https://doi.org/10.2352/ISSN.2470-1173.2019.11.IPAS-251

A Snowfall Noise Elimination Using Moving Object Compositing Method Adaptable to Natural Boundary

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Abstract

In recent years, the use of surveillance cameras is increasingly recommended and they have been installed in many places. Snowy conditions at the time of an accident were associated with the problem that cars and accident circumstances become difficult to discern in images shot during snowfall. Previous techniques proposed methods for elimination of noise caused by snow using image shift or dedicated filters for the elimination of snowfall in video. However, these are associated with issues such as inability to cope with heavy snowfall or moving objects fading from view or being hard to discern. The present study proposes a method for snowfall noise elimination by extracting moving objects using the travel and the size of the moving object region between continuous frames, and compositing images while correcting for brightness in the background images. By distinguishing between falling snow and other moving objects, we can prevent objects other than snowfall becoming invisible. Using video of actual vehicles driving in snowy conditions for our experiments, we confirmed that snowfall noise can be eliminated without moving objects in the video becoming invisible. Furthermore, we confirmed that moving objects can be incorporated into the composited background images without any sense that they are out of place.

Introduction

Large numbers of surveillance cameras have been installed in recent years in a variety of locations [1]. For instance, they are widely used to monitor conditions and incidents on highways or roads with low numbers of people present [2]. However, in snowy regions surveillance camera images are indistinct due to the effect of snowfall making the circumstances of traffic incidents for instance difficult to ascertain. To that end, various techniques have been proposed to eliminate snowfall in images and make other moving objects more distinctly visible.

Methods proposed include “A method of removing noise by using a Filter” [3], “Snowfall noise elimination using a time median filter” [4], “Real-time snowflake elimination adaptive to snowfall situations” [5].

The first method uses filters such as median and mean filters to eliminate snowflake noise in images. However, since the median value is the noise value when snowflake noise takes up over half the filter area, noise cannot be eliminated.

The second method applies a median filter onto a time axis. Snowflake noise is eliminated by altering the number of frames for median filtering in accordance with the amount of snowfall. In other words, the method requires a high number of frames at times of heavy snowfall. Accordingly, pixels are replaced from many images resulting in image distortion.

The third method eliminates snowflake noise in images using discrepancies in noise calculated from multiple neighboring frames. However, if images obtained from surveillance cameras contain a lot of snow flake noise, the number of similar pixels in the images is high. Accordingly, the amount of discrepancy cannot be calculated accurately and noise can therefore not be eliminated.

To solve the problems with the previous methods, the present paper proposes a method for snow elimination without any deterioration of moving objects by distinguishing between moving and static objects and, after eliminating the snow on static objects, compositing the moving objects.

To confirm usefulness of the proposed method, experiments were conducted using video of actual driving vehicles during snowfall. Results confirmed that the method is also useful in driving conditions where other techniques are proposed.

Proposed Method

Figure 1 is the flow chart for the proposed method, with each box containing a description of the processing step.

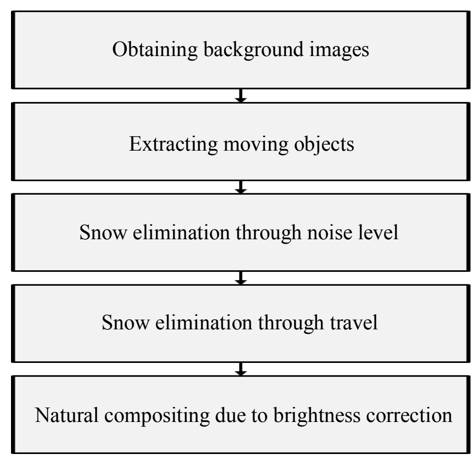


Figure 1. Flow chart

Background image generation using continuous frames

Surveillance cameras record continuingly and video therefore changes greatly with the changes in sunlight depending on whether it is day or night. These changes must be dealt with when acquiring background images. To that end, each frame is weighted and background images are created through compositing. Compositing is performed for each frame using the following equation (1).

$$Background(i,j) = (1-W) * Background(i,j) + W * InputFrame(i,j) \tag{1}$$

where Background is the background image; Input Frame is the input frame; i, j are pixel coordinates of images; W the weighting given to each frame.

For pixels of interest that have a moving object in it, specific pixels will change while the moving object is passing through and will become background once the object has passed through in the continuing shot. Therefore, pixel values where a static object is present multiple times due to weighting are emphasized strongly. In this way, background images without any moving objects are generated.

Extraction of moving objects by difference processing

It is possible to extract just the moving object that is not contained in the background image by obtaining the difference between the frame image and the generated background image. Figure 2 illustrates the extraction of the moving object: the top left image is the background image, the bottom left is the target frame, and the image on the right is the resulting image of the extracted moving object.

