Virtual Reality Model of Koumokuten Generated from Measurement

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Abstract

Contents generation from measurement is an effective approach to automatic modeling of real world objects. In this paper, we present a system to create virtual reality model automatically from measurement of real object and present a virtual reality model of Koumokuten clay figure, which is a great treasure at Nara Toudaiji Temple, generated from the system. 3D geometric model of Koumokuten is generated from range image measured by range sensor and color images of it are acquired by digital camera. In the measurement digital camera is mounted on the range sensor and camera parameters between range image and color images are estimated from calibration techniques utilizing calibration box before data acquisition. We get textured model by mapping the images onto the 3D geometric model using the camera parameters estimated from the calibration. And we show several example applications of the virtual reality model of Koumokuten. By utilizing the virtual reality model we get different appearance of Koumokuten.

1 Introduction

Creating virtual reality model at present mostly depends on manual operation of trained operators. However, it takes great costs and time and there is a great demand for automation. Contents generation from measurement is an effective approach to automatic modeling of real world objects. There are several research on this topics for cultural heritages. Levoy *et al.* digitized works by Michelangelo[1]. The Great Buddha of Kamakura[2] and the Campanile of UC Berkeley campus[3] are also modeled.

In this paper, we present a system to create virtual reality model automatically from measurement of real object and show virtual reality model of Koumokuten clay figure, which is a great treasure at Nara Toudaiji Temple.

3D geometric model of Koumokuten is generated from range image measured by range sensor, and color images of it are acquired by digital camera. In the measurement, digital camera is mounted on the range sensor and camera parameters between range image and color images are estimated from calibration techniques utilizing calibration box before data acquisition. We get textured model by mapping the images onto the 3D geometric model using the camera parameters estimated from the calibration.

The remainder of this paper is organized as follows. Section 2 present the system of generating virtual reality model. We show a virtual reality model of Koumokuten generated from the system in Section 3. Finally, we conclude the paper in Section 4.

2 System

2.1 Data acquisition

We measure 3D geometry of an target object by range sensor. Because of occlusions and the range of the measurement of the sensor, we have to measure it from several point and get partial 3D geometry models. By sequence of the techniques of alignment and merging described in [2], we can get unified 3D geometric model from the partial models. In this system, we utilize Minolta VIVID910 for image acquisition. The accuracy of VIVID910 is higher than 1mm, and enough for precise geometry modeling of Koumokuten.

We measure color images of the target object by Nikon D1x. Although VIVID can produce the color images as well as the 3D geometry, we utilize digital camera to get high quality images. The resolution of acquired images is 3008 x 1960. We mount D1x on top of VIVID(fig.1), and acquire range image and color image at the same time.

Figure 1: Data acquisition setup.

2.2 Calibration

The relative position and direction between range sensor and digital camera is necessary to map the image of digital camera onto the 3D geometric model measured by range sensor. Several researches have been done to estimate the relationship automatically[4, 5, 6]. However, the calibration before scanning approach is the most effective method and we adopt this approach.

We mount the camera on the range sensor, estimate the camera parameters(calibration) and measure an object by moving the range sensor around the object. The relationship between augmented image coordinate($tildem$) on the image and 3D coordinate($\tilde{M}$) on 3D geometric model is described in the following equation on the pin-hole camera model.

$$\tilde{m} = A[\ R \quad t\ ]\tilde{M}\ , \tag{1}$$

where A, R, t are intrinsic matrix, Rotation matrix, and translation vector, respectively. by estimating these camera parameters, we can map the images onto 3D geometric model. The camera parameters between 3D geometric model measured by VIVID and images taken by D1x by is estimated by utilizing the calibration box shown in fig.2 in the following way. First we measure the calibration box by both VIVID and D1x.

