figure 3 Stereo projection on dual screens

Figure 3 is a figure indicating the stereo visual range projected on this system's dual screen from an upper point of view. By using window projection, even if the user's viewpoint changes the projected plane is fixed thus there is no distortion on the visual located on the border of the two screens. However, if we cannot locate the precise spot for the left and right eye, the human viewpoint and projection datum point's location will differ resulting in distortion of the screen border.

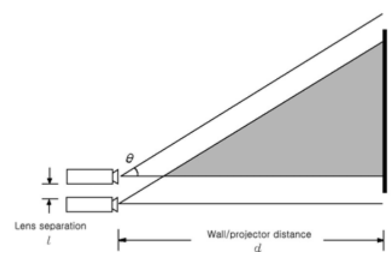

Figure 4 Passive stereo system [7]

By constructing a passive stereo system and using 2 LCD projectors as shown in Figure 4 allows us to use only the visual of the gray colored sector. As the characteristic of a projector, if a visual projected from 2 projectors are not horizontal, it will not be projected in the exact same shape on one screen. Thus, if we put Lens Separation as l, Projector Distance as d, angle as Θ, we are only using $(\frac{d\tan\theta - l}{d\tan\theta})\times 100(\%)$ of the projector's resolution. In this case, by using a projector that has lens shift functions, adjust the upper projector's projected visual down and the lower projector's projected visual up, and we now can use the whole resolution of the projectors.

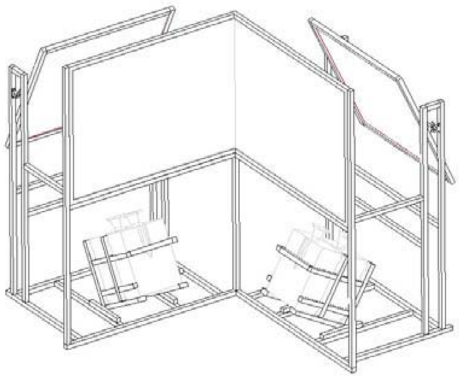

Figure 5 Dual projection system

Figure 5 is a 3D plan of a Dual Display System developed during this research. Using the rear screen used in rear projection methods, the user can interact with the visual on the screen without interference of the user and projection visual. Using 4 lens shift function installed LCD projectors to project the stereo visual we were able to utilize the whole 100% visual of the upper and lower projector. And for larger visuals shot from short distances the short-focus lens are attached. The image is projected on the screen by reflecting the projector's visual through an optical surface mirror, resulting in largely reduced system occupation space.

3.2 Tracking System using Infrared Camera

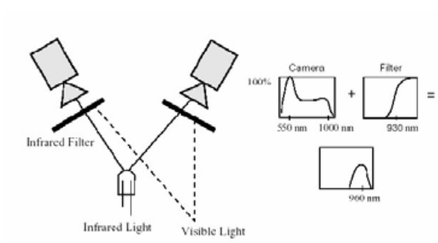

Figure 6 Principal of infrared filter [8]

In the immerse VR display system, for interaction of the visual on the screen and user, the user's 3D positioning information is required. There are various kinds of position tracking devices that can obtain a user's positioning information according to the method. Among these devices, wireless camera tracking has been intensely researched lately for the aspect that it enables free movement to the user for it does not have a wire connected to the sensors. In this research, we try to obtain the user's 3D information by utilizing 2 black & white CCD cameras. Regular CCD cameras can sense not only the visible ray range (400*nm* ~ 700*nm*) but also the infrared ray range (over 700*nm*).

Thus if we attach an infrared filter in front of the camera lens, the camera can only sense infrared rays. SONY XC-HR50 cameras were used in this system, and can sense rays that range up to approximately 1000*nm*. If we attach a filter that intercepts rays under 930*nm*, the camera only senses rays ranging around 960*nm* as shown in Figure 6.

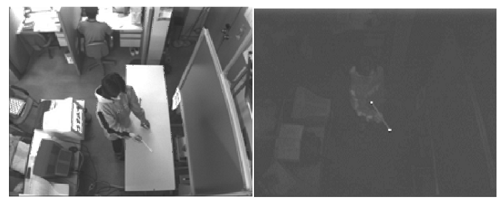

Figure 7 Before (left) and after (right).

In the infrared tracking system, targets are reflection markers. In the tracking range, clothes or other materials also reflect a little amount of infrared rays, but the reflection marker reflects the most. Thus, infrared light coming from the infrared filtered camera is only brightly reflected on the reflection marker as shown in Figure 7.

