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On a Technique for Evaluating Performance of Wipers Based on Forward Visibility

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Abstract

There is no clear criterion yet for evaluating wipers based on the performance of wiping raindrops and forward visibility. Moreover, when we evaluate a wiper by forward visibility, we should take into account not only the influence of raindrops but shielding effect by the wiper itself. In this paper, we propose techniques for measuring a wiper based on the its performance of wiping raindrops and shielding effect by the wiper.

1. Introduction

In order to keep car driving safe, forward visibility is quite significant. Especially, in a rainy environment, the level of forward visibility strongly gets affected by the performance of the wiper. Despite its importance, there are not many pieces of research about measurement of the efficiency of wipers based on the forward visibility under rainy conditions, although there are some research for reducing woolliness of images taken from an in-vehicle camera for sensing the outside environment by raindrops [1][2].

Driving in a rainy environment, driver's forward view is obstructed a lot by raindrops on the windshield. So, the driver has to wipe them out using a wiper to keep driving safe.

In current development of wipers, they simply try to widen the wiping area by wipers in order to enlarge the view area on the windshield. There are no more criteria for evaluating the performance of wipers yet. In addition, there is no explicit criterion for wiping speed of the wiper, which affects the efficiency of wiping out raindrops and visibility. We should consider not only the performance of wipers but the hiding effect of those wipers at the same time.

In the first part of this paper, we describe a process of sampling the forward view of drivers in a car under a rainy condition, which was constructed in a wind tunnel test room. Then, in the following sections, we describe an evaluation method for the performance of wipers considering their hiding effect using techniques of image processing.

2. Sampling a Footage of Driver's Forward View

We conducted an experiment to confirm the relationship between the efficiency of wipers and two kind of

Figure 1. The configuration of our experiment, a car and a background board in a wind tunnel room.

conditions, strength of rain and speed of wipers. Our experiment was conducted in a wind tunnel room, in which we can make artificial rainfall. In the room, we prepared a car and a rectangular background board, which was located in front of the car. A monochrome monotonous rectangular wave pattern was printed on the board as shown in Figure 1. We set a video camera on the driver's seat in the car. We took a footage from the driver's seat under several conditions including two levels of rainfall, "drizzle" or "heavy," and two levels of wiper speed, "slow (0.67Hz)" and "fast (1Hz)."

3. Evaluation of Wiping Efficiency

Our method consists of two parts of evaluations as follows: First, we evaluate the wiping efficiency of the wiper. Second we evaluate the hiding effect of the wiper according to its speed.

In this section, we describe the first part, evaluation the efficiency of the wiper. Here, we adopted a method of analyzing the footage we described in the previous section, using image processing techniques.

Particularly, we applied two-dimensional FFT (2D-FFT) to the footage. The left part of Figure 2 shows an image of a scene from the driver's seat where there are no raindrops on the windshield and the right part of the figure shows the 2D-FFT of the image. Similarly, Figure 3 shows an image in a rainy environment and its 2D-FFT. A lot of raindrops are on the windshield. Comparing the transformed images of Figure 2 and 3, we can observe more high frequency components in Figure 3 than Figure 2. Moreover, we applied a high-frequency filter and the inverse 2D-FFT in series to the right image of Figure 3 and obtained the image in Figure 4. We can

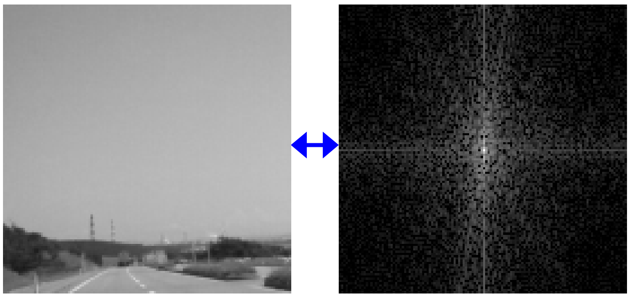

Figure 2. A pair of images of road looking from driver's seat and its 2D-FFTed image under a non-rainy condition.

