Commercialization of all-surrounding monitor with parking frame detection function

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Abstract

We, DENSO TEN commercialized surrounding monitor system using three-dimensional virtual projection view point technology, and it was adopted as Panoramic View Monitor by TOYOTA MOTOR CORPORATION. However, Panoramic View Monitor has been required for built-in parking frame detection function of IPA (Intelligent Parking Assist) that assists the parking for driver by controlling a steering wheel by detecting parking frame from camera image, and also required for integrating parking frame detection function and HMI (Human Machine Interface) function, and for the improvement of image quality because of high-resolution of four cameras for Panoramic View Monitor (digital transmission).

We already established approaching object detection technology based on image recognition technology with vehicle camera. In order to realize this parking frame detection, we have developed a new detection algorithm, and a high functional product involving new HMI technology such as brightness correction and others.

1. Introduction

In recent years, the automobile industry has been accelerating development of surrounding monitoring technology using millimeter wave radars, clearance sonars, and cameras in order to achieve autonomous driving.

Our company commercialized the Multi Angle Vision™ in 2010 as the world's first 3D surrounding monitoring system using 3D virtual projection viewpoint technology, which has been adopted by Toyota Motor Corporation as the Panoramic View Monitor. For the Panoramic View Monitor we recently commercialized, we were required to embed an IPA (Intelligent Parking Assist) parking space detection function that detects the parking space from camera images and controls the steering wheel to support the driver's parking, and combine this with a parking space detection function and HMI (Human Machine Interface) function, as well as to use higher resolution (digital transmission) for the four cameras for Panoramic View Monitor to improve the image quality.

Our company had established approaching object detection technology based on image recognition technology using vehicle-mounted cameras; however, in order to realize this parking frame detection, we have developed a new detection algorithm and a high functional product involving new HMI technology such as brightness correction and others.

This Review introduces these efforts.

2. Product outline

2.1 System outline

The following shows the system structure for the all-surrounding monitor with a parking frame detection function **(Fig. 1)**. Images from the four vehicle-mounted cameras installed on the vehicle are loaded into the surrounding monitoring ECU adopting the high-speed transmission signal 1, and via four deserializers, the camera image signal is fed to the main microcomputer and recognition microcomputer.

In the recognition microcomputer, parking frame detection processing is run for the input camera image signal, and the parking frame detection result is transmitted to the Intelligent clearance sonar/IPA-ECU via CAN communication. In the Intelligent clearance sonar/IPA-ECU, route calculation and target parking position calculation processing are run based on the parking frame detection result, and a steering signal is transmitted to the EPS ECU and the target parking position information is transmitted to the surrounding monitoring ECU.

Furthermore, in the main microcomputer, the target parking position information is rendered on a four-camera composite image and then output to the display via high-speed transmission signal 2.

