



A method to segment moving vehicle cast shadow based on wavelet transform

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ABSTRACT

In many image analysis and interpretation applications, shadows interfere with fundamental tasks such as object extraction and description. According to illumination, shadows interfere with moving vehicle extraction and location and recognition. For this reason, shadow segmentation is an important step in real-time vehicle recognition system. In this paper, we propose a simple and effective method for detection of moving cast shadows on a traffic surveillance scene. The proposed method exploits spectral and geometrical properties of shadows and relationship between the point in shadow region and space position and vehicle shape. Firstly, the cast shadows can be rough detected by spectral properties, and then feature points of occluding function are detected using wave transform, finally, the boundary between self-shadow and cast shadow is detected. The proposed method does not know in advance the light source direction and the color information of vehicle and background texture information. Our experimental results demonstrate that the proposed cast shadows segmentation method can detect the shadows regions accurately and completely. This is the foundation for future vehicle recognition and understanding.

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1. Introduction

The vehicle recognition system (VRS) in intelligent transportation system (ITS) is strongly tools of transportation management in modern city management (Benjamin et al., 1998; Cucchiara et al., 2003; Thirion, 1992). Many works on ITS aim at helping traffic flow management by providing information on how many vehicles are in the scene. Moreover, moving vehicle detection in a video sequence is very difficult question because of cast shadows. Moving cast shadows cause the erroneous segmentation of objects in the scene. Shadows provide relevant information about the scene represented in an image or a video sequence. They contain cues about the shape and the relative position of objects, as well as about the characteristics of surfaces and light sources. Despite this, in applications requiring the identification of objects, shadows modify the perceived shape and color, thus introducing a distortion in the object detection process. For this reason, the problem of shadow detection has been increasingly addressed over the past years.

Most of the proposed approaches take into account the shadow model described in Stauder et al. (1999). To account for their differences, the various shadow detection algorithms are divided into a

two-layer taxonomy in Prati et al. (2003). The first-layer classification is called deterministic approaches and statistical approaches, the second-layer classification is further divided the statistical approaches in parametric and nonparametric methods and divided the deterministic approaches in model-based and nonmodel-based method. And shadow detection techniques can be also classified into two groups in Elena et al. (2004): model-based, and property-based techniques. Model-based techniques (Cucchiara et al., 2003; Thirion, 1992; Koller et al., 1993; Prati et al., 2003; Dong et al., 2005) rely on model representing the a priori knowledge of the geometry of the scene, the objects and the illumination. Model-based schemes generally handle simple objects and are only applicable to the specific application they are designed for. The number and the complexity of the models increase rapidly if the aim is to deal with complex and cluttered environments with different lighting conditions, objects classes and perspective views. Property-based techniques (Stauder et al., 1999; Sexton and Zhang, 1993; Yang et al., 2005; Cucchiara et al., 2001; Martin and Jisnu, 2005; Jun-Wei et al., 2003; Elena et al., 2004) identify shadows by using features such as geometry, brightness or color of shadows. When the color between objects and shadows is as near as makes no difference, the property-based approaches are invalidation.

In this paper, we propose a simple and effective method for the detection and segmentation of cast shadows. The proposed method exploits spectral and geometrical properties of shadows and relationship between the point in shadow region and space position and vehicle shape. A hypothesis about the presence of a shadow

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is first generated on the basis of an initial and simple evidence, i.e., shadows normally darken the surface upon which they are cast. The validity of this hypothesis is further verified on each detected region using the occluding function by making use of hypotheses on geometric properties of shadows. Finally, the boundary between self-shadow and cast shadow becomes finding the feature points of occluding function using multi-resolution of wavelet transform. The proposed method does not know in advance the light direction and the color information of vehicle and background information.

We demonstrate that the proposed method can be applied to video sequences. Our experimental results show that the proposed method is robust and effective in detecting shadows. The paper is organized as follows. In Section 2, the spectral and geometrical properties characterization of shadows is described. The occluding function and its characterization and the detail cast shadows detection process describe in Section 3. Experimental results and conclusions are presented respectively in Sections 4 and 5.

2. The spectral and geometrical properties of shadows

A Shadow occurs when an object partially or totally occludes direct light from a source of illumination. Shadows can be divided into two classes: self and cast shadow (Stauder et al., 1999; Sexton and Zhang, 1993; Elena et al., 2004). An image in Fig. 1 can be divided into four non-intersectant regions: cast shadow region ω^c , self-shadow region ω^s , object region ω^o , and background region ω^b . A self-shadow is a part of the object, in this paper, the separation line L_{CD} in Fig. 1 between cast shadow and self-shadow can be detected by our proposed shadow segmentation method.

Let $S_R(\lambda)$, $S_G(\lambda)$, $S_B(\lambda)$ be the spectral sensitivities of the red, green, and blue sensors of a color camera, respectively. The color components of the reflected intensity reaching the sensors at a point (x, y) in the 2D image plane are

$$C_i(x, y) = \int_{\lambda} E(\lambda, x, y) S_{C_i}(\lambda) d\lambda \quad (1)$$

where $C_i \in \{R, G, B\}$ are the sensor responses, $E(\lambda, x, y)$ is the image irradiance at point (x, y) , and $S_{C_i}(\lambda) \in \{S_R(\lambda), S_G(\lambda), S_B(\lambda)\}$.