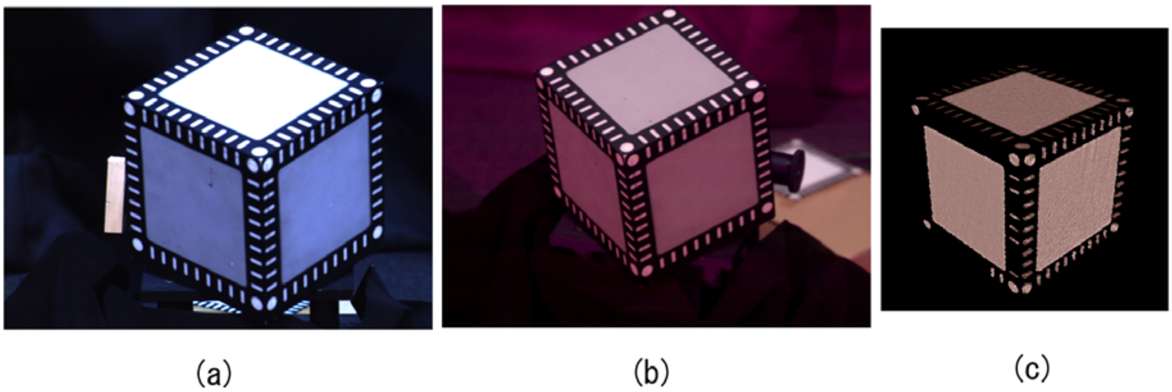

Figure 2: Calibration box:(a)color image by D1x, (b)color image by VIVID, (c)range image by VIVID

VIVID produces 3D geometry(fig.2(c)) and color image of the object(fig.2(b)) and the relationship between 3D geometry and image is known, that is, 3D coordinate of every pixel in image is known. On the other hand, D1x produces high quality color image (fig.2(a)). Second, we binarize the two images taken by VIVID and D1x, and make a virtual markers($*$ in fig.3), which are intersections of lines made by the elliptic markers along the edges of box. Because each pixel in the image taken by VIVID has 3D

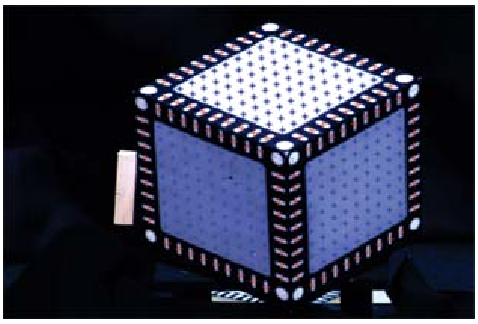

Figure 3: Extracted virtual calibration markers.

coordinate, from the virtual markers, we get pairs of image coordinate of image taken by D1x and corresponding 3D coordinate of geometric model measured by VIVID. By substituting these coordinates to equation(1), we get the camera parameters. By utilizing these parameters, we map the images taken by D1x onto 3D geometric model measured by VIVID.

By camera calibration we can map images onto 3D geometric model in geometrically correct positions. However, that is not sufficient to realistic modeling. Mapping images onto 3D geometric model results in color discontinuities between images in case that lighting conditions of each image acquisition are different.

We have to align colors between images. Though there are several researches about color alignment[6, 7, 8], we manually align colors for simplicity.

3 Results

We generated virtual reality model of Koumokuten, which is a National treasure at Nara, Toudaiji Temple. For the modeling of the virtual reality model 60 range images and color images were utilized. The unified 3D geometry model without texture are shown in fig.4.

Figure 4: 3D geometric model

By calculating the camera parameters between the D1x image and 3D geometric model measured by VIVID by utilizing calibration box, we got textured 3D geometric model and show it in fig.5.

Figure 5: Textured 3D geometric model

Once we get virtual reality model, we can utilize it for many applications. We show some examples below: Changing viewing point and illumination condition lead to different appearance of Koumokuten.

Viewing points are often restricted in case of real object. It is often the case we can not get close to a object because of barrier or we can not see the top of a object because we can not move it. However, we can view the model from arbitrary viewing points with virtual reality model(fig.6).

