INVITED PAPER Special Section on Electronic Displays

Method for Evaluating Performance of Wipers Based on Visibility

Takashi KITAYAMA[†a)], ***Student Member***, **Mikiko KAWASUMI**[†], ***Nonmember***, **Hatsuo YAMASAKI**[†], **Tomoaki NAKANO**[†], **Shin YAMAMOTO**[†], **Muneo YAMADA**[†], ***Members, and*** **Yuta DOI**[††], ***Nonmember***

SUMMARY There is no clear criterion yet for evaluating wipers based on performances of wiping raindrops and visibility in forward view. In the visibility evaluation in rainy driving, it is important to examine spatial frequency and contrast of objects in forward view. Spatial frequency and contrast of image which were affected by raindrops are calculated based on them of background board which were printed stripe patterns. Variations with time of power of analysed frequency and decreased contrast are synchronized with motion of the wiper for the all experimental cases. Moreover, we executed questionnaire, and evaluated the view of the background board. These results show that the proposed methods have been validated in evaluation with wiping performance.

key words: *wiper, visibility, wiping performance, frequency analysis, contrast*

1. Introduction

It is essential to ensure visibility in forward view while driving a vehicle safely, especially in a bad weather such as rain, snow and fog. Automobile wipers (also called windshield wipers) and washer with various improvements have been widely used in the past 100 years as a way to get clear forward view [1], [2]. There have been improvements not only in performance of wiping raindrops but also in decrease of chatter vibrations [3], [4], noise reduction [5], prevention of wiper blade reversal [6], and better wiper blade designs [7]. CAE was also introduced to improve wiper and washer performances [8]. These research results are utilized in many automobiles today for their front and rear windows, even for wiping headlamps. When we consider ensuring clear forward view, however, there is no established criterion yet to evaluate visibility. It follows that there has been no evaluation of wiper performance based on visibility. The only testing method at present is a visual check of the physically wiped area of the front window glass, which is a qualitative evaluation with human eyes. No method can be found to evaluate visibility in rain.

This is a study on evaluation of performance of automobile wipers in terms of visibility in rain, among several bad weather conditions for driving.

This method aims at quantitative evaluation of wiping performance with consideration to the driver's visual function to improve forward visibility. By adding this method to the traditional qualitative evaluation, wipers can be improved to be more suitable to the driver's visual function with better visibility and a new wiping system can be developed. Section 2 will discuss the current status and issues on visibility in rain. Section 3 will explain the evaluation method of wiper performance in this study. Section 4 will discuss the experiments to examine the validity of this method. Moreover, in Sect. 4, the effectiveness of this method will be shown by comparison between verification experiment and questionnaire of visibility.

2. Current Status and Issues of Visibility in Rain

When driving a car, it is essential to ensure clear forward view and check driving environment for safety. Visibility factors can be divided into "driving environment" and "driver's visual functions" as shown in Fig. 1. Generally, in any driving environment, basic functions such as the driver's eyesight and focusing among others greatly affect accurate understanding of objects in sight. When driving at night, night vision (inferior to static vision, significantly deteriorated in the elderly) instead of static vision in normal daytime should be considered. In backlit driving environment, sensitivity to "brightness (called glare)" should be taken into account along with eyesight. It is also necessary to consider age variation of drivers because visual functions change with aging. The target driving environment of this study is visibility in rain. Raindrops (amount of rainfall) and wipers (wiping speed) need to be considered in evaluating

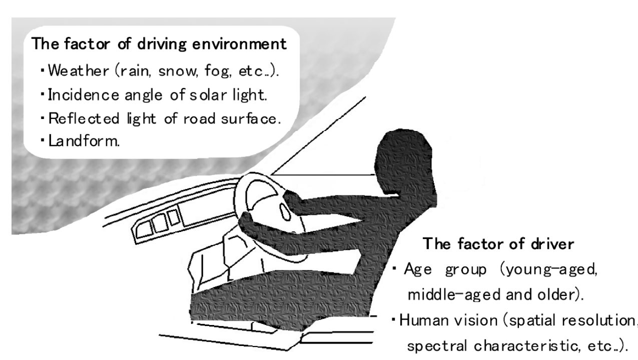


Fig. 1 Main factor of visibility in driving.

Manuscript received February 24, 2012.
Manuscript revised June 8, 2012.
[†]The authors are with Meijo Univ., Nagoya-shi, 468-8502 Japan.
[††]The author is with ASMO Co., Ltd., Kosai-shi, 431-0493 Japan.
a) E-mail: m0830008@ccalumni.meijo-u.ac.jp
DOI: 10.1587/transele.E95.C.1716

visibility under such environment. These two could become disturbing factors in vision because they exist between the driver's eyes and the objects to be recognized.

