Displacement measurement with phosphorescent spherical marker

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Abstract

Measuring three-dimensional positions with images has an advantage of simultaneous and contactless measurements of multiple points in a view. One of the most useful applications of image measurements is the motion capture system that can measure a change of pose of a target object in three-dimensional space. Motion capture systems can be used for easy calibration of machine tools and parallel mechanisms if its total accuracy is improved.

We have proposed phosphorescent spherical markers as optical markers for precise image measurements. The phosphorescent spherical markers can be detected in a captured image with milli-pixel precision which is about 10 times higher precision of retro-reflective markers conventionally used in motion capture systems. The milli-pixel detection is induced by two important features of phosphorescent spherical markers: (1) high sphericity, (2) high contrast between the marker and background.

In this paper, we report displacement measurement with two phosphorescent spherical markers. One of these markers was fixed on a vibration isolation table. The other marker was installed on a linear stage and moved 10 mm for displacement measurement. The initial distance between these markers was 100 mm. These markers were excited by two ultraviolet lights and captured by a camera right after switching off the lights. The shooting distance was 500 mm. The three-dimensional positions of these markers were calculated from the detected marker position and diameter in the captured image. The displacement amount of the moving marker was calculated as a change of three-dimensional relative position of the moving marker against the fixed one. The displacement of the moving marker was measured 150 times for evaluating its total accuracy. The precision and total accuracy of this displacement measurement were 0.88 µm in standard deviation and 1.03 µm in RMSE respectively.

1 Introduction

Image measurement of three-dimensional positions has an advantage of simultaneous and contactless measurements of multiple points in a view. In general, the relative precision of image measurement is from 10^{-4} to 10^{-5} [1], which means that the measurement precision corresponding to measurement range of 1 m is from 100 μm to 10 μm.

We have proposed phosphorescent spherical marker for precise image measurements [2]. The phosphorescent spherical marker can be detected with milli-pixel precision in a captured image, which corresponds to relative precision of 10^{-6}. In this paper, we apply the phosphorescent spherical marker to displacement measurement.

2 Phosphorescent spherical marker

A phosphorescent spherical marker is one of the optical markers for precise image measurements. This marker has two important features for high-precision detection: (1) high sphericity, (2) high contrast between the marker and background. These features lead to precise marker detection by fitting a circle to edge points on the marker contour. The relative precision of this marker was reported as 1.1 x 10^{-6} and 1.7 x 10^{-6} in horizontal and vertical directions respectively [2].

3 Displacement measurement with two phosphorescent spherical markers

To evaluate precision and total accuracy of displacement measurement with phosphorescent spherical marker, the change of three-dimensional distance between two markers was measured with image processing.

Figure 1 shows the experimental setup for displacement measurement. One of two phosphorescent spherical markers was fixed on a vibration isolation table. The other marker was installed on a linear stage and moved 10 mm for

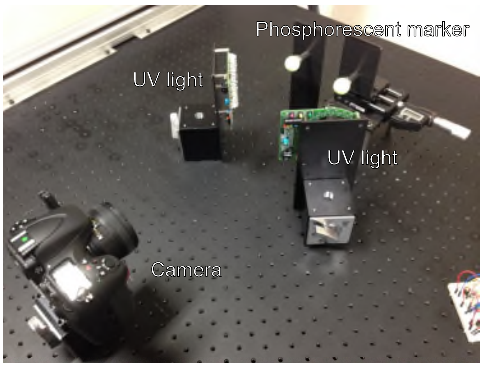

Figure 1: Experimental setup

displacement measurement. The initial distance between these markers was 100 mm. These markers were excited by two ultraviolet lights and captured by a camera right after switching off the lights. The shooting distance was 500 mm. The camera was Nikon D800E which resolution was 7360 x 4912 pixels. The lens installed in the camera was AF-S NIKKOR 50mm f/1.8G.

Figure 2 shows an example of captured images. These markers were detected in the captured image by fitting a circle to edge points detected by [3]. The three-dimensional positions of these markers were calculated from their detected center and diameter based on geometry. Displacement of the moving marker was measured as the change of three-dimensional distance between two markers. This displacement measurement was repeated 150 times for evaluating its precision and total accuracy.

Figure 3 shows the error of displacement measurement. The precision and total accuracy of this displacement measurement were 0.88 µm in standard deviation and 1.03 µm in RMSE respectively.

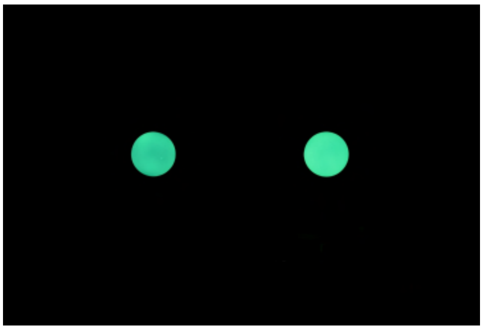

Figure 2: Example of captured image

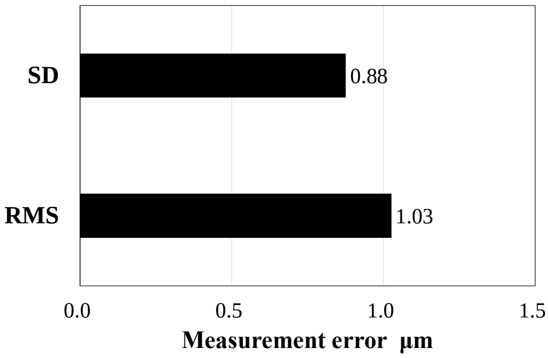

Figure 3: Precision and total accuracy of displacement measurement

4 Conclusion

We evaluated precision and total accuracy of measuring 10 mm displacement with phosphorescent spherical markers. The future work is to expand the range of displacement measurement.

Acknowledgment

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