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A Technique to Improve Shadow Areas for an Intelligent Facility-Surveillance System

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Abstract

Owing to recent developments in surveillance-system technology, there is growing interest in the construction of intelligent surveillance systems aimed at public facility management. Intelligent surveillance systems detect abnormal phenomena through monitoring by managers, and require further intelligent analysis of pictures. Such systems may have difficulty analyzing pictures that contain certain barrier elements. Therefore, preprocessing technology is necessary to improve these barrier elements before analysis of the pictures. Barrier elements in surveillance systems aimed at facility management include the unexpected appearance of obstacles or areas of shadow within the facility. Existing research on shadow areas does not make good use of any prior information that the intelligent surveillance system might have. It is mainly concerned with aerial photograph and therefore has limited application to facility management. Accordingly, this study proposes a technique that is suitable for application to facility-surveillance systems to predict and improve shadow areas in picture data. Further, this study examines the effectiveness of the proposed technique by means of an experiment.

Keywords: *Image processing, Shadow Area Improvement*

1. Introduction

In most modern societies, there is growing demand for surveillance systems for crime prevention, facility safety, and traffic enforcement. The demand for closed-circuit television (CCTV) that obtains the picture data from surveillance systems is also on the rise. Looking at the status of CCTV installation in Korean public institutions over the past five years, CCTVs installed for facility management account for the largest portion [1]. In the case of passive facility-surveillance systems that conduct surveillance with the naked eye, the degree of analyzing pictures differs according to the way the system is managed, and long-term surveillance is limited. Accordingly, attention is being directed towards intelligent surveillance-system technologies that can save on human-resource costs in the long term and that have continuous picture-analysis capabilities [2]. Such intelligent surveillance systems may generate erroneous results in cases where there are elements in the picture data that obstruct the analysis. Therefore, an intelligent surveillance system needs a form of pre-processing that improves the recorded picture data in advance. Impeding elements that may occur in an intelligent surveillance system aimed at facility management include the appearance of obstacles and areas of shadow within the facility. In the present case, it is the impediment by shadow areas that is of particular interest in the context of intelligent surveillance systems. The characteristics of an intelligent surveillance system are that it has pre-existing information about the facility (a

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main concern here due to the traits of the system), as well as date and time information, and the cameras that are necessary to estimate the shadow areas. However, existing research aimed at improving shadow areas in picture data is concerned mainly with wide-ranging aerial photographs, and has limited application to intelligent facility-surveillance systems. In addition, the existing research does not make sufficient use of the pre-existing information that facility-surveillance systems have. Accordingly, this paper proposes techniques in Section 3 to detect and improve areas of shade that may be applied to facility-surveillance systems. In Section 4, an experiment is described which was conducted using the picture data obtained from actual facilities in order to validate the results of the proposed technique. An environment with specific structures as objects was then constructed to verify the picture-improvement rate according to the threshold value used in the proposed technique. Finally, we draw conclusions in Section 5 and suggest possible directions for future research.

2. Related Work

Research to improve shadow areas is divided largely into a method based on overall image improvement, and one to detect and improve specific shadow areas [3−6]. The former method does not have a stage of extracting shadow areas, and therefore it has the advantage that more complex stages are unnecessary. However, non-shadow areas are also processed in the overall image, and therefore the inclusion of non-shadow areas may significantly influence the results. On the other hand, detecting and improving specific shadow areas can minimize the distortion of image data resulting from processing the entire picture. However, complex calculations are required to detect shadow areas, and there is a possibility of errors occurring at this stage. These can result in unnatural image effects, and an additional compensation stage may be needed, thus increasing the calculation complexity.

Representative methods for detecting specific shadow areas include expanding the shadow areas, using image classification, and tracking light sources. The method of expanding the shadow areas involves assigning seeds to pixels in the picture in a constant manner. Area expansion is conducted based on the seeds, in order to create neighboring pixels with similar brightness, texture or colors. A process to determine whether an area is a shadow is then performed with reference to a threshold value. Dynamic threshold values are needed here to identify shadow areas, and this has the disadvantage that the results differ according to the area characteristics and the initial location of the seeds. This method has the advantage of fast processing time and relatively high precision, but it has the disadvantage that precise shadow-area extraction is comparatively difficult. The final method of light-source tracking is one that utilizes the sun’s altitude, which is the fundamental mechanism of shade generation. The directional vector of the sun can be determined, and the method is very precise in estimating shade.