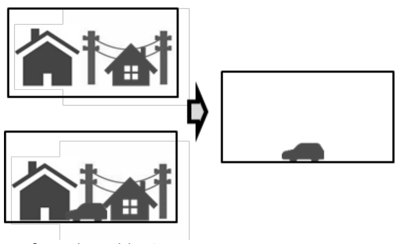


Figure 2. Extraction of moving object

Snow removal by size and speed of moving object

The image obtained by extracting moving objects contains, apart from the vehicle, large and small snowflakes. As shown in Fig. 3, snowflake size when shot by a permanently installed surveillance camera is large when snowflakes are recorded in the vicinity of the camera, and small when they are shot at a distance from the camera. The top image is a side view, and the bottom image illustrates what an image looks like when shot by an actual surveillance camera.

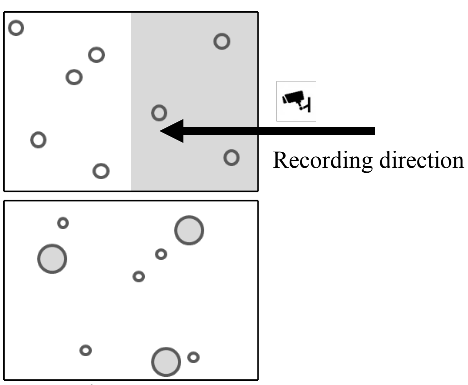


Figure 3. Illustration of image when recorded by actual surveillance camera

Opening processing is performed to eliminate small snowflakes. The top row in Fig. 4 shows processing using small pixel blocks and the bottom row shows processing for large pixel blocks.

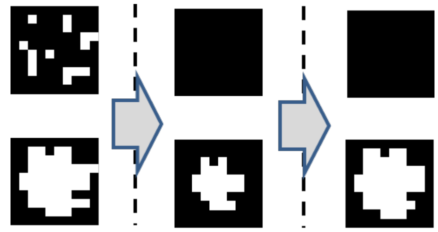


Figure 4. Opening processing

Since no distinction can be made between large snowflakes near the camera and vehicles based on size, this is done based on the velocity (travel) of the moving object. Large snowflakes constitute snow that is close to the camera, and since these are far nearer the camera than the vehicle, their travel is relatively larger. Based on this, we know that travel of snowflakes near the camera and of the vehicle differs. Figure 5 illustrates the travel of snow and vehicle. If a moving object extracted from continuous frames moves at a speed below a specific travel value it is judged to be a vehicle, if speed exceeds the specific travel value it is judged to be snow.

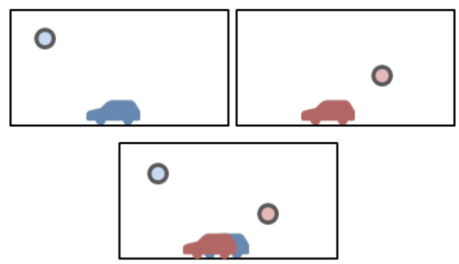


Figure 5. Vehicle and snowflake movement

Moving Object Compositing Method Adaptable to Natural Boundary

The extracted moving objects ultimately obtained are moving objects other than snow, such as vehicles. Since the moving object is not present in generated background images, images without snow can be generated by compositing just the moving object obtained here into the background images. This compositing process is illustrated in Fig. 6.

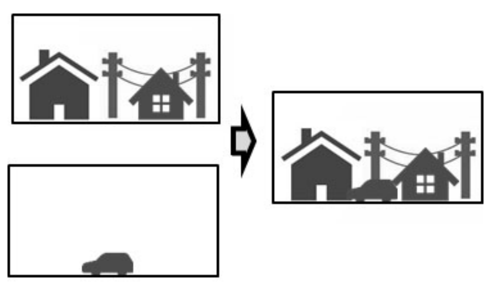


Figure 6. Compositing background image and moving object – Example

If brightness or coloring between images vary when compositing background images and moving object, the lines where images are joined are pronounced. To suppress differences in dark and light and color differences, brightness correction is performed to obscure image joints. Firstly, we focus on the pixels on the joint between two images that are stitched together and calculate the mean pixel values for each RGB in the area. Ratios are calculated based on the respective mean values for the two images and adapted to the peripheral region around the pixel of interest in the composited moving object image. Moreover, by adapting the calculated ratio in the horizontal direction of the pixel of interest too, it is adapted to the overall image of the moving object. Figure 7 illustrates the brightness correction. Brightness is corrected for each moving object.