There has been only one type of testing on wiper performance, as described below, to evaluate visibility in rain. There has been no quantitative evaluation with consideration to the driver's visual functions as well as raindrops (amount of rainfall) and wipers (wiping speed). Wiping all water on the glass surface does not bring a clear view. While sweeping drops of water, wiper blades form a thin and smooth water sheet on the glass surface and ensure vision. If wiper blades form an uneven water sheet failing to sweep water drops, refraction of light hinders clear view.

The representative testing of wiper performance is described in JIS R 3212 "Testing method of safe windshield for automobiles" [9]. In this method, two forward view areas, area A and area B, are set to evaluate forward view visibility. In each area, wiping area ratio to satisfy the performance test is determined. Wipers are operated on a dirty windshield at their slowest speed and the wiped area is measured by visual observation. In order to pass this test, over 98% of area A and over 80% of area B must be cleared. In high-speed driving, a similar test is done and over 98% of area A is required. It is obvious, therefore, that traditional wiping performance tests are done by visual observation and they are not quantitative. In addition, in such a test, only a physically wiped area can be confirmed and it is hardly an evaluation of visibility concerning rainfall amount and wiping motion. Establishing a quantitative evaluation method of visibility in rain will lead to improvement of wipers and development of a new wiper system. Moreover, because elderly drivers are increasing in number today, it will bring about a wiper system that gives good visibility to both young and old people. It is beneficial to include the driver's visual functions in visibility evaluation.

3. Proposed Method for Evaluation of Wiper

3.1 Basic Concept

In a laboratory equipped with a raining simulation system, a single-frequency rectangular-wave background board is set in front of the test vehicle and wipers are operated in falling rain. A camera set at the driver's eyesight position takes movies of the forward view. The movie is analyzed with image processing and a system to evaluate wiping performance will be proposed. This system can evaluate visibility considering the amount of rainfall and wiping motion as explained in earlier section.

Note that driver's visual functions in this study do not include difference in how objects appear depending on age. Figure 2 shows outline of the system.

Of the basic visual functions of the driver in examining visibility, the function related to "eyesight" is the most important. That is because it is the base of safe driving to recognize traffic lights and signs from a distance and understand their content while driving. The easiness of recognizing traffic lights and signs (visibility) largely depend on "resolution (detail-ness)" and "grades of light (luminance)," which correspond to "spatial frequency" and "contrast" in images taken by a camera. By considering these two factors, easiness of seeing objects (visibility) can be quantitatively measured. Figure 3 shows samples of spatial frequency and contrast in an image. Spatial frequency in an image refers to the interval of luminance variation. Smaller intervals and finer waves mean higher spatial frequency. Contrast in an image refers to the width of luminance variation. More clearly light and dark waves with larger difference in luminance mean higher contrast.

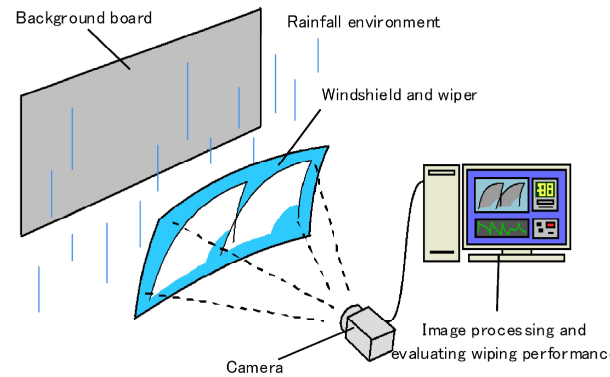


Fig. 2 Outline of system for evaluating wiping performance.

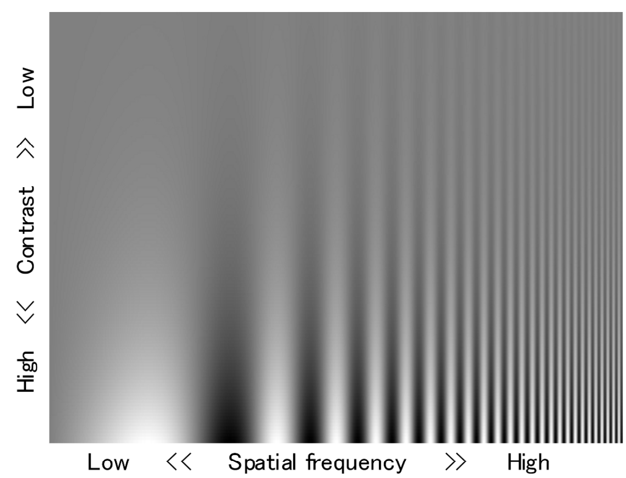


Fig. 3 Sample of spatial frequency and contrast (Contrast Sensitivity Function chart).