Among the various methods for detecting specific shadow areas, a good one to use in an intelligent facility-surveillance system is that of light-source tracking. An intelligent surveillance system already has the information about facility layout, camera locations, time, date, etc. Therefore, it has all the information necessary for light-source tracking, and as a result it is relatively easy to detect shadow areas using this method. However, the existing methods for shadow-area detection with light-source tracking are concerned mainly with aerial photographs, and therefore have limited application to intelligent facility-surveillance systems.

Therefore, this paper proposes a method for improving shadow areas that is applicable to facility-surveillance systems. The proposed method calculates the actual shadow areas of a facility through light-source tracking, then matches these to pictures, and finally produces an image that is suited to an intelligent facility-surveillance system. In addition, the shadow areas that are matched to pictures are compared with non-shadow areas, making it possible to further improve the former.

3. An Improvement Scheme for Shadow Areas

This chapter explains how to improve shadow areas for the intelligent facility-surveillance system proposed in this paper. The proposed method is applied as shown schematically in Figure 1. Firstly, the picture data obtained by a surveillance-system camera are used as the input, and the process of detecting shadow areas is initiated. In the parameter-input stage, temporal information (e.g., system year, month, day, hours, minutes, seconds), spatial information (e.g., facility height, longitude, latitude, azimuth), and camera information (e.g., focal distance, tilt angle, camera height) are entered. In the stage of light-source location, the temporal and physical information among the earlier input parameters is applied to the PSA algorithm and the solar direction vector is estimated [7]. In the stage of shadow-area calculation, a linear equation is utilized to project the directional vector of the light source on the structure of the facilities to calculate the actual shadow areas. In the shadow-area matching stage, the previously derived three-dimensional coordinates of the actual shadow area are matched to two-dimensional coordinates using camera calibration [8]. These two-dimensional coordinates are matched to the picture data to form shadow-area masks. The coordinates within the picture other than those of the detected shadow areas are then formed into non-shadow-area masks, thus completing the shadow-area-detection stage.

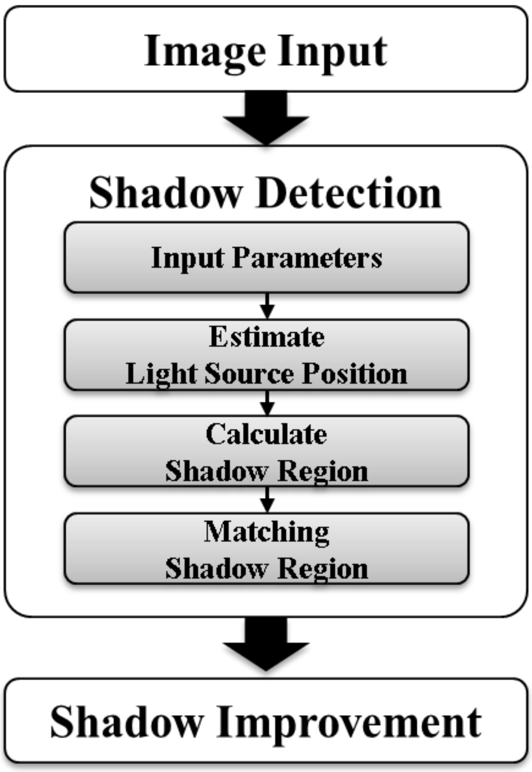

Figure 1. Proposed Process Flowchart

After this process, the stage for shadow-area improvement is initiated, aimed at enhancing the detected shadow areas. In this stage, shadow areas are improved by comparing the histograms of shadow and non-shadow areas. These histograms are derived using the shadow-area and non-shadow-area masks obtained in the shadow-area-detection stage. Compared to the red, green and blue (RGB) model that is generally utilized, the HSV model expresses colors in the three components of hue, saturation and value, and therefore intuitive understanding in the human visual system is possible. Accordingly, histograms are derived in the shadow-area-improvement stage based on HSV models, and only the brightness histogram is used to improve shadow areas, except for the colors of the facilities. However, when brightness values with insignificant frequency are considered in the derived histograms, those with little influence can still affect the histogram adjustment, with minimal corresponding improvement in the shadow areas. Accordingly, this paper established the minimum percentage a (as shown in formula 1) and derived the *totalSum* threshold, corresponding to the total number of pixels in each area. Only those cases where the histogram frequency *histbin(i)* of the brightness value within the picture data was greater than or equal to the threshold were then considered in deriving the minimum and maximum brightness values ($minV$ and $maxV$, respectively) among those with influence in each area.

$$threshold = totalSum \times a$$
$$minV = \min_{0 \le i \le 255}(\{i | histbin(i) \ge threshold\})$$
$$maxV = \max_{0 \le i \le 255}(\{i | histbin(i) \ge threshold\}) \quad (1)$$