The center of the 2D markers calculated from each camera can be converted to p_l & p_r of each camera's coordinate system by the camera's internal parameters. If p_l & p_r are the camera coordinates of a point P' projected on the image plane by each camera, using coordinates p_l & p_r and expression (2) we can calculate the camera standard coordinates of point P' [9].

$$ap_l - bR^T p_r + c(p_l \times R^T p_r) = T \qquad (2)$$

a, b, c are unknown constants, R is the camera's rotation matrix and T is the camera center's movement vector.

At this time, the camera calibration is not precise, so as in Figure 8 vector l & vector r do not exactly meet at one point. So P', the central point of the minimal distance between the two lines becomes the 3D coordination of the marker.

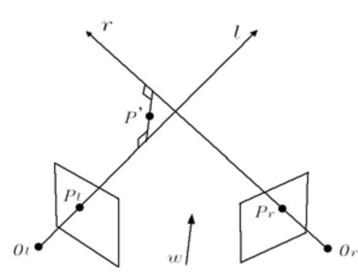

Figure 8 3D position by triangulation

Camera tracking is unable when the tracking object goes out of range or when an object interferes between the camera and the tracking object. But momentary disappearance or interference of the marker can be compensated to a certain amount by using marker location estimation. For marker movement estimation, this research uses change vector [10].

In the tracking system of our research, an algorithm that verifies if the user is in tracking range and that automatically sorts and initializes each markers location is included. This system automatically initiates the marker's location whenever the user enters the tracking range or the marker's position is lost during tracking. There are 4 infrared reflection markers that can be tracked in the tracking system. 2 are attached to the polarizing glasses and 2 are attached to the wand. So, even if each marker's 3D location can be calculated, an algorithm that can distinguish where each marker is attached to is needed. Distance between each marker is used for this distinction [11]. The distance between the markers attached to the polarizing glasses and wand are 17*cm* and 9.5*cm* respectively as shown in Figure 9. Each marker's 3D location is calculated, and two markers having a distance of 17*cm* are recognized as the ones attached to the polarizing glasses and two having 9.5*cm* as attached to the wand.

Figure 9 Polarizing glasses and wand

Figure 10 shows the screen when a tracking program is run on a tracking server. Each of the 4 tracked markers are sorted and indicated as a square box. Since it calculates the 3D location data at a rate of 30 times a second, it has the ability of real-time tracking.

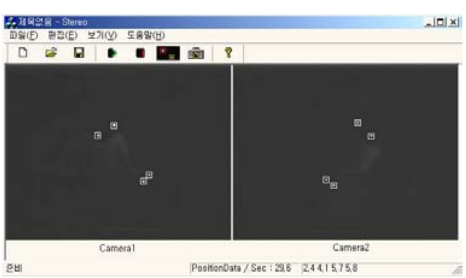

Figure 10 Tracking Images

The system features developed on this research are;

- Tracking Server : Pentium 2GHz, 512M, Oxygen GVX1 Pro, Meteor-2/Multi Channel.
- 2 Display Computers : Pentium 2.4GHz, 512M, ATI Radeon 9700 PRO.
- 3D Display : 4 SHARP XG-P20XDs, 4 Polarizing Glasses, REPOS Rear Screen/2 Optical Surface Mirrors.
- 2 Infrared Cameras : SONY XC-HR50, Infrared Filter, Infrared LED, DC Power Source.
- Polarizing Glasses, Wand(Infrared Reflection Marker Attached).
- Programming Language, Library : VC++ 6.0, OpenGL, Matrox MIL-Lite 7.1.

For position tracking using the camera, relative distance between the cameras and a tracking object is required according to tracking range, and the camera should be positioned at a location where it can track the object clearly without being interfered. The tracking system realized in this research is installed on the upper part of the dual display system. Figure 11 is the combination of a display system and tracking system developed in this research. The tracking server and display server are connected by TCP/IP and the tracking data is sent to the display server.

Figure 11 Immersive VR display system

4. 3D Digital Art Realization (VISCAN)

4.1 Interface

VISCAN is a 3D digital art production tool implemented using the immersive VR display system developed in this research. VISCAN is a drawing tool enabling 3D drawing, and unlike conventional 3D drawing tools based on 2D, the user can draw 3D drawings directly on 3D space and can observe the visual from different angles by moving around. The wand is used as a brush and indicator, and the wireless mouse is used as an input device. VISCAN is not only designed for painting with the brush but also voluminous 3D modeling.

Figure 12 Initial display of VISCAN

Figure 12 shows VISCAN's initial display. Resolution is 2048*768, and the left 1024*768 range of display is displayed on the left screen and the right 1024*768 range of display on the right screen. The function menu for selecting brushes or other functions is indicated by the icons on the left side of Figure 12, and the palette menu for selecting colors are on the right side. Each menu exists in 3D space, so in order to select a menu the user must touch the menu on the screen with the wand.

