

# Creating Virtual Walkthrough Environment From Vertical Panoramic Mosaic

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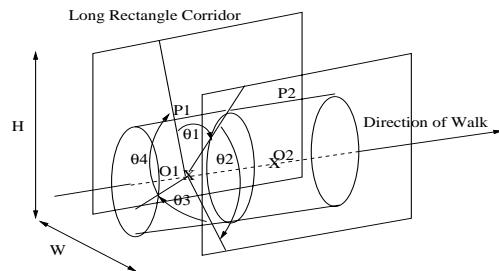
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## Abstract

In this paper, a novel algorithm for creating virtual indoor environments is described. First, a panoramic mosaic is generated from a series of photos taken with a camera rotates along a horizontal axis. Then, from the panoramic mosaic image, a non-fixed viewing point virtual walkthrough system can be created by defining manually the corners in the vertical panoramic mosaic. The side ratio of the virtual walkthrough system can be obtained from the panning angle subsequently. By applying the cylindrical projection technique, the texture for the sides of the virtual walkthrough environment can be projected in a more realistic way. Real images have been used to verify our proposed algorithm with satisfactory results.

## 1. Introduction

In recent years, image-based rendering is commonly used by most computer graphic applications to construct virtual walkthrough environments. A collection of images is used to synthesize the scenes instead of building a complete 3D model of the objects. There are commercial software packages such as *Cool3D<sup>TM</sup>* and *PhotoVista<sup>TM</sup>* that provide such tools for users to create and navigate inside image-based panoramic virtual walkthrough environments. Chen [1] suggested three basic elements that constitute the foundation of building a virtual walkthrough environment. First, a number of hot-spots of special interest are selected in the real environment. In each spot, a series of images is taken with respect to an observer standing at that spot. Second, these individual images are stitched together by some stitching algorithms [7] [8] [9] to form a number of panoramas. Also, special interest points and their "hot-spot" panoramas are linked together. Finally, images are texture mapped to give realistic display. A user can browse through links using panoramic viewers. Virtual navigation can be made possible by traveling from one node to another



**Figure 1. Definition on Our Approach**

by clicking visual prompts (eg. icons) or messages showing that it is possible to jump to somewhere else.

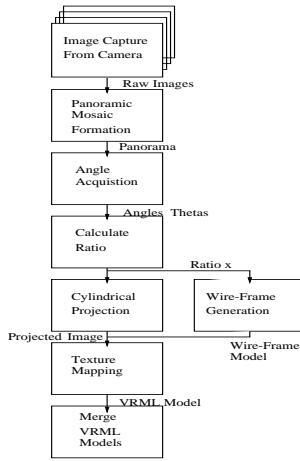
Referring to figure 1, our proposed approach is defined here: assuming an observer is viewing inside a long rectangular corridor and is given several vertical panoramic nodes  $P_i$  with centers  $O_i$  representing the  $i$ th panoramic node and its center. Also,  $r$  is the radius of the panorama,  $\{\theta_{i1}, \theta_{i2}, \theta_{i3}, \theta_{i4}\}$  are the angles from the center to the corners of a real indoor environment of the  $i$ th node. Our target is to estimate the ratio  $\frac{H}{W}$  which describes the ratio between the sides of the real environment, and project the panoramas to the faces of the virtual walkthrough environment for browsing.

Instead of describing the whole process in details, this paper would concentrate on our approach combining with some existing modelling techniques in creating a virtual room from panoramas taken from real scenes so that users can walkthrough it as if in a real indoor environment. Figure 2 shows an overview of our entire system.

The next section describes our approach. Experimental results on real images are presented in the last section.

## 2. Image Manipulation

A series of images are taken from the real environment using a digital camera. They are taken along the horizontal



**Figure 2. System Flow of our Approach**

axis. The position of camera is arbitrary as shown in Figure 4.