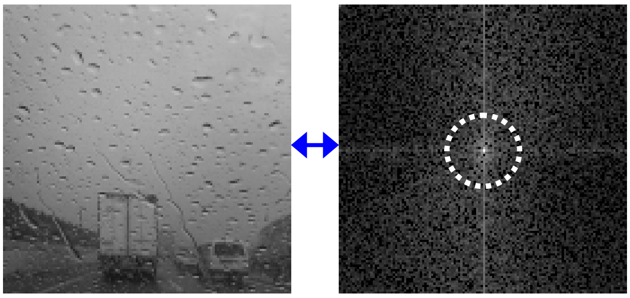

Figure 3. A similar pair of images for a rainy condition. (Dotted line: frequency components of background).

observe the raindrops clearly in the image, while the background scene is blurred. From the result we can assume that images of raindrops have a lot of high frequency components in it. We can, therefore, detect raindrops in given images by measuring high frequency components in the images and apply the method to measuring the efficiency of wipers. By measuring the component of a specific frequency associated to raindrops in the image, we measured the effect of raindrops on driver's view in a rainy environment, by which we define the wiper's efficiency.

Figure 4. An image of high frequency components in Figure 3.

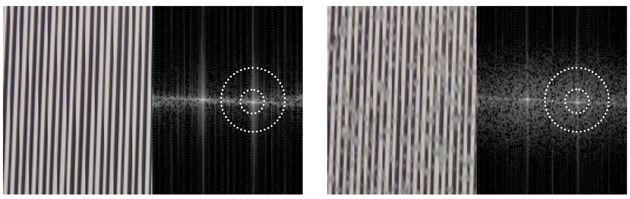

Figure 5. A pair of images of stripe printed board looking from driver's seat and its 2D-FFTed image under a non-rainy condition (left). A similar pair images for a rainy condition (right).

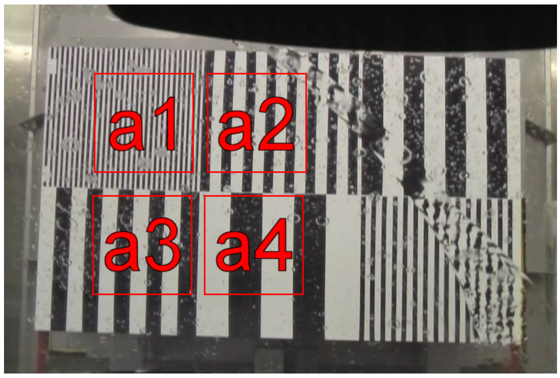

Figure 6. Area a1-a4 on the background board.

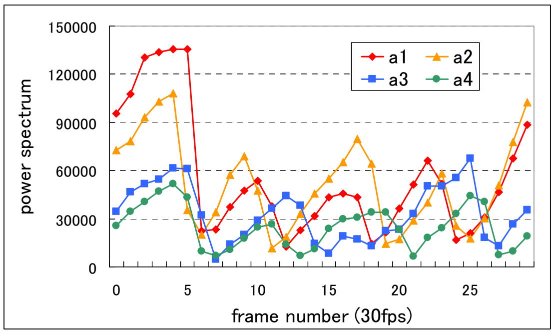

Figure 7. Variation with time of the power spectrum of high frequency component of the image of Area a1-a4.

We used a background board on which several types of stripe patterns are printed, applied 2D-FFT to each image in the footage, and measured the power spectrum of the specific component of frequency. The region between two dotted circle in figure 5 is the frequency area whose power spectrum was measured.

We conducted raindrop detection for four stripe patterns on the board to find an optimal pattern for detecting raindrops on the windshield. Figure 7 shows the time variation of power spectrum on each pattern (a1 to a4) shown in Figure 6, where the rain strength and wiper speed were both in high level, which showed that a1 was the most preferable pattern among the four patterns for measuring the amount of raindrops.

