Signal Processing 103 (2014) 367–379

Contents lists available at ScienceDirect

Signal Processing

journal homepage: www.elsevier.com/locate/sigpro

Efficient highlight removal of metal surfaces

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ARTICLE INFO

Article history:
Received 1 July 2013
Received in revised form
18 October 2013
Accepted 15 November 2013
Available online 21 November 2013

Keywords:
Image restoration
Highlight removal of metal surfaces
Video surveillance for rail transportation

ABSTRACT

This paper proposes a novel, simple but fairly effective algorithm based on polynomial calibration function and inpainting method to address the problem of removing large-scale highlights from metal surfaces in an image. Our algorithm works upon an underlying premise that neighboring pixels in space-time with similar intensities should have similar colors. The entire system mainly consists of four components. First, the candidates of highlight areas are identified based on a modified specular free model, and then these candidates are represented in HSV color space. Next, the color channel V is re-calculated by using a luminance calibration formula. Afterwards, highlight areas in H and S color channels are recovered based on a novel inpainting method. Finally, the restored image is obtained by converting the integration results from HSV back to RGB color space. The experimental results on a number of images captured from rail transportation scenario and comparisons with other state-of-the-art approaches demonstrate the effectiveness of the proposed work.

1. Introduction

In recent years, image denoising serves as a fundamental technique for many applications such as object recognition, digital multimedia entertainment, remote sensing image analysis and so on. The main processing of denoising is to reconstruct the original image by removing unwanted noise from a corrupted image [29–31]. Generally, image denoising has two main objectives which are noise reduction and restoration. For noise reduction, it is designed to preserve the original image as many details as possible by various filter methods [31]. Image restoration that aims at estimating the original image from a corrupted or noisy image has played an essential role in the development of many applications such as the protection of historical relics, special effects for movie imagery, redundant object removal from images, realistic modeling, and so on [1]. In this technique, highlight removal/restoration is one of the key problems and has attracted increasing attention in computer vision community.

Actually, many industrial applications significantly suffer from the problem of unexpected highlights on metal surfaces, for example, video surveillance systems for highway, railway, air, and sea transportations. In these transportations, metal material is widely used in the packages of products such as containers and iron cans. Large-scale highlights inevitably emerge due to the reflection on metal surfaces. The acquired videos with those highlights raise difficulties for both human subjective monitoring and automatic computer vision techniques such as segmentation, tracking, and recognition. To be specific, (1) in these video surveillance applications, human subjects are still required to frequently or real-time monitor the video data. Longtime stimulation from the large-scale highlight reflection easily incurs the fatigue of human visual system, which further substantially influences the reliability of monitoring; (2) some automatic computer vision-based surveillance techniques, like segmentation, detection,

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http://dx.doi.org/10.1016/j.sigpro.2013.11.021

tracking, and recognition, largely rely on the color or/and intensity information of images. The existence of large-scale highlights degrades image quality and accidently tampers with the original color and intensity values of pixels. As a result the performance of the image-based surveillance technique is dramatically dropped. For example, a complete target to be detected or recognized may be segmented into a few different regions, which may give rise to a wrong recognition. Fig. 1 displays a number of image examples with highlights by reflection on metal surfaces. From those samples, it is clear that the large-scale highlights are occurred on central region of metal surface.

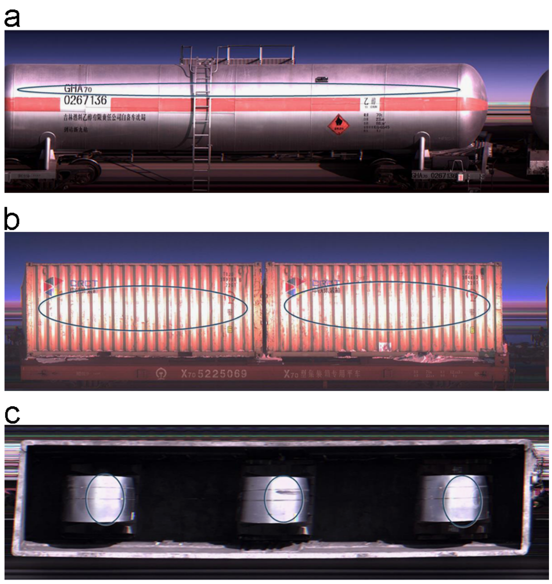

Fig. 1. Image examples with highlights by sun's reflection on metal surfaces (a) tank car, (b) metallic container, (c) rolled steel. Note highlight areas indicated by circles spread over the primary objects of each image example, which is considered as a large-scale highlight problem.