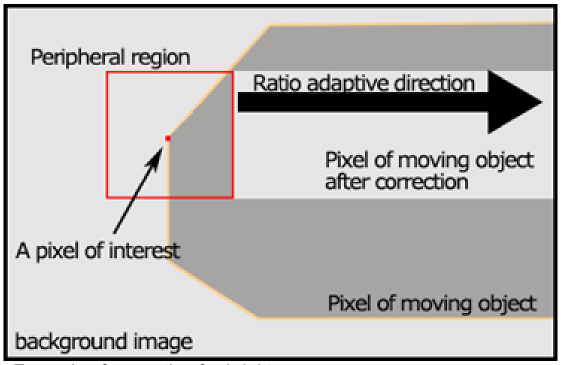


Figure 7. Example of correcting for brightness

Experiments and Results

To confirm the usefulness of the proposed method, we conducted experiments using images of vehicles driving during snowfall. We performed three experiments for this study to confirm usefulness in a variety of environments. Details of the images used in the experiments are listed in Table 1.

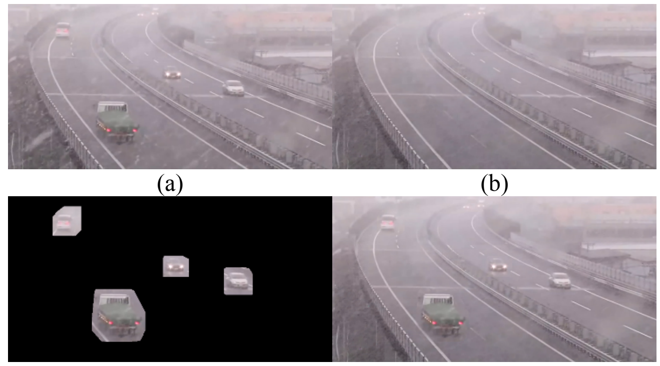
Table 1. Experimental image details

Experiment	Road type	FPS	Resolution
Exp. 1	Highway	29	720*480
Exp. 2	Local road	29	1280*720
Exp. 3	Alleyway	29	1920*1080

Experiment I

The images used in this experiment are of vehicles on the highway driving from the front in the picture away to the left. Since there are few obstacles on highways it is the type of road where vehicles are most likely to driving at speed. Figure 8 shows the experimental results. Figure 8(a) is the original image Fig. 8(b) the generated background image, Fig. 8(c) the image of the extracted moving objects and Fig. 8(d) the resulting image.

The resulting image clearly shows that, compared to the original image, the snow has been eliminated and visibility is better. Furthermore, it is clear that, in terms of the problem of moving objects such as vehicles fading, the entire shape of the car has been preserved.



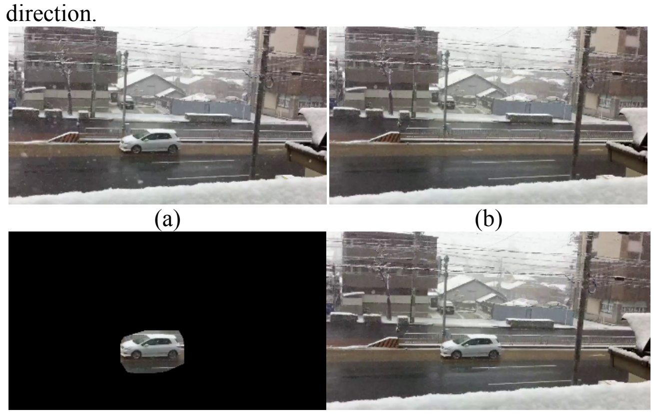
(a) (b) (c) (d)

Figure 8. Results of Experiment I

Experiment II

The images used in this experiment were taken on a local road. Different from Experiment I, speed on local roads is low. Moreover, whereas the line of travel in the image for Experiment I was almost vertical, in these images direction of travel is from right to left. Results are shown in Fig. 9, with Fig. 9(a) showing the original image, Fig. 9(b) the generated background image, Fig. 9(c) the image of the extracted moving objects and Fig. 9(d) the resulting image.

The resulting image shows that snow can be eliminated while still preserving the shape of a vehicle driving in a horizontal direction.



