

Campus Virtual Tour System based on Cylindric Panorama

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Abstract Virtual tour is a prominent problem in virtual reality research. In this paper, we review some virtual tour system and propose a project plan of “Virtual tour in Tsinghua University”. The core code and the prototype of the system are completed. Experimental results show that our design is feasible and effective. It can bring the feeling of reality and immersion.

Keywords: virtual tour, campus, panorama, immersion

1. Introduction

Virtual Reality is a very powerful and compelling technology which aims to mimic real world by computer-generated environment and engage all the senses of people. By kinds of advanced human-computer interfaces and emulation systems, a brand-new virtual world is maturing day by day with various applications, such as digital heritage, training simulation, digital carving and virtual concert and so on.

Compared with traditional graphic research, virtual reality technology emphasises on the interaction between user and system, i.e. the user could enter and experience the digital environment in real-time, feeling like being there actually. So, virtual tour is always an active and challenging topic of VR field.

Utilizing the environment construction technology which is the kernel of virtual tour, there are three ways to realize our tour in electric world: (1) convert all the real environment into electric models with 3D modelling toolkit. Environments created in this way could be seen in many 3D games, with great impact; (2) stitch the photographs of actualities into a picture of virtual environment. The virtual tour to CMU [4] is a successful example of this type; (3) mix the two methods above, setup the scene by 3D models combined with photograph conjoining. Though an extra running cost is produced and some more corresponding problems come out like load balancing and visiting bottleneck, there are some advanced instances of mixture modelling such as the Virtual Sagalassos Guide system by Marc Polleferys [2].

After the study on current research results and engineering experiences, considering the software/hardware status and aiming on the largest performance-cost-ratio, we choose the second, i.e. stitching photographs to form the virtual environment. We focus on the environment construction modelling and immersive visual display technologies, implement our novel algorithms in the experimental system of Tsinghua Virtual Campus System which performs satisfyingly and inspiringly (up to now, the system is completed partly, including some areas around the East Gate of Tsinghua University).

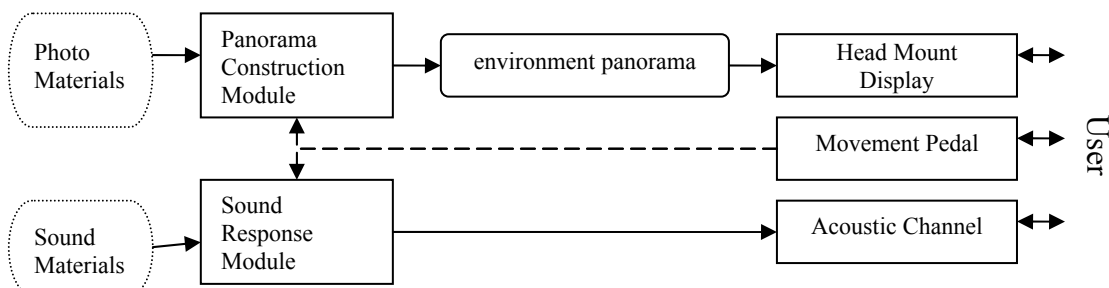


Figure 1. System Framework

The organization of this paper is as follow: 1. introduction; 2. the design of system framework, we present the architecture and logical function of our campus virtual tour system here; 3. environment model, which is the focus of our work. After analysis on the principles of panorama and image-matching, we propose a new high-quality Image Matching-Stitching algorithm; 4. display and immersion technology, which is another main contribution of this paper, including the proof to the feasibility and practicability of cylindrical projection, as well as our innovative algorithm for quick panorama projection and immersive tour; 5. experimental results, in this section, we show our simulation achievements, such as panorama generated, cylindrical display effect; 6. work conclusion and some possible aspects for further research.

2. System Framework

A completed campus virtual tour system is the composition of various technologies. The kernel of it is the sub-systems for environment models and user events processing, certainly, there are some other modules like user interaction and material management surrounding the kernel. To achieve the most lifelike feelings during user's virtual tour, we integrated acoustic and haptic interfaces and their response effects into our system besides traditional real-time visual display. In our design, a typical virtual tour experience is like this: the user starts off from somewhere in the campus, roams in some areas with the virtual locomotion device (for example, the user pedals to simulate walking or running), and the surroundings are displayed on his head mount. The user may also hear same background sound along with the scene changing (like the sound of water when he is getting closed to a fountain). The framework of system is in Figure 1.

