Panorama Space Modeling Method for Observing an Object

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Abstract. The conventional means of generating a panorama of an object entailed a significant limitation of having to implement a special photographing environment. This paper proposes a method for generating a panorama that allows the viewer to observe an object without having to construct a special photographing environment by geometrically modeling the photographing environment of the camera that observes the object. The Experiment and Evaluation section provides the result of using the proposed method to generate a panorama of a large object, which has not been feasible with conventional methods.

Keywords: Object Panorama, Panorama Space Modeling

1 Introduction

A background panorama provides substantial information and adequate environment that allow realistic observation of the background from the viewer's perspective. On the other hand, it only presents a very limited amount of information about a specific object within the virtual space:[1], [2]. The object panorama was devised to overcome this drawback. However, the same space modeling of the background panorama is used to model the space for object panorama, and the current level of object panorama merely involves capturing images while rotating the object and displaying the images in sequence. While this method allows easy generation of panorama for small models, it is difficult to implement a space for photographing large or highly valued objects such as pagodas and museum exhibits. Moreover, object panoramas cannot be created for object models that cannot be rotated.

In order to overcome the limitations of the current object panorama, this paper proposes a novel method for modeling the panorama space capable of providing detailed information in a general environment about the object regardless of its size, as well as a method for generating an object panorama based on the model.

2 Panorama Space Modeling Method for Observing an Object

In this chapter, the shape of the panorama space around the object is determined by taking into account camera's photographing environment. The geometric modeling process for applying the space to computer's virtual environment is also explained.

2.1 Determining the shape of the panorama space for observing an object

In general, panorama space modeling is closely associated with the photographing environment, including camera's position and the angle at which an object is viewed by the camera:[3], [4]. In the case of panorama's space model for observing the background, a simple panorama space of a cylinder or a sphere can be modeled by taking into account only the viewing angle because surrounding images are captured from camera's fixed position. Unlike a background panorama, modeling a panorama space model for observing an object requires incorporating the direction at which the object is viewed, in addition to the photographing angle from a fixed position.

Camera's geometric transformations under the photographing environment for observing an object can be divided into vertical rotation for viewing the object from a fixed position, and horizontal rotation with reference to the object. First, the image plane that captured the object is located in the focal distance of the camera. As shown in Fig. 1(a), consecutive vertical rotations at a fixed position allow the image plane to form a curvature, which is rotated from camera's position with reference to the x-z plane (Fig. 1(c)). Next, as shown in Fig. 1(b), horizontal rotation displacement is performed while maintaining the distance from the object, and the object is photographed through consecutive vertical rotations, creating a 3-D panorama space shown in Fig. 1(d).

2.2 Panorama space modeling

The panorama space shown in Fig. 1(d) is constructed as a set of circles with various radii according to the object center and the focal length of the camera, as shown in

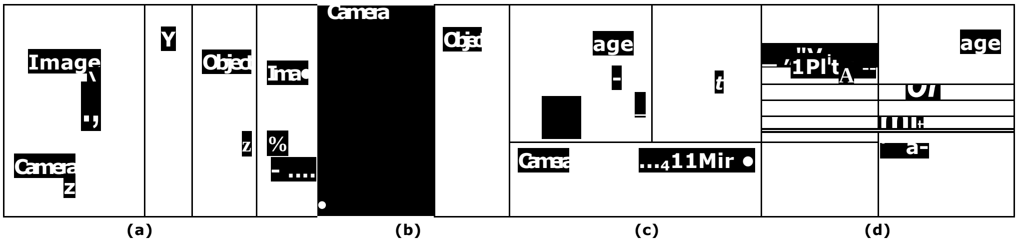


Fig. 1. Process of determining the shape of a panorama space for observing the object. (a) Vertical rotation transformation of the camera at a fixed position. (b) Horizontal rotation transformation of the camera around the object. (c) Consecutive vertical and horizontal rotation of the camera observing the object. (d) Determining the shape of the panorama space.