In order to evaluate wiper performance with these important visual features, a background board with a regular simple frequency pattern is placed in front of the test vehicle in the wiper performance evaluation system in Fig. 2. When images of the forward view are taken while wipers are in motion in raining environment, the spatial frequency and contrast of the board change because they are affected by raindrops on the windshield. Based on the original spatial frequency and contrast of the background board, variations are measured and analyzed through image processing. In this way, quantitative evaluation of wiper performance from

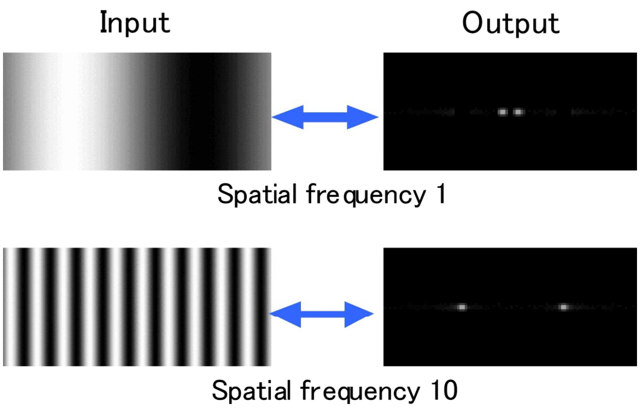


Fig. 4 Samples of 2D-DFT.

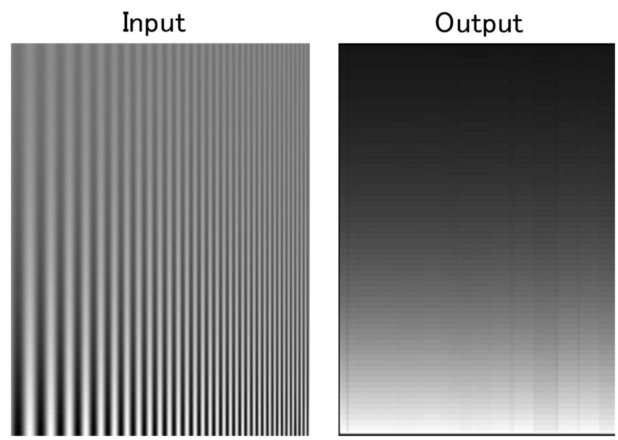


Fig. 5 Sample of local area contrast.

the aspect of visibility can be achieved. One factor to note is that the forward view visibility is also affected by raindrops that exist between the windshield and the background board. In this study, wiper performance is defined as the improvement rate of forward view visibility by wiping motion in raining environment. Therefore, the focus is on the visibility change caused by wipers sweeping away raindrops on the windshield.

3.2 Analysis on Spatial Frequency

In an analysis by spatial frequency, we pay attention to amplitude (power) of each spatial frequency of an image, and examine those changes caused by attached raindrops. When the pixel luminance level in each image position (x, y) is defined as $f(x, y)$, amplitude components $F(k_x, k_y)$ and power of each spatial frequency $P_s(k_x, k_y)$ can be calculated by the following formulas.

$$F(k_x, k_y) = \iint f(x, y) \exp\{-j2\pi(k_x x + k_y y)\} dx dy \quad (1)$$

$$P_s(k_x, k_y) = F(k_x, k_y)\overline{F(k_x, k_y)} = |F(k_x, k_y)|^2 \quad (2)$$

These are two-dimensional Fourier transformation formulas for an image. Power of each spatial frequency in an image can be obtained by carrying out one-dimensional Fourier transformation for the horizontal direction (x) and the vertical direction (y) respectively.

Figure 4 shows samples of two dimensional Fourier transform. Center of the output image is power of zero-spatial frequency. By looking at the relative location of each pixel with luminance from the center, wave direction and frequency of the input image can be obtained, and the luminance value tells the amplitude. Then, a quantitative evaluation of the wiping performance becomes possible by catching disorder of the wave generated by attached raindrops as a change in the power of each spatial frequency.

3.3 Analysis on Contrast

In an analysis by contrast, we pay attention to local contrasts in the overall image, and examine those changes caused by attached raindrops. When the maximum luminance in a local domain is defined as $L_{\max}$, minimum luminance as $L_{\min}$, contrast in the local domain $C(x, y)$ can be obtained by the following formula.

$$C(x, y) = \frac{L_{\max} - L_{\min}}{L_{\max} + L_{\min}} \quad (3)$$

Figure 5 shows sample of calculated local contrast. Input image is a horizontal sine-wave image with contrast decreasing towards the top. Based on the frequency of the input image, a local area is determined as 3 pixels on y and 15 pixels on x neighborhood. The local area was moved by one pixel, and the local contrast in each area was calculated in the whole area of the input image. The local contrasts in the whole input image were made into an output image. In the output image, the contrast beautifully decreases from bottom to top.