Moreover, from the result of the detection, we concluded that higher frequency background pattern was more suitable for detecting raindrops. Hence, we adopted the specific high frequency component of 2D-FFT on Area a1 as measure of intensity of the effect of raindrops on windshield, and we measured the time variations of the measure under four basic conditions, the combinations of drizzle and heavy rainfall and slow and fast wiper speed. The time variation of the power spectrum of wiper images is synchronized with the motion of the wiper for the all cases.

From the consideration above, we define the wipe-out ratio r of a wiper as

$$r = (s - s_{\min})/(s_{\max} - s_{\min}),$$

where s is the power spectrum at a specific time, and $s_{\max}$ and $s_{\min}$ are the maximum ad the minimum of the power spectrum in a certain time interval. r = 0.0 and r = 1.0 means completely wiped-out state of windshield

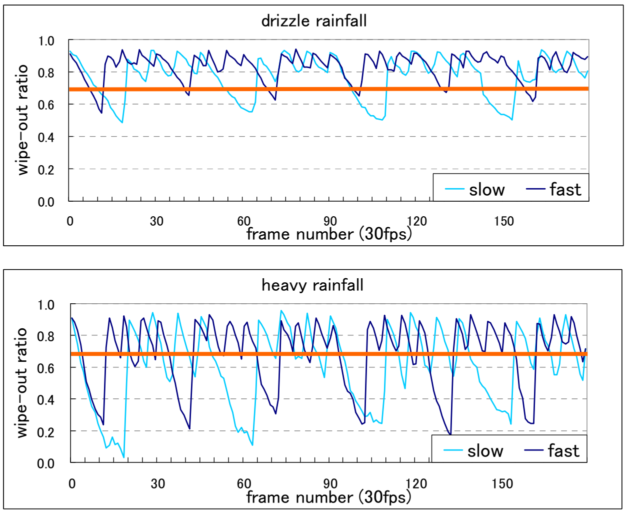

Figure 8. The time variations of the wipe-out ratio of a wiper under four basic conditions. The orange horizontal lines indicate 5% shielding ratio.

Table 1. The ratio of time intervals of 70%+ wipe-out ratio under the four conditions.

	wiper speed	
	slow	fast
drizzle rainfall	0.74	0.89
heavy rainfall	0.47	0.67

and state of windshield fully covered by raindrops respectively. Figure 8 shows the time variations of the measure under four basic conditions. Table 1 shows the ratio of cumulative time period when the wipe-out ratio is less than 70% in a time segment of 3 seconds. Although the ratios of the cumulative time period for slow and fast wiper speeds are close, the ratio for the slower wiper speed is definitely less than the ratio for the faster one for the both intensities of rainfall, which agrees with our experiences. We have not shown the effectiveness of wipe-out ratio completely. Further experiment have to be conducted to confirm whether the index robust.

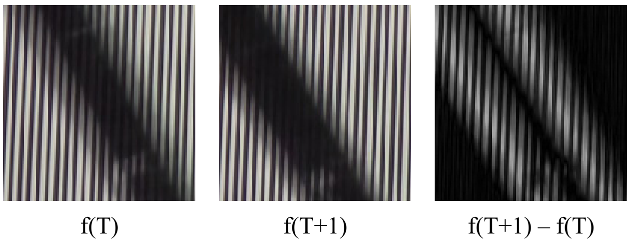

Figure 9. Subtraction of consecutive images.

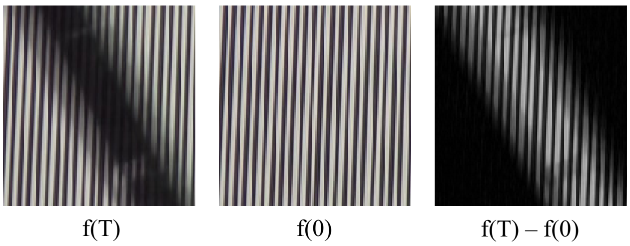

Figure 10. Subtraction of each image in the footage and the background image.