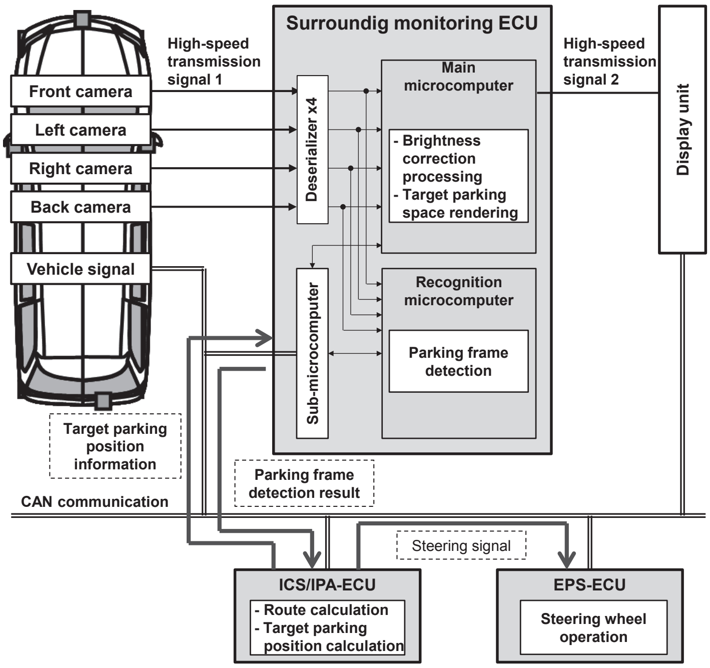


Fig. 1 System structure

2.2 Development of ECU that supports high definition cameras

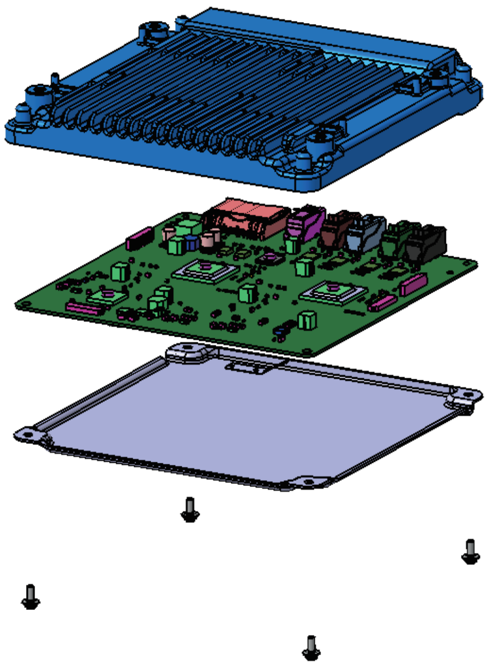
To successfully improve the image quality for the surrounding monitoring images, we changed the conventional VGA camera sensors (approx. 300,000 pixels) to QVGA camera sensors (approx. 1,200,000 pixels), and adopted high-speed transmission signal 1 as the image transmission method between the cameras and the surrounding monitoring ECU.

In order to achieve new HMI processing for the four high-resolution camera image signals, such as 3D-View and brightness correction between cameras, as well as to achieve the parking frame detection function, we used a high-performance microcomputer with almost double the conventional processing performance.

To achieve the high-resolution camera image signal processing, high-performance rendering processing, and parking space detection processing mentioned above in a single ECU, we adopted the low-profile/compact Surface Mount Device connectors for the high-speed transmission signal 1 and high-speed transmission signal 2 connectors, as well as integrated the microcomputers and microcomputer peripheral parts in high density and designed a dedicated compact power circuit.

2.3 Introduction of ECU structure

The following shows the structure of the developed product **(Fig. 2)**. This product consists of a single board and a chassis on the top and bottom. For the EMC measures, we introduced Shielded Twisted Quad connectors and Shielded Twisted Pair connectors for the high-speed transmission signal 1 from the four cameras and for the image output in high-speed signal 2. Also, to reduce heat from the two image processing microcomputers, we designed the upper chassis with an aluminum die-cast heatsink structure.



Size: 167 × 162 × 20 mm, Weight: 710 g

Fig. 2 Structure of the developed product

3. HMI technology development

3.1 Brightness correction technology for bird's-eye view

Conventional all-surrounding monitors simply combined images acquired from the four vehicle-mounted cameras and displayed that on the display. Then there was a remarkable difference in brightness between the cameras for the bird's-eye view due to changes in the environment around the vehicle.

For this system, we developed a correction technology that focused on differences in brightness from the same road reflected in each camera image.

The following shows the overall flow for correction processing **(Fig. 3)**.

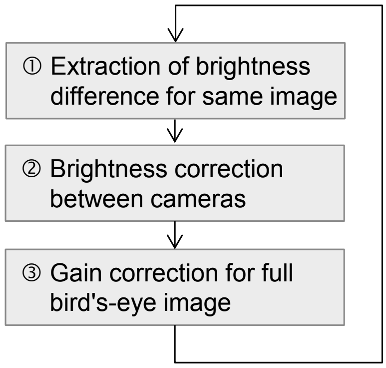


Fig. 3 Brightness correction processing flow

① Extract the brightness for the same area photographed by each camera and calculate the brightness difference.

② Correct bright images to be darker and dark images to be brighter, to diminish the brightness difference between cameras.

③ Correct the full bird's-eye view image to be brighter or darker.