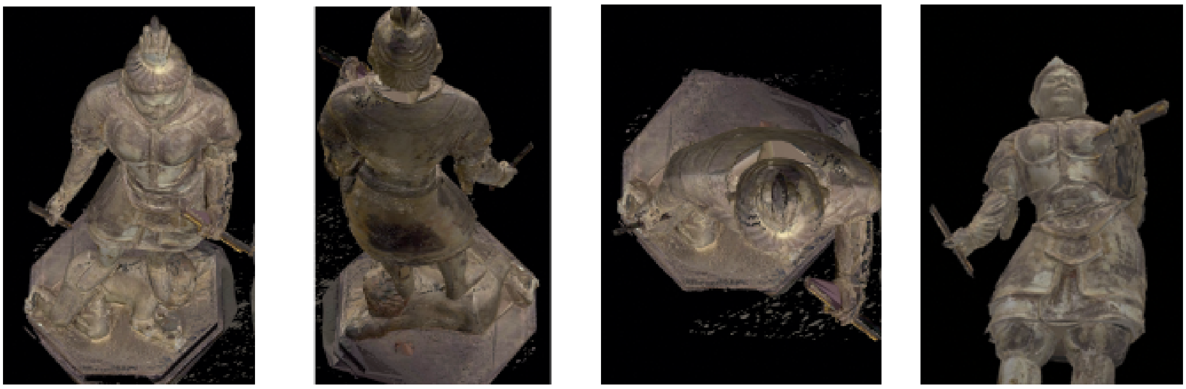

Figure 6: Changing viewing point.

And we can produce a cross section of the Koumokuten (fig.7). Because we have the precise 3D shape of Koumokuten, we can measure the dimension of Koumokuten and visualize it.

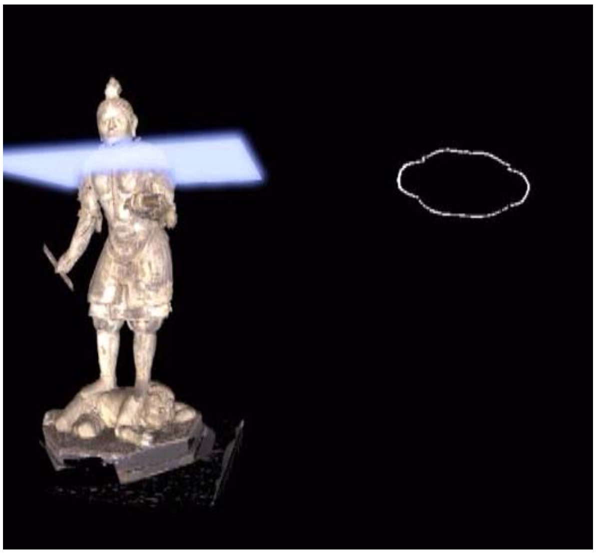

Figure 7: Cross section Image of Koumokuten

The other example is shown in fig.8. In this figure, we see Koumokuten under various illuminating conditions: sunrise, daylight, sunset. While we have to stay at Toudaiji Temple from sunrise to sunset to see how Koumokuten looks under different time of the day, we can see appearance change of Koumokuten very shortly with the virtual reality model.

The final example focuses on the expression of Koumokuten. We can see that the expression looks greatly different under different lighting conditions.

4 Conclusion

we presented a system to create virtual reality model automatically from measurement of real object and show virtual reality model of Koumokuten clay figure, which is a

Figure 8: Illumination change: sunrise, daylight, sunset (from left to right)

Figure 9: Expressions of Koumokuten face

great treasure at Nara Toudaiji Temple. 3D geometric model of Koumokuten is generated from range image measured by range sensor and color images of it are acquired by digital camera. In the measurement digital camera is mounted on the range sensor and camera parameters between range image and color images are estimated from calibration techniques utilizing calibration box before data acquisition. We get textured model by mapping the images onto the 3D geometric model using the camera parameters estimated from the calibration. And we showed several example applications of virtual reality model of Koumokuten. By utilizing virtual reality model we get different appearance of Koumokuten.

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