NOTE

Development of High Quality Image Processing LSI

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1 Introduction

In recent years, the price of a car navigation system has decreased by commoditization in the car navigation market, therefore to increase the added value of a product is needed. In addition, as high definition of home television and a PC monitor progresses, a large screen and the high definition are expanded to a small-sized display of a smartphone and the like. The same applies to a display of the car navigation system that is a FUJITSU TEN's core product (**Fig. 1**).

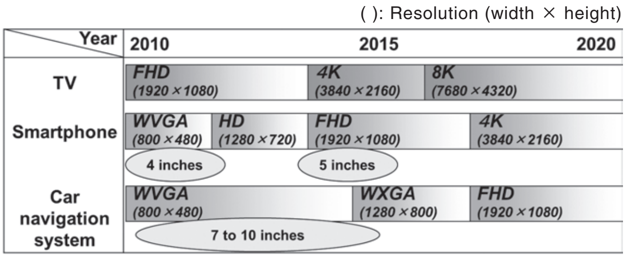

Fig.1 Trend of Display Resolution*(1)

Since the development of the high quality image processing LSI: "Vivid View Processor™" (hereinafter, referred to as VVP) in 2007, FUJITSU TEN has worked on high-quality image display and visibility enhancement. This time, we have developed the fourth-generation VVP4 including new technology: "high quality enlargement technology" and "distortion correction / viewpoint conversion technology for camera image."

This paper introduces FUJITSU TEN's challenge to the high image quality and visibility enhancement (VVP1, VVP2, and VVP3), and the newly developed VVP4 technology.

2 Efforts toward In-Vehicle High Quality Image Processing

2.1 Background

FUJITSU TEN thinks that a display for showing various pieces of information including a map of the car navigation system is one of the key interfaces which link people with vehicles, and is working on the development of its higher visibility and operability.

Fig. 2 shows the history of VVP that has been developed under the theme of "sharp / clear / vivid."

This section introduces the technology developed for VVP1 to VVP3, and the next section introduces the technology developed for VVP4.

2.2 Characteristics of VVP

(1) VVP1

①Optimal image correction technology by each image scene

The technology is characterized in that the LSI can analyze contour characteristic, color and gradation distribution by each image scene, and compensate to optimize "contour," "contrast" and "color" so that "sharp / clear / vivid" images are displayed (**Fig. 3**).

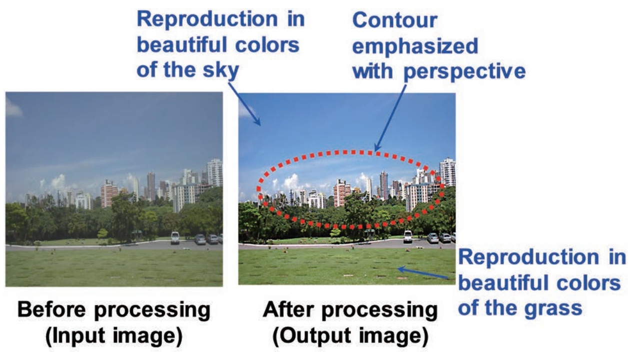

Fig.3 Example of Optimal Image Correction by Each Image Scene

* (1) According to a survey by FUJITSU TEN

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
History of developed technology	VVP1 ◆Optimal image correction technology by each image scene		VVP2 ◆Visibility enhancement technology for camera image		VVP3 ◆Image correction technology in direct sunlight ◆Backlight control technology				VVP4 ◆High quality enlargement technology ◆Distortion correction / viewpoint conversion technology for camera image		
Major VVP-equipped model	AVN777HD	AVN778HD	AVN779HD	AVN770HD	AVN-Z01	AVN-ZX02i	AVN-ZX03i	AVN-SZX04i	★Scheduled to be used for next model		

Fig.2 History of VVP

With this technology, textures of subjects, expression of luster and vividness on face were greatly improved.

(2) VVP2

①Visibility enhancement technology for camera image

The technology is characterized in that the visibility degradation is prevented by correcting the dark portion brightly and clearly. Specifically, brightness is properly corrected in the case of backlight that intensifies the contrast, and the proper brightness area is left as it is at night (**Fig. 4**).