4.2 Drawing using 3D Polyhedron

In drawing using 3D polyhedron (Figure 13), user can draw box, sphere, and cylinder shaped basic figures and depth polygons and objects in bodies of revolution.

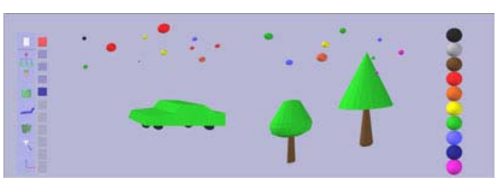

Figure 13 Drawing by polyhedron

4.3 Drawing using 3D Strokes

3D stroke is a 3D object that is produced by the wand moving through 3D space. Traditional brush strokes were expressed on 2D planes, but 3D strokes are capable through the immersive VR display system.

In this research, various types of 3D strokes being available broadened the selection range for expressing, and also presented a speedy real-time object modeling method. Generally 3D modeling took long processing time since it had to realize each and every one of the polygons. However, in this research one 3D stroke produces a part of the object. The produced part is selected by the menu and according to the part's characteristics the expression method of the stroke changes. This kind of expression is produced by a combination of the user's intention and the automatic object characteristic expression.

Figure 14 Drawing by basic 3D strokes

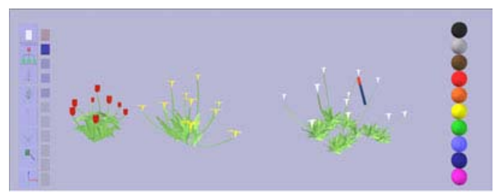

Figure 15 Flower drawing by auto 3D strokes

This type of 3D modeling enables easy and fast expression of objects with complicated shapes. 3D strokes are divided by basic 3D strokes using brushes, color pencils, and volume vectors etc (Figure 14) and auto 3D strokes that express an object with complicated shapes in one stroke (Figure 15).

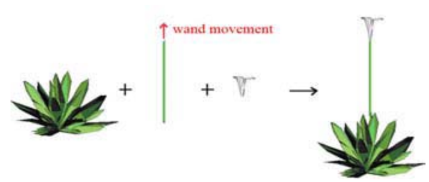

Figure 16 Auto 3D stroking process

For auto 3D strokes, the expression of the stroke differs by the object being drawn while the user moves with the wand. When the user wants to draw a flower, as shown in Figure 16, the bud and the petal is automatically drawn as the user draws the stem.

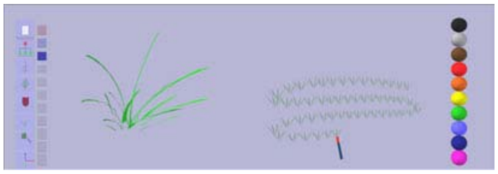

Figure 17 Basic strokes vs. auto 3D strokes

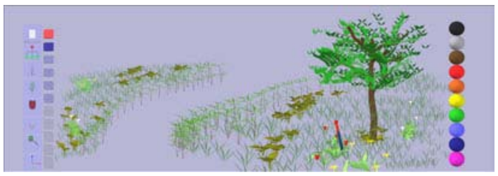

Figure 18 Drawing by compound stroking

The user can select the shape of the bud and petal, and the drawn direction is random, so expression is diverse even when the same type of flower is selected.

In case of plants and leaves, the user can draw each leaf using the basic 3D stroke in brush form or just use the auto 3D stroke to produce the object quickly. (Figure 17) Figure 18 is a scenery drawing using auto 3D stroke on VISCAN.

5. Conclusions

In this research, an immersive VR display system for digital art is developed and 3D digital art examples are implemented.

The display system was produced by the use of two perpendicular screens that widens the user's visible angle and broadens the space the user interacts with the visual. The camera tracking system using infrared rays tracks the user's viewpoint and wand's 3D location at a rate of 30 times per second. Through the automatic location tracking initialization process, the camera tracking system enables continuous tracking when the user enters the tracking range or when marker tracking fails. The user's 3D location data obtained from the tracking server is sent to the 2 different display servers through TCP/IP, and each display server produces a 3D visual for the left and right eye respectively. The screen produces a visual apt to the user's viewpoint movement and the user interacts with the screen's visual using the wand.

Through the system developed in this research, 3D digital art such as VISCAN was implemented. The system was also able to satisfy the artist's intention delivery, immersion, and interaction between spectator and work. As above, 3D digital art through immersive VR display system is a new form of digital art having high development potentials in this media and digital era.

Parts that should be researched further on afterwards are, making it attractive enough for normal artists to approach this kind of new media, and developing easy but exquisite and various 3D stroke and brushwork methods in order to fulfill message delivery intentions.

6. References

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