Next, when the current pixel *p* of the picture is within a shadow area, the histogram is adjusted based on the shadow and non-shadow areas (SA and nSA, respectively) derived earlier, and the $minV$ and $maxV$ values of the non-shadow areas. A shadow area is darker than a non-shadow area, and therefore, on average, the former has lower brightness values. In order to improve such shadow areas, they should be able to have higher brightness values. Therefore, in the method proposed in this paper, as shown in formula 2, the brightness value of *p* (*p.Value*) is adjusted to equalize a shadow-area histogram to be close to that of a non-shadow area.

$$p.Vvalue = n\mathrm{SA.minV} + \left(\left(\frac{p.Vvalue - SA.minV}{SA.maxV - SA.minV}\right) \times (nSA.maxV - nSA.minV)\right) \quad (2)$$

Figure 2 shows the overall process of the improvement stage for shadow areas.

4. Experiment

This chapter reports experiments that were carried out based on the picture data in Figure 3. We photographed the Business Incubation Center of Kyonggi University in order to examine the results of applying the proposed techniques. However, experiments with an actual facility involve a relatively large area, and it is difficult to determine whether such experiments are precise. Therefore, in order to calculate the errors and the degree of improvement of an estimated shadow area, a topographical grid environment was formed, giving the picture data of Figure 4 by arranging structural models in the topographical environment. In Section 4.1, we describe an experiment that was conducted to examine the errors occurring in the process of calculating shadow areas in the shadow-area-detection stage. In Section 4.2, the results of applying the proposed technique are checked. In addition, we experimented with the shadow-area-improvement rate according to the threshold values used in the proposed technique.

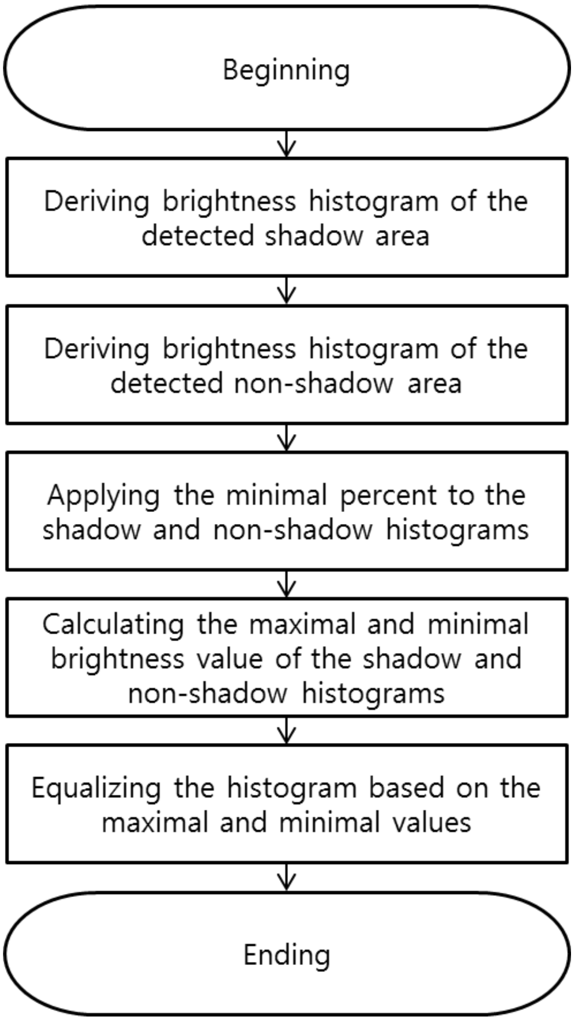

Figure 2. Shadow-Improvement Step Flowchart

Figure 3. Experimental Building Image

Figure 4. Experimental Fixed-Structure Image

4.1. An Experiment to Detect Shadow Areas

In this section, we describe an experiment that was conducted in order to verify the degree of error occurring while calculating shadow areas in the shadow-area-detection stage (see Figure 5). In the stage where the light-source location is estimated, the time-dependent solar direction vector was calculated in order to determine the coordinates of P_n, the shadow point on the topographical grid that is projected from the point P on the upper surface of the structure. In addition, for the quantitative analysis of errors as shown in Table 1, a comparison was made between the predicted line P_bP_n (based on the point P_b where point P is projected perpendicularly onto the ground) and the line $\overline{P_bP_n}$ measured in the actual topographic environment. The result was a maximum error rate of approximately 4%.

