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Wet/Dry classification method with reflect and incident light observed from single camera

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Abstract

In this paper, a method is proposed to detect a wet road area. The detection is based on the analysis of the reflection and the incident light. To obtain both reflection and the incident light from a single camera, the environment 3D shape is assumed that it can be modeled by 3 planes. Finaly, the efficiency is shown by the experiments.

1. Introduction

Recently, there are many researchers who work in the area of Intelligent Transport System (ITS). Specially, there is a great interest in the assist system for a safety drive which is mounted on the vehicle. The ITS can be divided in to 2 categories, whether the system it self is mounted on the vehicle, or not. The system mounted on the vehicle will process the information collected from the outside of the vehicle, and estimate or detect useful information for the safety drive.

In this paper, we propose a method which classifies the area on the road to dry, wet or indeterminable area. Proposed method uses the information obtained from a single camera, fixed on the vehicle. Wet detection is based on the statistics of the reflection intensity.

A wet road is dangerous compared to a dry road since the surface of the road is slippery. In previous works, many researchers used a polarization camera [2] or a camera fixed above the road[2, 3]. Compared to them, the proposed method uses a normal camera fixed on the vehicle. This is a big difference against the previous methods. The polarization lens is unnecessary, and camera can move as long as it is fixed on a vehicle. The road map of the wet area will be created after the vehicle run on the road.

In a near research field, polarization lens is used in the reflection analysis. Miyazaki *et al*. proposed a reflection analysis method to estimate the surface shape of the transparent objeects[4]. Yanghai *et al*. proposed a reflection separation method based on multilayer method[5]. The defference between the proposed method is that they separate the reflection. On the other hand, the proposed method compute the incident light from a single image.

Our method is composed by 3steps. First, the compute a spatial temporal image by registrating the top-view images. Next, the method computes the incident light corresponds to each area. Finaly, the area is classified to 3 types:wet, dry or indeterminable. The originality of the proposed method is the estimation of the incident light by using the environmental shape information. The incident and reflection is obtained by single camera.

The rest of this paper is organized as follows. Section 2 explains the wet road surface reflection attribution and the incident lights. Section 3 explains the method in each step, and Sec. 4 demonstrates the efficiency of the proposed method.

2. Theory

In this section, the reflection attribute and the computation of the incident light is described.

2.1. Specular reflection

When we compare between a dry asfart road and a wet surface, the largest difference is the reflection. The dry road looks grey, and the color is uniform along the road. The color is uniform since the surface has strong random reflection attribute. Thus, the reflection on the dry road is independent from the angle.

On the other hand, wet road surface shows different reflection attribute compared to the dry one. A damp road surface looks darker than the dry surface. This reflection light is trapped inside the moisture on the surface. If the road is wet enough, that it's covered by water, then the surface makes specular reflections.

Since the vehicle runs on the road, we can collect the reflection strength from different angle in the time domain. If the reflection strength changes due to the angular change, the surface has specular reflection. On the other hand, if it doesn't change, it can have 2 possibilities. first is that it has no specular attribute. second is the incident light did not change.

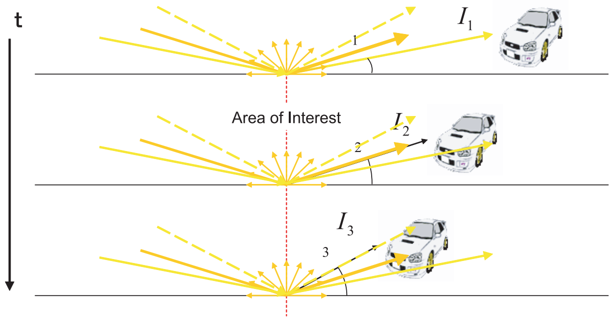


Figure 1: Draft image of the specular reflection and the random reflection

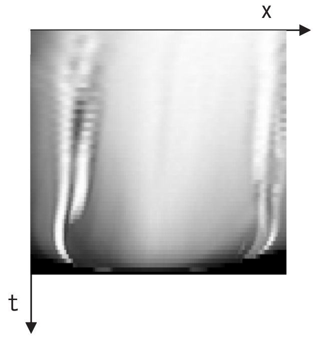


Figure 2: Spatial temporal image

2.2. Incident light

The classification between the dry area and the area which doesn't have enought change in the incident light requires the observation of the incident light.

If the camera is heading along the direction of the vehicle, both road and the environment must be captured in 1 image. If the distance between the camera and the environment objects are known, The position where the incident lights come from can be computed.

In sec. 3.2, we explain about the incident light computation. In this paper, instead of estimating the environmental shape, we assume that shape can be modeled by 3 planes.

3. Method

Proposed method is composed by 3 steps. First step tracks the points on the road to create a spatial temporal image. The second step is the computation of the feature from the spatial temporal image. The third step is the classification using 3 thresholds.