When the background board has a striped pattern, the local area contrast indicates a value high in the whole area. Therefore, a quantitative evaluation of the wiping performance becomes possible by catching decreased contrast caused by attached raindrops.

4. Verification Experiment

4.1 Experimental Method

We experimented to verify a quantitative evaluation of the wiping performance by the proposal method based on visibility. The visibility changes responding at amount of rainfall and speed of the wiper, then we tried analyzing under various conditions to assume them to be a parameter.

A camera was set in the position of the driver's viewpoint in a test vehicle in a laboratory with simulated raining environment. The background board was set 3 meters from the camera as in Fig. 6. The background board had mono-color simple short wave of 1.3 cycle/degree spatial frequency. Images of the forward view under the following experimental conditions were taken and analyzed.

1) amount of rainfall: 0 mm/h, 7.9 mm/h (drizzle), 30 mm/h

Fig. 6 Configuration of our experiment, a car and a background board in a laboratory.

Table 1 Subject's data.

Sex/Age	20	30	40	50	60	70	Total
Male	5	5	5	5	9	2	31
Female	5	5	5	6	9	0	30
Total	10	10	10	11	18	2	61

(medium), 55 mm/h (heavy)

2) speed of wiper: 0 Hz, 0.43 Hz (Int), 0.86 Hz (Low), 1.2 Hz (High)

horizontal illuminance in the room: 300 lux
average luminance of background board: 43 cd/m2
Intermittent wiping is equal in the motion speed to low-speed wiping but with half the wiping frequency.

Moreover we questioned about visibility of images of the forward view, and compared the results with the results of the analysis. Images used to question are 17 images of drizzle rain, 15 images of medium rain, and 10 images of heavy rain. They are different between of the amount of raindrops in each condition, and we presented them to subjects at random. Subjects of the questionnaire are shown in Table 1. Subjects saw them, and evaluated each image by 13 stages, from minus 6(when wiper is unnecessary) to plus 6(when wiper is surely necessary).

4.2 Experimental Results

4.2.1 Analysis on Spatial Frequency

Figure 7 shows the sample of analytical image. Spatial frequency to be analysed was in range from 1/20 to 1/5 Nyquist around the base frequency of the stripe pattern marked with the circles on Fig. 7. We integrated the power of each spatial frequency in this analysed frequency, and examined its chronological change. The power of the analysed frequency is large when raindrops adhere to windshield and the striped pattern of the background board is distorted, and visibility on spatial frequency is bad.

Figure 8 shows variations with time (10 sec) of power of the analysed frequency of intermittent wiper. The result such as an increase in power of the analysed frequency by attached raindrops and decrease in power of the analysed frequency by wiping was confirmed.

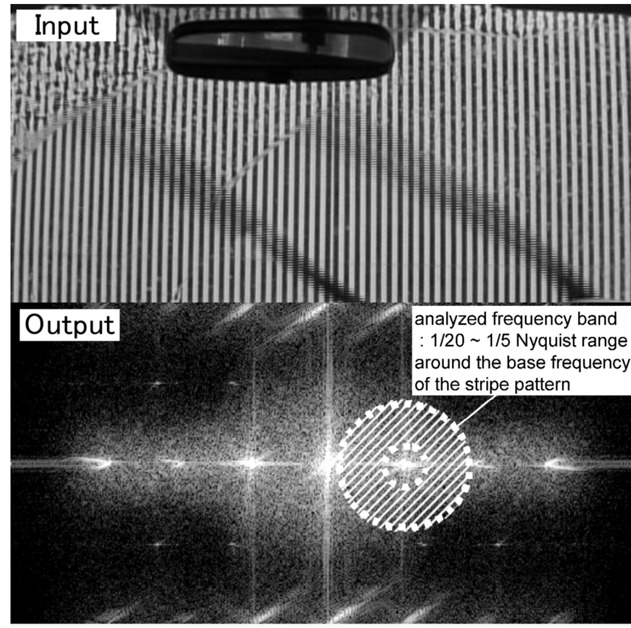


Fig. 7 Pair of images of forward view from driver's seat and its 2D Fourier space image.

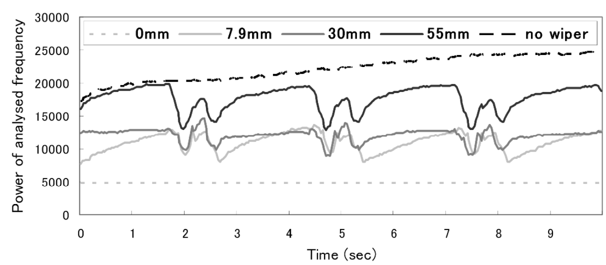


Fig. 8 Variation with time of the power of analysed frequency of intermittent wiper.