## 2.1. Panoramic Mosaic Creation

After the image photos are obtained, panoramic mosaic is created based on existing mosaic creation algorithm. Many researchers have developed techniques and software systems for capturing panoramic images of real-world scenes. In particular, Chen [1] has developed a method requiring less hardware and regular photographic frames over the whole viewing space. Szeliski [9] pointed out that mapping 3D world coordinates  $(x, y, z)$  onto 2D panoramic coordinates  $(\theta, v)$  with cylindrical projection is the first step to build a full view panorama:

$$\theta = \tan^{-1} \left( \frac{x}{z} \right), v = \frac{y}{\sqrt{x^2 + z^2}} \quad (1)$$

where  $\theta$  is the panning angle and  $v$  is the scanline. All the frames in a scene sequence are wrapped to construct mosaic images. Frame alignment with minor compensations for vertical jitter and optical twist is also needed for the construction process. The effect of camera motion have been cancelled out by various 2D or 3D parametric motion transformations [10]. These transformations also combined frames into complete panoramic images. In our current implementation, *Cool3D<sup>TM</sup>* was used to generate cylindrical mosaic system from 2D environmental snapshots. Information about horizontal translation  $t_x$  and vertical translation  $t_y$  for each input image are needed to estimate the incremental translational  $\delta t = (\delta t_x, \delta t_y)$  through a stitching algorithm which minimizes the intensity error  $E(\delta t)$  between two images. Figure 3a shows the mosaic segments constructed in our experiment.



**Figure 3. (a)Vertical Mosaic Section  
(b)Cylindrical Projection Sections**

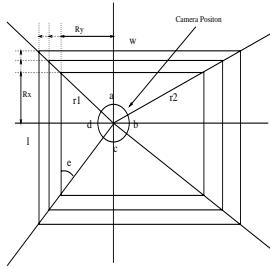
## 2.2. Cylindrical Projection

After completed the construction of virtual mosaic images, they are wrapped onto a sphere or cylinder surface by using image viewer software with texture-mapping. Only a portion of the panoramic image can be seen every time by a user on the image plane. A texture window is therefore formed by the bounding rectangle. As vertical edges are curved when projected on image plane, these vertical edges in the panorama segment are rectified through the process mentioned in [2].

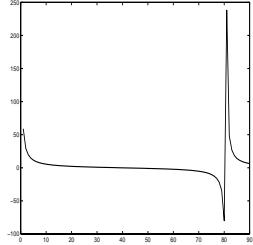
## 2.3. Measurement of Panning Angles

Imagine what a user can observe when he/she is standing at the center of a panorama. As the environment is an indoor one, the observer should have an angle when observing the corners of the indoor environment. The angles have to be determined before building the virtual walkthrough environment for the indoor real environment. This can be done by two approaches. A calibrated method of installing a plate containing the reference angle so that the angles can be measured while taking photos, or measuring the pixel number after generating the cylindrical wrapped image and estimate the angle from the image. The latter one is used because the accuracy is higher and it is more convenient to do so.

When the panorama is generated from some commercially available software, i.e. *Cool3D<sup>TM</sup>*, it can be fed into a matlab program to define the panning angle. Users can define the panning angle by selecting the corners in the indoor panorama. These panning angles are necessary for the estimation of the side ratio.



**Figure 4. Cylindrical Projection Sections**



**Figure 5. Plot of Ratio  $x$  w.r.t. angle  $e$**

## 2.4. Estimate Side Ratio

After obtaining the angles, equations can be worked out so that the side ratio can be found. Given angles  $\{a, b, c, d, e\}$  as shown in the Figure 4, side  $\{l : w\} = \{x : 1\}$  and view distance  $\{r_1, r_2\}$ . By the Sine formula, three equations are defined as following:

$$\frac{x}{\sin d} = \frac{r_1}{\sin e} \quad (2)$$

$$\frac{r_1}{\sin(3\pi/2 - a - d - e)} = \frac{1}{\sin a} \quad (3)$$

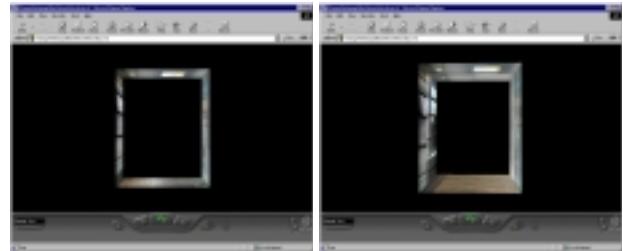
$$\frac{r_2}{\sin(c - e)} = \frac{x}{\sin b} \quad (4)$$

