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Marker detection in blurred images for high-precision measurement

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Abstract
In this paper, we propose a method to detect markers in blurred images with high precision. An image blur decreases contrast between a marker and background. This leads to an increase of uncertainty of the marker position. The proposed method reduces the increase of uncertainty of detecting marker position with an increase of image blur. The proposed method estimates degrees of image blur by analysing intensity distribution of the marker contour. The estimated degrees of image blur are used for controlling the window size of edge detection on the marker contour. This adaptive control makes edge detection in blur images precisely. The proposed method of marker detection with the adaptive control minimizes the effect of image blur on precision of the detected marker position. In focused images, fluorescent spherical markers were detected with precision of 1.7 x 10^{-3} pixels. In images blurred with 19 pixels, fluorescent spherical markers were detected with precision of 2.5 x 10^{-3} pixels with the proposed method, in contrast, with precision of 11 x 10^{-3} pixels with a conventional detection method. In images blurred with 27 pixels, fluorescent spherical markers were detected with precision of 4.0 x 10^{-3} pixels with the proposed method, in contrast, with precision of 25 x 10^{-3} pixels with a conventional detection method. These results show the effectiveness of the proposed method on precise marker detection in blurred images.

Precise Detection, Blurred Image, Fluorescence, Spherical Marker

1. Introduction

The relative precision of motion capture systems, one of the most successful applications of image measurement, is about from 10^{-4} to 10^{-5} [1]. Retroreflective spherical markers are generally used in the motion capture system and detected with weighted centroid method. Precision of the marker detection is about from 0.05 pixels to 0.02 pixels [1, 2].

Fluorescent and phosphorescent spherical markers can be detected more precisely than retroreflective ones with edge-based detection method [3, 4]. Precision of Fluorescent and phosphorescent spherical markers is about 0.001 pixels, which is milli-pixel detection. These markers have a possibility of applying image measurements to measuring motion of precision mechanical systems.

An image blur decreases contrast between a marker and background. This leads to an increase of uncertainty of edge and marker detection. In this paper, we propose a method to detect fluorescent and phosphorescent spherical markers in blurred images with high precision. In the proposed method, window size of edge detection [5] is controlled adaptively toward degrees of image blur.

2. Marker detection adaptive to image blur

As shown in Figure 1, the size of search window for edge detection is fixed in conventional marker detection algorithms [3, 4]. In blurred images, intensity change around image edge spreads wider than in focused images. The search window of fixed size cannot contain whole change of intensity around blurred image edge, which leads to increase uncertainty of detected edge position.

In this paper, we propose an algorithm to control window size adaptive to blur width as shown in Figure 2. Search window of blur width size can contain whole change of intensity around image edge. Degrees of image blur are estimated by fitting intensity distribution generated from the Gaussian blur model [6] to observed intensity change. Marker positions are detected by fitting a circle to edge points on the marker contour detected by [5] with the adaptive window size.

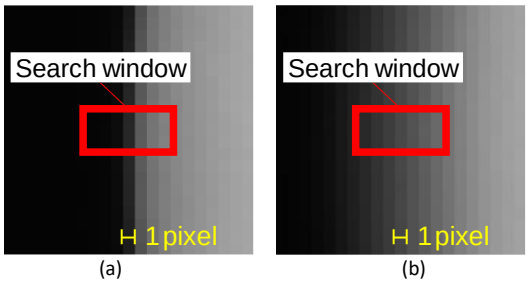

Figure 1. Fixed size of search window for edge detection: (a) appropriate window size in focused image, (b) inappropriate window size in blurred image

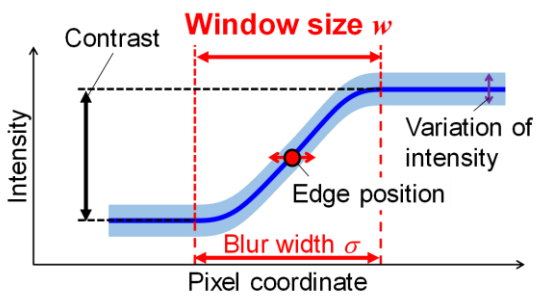

Figure 2. Adaptive control of window size to be equal to estimated blur width

3. Simulation of marker detection in blurred images

Precision of marker detection was evaluated with simulated blurred images and quantified as standard deviation of detected marker positions.