Here, power of the analysed frequency in each condition and time is defined as $P_s(t)$. Power of the analysed frequency with the best view in each precipitation amount as $P_{s\,\min}$, and power of the analysed frequency with the worst view when the front glass is covered with raindrops as $P_{s\,\max}$. Wiping rate $W_P(t)$ affected by spatial frequency is defined as in the following formula.

$$W_P(t) = \frac{P_{s\,\max} - P_s(t)}{P_{s\,\max} - P_{s\,\min}} \tag{4}$$

We calculated wiping rate by the spatial frequency of all experimental conditions by this formula. Figure 9 shows average of the wiping rate by spatial frequency under all experimental conditions. It indicates general decrease of wiping rate as precipitation amount increases.

However, in medium rain, there was not much change in time. Moreover, wiping rates of the drizzle rain and the medium rain did not have a big difference, though the amount of rainfall of the medium rain was larger than that of the drizzle rain. The reason seems to be that very fine raindrops in medium rain clouded the whole view as in a

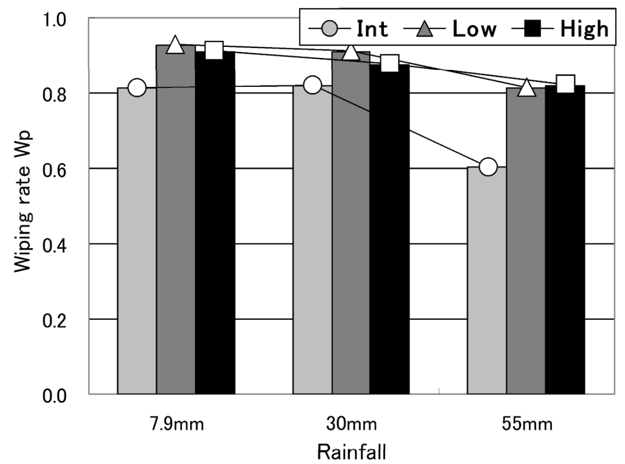


Fig. 9 Average of wiping rate under all experimental conditions (spatial frequency).

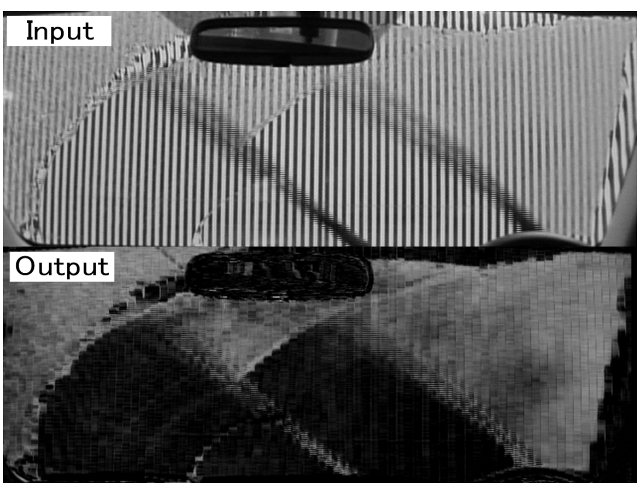


Fig. 10 Pair of images of forward view from driver's seat and its contrast image.

fog, which caused little change in the spatial frequency of the background board.

4.2.2 Analysis on Contrast

Figure 10 shows the sample of analytical image. Because the background board has a continuous rectangular wave with horizontal high contrast in a good viewing condition, 3 pixels on y and 7 pixels on x neighborhood was taken for calculation of local contrast. The local area was moved by one pixel, and the contrast of the local area was calculated in the whole area. When raindrops don't adhere, the contrast of the local area has a high value in the whole area because of the striped pattern of the background board. Based on this high contrast when raindrops don't adhere, we integrated amounts of a decrease in contrast of the local area in the whole area caused by adhesion of raindrops. We calculated average of the decreased contrast per pixel, and examined its time transition. The decreased contrast is large when

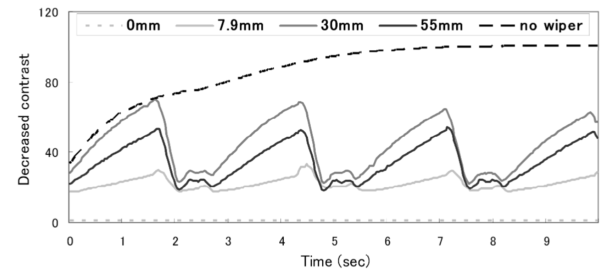


Fig. 11 Variation with time of the decreased contrast of intermittent wiper.