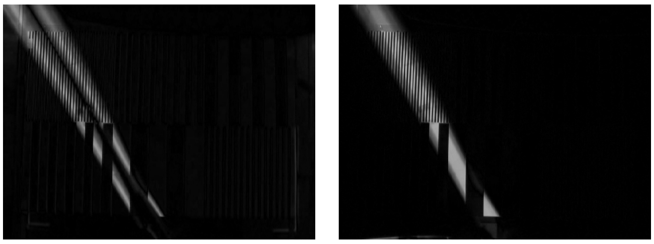

Figure 11. Subtraction images by the two methods, the consecutive subtraction method (left) and the background subtraction method (right).

4. Front Visibility Shielding Ratio of Wipers

In this section, we describe a method for measuring shielding effect of wipers using subtracted images and its analysis.

In order to detect the shielding effect of the wiper itself, we sampled a footage under a non-rainy condition where from the driver's seat, when the wiper moved in two modes, slow and fast modes. We adopted two methods for detecting wiper's position in the footage. The first one is a method of computing subtraction of consecutive images (See Figure 9), and the second one is that of computing subtraction of each image in the footage and the background image (See Figure 10). The second one is not always tractable because we cannot always detect the background images (sometimes background might change).

Figure 11 shows subtracted images generated from a image in the footage by the both methods respectively.

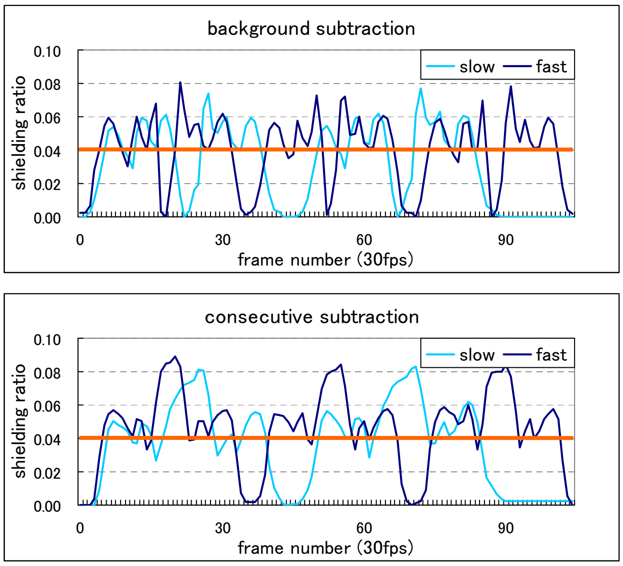

Figure 12. The time variations of the shielding ratio for the four cases. The orange horizontal lines indicate 4% shielding ratio.

Table 2. The ratio of time intervals of 4%+ shielding ratio under the four conditions.

	wiper speed	
	slow	fast
consecutive subtraction	0.48	0.62
background subtraction	0.51	0.68

The shielding ratio of an image is defined as the ratio of brightness by full brightness. Figure 12 show the time variation of the shielding ratio for the four cases. Moreover, the average shielding ratios for the four cases are shown in Table 2 for three seconds. When the wiper's motion is the slow mode, the shielding ratio is less than that of the fast mode. The result was some what different for the two ways of sampling methods we described above. The shielding method we proposed here can be an index for evaluating the shield effect of the wiper itself.

5. Conclusions and Future Work

We defined an index for evaluating wiping out efficiency of a wiper by analyzing a footage taken from the driver's seat. The index is calculated from the 2D-FFT images that are generated by applying the transformation to each image in the footage. In addition, we defined another index for evaluating the shielding effect of the wiper itself. By experiments, we have confirmed that under two kinds of rainy environment, faster wiper motion always makes the wipe-out ratio higher. We have not checked further characteristics on the indices yet. The analyses are for the future work.

From Table 1 and 2, faster wiper motion makes better wipe-out ratio, while the shielding ratio is somewhat higher. So, we have to develop a trade-off evaluation method for determine a optimal speed of the wiper from a point of view of human engineering. Some more experiments for more varieties of rain patterns and more levels of wiper motion speed should be conducted to refine the indices. These are for the future work.

References

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