In our framework, the pedal is the main data source for system, it records the position information and some necessary response instantly. The head mount display (HMD) is the primary display device. Besides, it can collect some details about user's status for more intelligent feedback as well, e.g. automatically change the display content when the user raise his head or reversely. The acoustic channel can be constituted by stereo-sound earphone, it is a pure output device which sets out different sounds with scene variety. Of course, we also have to adjust the volume of background sound along with user's movement. Overall, we have seized the three significant elements of user's feeling, tried the best to bring him total immersive experience in the campus virtual tour from vision, acoustics and locomotion.

The functional structure of system is shown in Figure 2. Presently, our research is emphasised on environment modelling and display module inside the dashed line frame of Figure 2. For it is not only the key point of a virtual tour system, but also a part that needs dedicatedly designed algorithms mostly. Further more, allowed by our current experimental condition, we can implement this module separately to be a demo program, which helps to

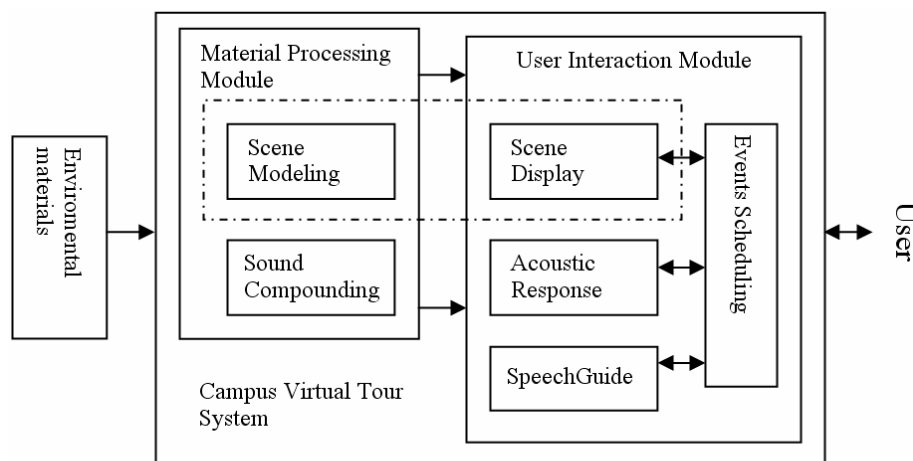


Figure 2. Functional Structure of Campus Virtual Tour System



Figure 3. Route Panoramas

exhibit the algorithm performance, and finally, to prove the usability and practicality of this project.

3. Environment Model

As mentioned above, we use real photo stitching for the scene of the virtual tour. The observer feels like standing in the campus, and every object around can be seen with the adjustable visual angle. The effect is like Figure 3, a route of the city. The panorama is constructed by Jiang Yu Zheng et al.

The campus virtual environment is composed by regions of static sceneries. The observer at the center can view the virtual scene at all directions. Each region can be constructed by a photo with Inverse Projection process. After synthesizing all the regions by the Image Matching-Stitching, we obtain a 360° cylindrical panoramic image, i.e. the virtual space. We can not only view any part of the scene, but can also move slightly around the center.

3.1 Material Collecting

Original scene pictures are shot by a digital camera at a fixed point in the campus. To avoid the elevation deviation of the lens, it is better to place the camera on a tripod. Sufficient light is necessary at the spot. Moving objects will harm the effect of stitching (such as a walking man may appear in multiple pictures), so we choose early morning to take the pictures when passers-by are relatively rare. But another problem comes because of the slanting sun at early morning or evening: the brightness of the pictures differs greatly in different directions. This brings difficulty for generating the panorama. We give an amendatory but not perfect method in later sections. Besides, any two adjacent pictures should have no less than 15% part of superposition in order to be matched properly and stitched with soft transition.

3.2 Creating Panorama

With the original material acquired, we stitch the pictures and generate a 360° panorama. This process is composed by following procedures.

- Image Inverse Projection

In regular photos, the image is projected on a flat film. And since we need a cylinder for the panorama, a process of Inverse Projection should be performed. As the following figure shows, P is a point on the flat photo, and Q is the corresponding point on the cylindric photo.

