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Automatic Generation of Training Data for Long-Range Nighttime Recognition Using a Long-Baseline Stereo Camera

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In ADAS (Advanced Driving Assistant System), ADB (Adaptive Driving Beam) technology contributes to the reduction of traffic accidents by enhancing safety during night driving. ADB improves driver visibility by appropriately controlling high and low beams according to the presence of oncoming or preceding vehicles. In the performance evaluation in the development of ADB, it is necessary to verify under nighttime low-light conditions that high beams are properly controlled. For this purpose, an evaluation environment capable of recognizing and judging oncoming and preceding vehicles from a long distance is required.

From this background, in image recognition development for ADB using a forward-facing monocular camera, it is essential to accurately evaluate recognition performance for long-range nighttime vehicles. This requires a reliable ground-truth ranging method and an efficient technique for generating training data. However, in the long-range region of approximately 700 m, distance measurement itself becomes difficult, and creating training data requires substantial manual annotation effort, which remains a major challenge.

In this study, we propose an automatic training data generation technique for long-range nighttime vehicle recognition by utilizing distance measurement results obtained from a long-baseline stereo camera. The stereo camera provides reliable ranging information for distant vehicles, and its overview is shown in Fig. 1. By leveraging these ranging results, the proposed method generates training data for images captured by an ADB-oriented forward-facing monocular camera.

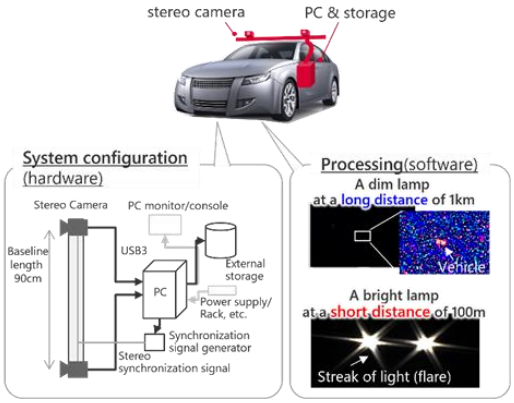

Fig. 1 Overall System Concept

The proposed method adopts a two-step association approach. In the first step (STEP1), two-dimensional detection bounding boxes of vehicles obtained by the stereo camera are aligned with the forward-facing monocular camera image using a calibration-based geometric transformation. In the second step (STEP2), vehicle lamp light sources are re-searched within the surrounding region of the aligned area to compensate for residual alignment errors. By combining geometric projection with light-source-based refinement, the two-step association method enables accurate generation of annotation bounding boxes for long-range nighttime vehicles. The concept of the proposed method is shown in Fig. 2.

The effectiveness of the proposed method was evaluated using nighttime driving data collected on a 1 km straight road. When only STEP1 was applied, the correspondence accuracy was 57.2%. By introducing STEP2, the accuracy improved significantly to 98.9%, confirming that highly accurate annotation boxes can be generated. In addition, while manual ground-truth annotation required approximately 8 hours per 1,000 images, the proposed method reduced the processing time to about 45 minutes per 1,000 images, achieving approximately 90% reduction in annotation workload.

Furthermore, a vehicle detection AI model was updated using the automatically generated training data. As a result, the nighttime vehicle detection accuracy improved from 72.4% to 90.7%, demonstrating a significant improvement in recognition performance for long-range nighttime vehicles.

These results indicate that the proposed method not only improves annotation accuracy but also greatly reduces annotation cost. The method contributes to improving evaluation efficiency in image recognition development for ADB using a forward-facing monocular camera and provides an effective framework for generating training data and updating vehicle recognition models under nighttime conditions.

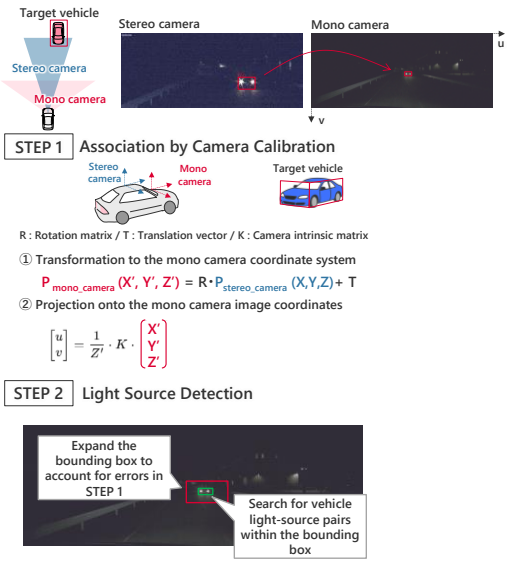

Fig. 2 Concept of Automatic Training Data Generation