Fig. 2(a). The radius *(r)* of the bottommost circle inside the object can be determined by the planar width (I„,) of the image captured while viewing the object horizontally parallel to the ground. The radius of the circle inside the object, which varies according to the horizontal rotation of the camera at the fixed position, can be written using camera's focal length (F_e) as Equation (1):

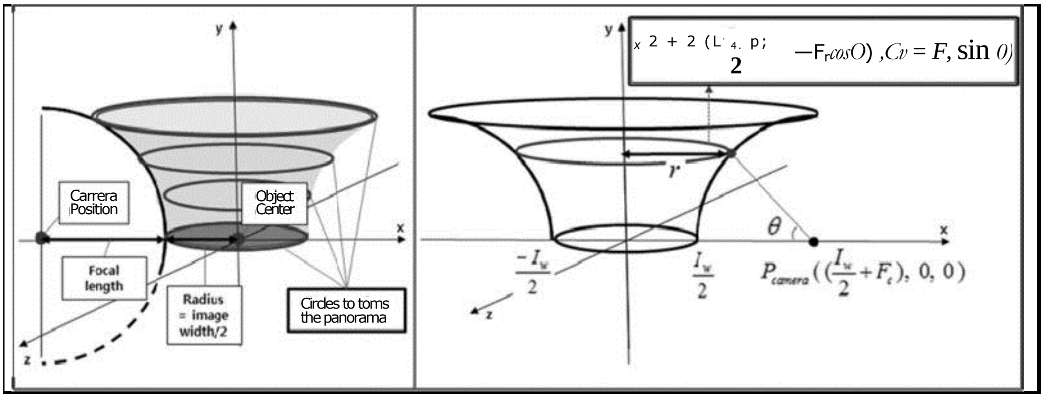
2.2 Panorama space **modeling**

The panorama space shown in Fig. 1(d) is constructed as a set of circles with various radii according to the object center and the focal length of the camera, as shown in Fig. 2(a). The radius *(r)* of the bottommost circle inside the object can be determined by the planar width (I_w) of the image captured while viewing the object horizontally parallel to the ground. The radius of the circle inside the object, which varies according to the horizontal rotation of the camera at the fixed position, can be written using camera's focal length (F_e) as Equation **(1):**

$$\begin{cases} r = F\cos\theta - F, \quad / 2 \; (0° \; \theta \; 90°), \\ r = 4/2 + F_c - F_c\cos\theta \; (90° \; 180°). \end{cases} \quad (1)$$

Since the vertical rotation angle photographing the object is between 0° and 90°, the panorama space can be modeled using Equations (1) and (2), as shown in Fig. 2(b). In Equation (2), x, y, and z indicate coordinates in the 3-dimensional space.

$$\begin{cases} y = F, \sin\theta \; (0° \; \theta \; 90°), \; x^2 + z^2 \\ = (F, \cos\theta - F, - I_w/2)^2 . \end{cases} \quad (2)$$



(a) **(b)**

Fig. 2. Panorama space modeling. (a) Panorama space constructed with a set of circles. (b) Geometric space modeling.

Therefore, a panorama image capable of observing the object can be generated by mapping the image of the object captured from vertical and horizontal rotations of the camera on to the panorama space model.

3 Experiment and Evaluation

In order to test the method proposed in this paper, we chose a large Korean cultural relic—the Cheonsusa Five-story Pagoda (approximately 5 m high)—panorama of which cannot be generated using the conventional method. A computer program was implemented based on C++ and OpenCV to observe the captured images in the virtual environment.