Assume the center of the photo has the coordinate value (0, 0), which is same in both photos. Then $Q(x, y)$ is projected from $P(r \cdot \tan(x/r), y/\cos(x/r))$, where r is the radius of the cylinder.

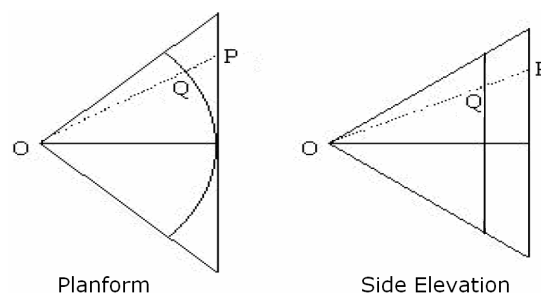


Figure 4. Image Inverse Projection

This process is the first step of picture stitching. If the photos are taken under the “Panorama Mode” of the camera, this step can be omitted.

- Image Matching

The simplest method to stitch two adjacent pictures is extremum points matching. The relative position can be decided by some points in the pictures such as the points with maximum or minimum brightness values. But these points may belong to different objects in the scene and thus results in match error. Neither can we avoid moving objects in the scene, as they are possible to bring moving extremum points which also cause error.

So in order to match the objects correctly, we use a slower but much more robust algorithm, column matching. The relative positions are acquired as follows. Pick the leftmost column of the right picture, and then put this column of pixels into the right part of the left picture. At each position, this column is superposed on a column of the left picture. We compute the “normalized Euclidian distance square” between the two superposed columns of two pictures, i.e. the sum of the difference square of each pixel on the two pictures dividing the number of pixel superposed. The position with the minimum distance is the one chosen as the relative position. Thus, small disturbances in the scene will not affect the matching of a whole column. Even if the brightness of the two column differs greatly due to the changing aperture, the algorithm can still find the correct match in most cases. The details are as follows (n is the number of pixels on a column).

1. Randomly pick a column from the right picture as $c1$, in its left 15% part; $i = 1$;
2. Take the i th rightmost column of the left picture as $c2$.
3. Let $k = \lfloor n/2 \rfloor$;
4. Compute the “normalized Euclidian distance square”

$$Dist = \frac{\sum_{0 \leq i < n-k \wedge -k \leq i < n} (c1[i] - c2[i+k])^2}{n - |k|}$$

Record the minimum distance and its position.

5. $k = k - 1$; if $(k > -\lfloor n/2 \rfloor)$ goto 4.
6. $i = i + 1$; if the i th rightmost column is still the the 15% part, goto 2.
7. Stitch the picture according to the position with minimum distance. Algorithm ends.

Note that we allow the pictures’ relative position to deviate at most $\lfloor n/2 \rfloor$ vertically, i.e. the elevations of two adjacent pictures cannot differ more than 50% of the vertical visual angle. With a tripod, the elevations of all the pictures are very close and certainly satisfy the constraint here. Even without a tripod, the pictures should also keep an approximately constant elevation because the final panorama takes the intersection of the vertical visual angles of all the pictures, and deviation of elevations will bring large waste of materials. So we regard the pictures with more than $\lfloor n/2 \rfloor$ pixels deviation as invalid.

- Picture Stitching

After finding the match position, we stitch the two pictures. Simply stitching the two parts from the pictures will cause an obvious dividing line on the scene due to brightness discrepancy. As mentioned above, the picture brightness are decided by the direction of the sun and the lens. Before stitching, we first multiply the RGB value of each pixel in the pictures by a normalization factor c so that for each picture, the sum of the brightness of its pixels equals to a constant. This can compensate for the brightness discrepancy to a certain degree. Then we put together the three parts of the two pictures: left part of the left picture, right part of the right picture, and the middle transition part. The RGB values of the pixels in the middle part are computed from a linear interpolation of the two pictures, which can ensure the smoothness of transition. This is why we want the two original pictures to have no less than 15% part of superposition.

To stitch all the pictures into a long panorama, the last step is to connect the head and tail of the long picture. We stitch the left most picture to the right, and from the change of its height we get the accumulative error of the tilted lens. In our practice, we rotate the panorama for 0.8° clockwise and make it possible to be pasted on a cylinder head to tail.