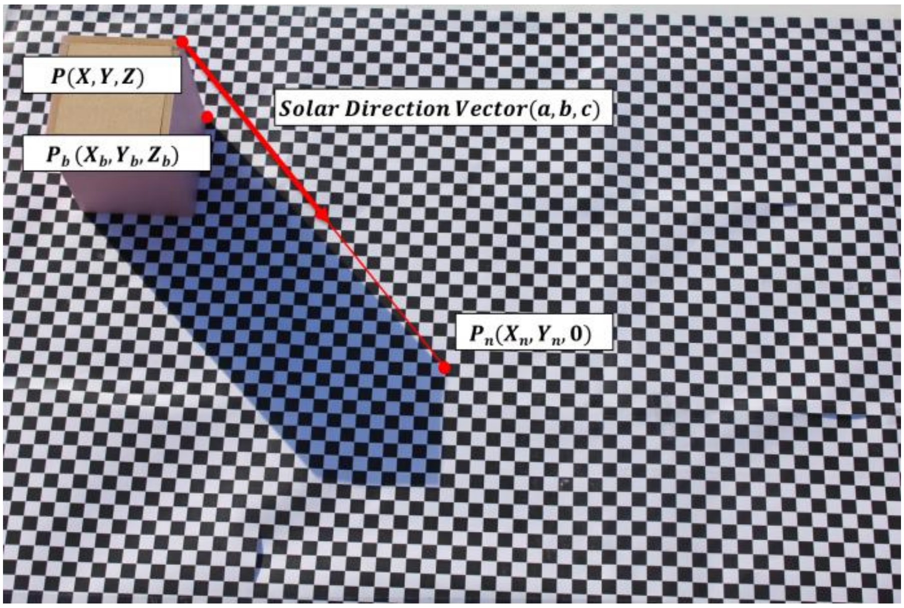

Figure 5. Shadow-Area Calculation Experiment

Table 1. Error Rate of Shadow-Area Calculation

P_n	Time	Predicted Length of $\overline{P_b P_n}$(cm)	Predicted Length of $\overline{P_b P_n}$(cm)	Error Rate (%)
P_1	PM 3:10:28	27.9	27.09	2.99
P_2	PM 3:15:20	28.77	28.02	2.68
P_3	PM 3:20:30	29.77	28.74	3.59
P_4	PM 3:25:58	30.93	29.84	3.66
P_5	PM 3:30:12	31.91	30.73	3.83

