

Optimization of All-Around View Image Quality and Camera Calibration Method

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ABSTRACT

This paper describes the methods adopted to improve the image quality of the all-around view system. This system uses multiple vehicle-mounted cameras to capture images of the circumstances around the vehicle. The images undergo viewpoint transformation and are synthesized to create a single image seen from a virtual perspective overhead. The specific methods discussed here concern optimization of the design parameters for the camera orientation and a camera calibration method that does not involve physical movement of the cameras.

INTRODUCTION

Vehicle-mounted camera systems that serve to assist the driver's outward field of view have become increasingly common in recent years. Cameras are being applied to provide a rear view of the area behind a vehicle when backing up, a side view of the area near the front wheel when positioning a vehicle alongside the curb, and a front side view of the situation to the right and left sides to aid the driver in entering an intersection with poor visibility. Thanks to the higher operating speeds of electronic control units (ECUs) today, camera applications that can correct camera distortion and show drivers images in real time are also becoming more common.

We have been proceeding with research on an all-around view system, based on the concept that a system capable of showing the circumstances around a vehicle from a single overhead perspective would give drivers easy-to-understand visual assistance.⁽¹⁾⁽²⁾ This all-around view system provides the driver with an overhead view of the situation surrounding the vehicle as if looking down at it from above, which is obtained by applying viewpoint transformation to images taken with cameras mounted all around the vehicle.

In developing the all-around view system using four cameras mounted at the front, rear and on both sides, there were two issues in particular that were addressed. These were (1) a partial decline in all-around view image quality, (2) camera calibration. This paper presents an

analysis of the factors causing each of two issues in the system and examples of their respective solutions.

SYSTEM CONFIGURATION

As shown in Figure 1, the all-around view system is composed of four cameras (referred to here as real cameras) mounted at the front, rear and on both sides of the host vehicle. The front camera that captures a view of the area ahead of the vehicle is mounted near the grille. The right and left side cameras that provide views of the area on either side are incorporated in the bottom of the outside mirrors. The rear camera that shows the area behind the vehicle is mounted on the rear spoiler. Each camera is pointed downward to provide a view of the ground. Wide-angle cameras are used in order to obtain images around the entire vehicle with just four cameras. The all-around view system performs a viewpoint transformation process on the images taken with these four real cameras in order to create an overhead view as seen from a virtual camera positioned above the vehicle, as shown in Fig. 1.

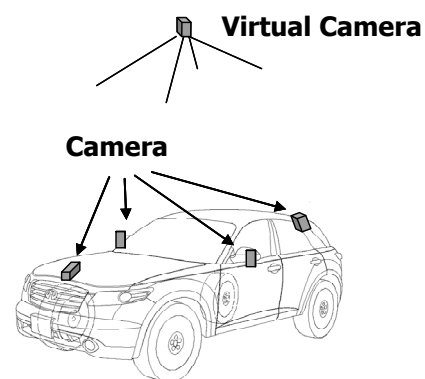


Fig. 1 Vehicle-mounted real cameras and virtual camera

Figure 2 outlines the operation of the all-around view system. As the first step, the system performs a viewpoint transformation process on the images taken with the four real cameras. Viewpoint transformation refers to an image processing technique whereby the signals of the real cameras are converted to the corresponding signals of the virtual camera. Specifically, a calculation is made for a light ray vector incident on

one pixel of the virtual camera to determine which of the light ray vectors incident on the pixels of the real cameras it corresponds to via an arbitrary datum plane. The parameters used in the calculation are the camera position, orientation, angle of view and lens distortion. Viewpoint transformation to the virtual camera image is accomplished by performing this calculation for all the pixels of the virtual camera. The ground is used as the datum plane in the viewpoint transformation process. A specified area of the image taken by each real camera is extracted, and the pixels are plotted to create the image of the virtual camera that is pointed straight down from over the vehicle. The four viewpoint-transformed images obtained from the respective real camera images are then synthesized to create one image looking down at the vehicle from overhead. The resultant overhead view is what the system presents on a dashboard monitor for the driver.

