# Panorama Image Interpolation for Real-time Walkthrough

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**Figure 1:** a) *Using 4 different view panoramas taken at square corners, it is possible to make a view at arbitrary location inside the square. Results image at different user locations: b) reference location (no interpolation), c) center and d) opposite corner.*

## Abstract

We propose a method to generate new views of a scene by capturing a few panorama images in real space and interpolating captured images. We describe a procedure for interpolating panoramas captured at four corners of a rectangle area without geometry, and present experimental results including walkthrough in real time. Our image-based method enables walking through space much more easily than using 3D modeling and rendering.

**Keywords**: virtual reality, panorama image, view interpolation

**Concepts**: **• Computing methodologies ~ Image manipulation;** *Computer graphics; Graphic systems and interfaces; Virtual reality*

## 1 Introduction

Image-based approaches have great potential on virtual reality or virtual walkthrough systems compared with computer graphics approaches in terms of cost and image reality as described in [Shum and Kang 2000] or [Aliaga et al. 2003]. Recently, omnidirectional cameras are becoming popular and so are sharing panorama movies which have been already supported on YouTube et al. The concept is similar to QuickTime VR which is proposed in [Chen 1995]. It plays panorama movies just along the axis of time as it was shot but has no degrees of freedom except for view direction. A representative of another type of application is Google Street View which is already used on a daily basis. While the service allows selecting the way to go next at junctions of pre-defined road network, the transition of view point is discrete and users are forced to jump to next location abruptly.

Building plenoptic function in the space proposed in [Adelson and Bergen 1991] makes it easy to implement walkthrough by only extracting slice from the plenoptic function based on given condition. But it needs to sample enormous data of light ray lit in the target space and it is practically impossible to capture them densely. By omitting partial information, lower dimensional functions were reported in [Gortler et al. 1996] and [Levoy and Hanrahan 1996]. Recently, an easier way to substitute it is proposed in [Zhao et al. 2013] which interpolate two images depending on relative location of viewpoint. We extend such an interpolation technique to two dimensions that enables simplified walk-through in real space.

## 2 Technical Approach

We inspect the effectiveness of our approach with minimal structure using four panorama images located on each vertex of a square in real space as illustrated in Figure 1. Our primal purpose is to establish a walkthrough procedure running on inexpensive PCs in real-time. To make a novel view inside the square region, the procedure includes a view interpolation originated from four captured panoramas. In this method, we have two steps, image deformation and image transfer.

### 2.1 Image Deformation

We start by making correspondences between each pair of four panorama images. [Zhao et al. 2013] proposed some techniques to mark feature points and make correspondences on feature points between each pair of panorama images, however, it is very difficult to process it automatically without errors. We currently leave this problem provisionally and make them manually. We then map feature points on each of 2D images to a sphere using polar coordinate system which gives us a point cloud with all points belonging to the surface of the sphere. This allows us to triangulate the point cloud using the convex hull algorithm while being careful to keep the same topology for each panorama. Thus we obtain four polygon meshes with different forms but the same topology.

The location of the view point and viewing direction is given according to user operations during interactive navigation. We generate new view at current location and towards current view direction by image transformation. We first create an interpolated

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polygon mesh using the Slerp (Spherical Linear intERPolation) function twice on four original polygon meshes in similar manner to bi-linear interpolation. This process allows creating a new mesh at the current view point location with the same topology as original panorama images.

### 2.2 Image Transfer on a Sphere

We then create a new panorama on a sphere by projecting original image using texture mapping in the procedure described below.

The sphere is modeled as a mesh on which vertices are arranged on a regular basis independent of deformed polygon mesh, and we create a panoramic view at the current location according to the following steps. For any vertex $x$ of the sphere mesh, we cast the ray $r$ passing by $x$ and the center of the sphere $C$. We next search for the intersection between the ray $r$ and a triangle $T$ belonging to the previously deformed polygon mesh, giving a new point $x'$. Then we calculate the barycentric coordinate of $x'$ in the specified triangle $T$. This gives us the relative position of the vertex $x$ projected onto the polygon mesh as illustrated in Figure 2.
To get (u, v) coordinate for $x$, we refer to one of the original panorama images called $P_{ref}$. We use the previously computed barycentric coordinate and retrieve the point $x'_{ref}$ inside the corresponding triangle $T$ of the polygon mesh of $P_{ref}$. The (u, v) value of $P_{ref}$ is used for $x$.
Repeating this process for every vertex of the sphere mesh allows creating a complete uv map. Finally, the standard rendering procedure with a camera located at the center of the sphere and in the direction of current view generates a new view for a given condition with predefined field of view.

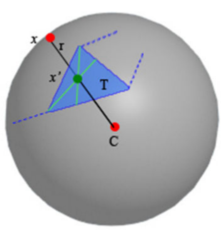


***Figure 2:*** *the ray r passing by the vertex x and by the center of the sphere C intersects the triangle T in x'. Then the barycentric coordinate of x' is computed (green lines). T is one triangle of the polygon mesh.*

## 3 Result and Future Work

We inspected the behavior of the prototype with four panorama images captured in a conference room. We can walk around the room with little stress as expected with frame rate being almost 60fps. We also observed some distortion in rendered image which becomes larger as view point go further away from the original location $P_{ref}$.

We have mainly two problems to be solved at this moment. The first one is the triangulation on original panorama images. Though we currently focused on real-time rendering for interactive walk-through and made triangle mesh on each original panorama image and correspondence between two of four panoramas manually, it is necessary to reduce labor for them from the view point of practicability. [Zhao et al. 2013] proposed the way to generate triangle meshes and correspondence automatically, while executing it completely without errors will be very difficult. Some assistance techniques for semi-automatic operation will be useful.

Another major problem is distortion on generated images. Currently we use only image data captured as panorama images with no geometry information. [Zhao et al. 2013] proposed estimation on three-dimensional location of feature points in real scene. In other words, it is trade-off between image-based method and geometry-based rendering from the view point of quality and efficiency. It is expected to reduce distortion without decreasing frame rate.

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