As the brightness difference between cameras fluctuates depending on the mounting position of the camera, camera characteristics, and the peripheral environment (driving situation), we evaluated various situations and tuned the correction rate **(Fig. 4)**.

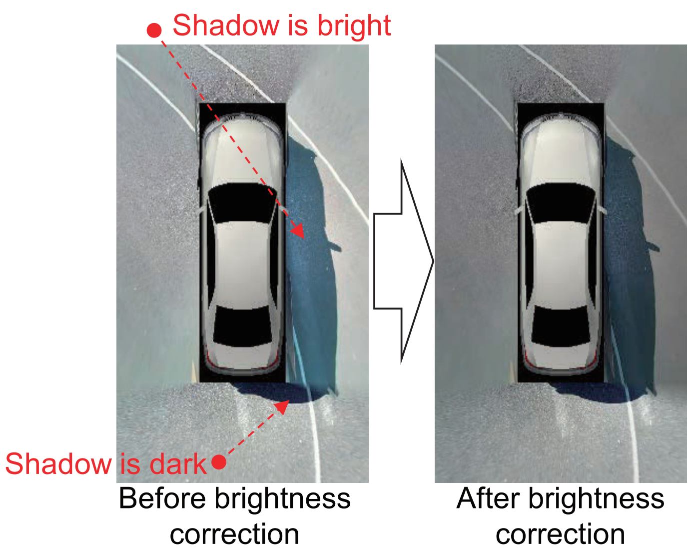


Fig. 4 Processing result for brightness correction

3.2 Image design by high-definition cameras

Due to the change from analog cameras to digital cameras, the data size for images taken by the all-surrounding monitoring system increased approximately fourfold for each camera, and a high-definition camera image could now be displayed on the display. However, for the bird's-eye view that looks down on the vehicle, it was necessary to raise the reduction rate for the high-definition camera images to match the amount by which the road is displayed on a reduced scale to make the composite bird's-eye view. This processing caused image noise (moiré).

After an investigation, we discovered that this image noise (moiré) occurred due to the thinning (drop out) of pixels from reducing the original camera image all at once. Therefore, as a countermeasure, we created images with an aspect ratio of 1 to 2, 1 to 4, and 1 to 8 in advance before making the composite bird's-eye image and used these images to combine the bird's-eye image, thus enabling us to reduce the image noise **(Fig. 5)**.

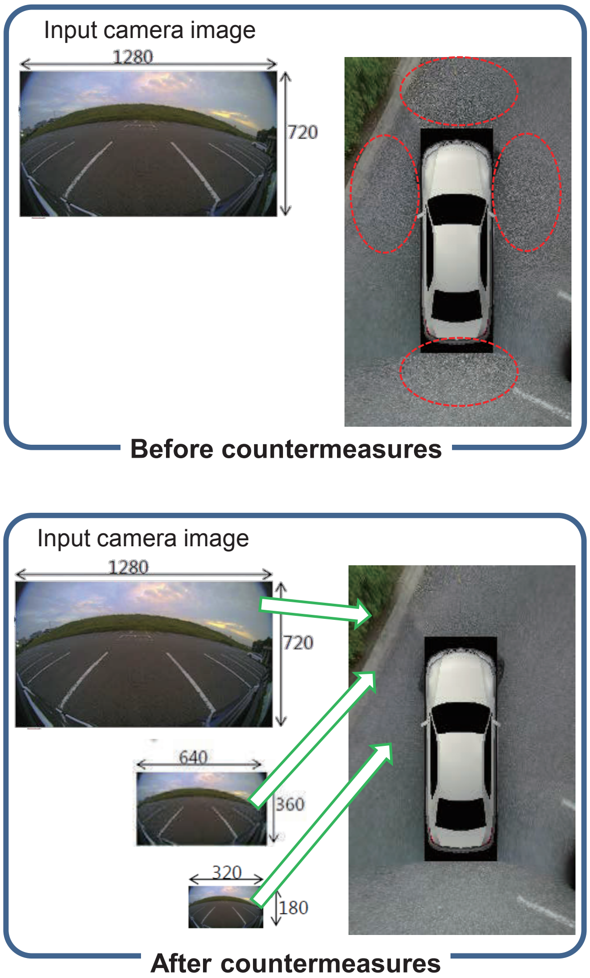


Fig. 5 Processing result for digital image noise countermeasures

3.3 IPA-linked HMI

We also improved the information to be displayed during parking control by linking between the Panoramic View Monitor and the IPA compared to the conventional IPA system. The following introduces the improved content.