4.2. An Experiment to Improve Shadow Areas

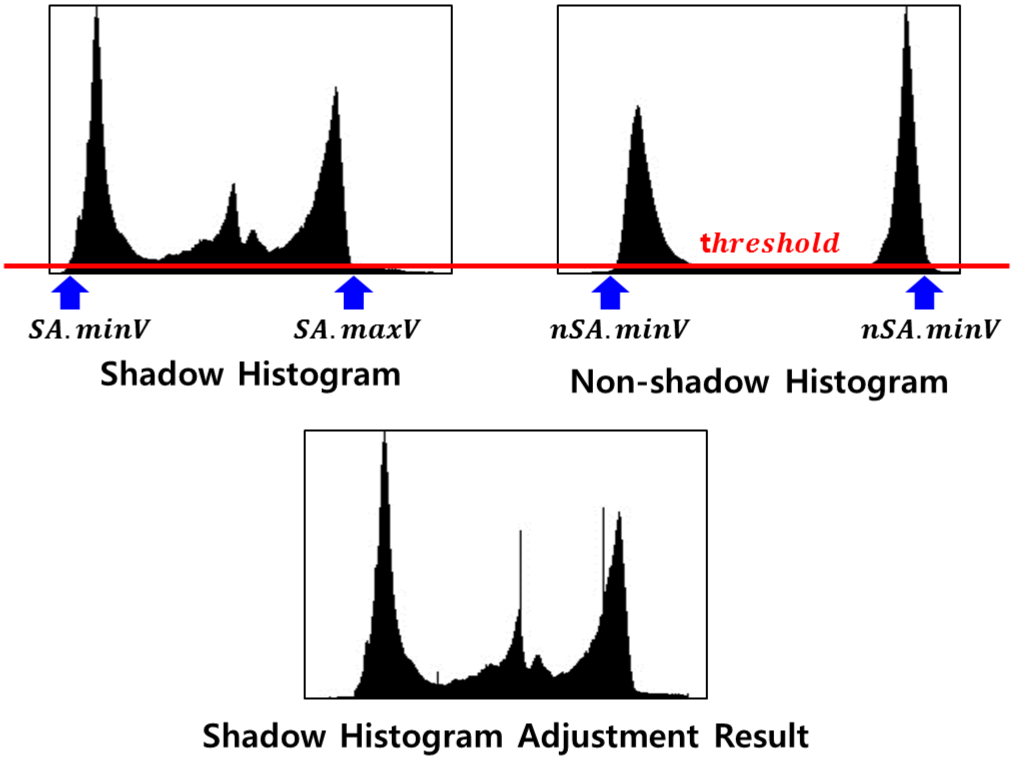

Figure 6. Histogram Adjustment for Shadow Improvement

This section shows the experimental verification of the results of improving shadow areas through the technique proposed in this paper. The proposed technique calculates the minimum and maximum values of the shadow-area and non-shadow-area brightness histograms in the shadow-area-improvement stage. Then, as shown in Figure 6, the non-shadow-area brightness histogram is adjusted and improved by means of the threshold value while applying the minimum percentage *a*. Figure 7 illustrates the result of applying this process to the picture data of the Kyonggi University Business Incubation Center.

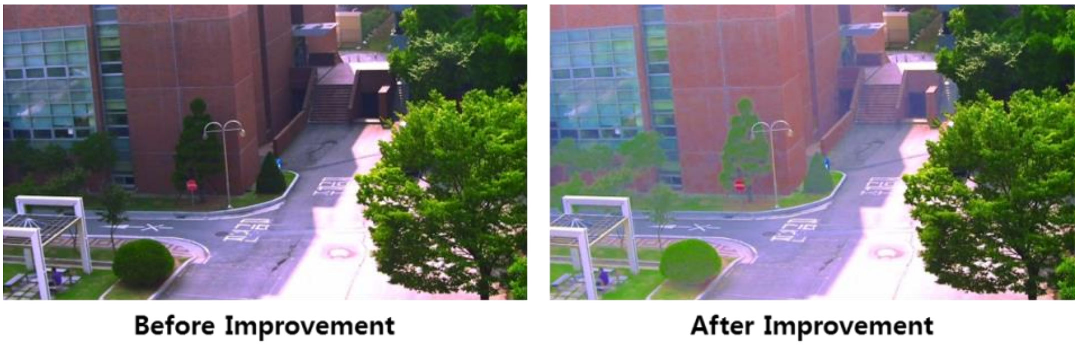

Figure 7. A Result of Shadow-Area Improvement

However, a threshold value applying the minimum percentage *a* is used in the proposed technique, and therefore the improvement result may differ according to the value of *a*. In order to check the dependence of the improvement result on the threshold value, an experiment was conducted with the geometrical structure as the object and the minimum percentage *a* set at 0%, 0.01%, 0.1% and 1%. With *a* = 0%, as shown in Figure 8, a histogram with an average brightness value of 103 was adjusted to one with an average brightness of 115. With *a* = 0.01%, there was an improvement to a histogram with an average brightness of 123. With *a* = 0.1%, there was the greatest improvement in the average brightness value to a value of 138, as shown in Figure 10. Lastly, with *a* = 1%, the average brightness value was improved to 133, as shown in Figure 11.