With this technology, the image quality of night-time rear of the vehicle and front/side images captured by an in-vehicle camera was optimally corrected, and the visibility was enhanced.

Fig.4 Example of Visibility Enhancement

(3) VVP3

①Image correction technology in direct sunlight

The technology is characterized in that the deterioration of visibility that occurs in the case where the sunlight shines on the display (vividness is decreasing and the image looks totally washed out) is prevented, by correcting gradation / saturation of the image according to the illuminance degree of the sunlight on the display (**Fig. 5**).

With this technology, the visibility under in-vehicle environment (season, time of day, vehicle shape/size, location) was improved.

Fig.5 Exmaple of Image Correction Processing in Direct Sunlight

②Backlight control technology

The technology is characterized in that the image displayed on the display has the same visual quality as the original image even if the backlight luminance is reduced (reducing power consumption), by combining the adjustment of backlight luminance depending on brightness of the image with the image correction according to the backlight luminance (**Fig. 6**).

With this technology, we were able to achieve power saving (LED backlight power consumption is reduced by 24% average*(2)) and higher image quality (the contrast ratio is improved more than twice*(3)).

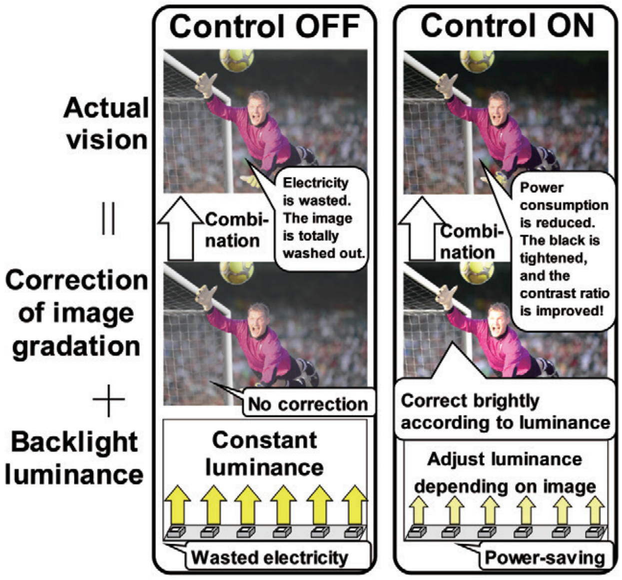

Fig.6 Example of Backlight Control Processing

3 Introduction of New VVP4 Technology

This section introduces the new VVP4 technology: "high quality enlargement technology" and "distortion correction / viewpoint conversion technology for camera image."

3.1 High Quality Enlargement Technology

(1) Problem of conventional technology

When a low-resolution image of a rear-view camera and a DVD, etc. is displayed on an in-vehicle large-screen / high-definition display, enlargement processing is required. Since the conventional enlargement processing (linear interpolation / bicubic interpolation) uniformly interpolates an input image in a horizontal direction or in a vertical direction, and there was a problem that "blurring" and "stair-like jaggies" occur in the vicinity of the edge on which bright and dark parts suddenly change. **Fig. 7** shows the problem associated with enlargement.

＊(2)＊(3) In the case of the product manufactured in 2011 compared to the conventional FUJITSU TEN models

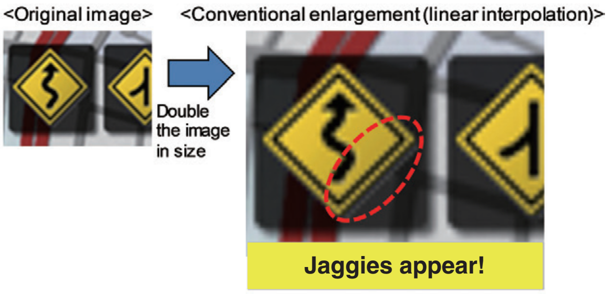

Fig.7 Problem Associated with Enlargement Processing

(2) Outline of new technology

This technology analyzes an edge on the pixel data around an interpolation position of the enlarged image, and performs interpolation processing according to the magnitude and angle of the edge. Thus, "smooth" and "sharp" enlargement processing as compared with the conventional one becomes possible. **Fig. 8** shows the processing flow of this technology.