① Parking frame selection HMI

In the conventional IPA system, the driver selected from multiple parking frames that were recognized in the image by turning the steering wheel left or right. However, with Panoramic View Monitor, we changed to the HMI so as for the driver to be able to directly select the target parking space by touching the screen **(Fig. 6)**.

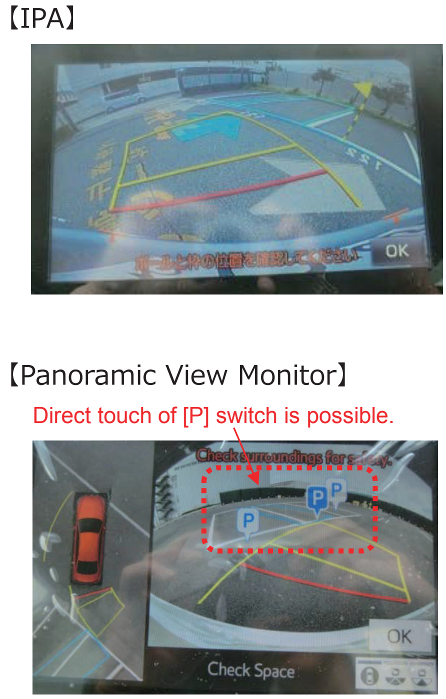


Fig. 6 Parking space selection HMI

② Direction change position HMI

In the conventional IPA system an indicator was used to display the distance to the position for changing directions. However, the Panoramic View Monitor rendered an arrow to indicate the direction change position on the road in the bird's-eye view and front/back camera images, thus it realized an intuitively easy-to-understand display **(Fig. 7)**.

【IPA】

Fig. 7　Direction change position HMI

③ Parallel departure HMI

The conventional IPA system displayed the direction selection for departing parallel parking using a vehicle illustration without camera images. In Panoramic View Monitor, we have changed the specifications so as to display this illustration combined with a bird's-eye view image to confirm the surroundings before departure **(Fig. 8)**.

【IPA】

Fig. 8　Parallel departure HMI

4. Development of parking frame detection algorithm

4.1 Outline of parking frame detection processing

The following shows an outline of the parking frame detection processing **(Fig. 9)**. The conventional IPA detected the parking frame using only the rear camera. However, this system detects the parking frame using the side cameras as well, in order to improve the parking frame detection rate and the detection accuracy.

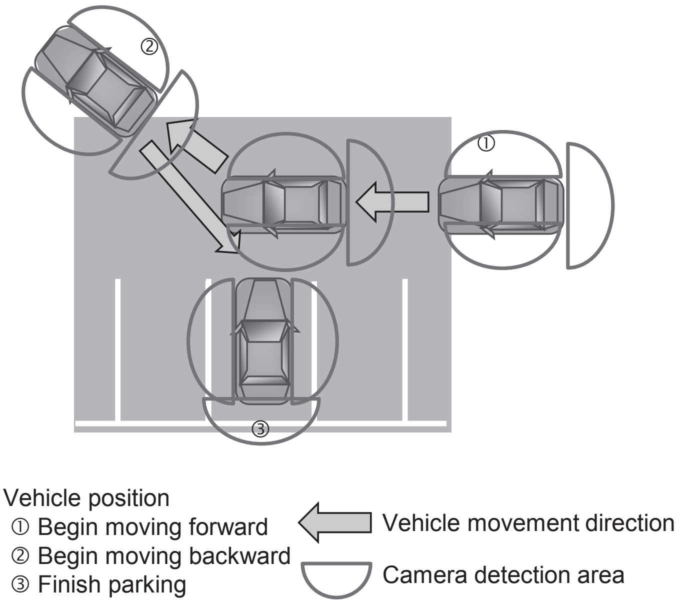


Fig. 9 Outline of parking space detection processing

4.2 Parking frame detection processing flow

The following shows the parking space detection processing flow **(Fig. 10)**. First, the parking frame lines are detected from the images of the side cameras and rear camera. Next, the parking frame is constructed from this line information and the past parking frame detection results. The information for the detected parking frame is sent to the Intelligent clearance sonar/IPA-ECU at a certain frequency.

