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Integration of fuzzy Markov random field and local information for separation of moving objects and shadows

Badri Narayan Subudhi [a], Susmita Ghosh [b], Sung-Bae Cho [c], Ashish Ghosh [d,*]

[a] Department of Electronics and Communication Engineering, National Institute of Technology, Faramagudi, Ponda Goa, 403401, India
[b] Department of Computer Science and Engineering, Jadavpur University, Kolkata 700032, India
[c] Soft Computing Laboratory, Department of Computer Science, Yonsei University, Seoul 120-749, South Korea
[d] Machine Intelligence Unit, Indian Statistical Institute, Kolkata 700108, India

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A B S T R A C T

Major contribution of this article is to devise an efficient *moving cast shadow* segmentation technique that separates out the moving objects from their shadows casted on the background. It follows two major steps: background separation and shadow detection. For background separation, initially a background model is built. For a particular pixel location we construct the background model by taking the median of pixel values at the corresponding pixel locations in the temporal direction. To suppress the effects of quick change in illumination, and color frequency variation of texture background, in the proposed scheme we have extracted the RGB color features and ten local features at each pixel location in the considered target image frame and the constructed reference image frame. For background separation, a difference image is generated by considering pixel by pixel absolute difference of the thirteen dimensional target image frame and the constructed background model. This is followed by a spatial MRF constrained fuzzy clustering to find the moving regions in the considered scene. The maximum a'posteriori probability (MAP) estimate of the fuzzy statistic based MRF are obtained by fuzzy clustering. The MAP of the MRF constrained fuzzy clustering provides a binary image, where the moving objects with the *moving cast shadow* are identified as one group and the background is obtained as another group. To segment the moving object from its shadow we explore a three stage shadow analysis technique. It uses analysis of *rg* color *chrominance* property of shadow, local gray level co-occurrence based shadow processing followed by boundary refinement to separate out the regions corresponding to the *moving cast shadow* and moving objects. Performance of the proposed scheme is tested on several test video sequences. Effectiveness of the proposed scheme is verified by comparing the results obtained with those of some of the state-of-the-art techniques.

1. Introduction

Detection and tracking of moving objects are two important tasks in computer vision. It has numerous important applications: visual surveillance [35], face and gait-based human recognition [52], activity recognition [32], dynamic scene analysis [17], robotics [49], etc. It is observed that in vision systems, the capability of extracting moving objects from video is affected

* Corresponding author. Tel.: +91 3325753110.
E-mail addresses: subudhi.badri@gmail.com (B.N. Subudhi), susmitaghoshju@gmail.com (S. Ghosh), sbcho@cs.yonsei.ac.kr (S.-B. Cho), ash@isical.ac.in (A. Ghosh).

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by noise, illumination variation, vegetation changes, shadow, etc. Since a shadow moves with the foreground object, static background segmentation techniques cannot differentiate them from moving objects. A shadow can create problem in moving object detection. Hence, detection and elimination of shadow from a video scene is an essential task.

A shadow in a scene appears when an object in the scene totally or partially occludes the direct light coming from the light source to reach the background. The part of an object that is not illuminated directly by light is called self-shadow, while the area on the scene blocked by the object (and not illuminated by light) is called cast shadow. The cast shadow has two parts: *umbra* and *penumbra*. The umbra corresponds to the area where the direct light is totally blocked; whereas, the area where light is partially blocked is called penumbra. Most of the shadow analysis techniques assume that umbra does not exist and it is a part of penumbra. If the object is moving, the cast shadow is known as *moving cast shadow* otherwise, it is called *still shadow*. In most of the cases, the moving cast shadow for a particular moving object in a scene occurs as a compact region, and is called compact shadow. It is quite common in a video processing system that the moving cast shadow will be detected as a moving object with a conventional background subtraction scheme [1,22,42].

