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We propose a system for rain and [redacted]ion using [redacted]icle sen[redacted]
sors. Fog density is calculated fr[redacted]g vehicle's visibi[redacted]y a[redacted]
in-vehicle camera and inter-vehicle [redacted]illimeter- ave[redacted]- ave[redacted]
ainfall determination is achieved [redacted]aindrops on a indshield from [redacted]
vehicle camera images. periment[redacted]cle camera images and rad[redacted]
collected hile driving vehicles in f[redacted]and fair conditions d[redacted]
the accuracy and the applicability [redacted]

Recently great advances have been se[redacted]elopment of ITS technology[redacted]
assistance and navigation with the aid [redacted] and sensors are being active[redacted]
oped. In particular, in-vehicle camera[redacted]ommonly utilized since they[redacted]
important visual information. Driving is [redacted]lt in adverse weather conditi[redacted]
in fair conditions, so accident rates dra[redacted]crease. Weather changes temp[redacted]ly
and spatially, so it is important to develo[redacted]s that recognize weather in real-tim[redacted]
by in-vehicle sensors for driver assistance[redacted]

In this paper, we propose a weather r[redacted]system and focus on rain and [redacted]
using an in-vehicle camera and a -wave[redacted]ce. Figure 1 shows an overview[redacted]
our system. From in-vehicle camera images a[redacted]ave radar data, our system outp[redacted]
two kinds of weather information around a ve[redacted] density and a determinati[redacted]
rain. Auto-wiping, automatic lighting of fog lan[redacted]and break control, and [redacted]
of attention are examples of potential assistance t[redacted]realized with resp[redacted]
system.

RELATED WORKS

Koschmieder's model expresses the degradation of brightness by atmospheric scattering [1]. Based on this model, Narashimhan and Nayar proposed a method that restores

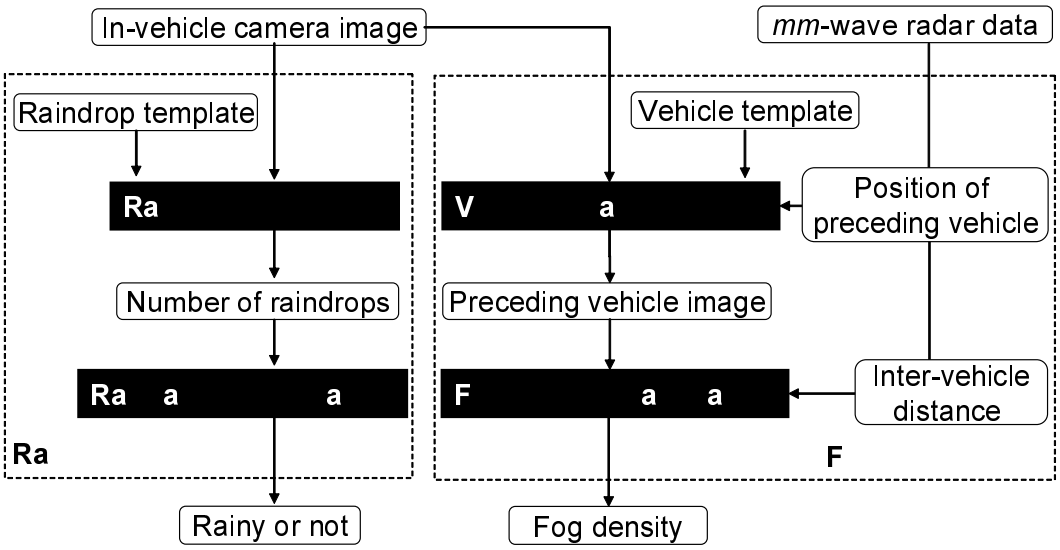

Figure 1: System overview

the contrast of images captured in foggy conditions [2]. Techniques of visibility enhancement and contrast restoration for driving assistance which use this model have also been developed [3, 4]. According to Cavallo et al., under foggy conditions the distance to a preceding vehicle's tail-light is perceived to be 60% further away than under fair conditions [5]. For real-time estimation of visibility in foggy conditions using in-vehicle stereo cameras, Kuwon proposed Motorists Relative Visibility (MRV) [6], and Hautiere et al. proposed a method to estimate visibility distance [7]. To realize fog lamp automation, Leleve and Rebut tried to estimate visibility using an in-vehicle camera [8].

ALGORITHM

Our system calculates fog density using both an in-vehicle camera and a -wave radar device [9, 10] (Fig. 1). To evaluate fog density, we focus on the relationship between visibility degradation of a preceding vehicle and inter-vehicle distance (Fig. 2). -wave radar is utilized with an in-vehicle camera, since it can measure distance without being influenced by adverse weather.

Vehicle Image Clipping

Figure 3 shows the process of vehicle image clipping. A preceding vehicle region is detected by template matching in a candidate rectangle area with a vehicle template image. The candidate area's size and position are determined from information provided by -wave radar, including inter-vehicle distance and vehicle position in the image. The template image and each rectangle image in the candidate area are normalized to restore the contrast degraded by fog before calculating their similarity. Similarity is defined as their inner product. Our system clips a rectangle image that gives the largest similarity as the preceding vehicle image.

When this method was applied to 10,028 images, clipping accuracy was 92.86%. Here, all images included a preceding vehicle. In this experiment, a typical vehicle image captured under fair conditions was used as the template image.

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Figure 4: Scattering coefficients for various foggy conditions

EXPERIMENT

Setup

We equipped a vehicle with an in-vehicle camera and a -wave radar device, which provides two kinds of information: distance and relative speed to preceding objects. From such information, our system finds the candidate position and size of a preceding vehicle in a captured image. Two vehicles of different colors and shapes were prepared as preceding vehicles. We collected data for this experiment while driving the vehicle in fair and various foggy conditions. Data were classified into three classes of fog density: Light, Moderate and Dense, by human subjects. Some were used as training data to determine the thresholds about fog density between two classes, and others were used as test data for system evaluation.

Results and Discussion

We compared the determinations obtained by our system with human subjects to evaluate the performance of our system. Table 1 shows the confusion matrix for determinations by the proposed system and by human subjects. The numbers in parentheses are the percentages of the element to the total number of elements in each row; the percentages in diagonal elements represent the precision rate for each class. For all classes, the overall precision rate was 84%. As for the precision of each fog density level, Light 88%, Moderate 73%, and Dense 92% were obtained. The results demonstrate that our system worked well, despite the variation of vehicles.

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