Figure 3 shows examples of simulated images. Image size was 531 x 531 pixels. The marker diameter was 330 pixels. Intensities of the marker and background were 180 and 3 respectively. Blurred images were simulated with the Gaussian blur model [6], and degrees of image blur were from 1 to 31 pixels. Shot noise [7] was added to each blurred image, and 10000 images were generated.

3.1. Relationship between image blur and window size for edge detection

Precision of marker detection in the blurred images was evaluated with various size of search window from 7 to 51 pixels.

Figure 4 shows the result of relationship between precision of marker detection and window size. As seen in this figure, smallest variation of detected position in each image blur was obtained when the window size to be equal to degrees of image blur, which is indicated by filled circle.

These results show that the best window size is degrees of image blur.

3.2. Precision of marker detection with adaptive search window

Figure 5 shows comparison of precision of detecting marker between adaptive and fixed window size. This figure was obtained by rearranging data in Figure 4 with focusing on the proposed and conventional methods. In the conventional method, the window size was 7 pixels [3, 4]. Figure 6 shows the reduction rate of variation of detecting marker in blurred images by the proposed method toward the conventional one.

These figures show that the proposed method of adaptive search window can detect markers in blurred images more precisely than the conventional method of fixed search window. The standard deviation of detected marker positions was less than 0.005 pixels even if there was 31-pixel image blur.

4. Conclusion

This paper proposes an algorithm to detect marker position precisely in blurred images with adaptive search window. The proposed method reduced variation of detecting marker position about 90% by comparing to conventional one when image blur was 31 pixels.

Acknowledgment

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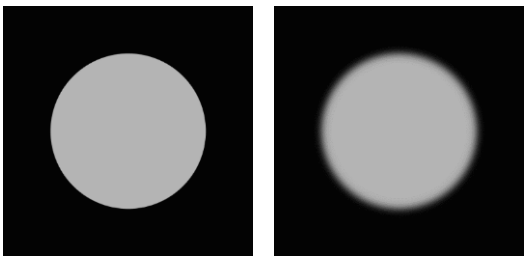

(a) (b)

Figure 3. Simulated images of marker to detect: (a) focused image, (b) blurred image

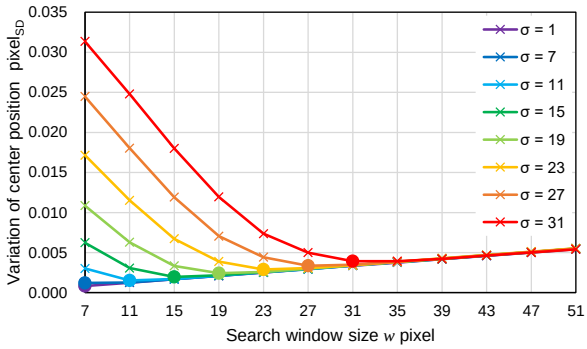

Figure 4. Precision of marker detection with adaptive edge detection when changing degree of image blur

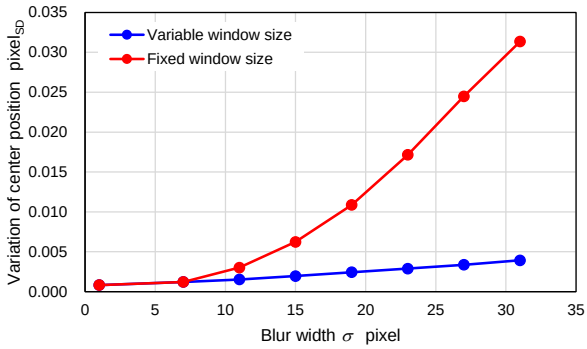

Figure 5. Precision of marker detection comparing between variable and fixed window size algorithms when changing degree of image blur

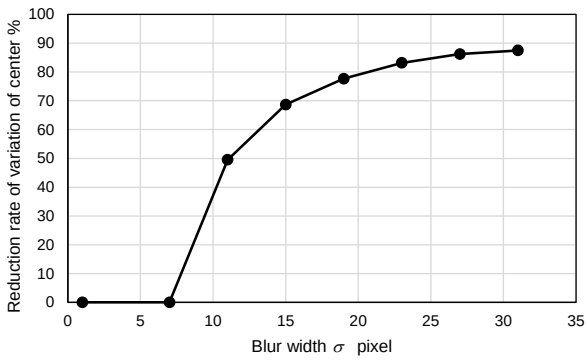

Figure 6. Reduction rate of marker detection uncertainty with the proposed method of variable window size by comparing with conventional one of fixed window size