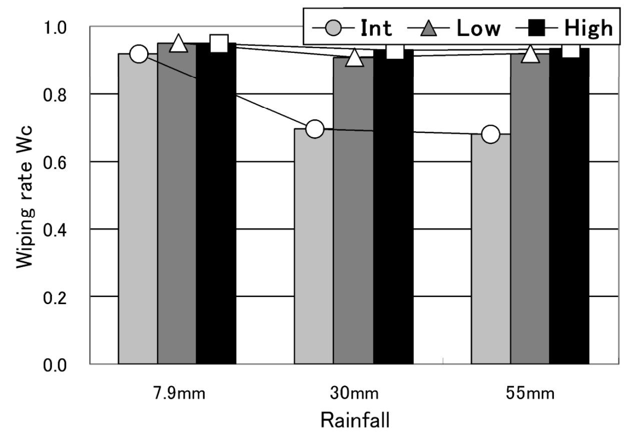


Fig. 12 Average of wiping rate under all experimental conditions (contrast).

raindrops adhere to windshield and the windshield becomes cloudy, and visibility on contrast is bad.

Figure 11 shows variations with time (10 sec) of decreased contrast of intermittent wiper. This result shows decrease of contrast caused by attached raindrops and recovery of high contrast due to wiping.

As in the evaluation by spatial frequency, wiping rate $W_C(t)$ by contrast is defined as in the following formula. Average contrast in each condition and time frame is represented by $C(t)$, average contrast in the best viewing condition in each precipitation amount by $C_{\max}$, and average contrast in the worst viewing condition by $C_{\min}$.

$$W_C(t) = \frac{C(t) - C_{\min}}{C_{\max} - C_{\min}} \tag{5}$$

We calculated wiping rate by the contrast under all experimental conditions by this formula. Figure 12 shows average of the wiping rate by contrast under all experimental conditions. The result of the wiping rate's greatly decreasing in medium rain was shown unlike the result by the spatial frequency. Small raindrops like the fog in medium rain apparently clouded the whole view to equalize brightness more than big raindrops in the heavy rain. As a result, it is thought that the contrast of medium rain decreased as greatly as the heavy rain, though the amount of rainfall of the heavy rain was larger than that of medium rain.

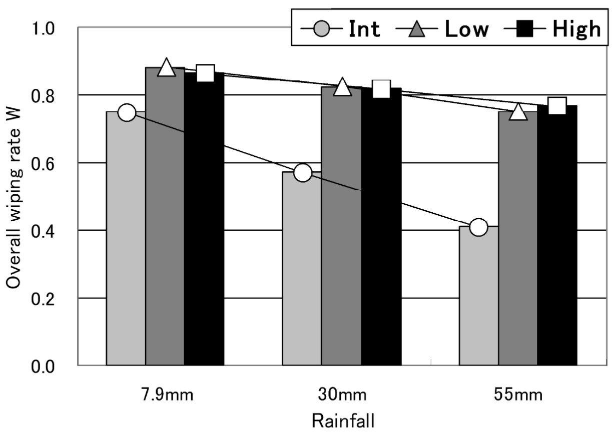


Fig. 13 Average of wiping rate under all experimental conditions (spatial frequency and contrast).

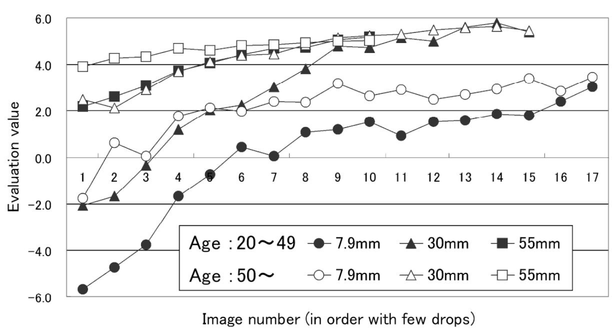


Fig. 14 Average of evaluation value in each image of all subjects (Comparison between youths and seniors).

4.2.3 Overall Evaluation of Visibility

When wiping rate by spatial frequency is compared with that by contrast, different results were obtained because of different raindrop conditions. This suggests that it is necessary to examine visibility in terms of both spatial frequency and contrast. If either of W_P or W_C becomes "0", overall wiping rate W becomes "0", which means the "unable to see".

Therefore, W is defined as in the following formula of multiplication, using wiping rates by both spatial frequency and contrast.

$$W = W_P \times W_C \tag{6}$$

Figure 13 is a graph of overall wiping rate under all conditions. The result showed that visibility decreased as precipitation amount increased.