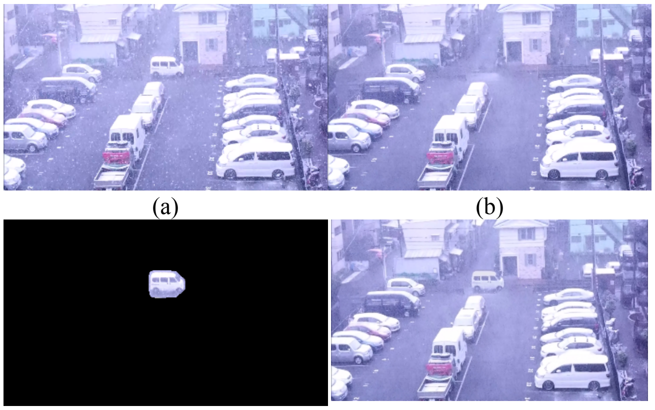
(a) (b) (c) (d)

Figure 9. Results of Experiment II

Experiment III

The images used in this experiment are of an alleyway with few people passing through. Velocity of cars passing through a narrow alleyway is even lower than in Experiment II. Results are shown in Fig. 10, with Fig. 10(a) showing the original image, Fig. 10(b) the generated background image, Fig. 10(c) the image of the extracted moving objects and Fig. 10(d) the resulting image.

The resulting image shows that despite the complex environment containing buildings and utility poles, snow details have been eliminated and road information can be easily ascertained.



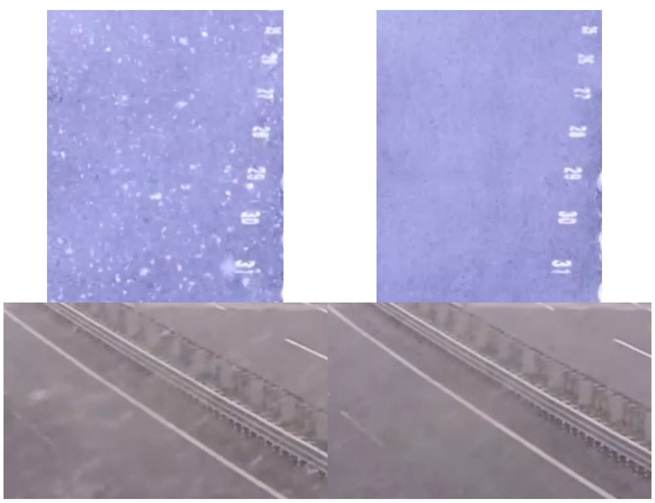
(a) (b)

(c) (d)

Figure 10. Results of Experiment III

Discussion

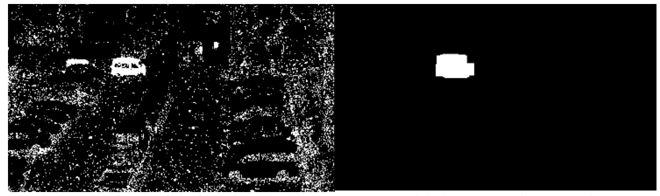
Based on the experimental results, we were able to confirm that snow can be eliminated for various environments. Moreover, regarding the problem with previous methods where small snow details remained, we confirmed that they can be eliminated through opening processing. It was also confirmed that white numbers or white lines on the road surface which are similar to white snowflakes do not fade and that numbers can be clearly ascertained. Figure 11 shows a comparison between input frame and processed results.



Input frame Processed results

Figure 11. Elimination of small snowflakes - result

In relation to moving objects, it was confirmed that moving objects alone could be accurately extracted from the subtraction image. Moreover, it was confirmed that the vehicles had not faded in the post-processing image, and the shape of the vehicle could be clearly seen. Figure 12 shows the extracted image of the vehicle and Fig. 13 shows a comparison between the input frame and the processed results.



Subtraction image Vehicle extraction result

Figure 12. Vehicle extraction from subtraction image

Input frame Processing results

Figure 13. Compositing results for vehicle

Before correcting for brightness, composited borders could be clearly confirmed since the brightness around the moving object and the background image differs. After correcting for brightness, it could be confirmed that the borders around the moving object had disappeared. Smooth composting through correction for brightness was thus confirmed to be successful. Figure 14 shows examples before and after correction for brightness.

Before correction for brightness After correction for brightness

Figure 14. Correction for brightness - comparison

Conclusion

In the present study, we propose a technique to eliminate snowfall noise using travel and differential area and to achieve smooth compositing borders. With the proposed method background images without any moving objects are obtained, thus allowing for the extraction of moving objects using the difference between the background image and the moving objects. Snowflakes are eliminated by distinguishing between the snow and other moving objects by means of the size and velocity of the extracted moving objects. Subsequently, by correcting for brightness in the generated background images combined with the extracted moving object, it is possible to achieve natural compositing of the image joints. To confirm usefulness of the proposed method, processing was applied in experiments with images taken in various environments including a local road, highway, etc. Results confirmed that the proposed method is useful in any environment, independently from the size or velocity of monitored objects, that is vehicles. Previous methods were associated with the problem that moving objects faded and became difficult to discern when snow was eliminated. But as a result of the proposed method, it was confirmed that moving objects do not fade and that their shape is preserved.

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