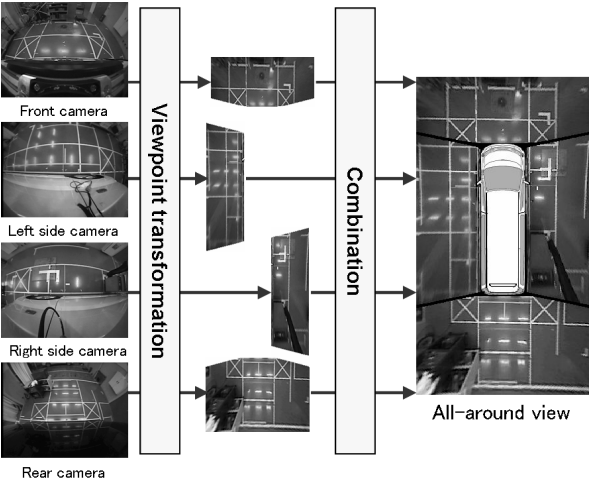


Fig. 2 Flowchart for creating an overhead view

Figure 3 is a block diagram of the system configuration. First, one image frame from each real camera is input into a corresponding input buffer. The image converter then plots the pixels of the camera images stored in each input buffer in reference to an image conversion table (memory map) that lists the rules for viewpoint transformation. Finally, a viewpoint-transformed image is synthesized from the pixel plots of each real camera image and stored in an output buffer. After the pixels of one overhead view frame have been plotted, the resultant image is shown on the dashboard monitor.

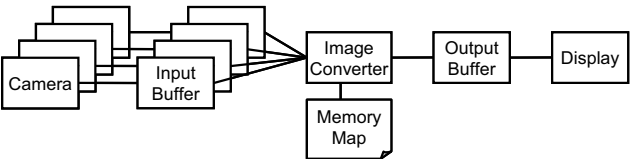


Fig. 3 Block diagram of the system

IMAGE QUALITY IMPROVEMENT BY OPTIMIZING CAMERA PARAMETERS

As explained earlier, the all-around view system performs a viewpoint transformation process on four real camera images to create an overhead view. However, the real-world ground area shown by one pixel in a virtual camera differs from the real-world ground area captured by one pixel in a real camera image. Consequently, one pixel of a real camera image may be plotted in several pixels in one portion of an overhead view. That condition is referred to here as "partial digital zooming" and the pixels of the overhead view become coarser as a result, causing a decline in image quality.

Figure 4 shows the calculated area of an overhead view where partial digital zooming has occurred. The dot distribution in the figure is the area where one pixel of a real camera image is plotted in more than two pixels in the overhead view. In other words, it is clear from the figure that the image quality has declined in the area where the dots are distributed. The area of dot distribution and quantity of dots vary depending on the real camera's installation position, orientation relative to the ground and angle of view.

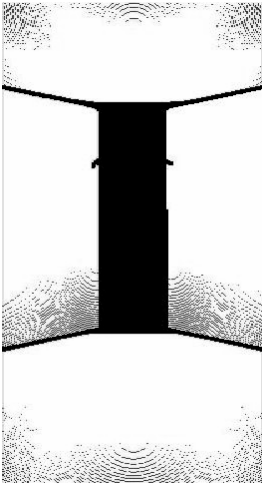


Fig. 4 Image with partial digital zooming

In view of these factors, it was reasoned that the image quality of an overhead view could be improved by optimizing the camera orientation and angle of view so as to reduce the frequency of occurrence of partial digital zooming. Various camera parameters might be considered, including the XYZ coordinates of the camera installation position, the camera orientation in terms of yaw, pitch and roll, the camera's angle of view θ , the number of camera pixels, aspect ratio and lens distortion, among others. In this study, it was decided to use the camera orientation components of yaw, pitch and roll and the camera's angle of view θ as the variable parameters.