After combining the equations and eliminating  $r_1$  and  $r_2$ , they become

$$\frac{\sin(-\pi/2 + d + e)}{\sin a * \sin(c - e)} = \frac{x}{\sin b} \quad (5)$$

As angles  $\{a, b, c, d\}$  are known, and only three unknowns  $\{x, r_1, e\}$  with three equations. These equations can be solved by iteration using some initial values. After the ratio  $x$  is found, a virtual environment with the side ratio  $x$  can be generated. Figure 5 shows the graph obtained from different value of ratio  $x$  with respect to angle  $e$ .

The angle  $e$  should lie between  $0$  to  $\pi/2$ . The range is divided into 18 initial values and ratio  $x$  can be found. There are a total of 18 possible solutions. Those unreasonable solution (eg. negative or very small) will be rejected.



**Figure 6. VRML result of (a) a segment (b) merged segments of corridor**

**Table 1. Comparison of Side ratios**

	Side ratio ( $l : w$ )
Actual	1.36:1
Estimated	1.36:1

**Table 2. Comparison of Camera positions**

	Camera position ( $r_x/l, r_y/w$ )
Actual	(0.422, 0.515)
Estimated	(0.420, 0.523)

## 3. Experimental Results

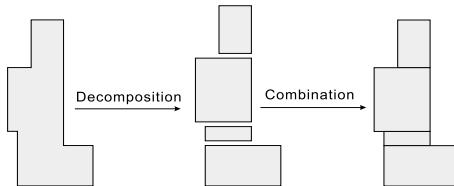
### 3.1. Virtual Environment Creation

For our virtual walkthrough environment creation system, with our Matlab 5.3 implementation executed on an Ultra- Sparc One, it takes about 20 minutes to synthesize a 9300x1000 pixels panorama. The smoothness of walking through the environment is much superior than the algorithm existing. Figure 6(a) shows the implementation result of creating virtual walkthrough environment. Several panoramas can be merged to form a larger environment as shown in the figure 6(b).

The calculation can be verified with the actual measurement of the environment. Table 1 shows the comparison between the actual side ratio and the estimated result. Moreover, table 1 shows the comparison between the actual camera position and the estimated result. In both tables, it is observed that our estimations are close to the real data.

### 3.2. Building virtual environments for complex scenes

Some complicated environments in real scenes, which are not simply rectangular in shape, can also be formed by



**Figure 7. Creating complicated virtual environment by decomposition**

this method. However, it cannot be applied directly. In such cases, the complicated scenes are decomposed into several rectangles of different sizes and orientations. After the decomposition, our method is applied onto each of those rectangles and the models are created for each of them. Finally, the models are combined together according to the way they are separated and thus the required virtual environment of the entire complicated scene can be obtained. Figure 7 shows the idea of creating complicated virtual environment by decomposition.

#### 4. Discussion and Future Directions

An algorithm has been implemented to create an indoor virtual walkthrough environment with non-fixed viewing point. Though there is still room for improvements, our method can provide a realistic environment on the web for ordinary users with minimal sacrifice in image quality and execution speed. This algorithm requires very few human interaction and highly automated during the generation of an environment by a computer. Users are required to click on four points for the corners of the indoor environment and the computer will execute all the calculation, fine tuning and virtual walkthrough environment generation, as compared to some other modeling tools, e.g. View Morphing, requiring users to select hundreds of corresponding points

The following possible enhancements are currently investigating: Other computer vision tools may be applied to enhance both speed and output quality in creating virtual environments. For instances, epipolar geometry [11] may be used to estimate the fundamental matrix  $F$  and the reduction of the 2D feature matching search space down to 1D. This can be done because there exist some viewpoint differences among starting and ending nodes. Information about  $F$  with model fitting methods like RANSAC [3] can help to drop out significant portions of false matches which effectively increase the image quality in synthesized views.

#### 5. Acknowledgement

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