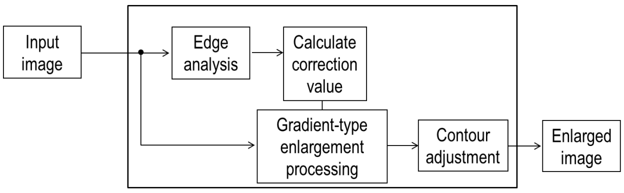

Fig.8 High Quality Enlargement Functional Block Diagram

Each processing is as follows.

①**Edge analytical processing:** Calculate the luminance gradient in X and Y directions from the input 4×4 pixel image around the interpolation position of the enlarged image, and calculate the vector of the edge.

②**Calculation of correction value:** Determine the interpolation angle and the interpolation reference pixel for enlargement processing from the calculated vector of the edge. Then, perform the optimum correction by position so as to strongly correct the part where the edge is strong and to weakly correct the part where the edge is weak.

③**Gradient-type interpolation processing:** Carry out an interpolation operation using the interpolation angle and the interpolation reference pixel to generate an enlarged image. Based on the conventional bicubic interpolation having a contour enhancement effect ("sharpness"), by combining the gradient-type interpolation capable of realizing "smoothness," the enlargement processing having both "sharpness" and "smoothness" is realized (**Fig. 9**).

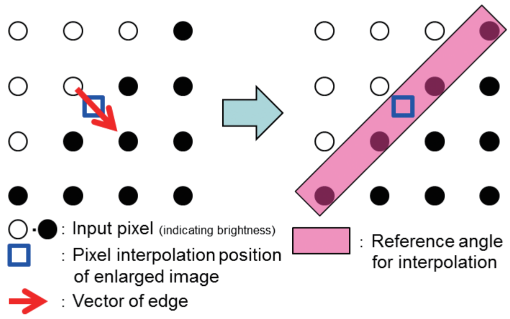

Fig.9 Edge Analysis and Gradient-Type Interpolation Processing

④**Contour adjustment processing:** While on the other hand a contour is enhanced in the bicubic interpolation, an unnatural edge that the input image does not have appears in relief (overshoot / undershoot). To prevent this, by specifying the part where the overshoot / undershoot occurs and by comparing the difference in brightness between the part and its surrounding pixels, the overshoot / undershoot of the unnatural edge is prevented, and the contour is naturally emphasized (**Fig. 10**).

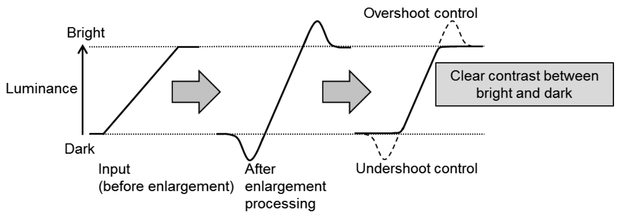

Fig.10 Contour Adjustment Processing

(3) Effect of developed technology

By applying this technology, even if images are enlarged, "sharp" and "smooth" images having no "jaggies" and "blurring" and utilizing the performance of a high-definition display can be displayed.

Finally, **Fig. 11** shows the result of comparison with the conventional technology.