4.2.4 Comparison with Result of Questionnaire

Figure 14 shows average of evaluation value in each image of all subjects. Image numbers of X axis of the graph were assigned to each image used to questionnaire. The larger the image number is, the more raindrops are included in the image. All subjects wanted to move the wiper as the amount

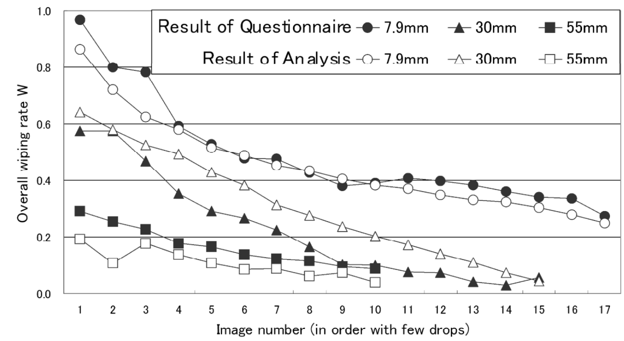


Fig. 15 Comparison between result of analysis and result of questionnaire.

of raindrops increases. And, there was a great divergence in the result among seniors and youths. In all conditions, seniors wanted to wipe raindrops at a stage that was earlier than young people.

Figure 15 shows a result of comparing the result of evaluation by questionnaire with the result of analysis by proposed method. In the graph, the result of questionnaire was normalized so that "−6" and "+6"of the result of questionnaire may become "1" and "0" respectively. This result shows that wiping performance can be evaluated with a fair degree of precision by the proposed method in respect of visibility. However, in the situation in which raindrops had began to adhere, there were slightly different between result of the analysis and result of the questionnaire. It is thought to be due to the differences between subject impression and adherence position of raindrops.

Moreover, some difference was always seen in the result of medium rain. It is considered that the decrease in the contrast by misty rain is perceived as a bigger decrease in visibility on human's sense.

4.3 Discussion

Spatial frequency and contrast variation of forward visibility due to influence of raindrops and wipers were analyzed and wiping rate in each precipitation amount and wiping speed was calculated and compared. Visibility decreased as precipitation amount increased, and higher visibility was maintained with low and high speed wipers than with intermittent wiping. Therefore, it was confirmed that this method enables quantitative evaluation of wiper performance.

No significant difference was observed between the analysis results of low speed wipers and high speed wipers in this experiment. There is a possibility in high speed wiping that the wiping rate may greatly change with much more rain such as typhoons. Under normal rain, however, it is assumed that attached raindrops and high speed wiping equally disturb visibility, which means that it is highly possible that enough visibility can be maintained by low speed wiping.

In order to find the best wiping speed for good visibility, it is necessary to include decrease in visibility by motion of wipers in the evaluation. In this study, high frequency factor of wipers when they momentarily stop in repeating motion appeared as instantaneous rise in output and it affected the evaluation result. On the other hand, there was no big difference caused by motion of wipers in contrast. The main reason for this was that it was an evaluation of the whole view. The decrease in visibility by the motion of wipers is partial. Therefore, evaluation of location-dependent partial visibility is needed for the evaluation of visibility including the motion of wipers. Quantitative evaluation including visibility decrease by motion of wipers, as well as evaluation method of location-dependent partial visibility, is worth further research.

5. Conclusion

This study proposed a quantitative evaluation method of wiper performance under raining condition based on visibility. The method focuses on such two visual features as spatial frequency and contrast. In the proposed evaluation system of wiper performance, a background board was set in front of a test vehicle in the laboratory, movies of forward views while operating wipers in rain were taken, and they were analyzed by image processing. Precipitation amount and wiping speed in the laboratory were used as parameters when movies were taken. Variations in spatial frequency and contrast of the obtained images were analyzed and wiping rate was defined and calculated. We questioned concerning visibility, and compared the result with the defined wiping rate. As a result, it was confirmed that quantification of visibility that changes with precipitation amount and wiping speed is possible and that the proposed evaluation method in addition to the traditional qualitative method was useful.

Some further research issues are to find the best wiping speed, development of an evaluation method to examine different wiper performance due to kinds and deterioration level of wipers, and so on. In addition, we would like to propose an evaluation method considering visual functions of not only general but also elderly drivers. We hope to find solutions for these issues and to establish a practical evaluation system of wiper performance.