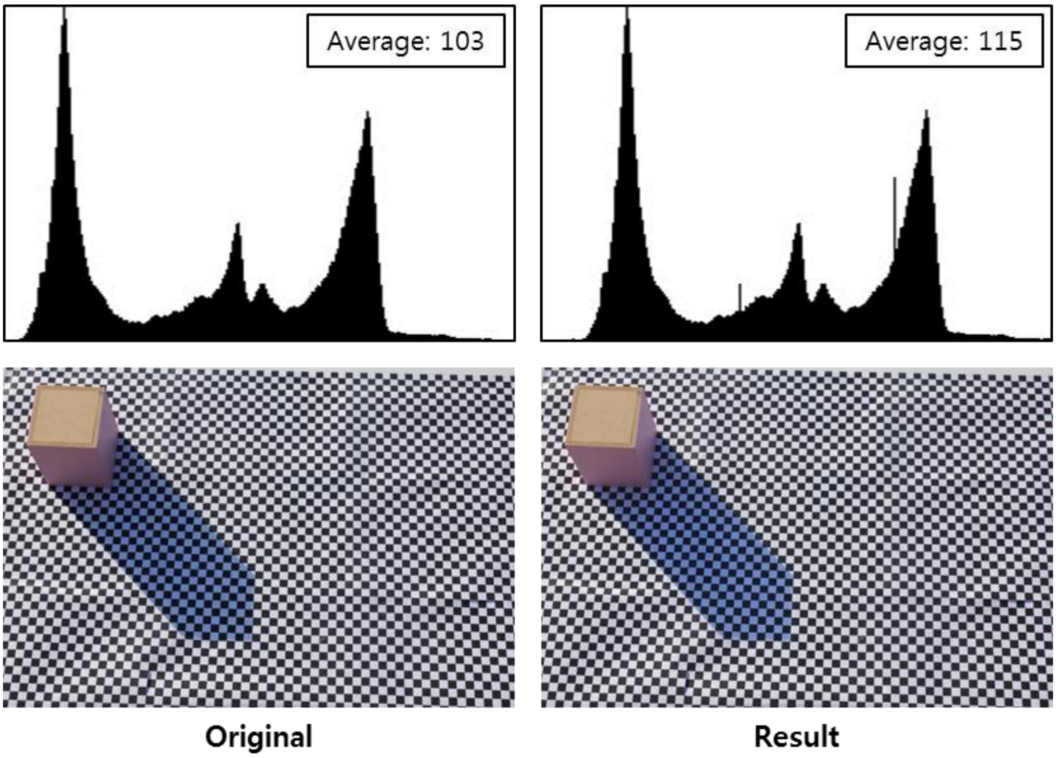

Figure 8. The Result of Applying *a* = 0%

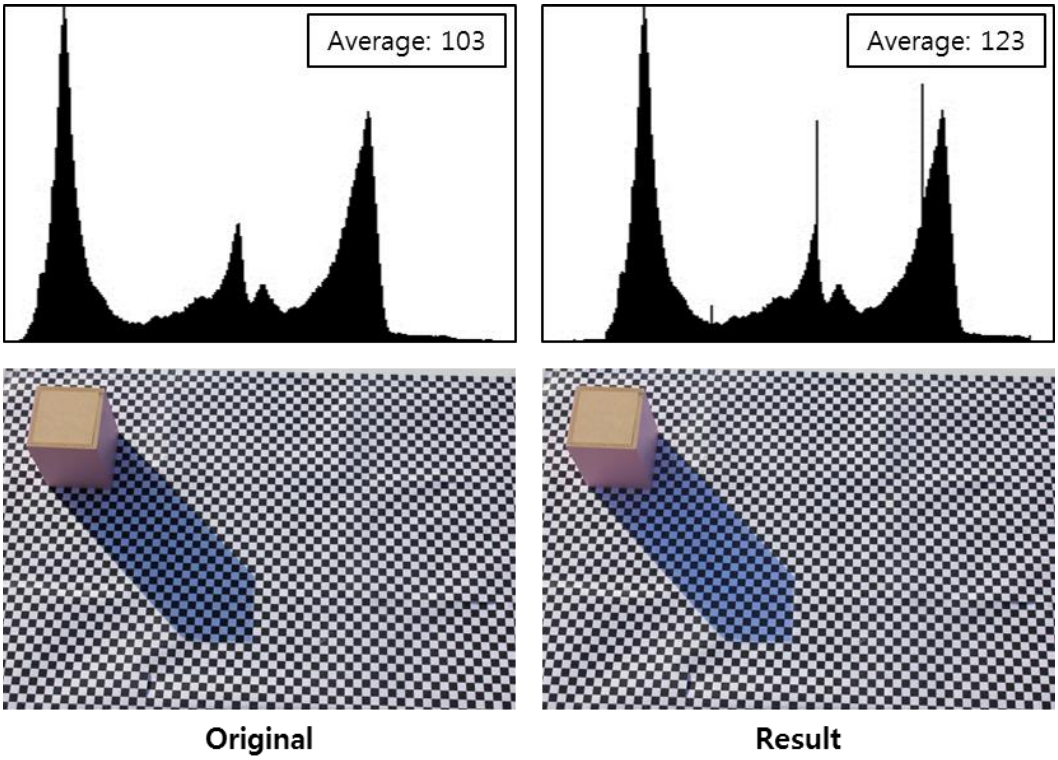

Figure 9. The Result of Applying *a* = 0.01%

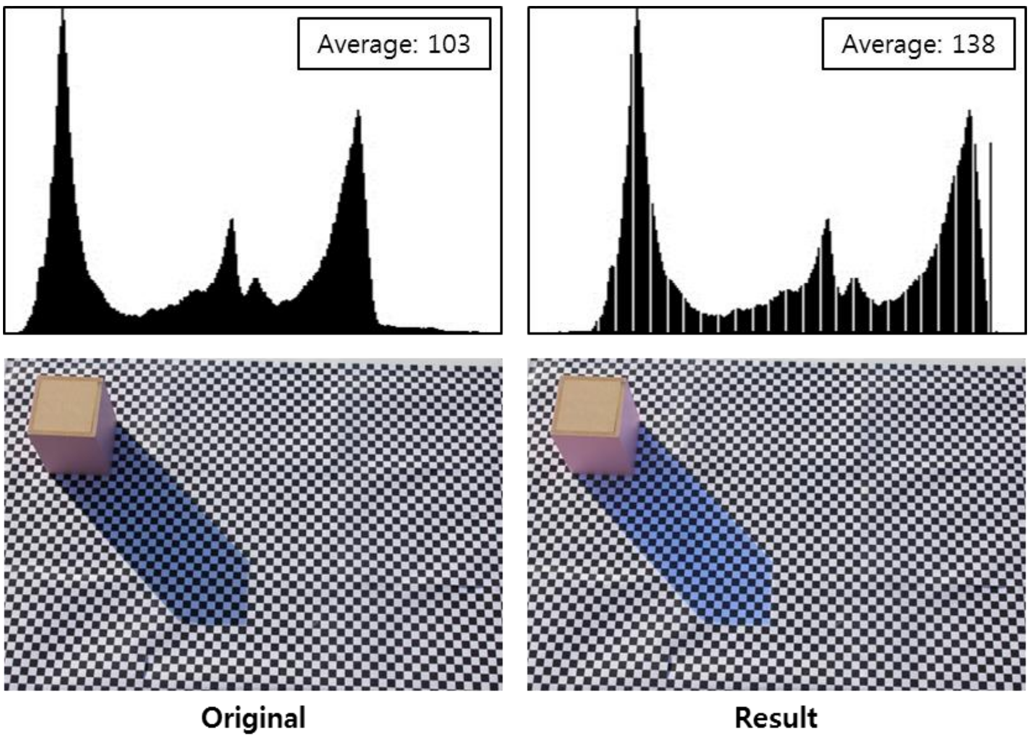

Figure 10. The Result of Applying *a* = 0.1%

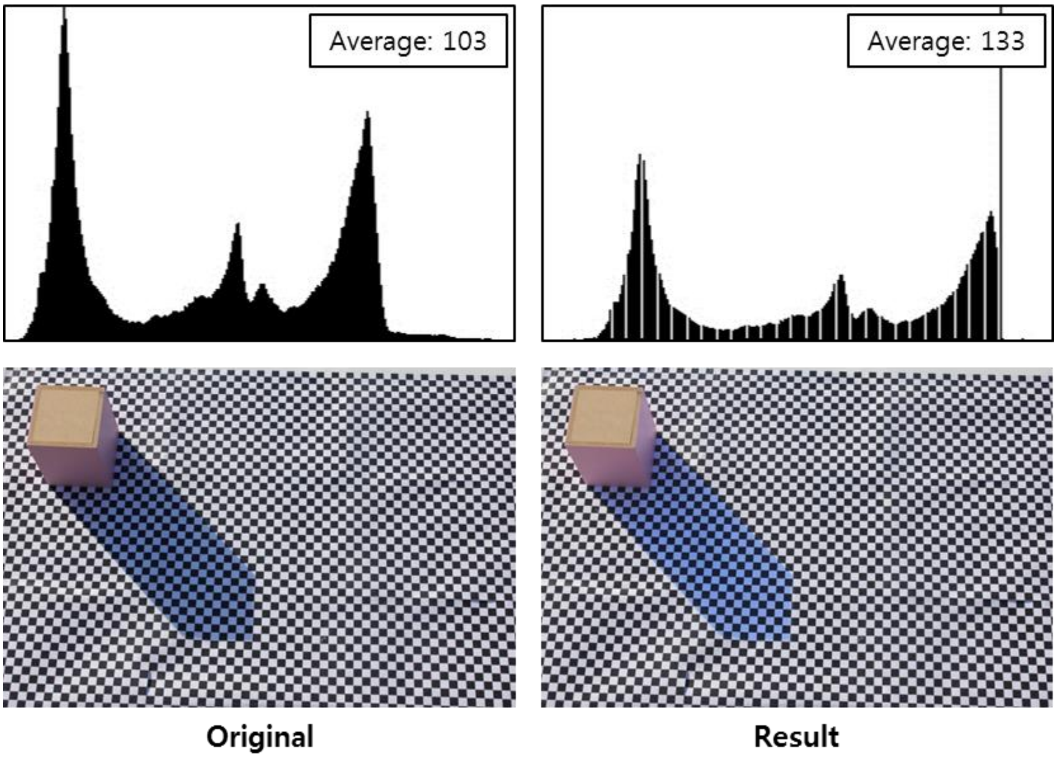

Figure 11. The Result of Applying *a* = 1%

The improvement rate was calculated as shown in formula 3 in order to conduct a quantitative comparative analysis of the improved result of applying each minimum percentage a. Here, the improvement rate is calculated by comparing the average of the histograms before and after the improvement. The term $\Delta HistAvg_{Before}$ refers to the average difference between the shadow and non-shadow histograms before improvement, and $\Delta HistAvg_{\mathrm{After}}$ signifies the average difference between the shadow and non-shadow histograms after improvement. The improvement rates derived with the formula are 30.77%, 51.28%, 89.74% and 76.92% for each respective value of a, as shown in Figure 12. Therefore, it was verified that the highest improvement rate is with a = 0.1%, and