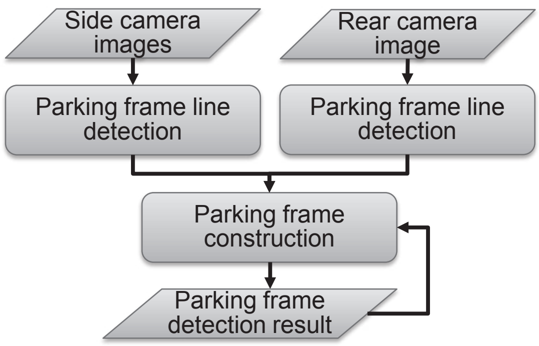


Fig. 10 Parking space detection procession flow

After market environment investigation, we discovered that parking frames in the actual field are mainly double-lines. Based on this investigation result, we have developed parking frame line detection processing and parking frame construction processing to be able to detect these double-line parking frames.

For double-line parking frames, for proper detection, it is necessary to detect the two inner lines. However, faded parking frame lines, stains or cracks in the road, or lines from other patterns could be detected, thus preventing proper detection of the inner lines and causing false detections. Therefore, first of all, we adjusted the detection sensitivity in the parking frame line detection part to be able to detect faded lines.

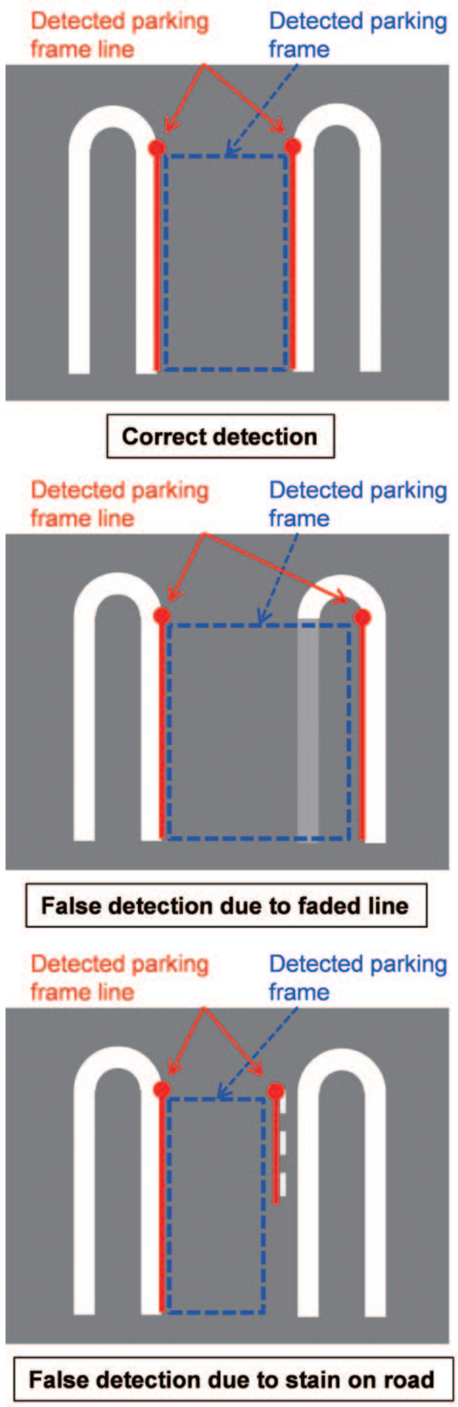


Fig. 11 Detection example of a double-lined parking space

Next, in order to prevent lines with cracks in the road or other patterns from being used for constructing the parking frame, we have removed the line information in the parking frame construction part based on the structure information, which allows the system to correctly construct the parking frame using the inner lines **(Fig. 11)**.