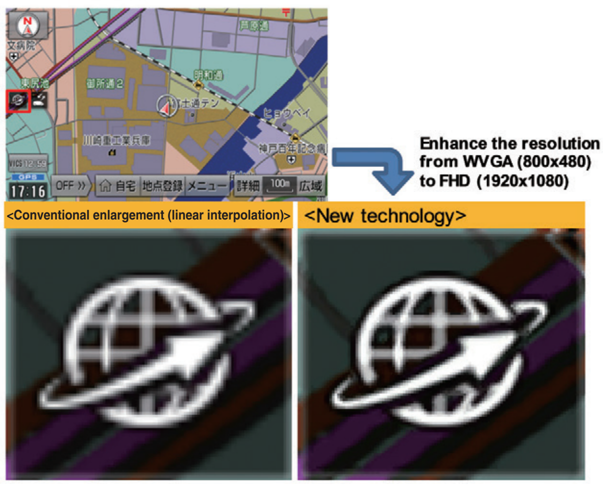

Fig.11 Comparison of Conventional Technology and New Technology

3.2 Distortion Correction / Viewpoint Conversion Technology for Camera Image

(1) Problem of conventional technology

In the case of a rear-view camera mounted at a low position, such as a Kei car, the problem was that it was difficult to grasp the size of space because the distant visual field of the image on the display was narrow. In addition, the images captured by a wide-angle lens had the problem that a normally straight object appeared curved due to the distortion peculiar to the lens. **Fig. 12** shows the visions by mounting position of the camera.

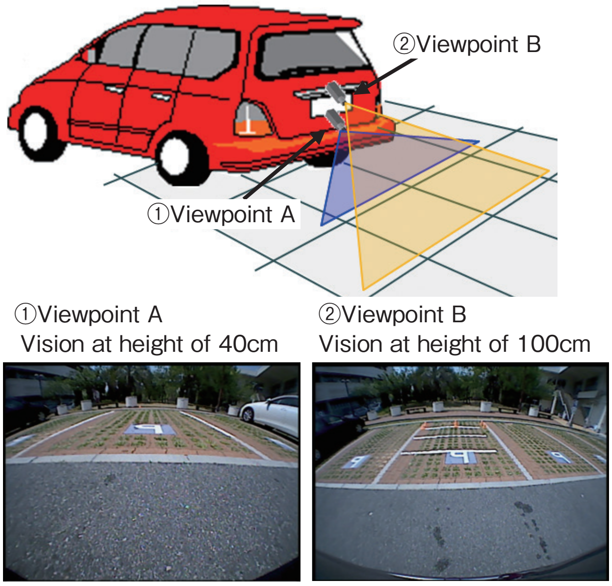

Fig.12 Comparison of Visions by Mounting Position of Rear-view Camera

(2) Outline of new technology

This technology converts the input image of the rear-view camera installed in the low position into the virtual viewpoint image from the higher position, and performs the distortion correction processing.

Fig. 13 shows the processing flow of this technology.

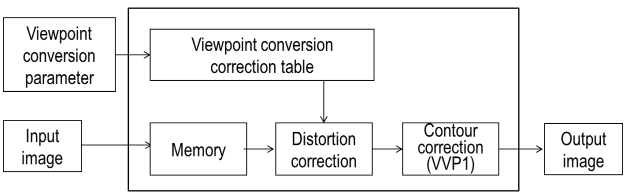

Fig.13 Distortion Correction / Viewpoint Conversion Function Block Diagram

Each processing is as follows.

①Viewpoint conversion processing

Convert the rear-view camera image into the road surface projection image, and generate the image viewed from the virtual viewpoint using the road surface model image (**Fig. 14**).

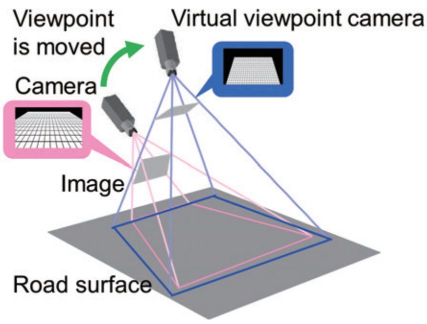

Fig.14 Viewpoint Conversion Processing

When an image is projected on the road surface model, there are problem (a) that a three-dimensional object (vehicle, building, person, etc.) is unnaturally enlarged in a vertical direction and problem (b) that "blurring" increases as the distance becomes farther.

To solve the problem (a), convert the road surface model which is projected on the unnatural image into the road surface correction model which is projected on the natural image, using a correction function according to the virtual viewpoint position (**Fig. 15**). To solve the problem (b), apply the image correction technology of VVP. Accordingly, high image quality has been realized as shown in **Fig. 16**.