References

[1] JSAE: Handbook of Automotive Engineers, chapter of design and body, pp.157–161, 2004. (in Japanese)
[2] T. Yano and T. Sakurai, “Testing and measurement method of visibility performance,” J. JSAE, vol.48, no.3, pp.37–42, 1994. (in Japanese)
[3] R. Suzuki and K. Yasuda, “Chatter vibrations of an automotive wiper: 1st report, modeling of a one arm wiper and the vibration characteristics,” Trans. Jpn. Soc. Mech. Eng., vol.66, no.641, pp.31–37, 2000. (in Japanese)
[4] R. Suzuki and K. Yasuda, “Chatter vibrations of an automotive wiper: 2nd report, quenching of chatter vibrations by harmonic excitation normal to sliding surface,” Trans. Jpn. Soc. Mech. Eng., vol.66, no.644, pp.1110–1115, 2000. (in Japanese)
[5] Y. Yukiho, Y. Ohashi, M. Ishikawa, I. Teshirogi, M. Sakakibara, and A. Aoki, “Windshield wiper motor noise reduction,” J. JSAE, vol.51, no.2, pp.24–29, 1997. (in Japanese)
[6] S. Okura, T. Oya, and S. Shimizu, “Complete 3D dynamic analysis of blade reversal behavior in a windshield wiper system,” Trans. JSAE, vol.34, no.4, pp.131–138, 2003. (in Japanese)
[7] S. Okura, T. Oya, and S. Shimizu, “Optimum design of windshield wiper blade for vehicle using nonlinear programing,” Trans. JSAE, vol.35, no.2, pp.159–165, 2004. (in Japanese)
[8] K. Kaminaga, Y. Hurukori, T. Komoriya, and K. Takada, “Study of CAE application for developments of wiper and washer performance,” Subaru Technical Review, no.30, pp.205–209, 2003. (in Japanese)
[9] JIS R 3212, “Testing method of safety windshield of vehicle,” 1998. (in Japanese)

Takashi Kitayama received the B.E. and M.E. degrees in Department of Information Engineering from Meijo University, Nagoya, Japan, in 2008 and 2010, and he has now engaged in the research on the performance evaluation of the wiper in the postgraduate course in the postgraduate course of Science and Technology in Meijo University, Nagoya, Japan.

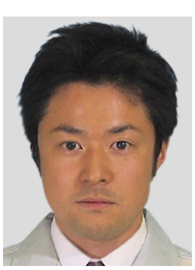
Mikiko Kawasumi received the B.S. degree in Mathematics from Tsuda College in 1988 and Ph.D. degree from Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology in 2008. She joined Toyota Central Research and Development Laboratories, Inc. in 1988 and has been engaged in the research and development of color vision for industrial inspection and design of the vehicle. She became a full-time lecturer at the Faculty of Culture and Creativity, Aichi Shukutoku University in 2000, an associate professor in 2002 and a professor in 2009. In 2011 she was transferred to Faculty of Science and Technology, Meijo University as an associate professor. Currently, she is studying on information design methods based on human feeling.

Hatsuo Yamasaki received the B.E. degree in electrical engineering from Meijo University, in 1971, and the Dr. Eng. degree in Information System Engineering from Meijo University, in 2006. Since 1971, he worked with the computer room. Since 1984, he has been with Graduate School of Science and Technology from Meijo University, as an Assistant, and a Lecturer. Since 2003, he has been with the Center for Computers and Information Technology, Meijo university, as an Associate Professor, and Professor. His research interests and activities include the human interface of the vehicle (Display Method of In-vehicle Display System Based on Reduction in aged Visual or Auditory Function), Information Education and e-Learning. He is a member of IEEJ, JSAE, JSiSE, JSET and etc.

Tomoaki Nakano received the B.E., M.E. degree in Electrical and Electronic Engineering from Nagoya University, Nagoya, Japan, in 1980 and 1982, and 1990, respectively. He joined Toyota Central Research and Development Laboratories, Inc., Aichi-ken, Japan, in 1982. Since then, he has been engaged in the research and development of machine vision for industrial inspection and driver assist and human interface on the vehicle. He became an Professor of Meijo University, Nagoya, Japan. Currently, he is working on a display method and a warning method for elder while driving.

Shin Yamamoto received the B.E. degree in Electrical Engineering from Gifu University, Gifu, Japan, in 1965 and the D.E. degree in Electrical Engineering from Nagoya University, Nagoya, Japan in 1984, respectively. He joined Toyota Central Research and Development Laboratories, Inc., Aichi-ken, Japan, in 1965. Since then, he has been engaged in research and development of machine vision for FA and ITS system. Since 1998, he has been a Professor in the Information Science Department, Meijo University, Nagoya, Japan. His current interests include human-machine interface in automobiles.

Muneo Yamada received the B.E. degree and the M.E. degree from Meijo University, Nagoya, Japan in 1989 and 1997 respectively, and the Ph.D. degree from the Aichi Prifectural University, Japan in 2006. From 1990 to 2007 he joined Nagoya Electric Works Co., Ltd. Since 2008, he has been an Associate Professor of the Department of Information Engineering, Faculty of Science and Technology, Meijo University, Nagoya, Japan. His research interest includes image processing and image understanding on intelligent transportation system. He is a member of IPSJ, IEEJ, JNNS and JSAP.



Yuta Doi ASMO Co., Ltd. engineer of development dept from 2006. He has researched and developed wiper-system products for automotive. He is a member of JSAE.