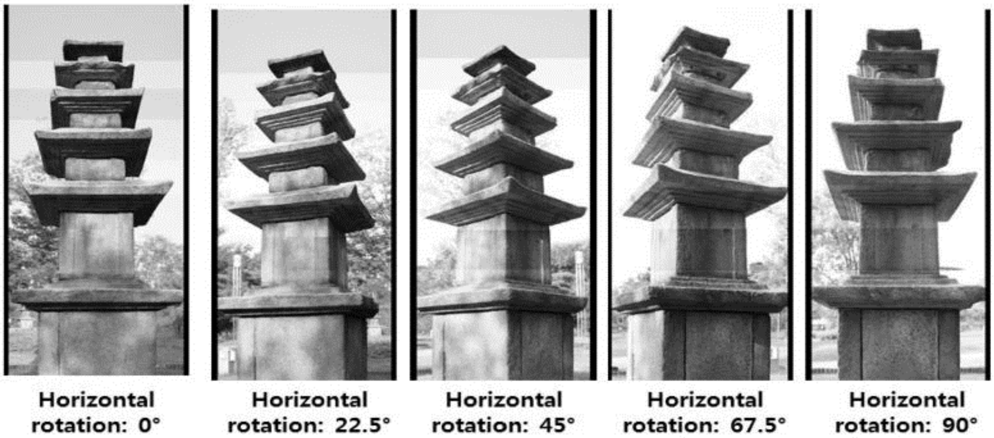


Fig. 3. Matching of images captured from horizontal and vertical rotations

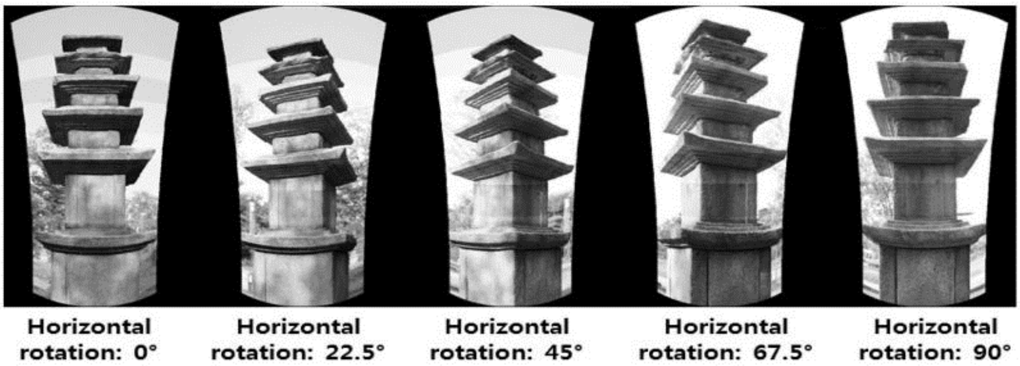


Fig. 4. Results of mapping matched images on to the panorama space

Fig. 3 displays the results of matching images captured while horizontally rotating and moving the camera by about 22.5° from 0° to 90° with reference to one side of the pagoda, and increasing the vertical rotation angle by about 5° at the displaced position. Fig. 4 displays the results of mapping the matched images on to the panorama space modeled using Equations (1) and (2). The radius (r) and the focal length(F,) required for modeling the panorama space were calculated using the image size and camera parameters:[5], [6], [7]. Fig. 5 shows the results of coinciding viewer's position with the camera position in the virtual environment to observe the generated panorama, and viewing the object.

Fig. 5(a), (b), (c), and (d) are sequential panorama images as the horizontal rotation angle is increased in 5° increments. Increasing the angle enhances the perspective, providing a realistic feeling of viewing the object upward from the front. In Fig. 5(e), (f), (g), (h), and (i) that correspond to the viewer rotating and shifting the position from 0° to 90° with reference to the object, detailed information about the object can be observed.

The conventional method for generating a panorama to view an object involved implementing a special photographing space adequate for the object's size, and capturing images while rotating the object within the space. However, this method severely restricted the diversity of the objet panorama due to the difficulty of constructing a photographing space according to the object's size. Using the method proposed in this paper, we were able to geometrically model camera's photographing environment with reference to a fixed object, and generated a panorama image that is not restricted by object's size and not confined to the photographing space.

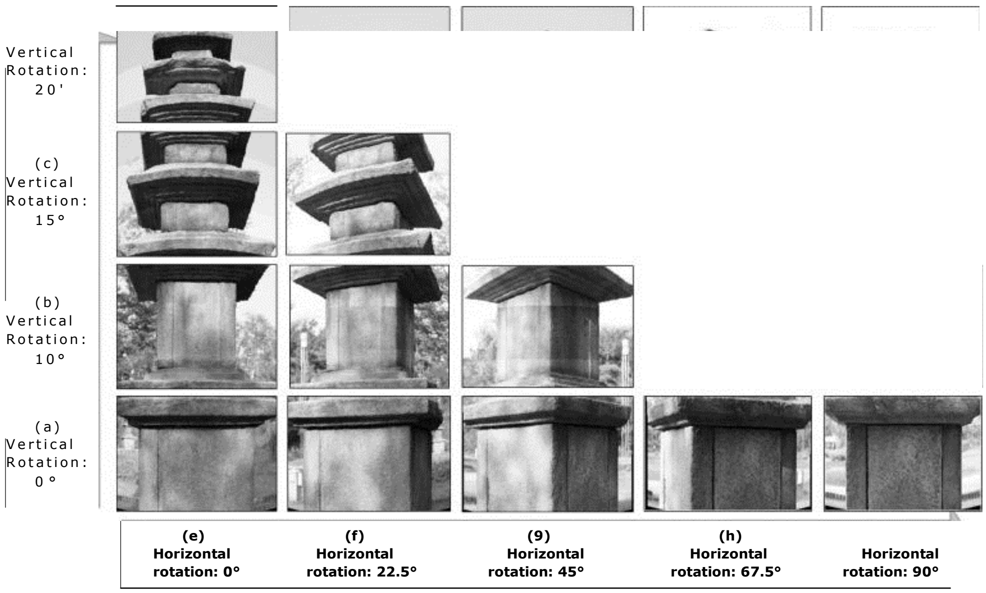


Fig. 5. Panorama image of the object

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