Since image irradiance is proportional to scene radiance, for a pixel position (x, y) representing a point $\vec{p}$ in direct light, the sensor measurements are

$$C_i(x, y)_{lit} = \int_{\lambda} \alpha (L_a(\lambda) + L_b(\lambda, \vec{p}) + L_s(\lambda, \vec{p})) S_{C_i}(\lambda) d\lambda \quad (2)$$

where $L_a(\lambda)$, $L_b(\lambda, \vec{p})$, $L_s(\lambda, \vec{p})$ is the ambient reflection term, the body reflection term, and the surface reflection term, respectively, and λ is the wavelength, and α is the proportionality factor between radiance and irradiance.

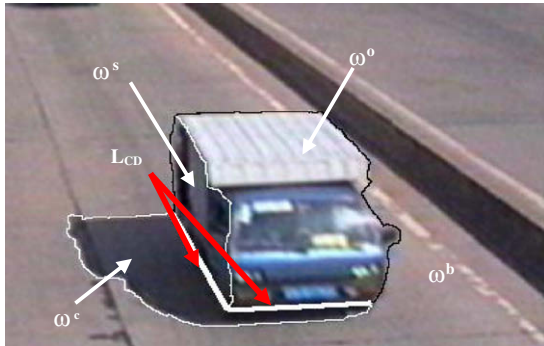


Fig. 1. Shadow area division.

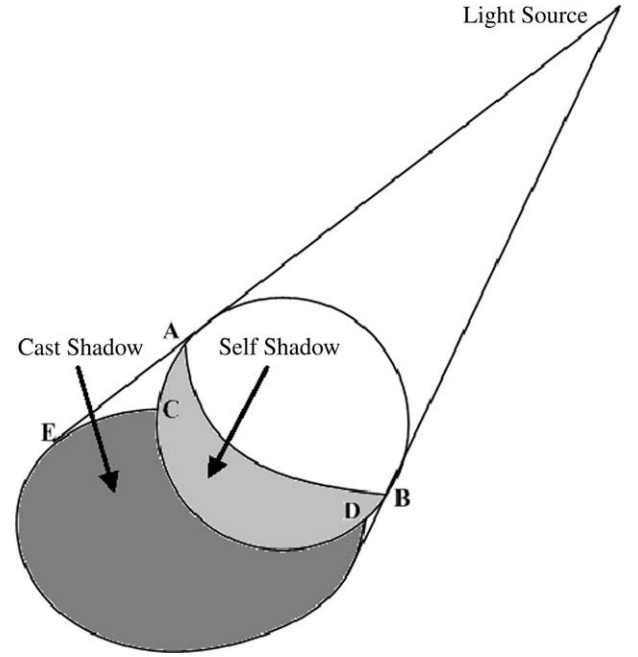


Fig. 2. Shadow line definition.

Giving a color vector $\vec{C}(x, y)_{lit} = (R_{lit}, G_{lit}, B_{lit})$, for a point in shadow the measurements are

$$C_i(x, y)_{shadow} = \int_{\lambda} \alpha L_a(\lambda) S_{C_i}(\lambda) d\lambda \quad (3)$$

Giving a color vector $\vec{C}(x, y)_{shadow} = (R_{shadow}, G_{shadow}, B_{shadow})$, it follows that each of the three RGB color components. If positive and not zero, decrease when passing from a lit region to a shadow one, that is

$$\begin{cases} R_{shadow} < R_{lit} \\ G_{shadow} < G_{lit} \\ B_{shadow} < B_{lit} \end{cases} \quad (4)$$

This is the spectral properties of shadows.

On the other hand, the geometric appearance of a shadow depends on objects and scene layout. However, it is possible to identify some geometrical characteristics of shadows, the shadow boundaries, without any knowledge of the structure of the object or of the scene. Shadow boundaries can be classified into four classes (Prati et al., 2003): shadow-making lines, shadow lines, occluding lines, and hidden shadow lines. These lines are depicted in Fig. 2. Shadow-making lines AB, separate the illuminated surface and the non-illuminated surface of an object. They appear to be the outlines of an object if the position of the observer is aligned with the direction of the light source. The projections of the shadow-making lines in the direction of light rays are called shadow lines DE. Occluding line CD, separate an object from its cast shadow. A hidden shadow line CE, is a shadow line corresponding to a non-visible shadow-making line.

3. Cast shadow segmentation algorithm

We exploit the spectral and geometrical properties described in Section 2 to automatically segment shadows in video sequences. Firstly, the shadows can be rough segmented using the spectral properties of shadows. In order to segment the boundary between self-shadow and cast shadow, we define the occluding function, and its characterization are described. Finally, the occluding line

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