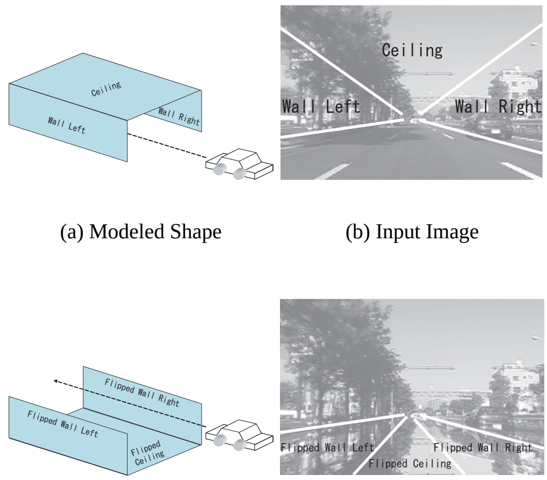
3.1. Tracking

For the tracking of the points on the road, we apply the tracking method proposed by Teshima *et al*[6].

A video sequence can be expressed as a 3 dimensional set of pixel expressed by x, y and t. In this paper, x and y express the 2 axes of the image and t expresses the time domain, respectively. On the other hand, the spatial temporal image is expressed by x and t as shown in Fig. 2. Each column express the same place.

3.2. Observation of the incident lights

To compute the variance of the incident lights, we make a spatial temporal image of the incident light based on the 3D environmental shape. In this paper, we do not estimate the 3D environmental shape but assume that it can be modeled by 3 planes. Two walls, ground and the ceiling, as described in Fig. 3 (a).



(a) Modeled Shape

(b) Input Image

(c) Flipped Model

(d) Virtual Incident Light Image

Figure 3: Input image and the incident light

First, each plane is projected in the input image by the known camera parameters(Fig. 3(b)). Each model's corresponding area in the image is preserved as a texture. Next, each plane is flipped against the ground and again projected to the image as shown in Fig. 3 (c). On the image, texture mapping is done to the flipped moedl's corresponding area by the preserved texture. Then the image appears that the entire ground is made by a specular reflection material. We call this image "Virtual Incident Light Image".

In Sec. 3.1, we tracked the pixel of the input image and made the spatial temporal image of the reflection light. By tracking the pixel of the virtual incident light image, we can have the spatial temporal image of the incident light.

To assume the environmental shape as a plane, distance between the camera and the environment object is required to be long enough.

3.3. Computation of the Features

After the tracking, spatial temporal image of both reflection and the incident light are obtained. In these images, each column expresses the 1D temporal signal of the reflection on the same position and the corresponding incident light. For each signal, 3 types of feature value are computed. The variance of the reflection light, average of the reflection light, variance of the incoming light.

The classification is done based on the 3 feature values. Each area is classified as dry, wet or indeterminable.

First, the decision can't be done if the incident light is constant. In that case, reflection will not change. Thus, it will be classified as indeterminable. For the variation of the reflection, we calculate the variance of the incident light among the time domain.

Second, if the area is determinable, i.e. if the incident light change during the time, the area will be determined based on the variance and the avearage of the reflection. From some pilot experiments, we know that the wet area has both high variance and average.Thus, if the area has both high variance and high average, the area is detected as wet, otherwise dry.

4. Experiments

Experiments has been done with both wet road and the dry road to demonstrate the efficiency of our method.

The parameters used for each experiment is shown in Table. 1. The example of input image sequence is shown in Fig. 4 and 6. The result is shown in Fig. 5 and 7.

In each video sequence, the motion of the camera is tracked and the spatial temporal image of both reflection and the incident light are created. By computing the statistics described in Sec. 3.3, each area is classified as wet, dry or indeterminable. In these result images, the wet area is surrounded by black line, the dry area is surronded by whilte line and the indeterminable area is surrounded by grey line. Each result is summarized by the following table 2.

5. Conclusion

In this paper, we propose a method which detects dry area on the road surface based on the statistics of the reflection and the incident light. To compute the incident light, the 3D environmental shape is modeled by 3 planes. By flipping each plane against the ground, the virtual incident light image is created.

The detection rate of the wet area was 99.44 % and the recall rate was 90.68 % On the other hand, detection rate of the dry area was 75.65 %.

Figure 4: Example input images of wet road

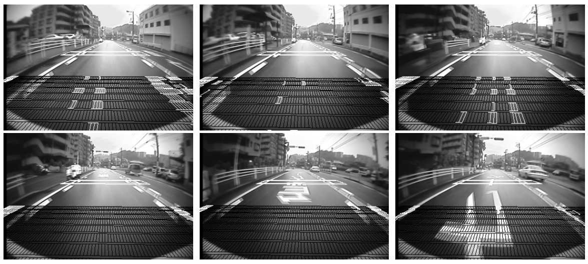


Figure 5: Result images of wet road

References

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Table 1: Experiment parameters

Parameter	Wet road	Dry road
Length of Area	800mm	800mm
Width of Area	80mm	80mm
Length of Survilance	60m	60m
Width of the road	18m	30m
Height of the ceiling	20m	20m
threshold of the variance of the reflection	300	
threshold of the avearage of the reflection	130	
threshold of variance of the incident	100	

Figure 6: Example input images of dry road

Figure 7: Result images of dry road

Table 2: Summarized result of the Experiment

classified result	Dry road	Wet road
dry	9020	2904
wet	174	31122
indeterminable	1126	294

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