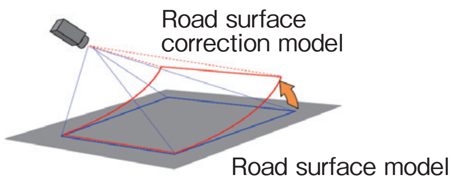

Fig.15 Road Surface Model Correction

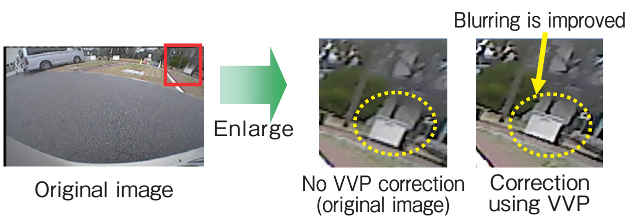

Fig.16 Image Correction Using VVP Technology

②Distortion correction processing

Convert the coordinates from the pixel location A (X, Y) before correction to the pixel location A' (X', Y') using a distortion correction table, and correct the image distortion due to lens characteristics (**Fig. 17**).

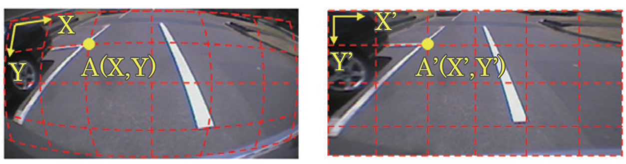

Fig.17 Distortion Correction Processing

(3) Effect of developed technology

By converting the rear-view camera image into the image viewed from an arbitrary virtual viewpoint position, it is possible to "clearly" recognize the three-dimensional object around the car, distance and others.

Finally, **Fig. 18** shows the difference in visions due to conversion of viewpoint position of the rear-view camera installed at a low position.

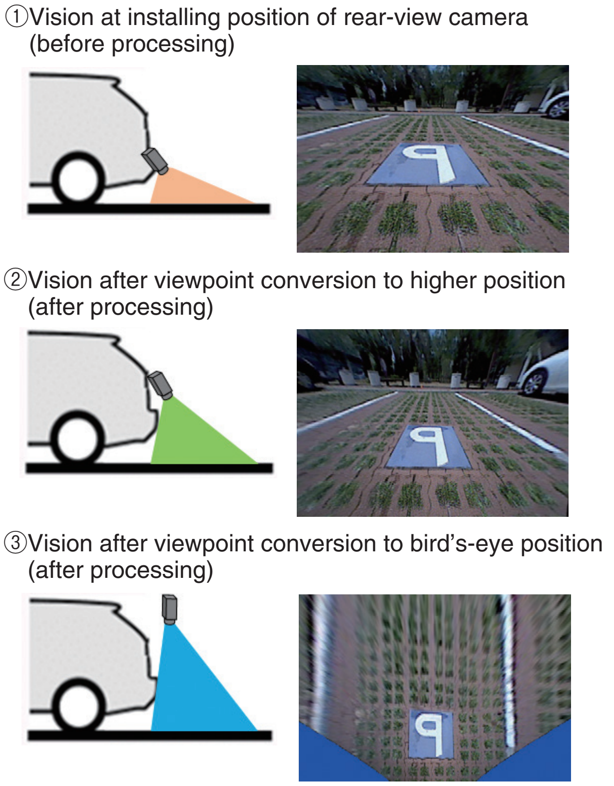

Fig.18 Comparison of Visions by Viewpoint Position of Rear-view Camera

4 Conclusion

With these developed technology, we were able "to display the high-quality images corresponding to an in-vehicle large-screen / high-definition display" and "to significantly enhance the visibility when driving a vehicle in reverse." The VVP4 is scheduled to be used for the next model product.

Fig. 19 shows the appearance of VVP4.

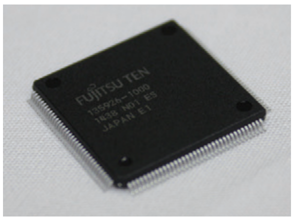

Fig.19 Appearance of VVP4

In the future, the in-vehicle display is expected to be applied to a vehicle cockpit such as a center display and a head-up display. We will make efforts to develop the technology that can contribute to customers' comfort-and-convenience / safety-and-security by watching their trends and market needs.

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