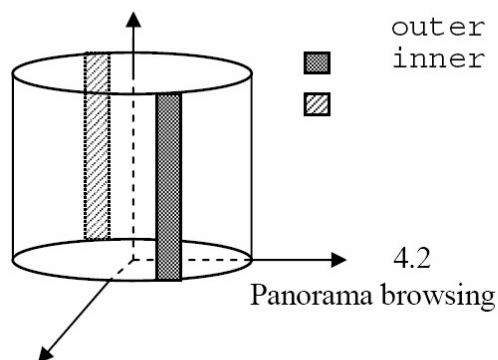


Figure 5. Cylinder texture directions



(a)



(b)

Figure 6. Stitching Effect

4. Display and Immersion

Based on the panorama, we can display the virtual campus and show it to users with immersion. The core of this section is the model that maps the 2-D panorama in to a 3-D space and gives users maximum realistic feelings.

As described in [1], there are generally three kinds of panoramas: spherical panorama, polyhedral panorama and cylindrical panorama. The former two kinds can display scenes of all directions, while the last one is a simplified mode without the scenes of top and bottom. However, research on solid vision shows that human eyes have vision range 100° horizontal and 60° vertical, and the horizontal superposed vision range is 120° . Our cylindrical panorama can generate vision range 100° horizontal, 30° vertical. So it can provide strong feeling of immersion and reality, enough for our virtual campus system. And because of its simple algorithms compared to spherical and polyhedral ones, we choose the model of cylindrical panorama.

4.1 Panorama projection

By the image inverse projecting process, the pictures are converted into the images on the inside face of a cylinder. Therefore the long picture constructed by stitching can be directly rolled up and form a cylindrical panorama. When we place the virtual camera at the center of the cylinder, we can see the surrounding scene like standing in the campus.

In practical programming, we can hand the tedious computations to OpenGL. The texture mapping can be applied to achieve cylindrical projection directly. Experiments show that OpenGL has high efficiency and precision. Though it does not support mapping the textures on cylindrical faces, we can cut the picture in to long thin stripes and map them on hundreds of thin rectangles which encircle the cylinder. Due to the limited screen resolution, the effect of this approximate cylinder is same to a real one. We use some small tricks such as dividing the whole panorama into eight big blocks of textures. Each time we only display the front half of the scene so that the memory and computing time is saved. Another point to note is that OpenGL textures are directed. As figure 5 shows, the inner and outer face of a rectangular slice are independent. The texture is mapped on the face where the four points are given by a clockwise order. And here we must make the texture appear on the inner face of the cylinder.

4.2 Panorama browsing

In the virtual campus system, we first implement the basic functions: (1) Users can change the horizontal vision angle to observe the full scene. (2) Users can move inside the virtual scene within a small range, and can approach or depart from objects. Besides, automatic browsing, i.e. let the vision angle increase at a certain rate, is also adopted. The practical results are shown in next section.

5. Experimental Results

5.1 Panorama effect

The full scene of the East Gate Plaza of Tsinghua University is generated by our algorithm based on the pictures we took. Figure 7 shows part of the unrolled cylindrical panorama. There is no obvious mark of picture stitching in the figure. So the effect achieves the expected level.



Figure 7. Tsinghua University East Gate Panorama (part)

5.2 Browsing effect

When walking in the scene, the key part to the user is the image displayed on the screen (or on the head mounts display). Figure 6(a) shows part of the screen when the system is running. We can see a stitching line of two pictures in the middle. And the original two pictures are shown in figure 6(b) which clearly reveals the different light status caused by different lens directions. Thus we can see the effect of the stitching algorithm.

6. Conclusions and Future Works

We implemented a virtual campus panorama system based on picture stitching. This system is robust, adaptive and easy operating. By taking digital photos and utilizing OpenGL library, we generate a panorama by the program and browse the virtual scene on the cylindrical panorama. Of course, a full virtual campus system need other components. Future works may include: constructing a sound feedback system by picking the sound information at several points of the campus. If circumstances permit, the system can be transplanted into head mount display and movement pedal so that users can visit the campus virtually just like walking in it.

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