A moving cast shadow detection scheme includes three fundamental steps: moving regions identification, shadow suppression and postprocessing. The former two are very important. The moving region identification stage uses different techniques: template matching [66], motion analysis [17], background subtraction (BGS) [3], etc. to identify the moving regions from different image frames of the considered video sequence. Among them the BGS technique is popularly used in shadow detection literature. Different BGS techniques like frame differencing [4], Gaussian mixture model [55], kernel based scheme [13], sparse local information based model [33], block alarm model [10], motion driven statistical model [30], fuzzy modeling [2,43], neuro-fuzzy model [5,6] etc., are popular and successfully used in the literature. The said scheme provides results which misclassify the moving cast shadow as a part of the moving objects. Hence, in the second stage of processing, a shadow detection technique is used to distinguish the shadow regions from the moving object regions. The post processing stage may finally detect compact shadow and moving object regions. The problem of shadow detection has attracted great interest in computer vision community.

The task of shadow detection becomes more critical if the shadow is cast on a textured surface [1]. The texture patterns are the results of physical surface properties such as roughness or oriented strands which often have a tactile quality, or they could be the result of reflectance differences (such as color) on a surface. In a real life video, textural patterns are very common and they also create problems in identifying the actual objects present in the scene. At the same time, the textural property of a region does not change if a shadow is cast on it.

In this paper, we propose an efficient moving cast shadow segmentation technique (for the sequences captured by fixed camera) that separates the shadows of the moving objects cast on a textured background. The algorithm follows two major steps: background separation and shadow detection. For background separation, initially a background model is built. For a particular pixel location, the background model has been constructed by taking the median of pixel values at the corresponding location in temporal direction. This gives a stable background model. For moving object detection we have used an absolute difference of the target image frame and the constructed reference background model followed by a spatial MRF constrained fuzzy clustering technique [8]. For spatial constrained fuzzy clustering, the RGB color and textural features (local) [20,53] are used. The MAP estimate of the fuzzy statistics based MRF are obtained by fuzzy clustering. The MAP of the MRF constrained fuzzy clustering scheme provides a binary image, where the moving objects with the moving cast shadows are identified as one class and the background as another one. To segment the moving objects from their shadows, a three stage shadow processing technique is followed. The technique uses an analysis of *rg* color chrominance property of shadow [64], local GLCM feature based shadow processing followed by boundary refinement to find the moving cast shadows and the moving objects in a scene.

The proposed scheme is successfully tested on different video sequences (indoor and outdoor) both for object detection and shadow removal, to prove its effectiveness. Different video sequences considered are with different background textures like grass field, road, floor carpets, wall and speckling water. It is observed that the proposed scheme effectively segments object in presence of visible and invisible shadow with compact shadow region. The performance of the proposed shadow detection technique is tested on several test video sequences. To validate the proposed scheme, results obtained by it are compared with those of the texture integration based shadow estimation technique [59], the adaptive shadow estimation technique [11] and gradient correlation based shadow estimation scheme [47,48]. The effectiveness of the proposed scheme is evaluated by three performance evaluation measures: *shadow detection rate*, *shadow discrimination rate* and *combined score* [11,42]. A preliminary experiments of the proposed work is reported in [57].

The organization of this paper is as follows. Section 3 presents the block diagram and the overview of the proposed technique in detail. The proposed background subtraction scheme used for separating the moving regions from the textured background is described in Section 4. The proposed shadow detection technique is narrated in Section 5. The data set used in the experiments and the results are analyzed in Section 6. Finally, Section 7 draws the conclusions and future work.

2. Literature on shadow detection

A recent survey on shadow detection techniques [48] has summarized the shadow detection taxonomy into four types: *chromaticity* based, physical property based, geometry based and texture based.

Chromaticity based shadow detection techniques use *chrominance* property of light or different invariant color models [14] to find out the characteristics of shadow from a given video scene. Salvador et al. [46] have studied a robust object and shadow separation scheme using color invariance property of shadow. The authors have used $c_1c_2c_3$ (a photometric invariant color features extracted from RGB color model) color invariant model in this regard. A robust moving object detection scheme that detects the