Most previous works [5–14] aim at dealing with highlights of textured surfaces but remain highlight removal of metal surfaces unsolved. The illuminated diffuse reflection has equal luminance from all directions on textured surface rather than at just one angle as in the case of specular reflection. Although most of materials can give diffuse reflection relatively, a few materials, such as metals and glasses, are lack of rough textured surface, thus only generating specular reflection. The core idea of traditional highlight removal methods is to hypothesize that the object is a specular free (SF) surface, which is unfortunately devoid of specular effects. From this perspective, the traditional highlight removal algorithms are not appropriate for the highlight reflected on the metal surfaces.

In this paper, we propose an efficient algorithm to remove large-scale highlights on metal surfaces for the sake of facilitating the video surveillance of railway transportation. As shown in Fig. 2, our algorithm mainly consists of four steps. First, the candidates of highlight areas are identified based on a modified SF model, which are then represented in HSV color space. Next, the color channel V is re-calculated by using luminance calibration formula. The motivation of this step is to reduce the highlight variance for further processing. Afterwards, each pixel within a highlight area in H and S color channels is approximated with new intensity by using a novel inpainting method that can automatically estimate optimal value from a set of corresponding neighboring pixels. Finally, the restored image is obtained by converting the integration results from HSV back to RGB color space.

The main contributions of this paper can be summarized as follows: (1) we theoretically analyze and deduce that the traditional dichromatic reflection model is inappropriate to solve the problem of removing highlights on metal surfaces; (2) we propose a novel algorithm that combines polynomial calibration function and the inpainting method in order to effectively remove large-scale highlights of metal surfaces. The proposed algorithm is simple and fast. To the best of our knowledge, our work is among the earliest efforts that

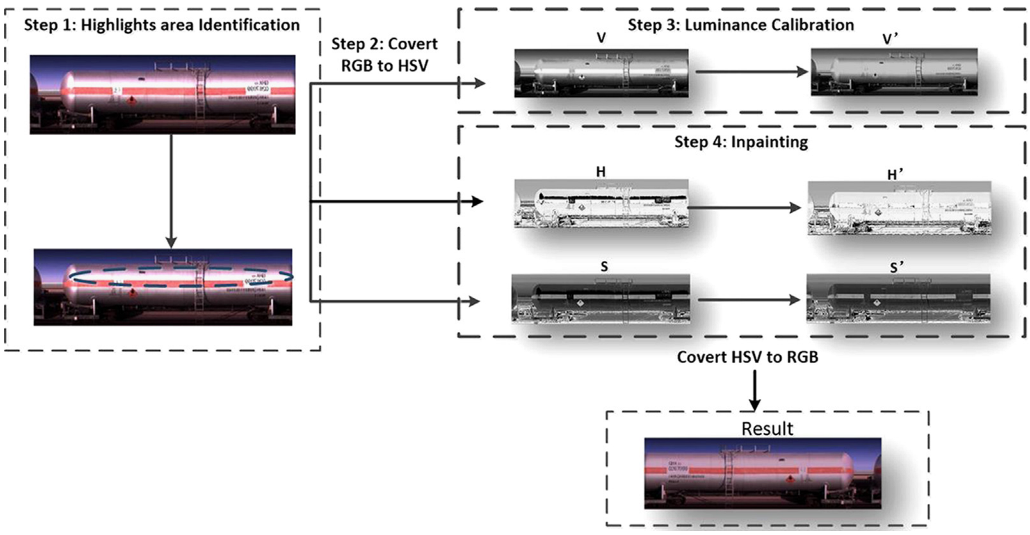

Fig. 2. The processing architecture of the proposed algorithm.