4.3 Parking frame detection performance evaluation

As a performance evaluation for the parking frame detection, we performed a basic performance evaluation using an evaluation matrix and larger scale field evaluation, based on market investigations.

In the basic performance evaluation using an evaluation matrix, in order to grasp the variation and performance limitations and confirm market quality, we created an evaluation matrix to visualize the completeness of the market environment through setting parameters such as parking frame shape, road status, brightness, and weather, and then we determined priority based on the encounter rate in the market to narrow down items for evaluation **(Fig. 12)**.

In the larger scale field evaluation, in order to confirm differences between individual parking frames and evaluate parking frames that were not handled in the evaluation matrix, we selected evaluation situations from combinations of parameters, such as application, regionality, number of vehicles, and parking frame structure for evaluation.

As the result of these evaluations, we confirmed that the majority of parking frames in the market could be detected.

5. Conclusion

Here, we introduced efforts related to HMI technology involved in the introduction of digital transmission for cameras, image recognition technology for detecting parking frames from camera images, and the development of a vehicle-mounted ECU implementing the technologies above. The system we developed was adopted in Toyota Motor Corporation's "Crown," which went on sale in June of 2018.

Moving forward, in order to respond to the rapid spread of autonomous driving, we will engage in new HMI technology and image recognition technology to develop driving support systems that provide drivers with a further sense of security and to contribute to the safety of the automobile society in future.

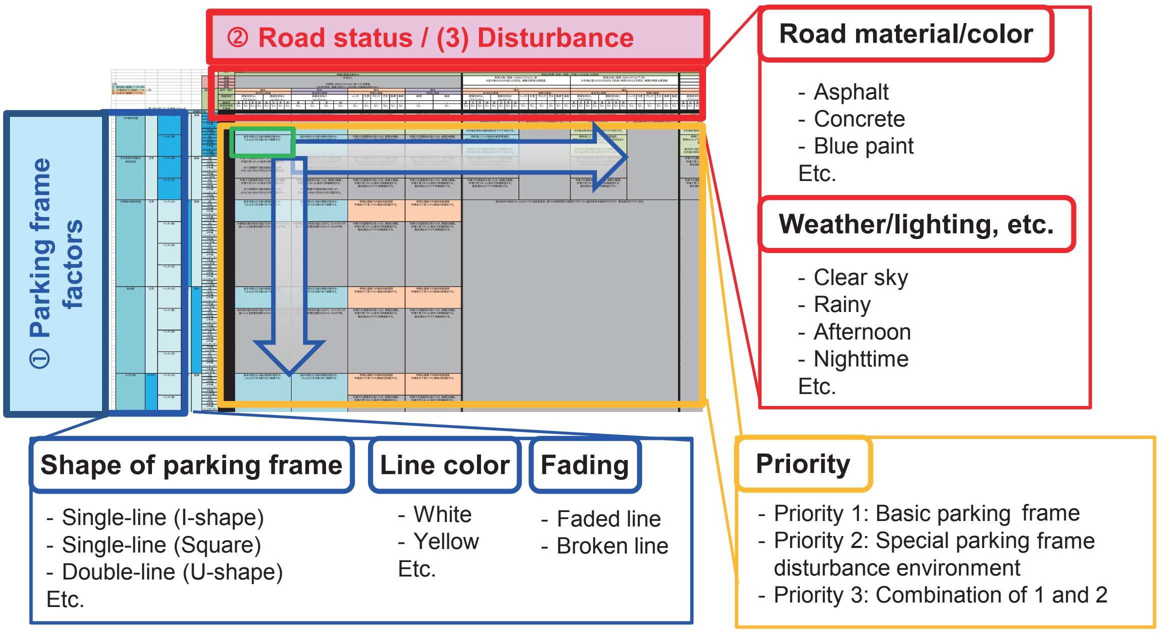


Fig. 12 Evaluation matrix

6. Acknowledgments

Lastly, we would like to express our gratitude to those in the Second Leading Safety Development Department and the 22nd Development Section of Toyota Motor Corporation, as well as those in cooperating companies and related departments for their cooperation in this development.

- Multi Angle Vision™ is a trademark of DENSO TEN Limited.
- CROWN is a registered trademark of Toyota Motor Corporation.

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