the lowest improvement rate is with a = 0%. These results show that the improvement rate does not increase in a constant manner with increase of the minimum percentage a. This is because the equalization degree decreases when the value of a is excessively large, as shown in Figure 13. Therefore, a better improvement rate is achieved when an appropriate value of a is set according to the construction environment of the facility-surveillance system.

$$Improvement\ Rate(\%) = \frac{(\Delta HistAvg_{Before}) - (\Delta HistAvg_{After})}{(\Delta HistAvg_{Before})} \times 100 \tag{3}$$

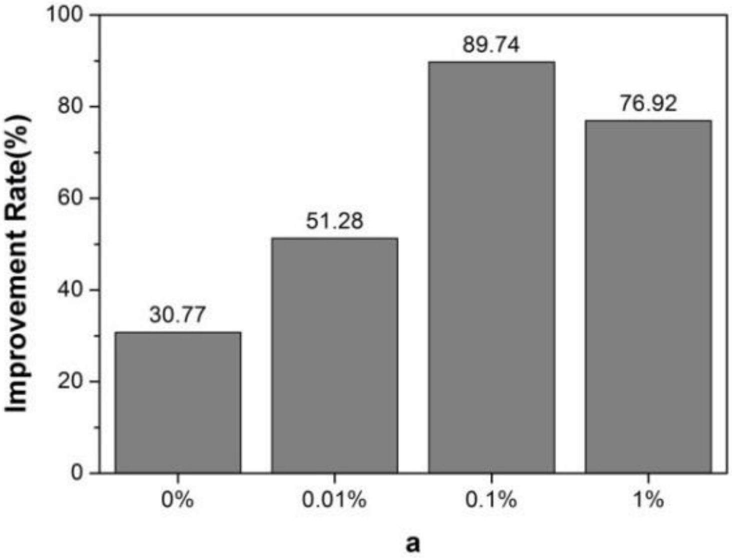

Figure 12. Improvement Rate According to Minimum Percentage *a*

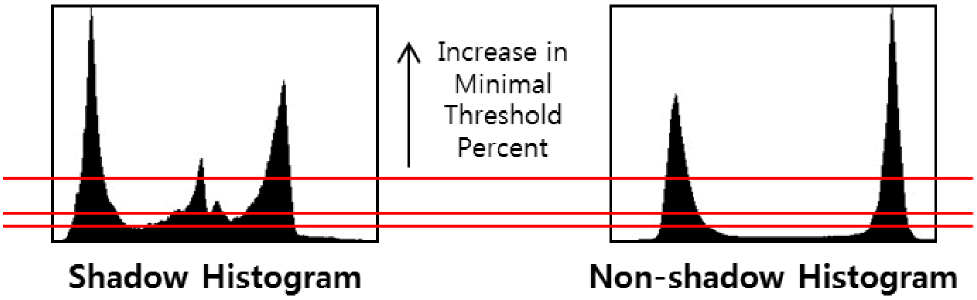

Figure 13. Variation with Increase in Minimum Percentage

5. Conclusion

This study proposed a technique to detect and improve shadow areas for an intelligent facility-surveillance system. In the shadow-area-detection stage of the proposed method, the shadow-area coordinates were estimated through light-source tracking and were matched to images through camera calibration, enabling shadow-area detection. In addition, in the shadow-area-improvement stage, a minimum percentage was applied to improve shadow areas based on influential brightness values.

Furthermore, this study verified the improvement results by experimentally applying the proposed technique. The improvement in shadow areas was verified through image data obtained from actual facilities. The image-improvement rates were calculated and analyzed according to various minimum percentage values, with specific structures as the subjects. It was determined that an appropriate minimum-percentage setting is necessary for better improvement rates of the proposed technique in a facility-surveillance system.

Future research will focus on additional compensation for the errors occurring in the technique proposed in this research, and will apply the proposed technique to an actual intelligent-surveillance-system environment. In addition, in order to overcome unexpected barrier elements occurring in the facility's shadow areas, research to track and improve the shadow areas reversely will be conducted.

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