Highlights and shadows multi-image correction while remaining objects shading

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Résumé – Selon les propriétés de surface d'un objet et les conditions d'acquisition, des effets optiques supplémentaires comme des spécularités ou des ombres peuvent apparaitre sur l'image. Ces régions avec des valeurs d'intensité très élevés ou au contraire très faibles, sont gênantes pour l'apparence de l'objet et surtout pour le traitement automatique des images (e.g., reconstruction stéréophotométrique, segmentation, etc.). Pour le cas de plusieurs images ($n \geq 2$), acquises avec une position de camera fixe et des directions d'illumination variées, chaque image de la séquence a ses propres zones de spécularités et d'ombres. Le but de notre travail est de corriger automatiquement les régions avec des valeurs d'intensités aberrantes, tout en conservant les particularités de distribution de la lumière de chaque image nécessaire, par exemple, à la reconstruction stéréophotométrique. L'approche de fusion des images proposée est basée sur les informations de la même région dans les autres images de la séquence initiale. La méthode permet la correction de larges zones avec des spécularités et des ombres en conservant la texture complexe de la surface de l'objet.

Abstract - Due to object surface properties and conditions of image acquisition, additional optical effects such as highlights and shadows can occur on images. These regions contain abnormally bright or dark image pixel values which affect object appearance and further automated image processing (e.g., photometric stereo, segmentation, etc.). For the case of several ($n \geq 2$) initial images which are taken with the fixed camera position and with different illumination directions, each image of the sequence has its own zones of highlights and shadows. We aim at correcting these zones remaining shading aspects and principal illumination direction of each initial image. The presented images fusion approach is possible thanks to the proposed function which is based on exploring information of the same image region in all images of the initial sequence. The method pretends to correct large abnormally bright and dark regions remaining even complex surface texture.

1 Introduction

Highlights and shadows are optical effects which appear in images due to photographed object surface particularities and specific conditions of image acquisition, [1, 2]. These effects make more difficult further image processing. In order to avoid this negative influence we propose to correct highlight and shadow regions of initial images while still remaining general surface shading which can be important for further scene analysis, e.g. photometric stereo, or rendering.

The problem of highlights and shadows removal has been already treated in many algorithms [3, 4]. The easiest existing approach is to use median value of all images of the sequence. There exist more sophisticated methods which propose to combine several images [5, 6] or to analyze distribution of pixel intensities in color space [7] in order to obtain an image without specularities or to use polynomial texture mapping [8] and graph cut approach [9] in order to correct shadowed zones. Even if the mentioned methods are rather efficient for shadowed or highlighted zones correction in the most cases they do not manage the both optical effects at the same time and do not remain general surface shading important for further processing, especially for photometric stereo reconstruction [10]. In [8] the authors propose to correct simultaneously highlights and shadows using additional prior knowledge about illuminating directions, which is not always accessible.

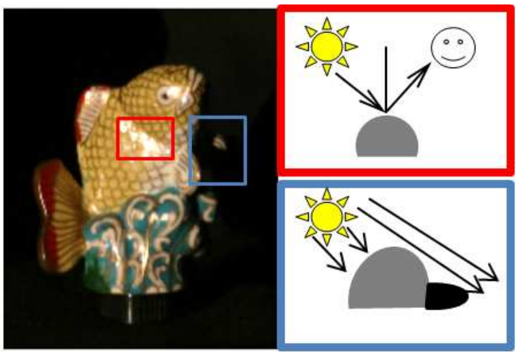


Figure 1: Highlights and shadows origins

Highlighted and shadowed zones can be simultaneously present in image, Fig.1. Images with different illumination are able to complement information about pixel intensity with different shading. The more images in such a sequence we have and the more uniformly positions of lighting sources are distributed in space for each image, the more complete information about object shading we are able to obtain. The method presented in this work propose to make image fusion in order to correct highlights and shadows while remaining all general shading particularities of each initial image.

2 Proposed method

2.1 Method description

The main idea of the proposed method is to use information about shadowed and highlighted regions presented in all initial images in order to correct abnormally high and dark pixels. The proposed method was specially developed for image sequences made from the fixed position of camera and varying lighting directions. These data are typical for photometric stereo algorithms [10] but can also be used to obtain an image of the specular (e.g., metallic) object without highlights and shadows for its further processing.

Let us have n images in initial sequence made with the fixed camera position and varying illuminations. Regions of highlights and shadows are presented in all images but they appear in different parts of object surface. One of the possible ways to detect abnormally high and dark pixel intensities is to compare each pixel with the same pixel in other images by the means of ratio values. To detect highlight and shadow zones in the first image (I_1) the following operation is done for each pixel position:

$$W_1 = mean\left\{\frac{I_1}{I_2};\frac{I_1}{I_3};..;\frac{I_1}{I_n}\right\}. \quad (1)$$

Values of ratio for shadowed regions will be close to "0" and vice versa highlighted zones will give ratio value over "1". Zone of shading without intensity outliers such as highlights and shadows will be defined between "0" and "1" with some margins from the both sides, Fig.1. These margins as well as correction rate can be presented with continuous function $f(W)$:

$$f(W) = \frac{k_{high}}{1+e^{-\alpha_{high}(W-th_{high})}} - \frac{k_{shad}}{1+e^{-\alpha_{shad}(W-th_{shad})}} + k_{shad}, \quad (2)$$

where k_{high} and k_{shad} are highlight and shadow regions correction rate, th_{high} and th_{shad} define values of ratio from which we suppose that the pixel has abnormally high and low values respectively, with α_{high} and α_{shad} we are capable to regulate gradation between corrected and non-corrected zones of highlights and shadows (the higher value of α_{high} and α_{shad} is, the more strict transition we obtain).

After all these parameters are defined the correction of the first image (I_1) is simply made like the following:

$$\tilde{I}_1 = \frac{I_1}{W_1^{f(W)}}. \quad (3)$$

Due to correcting function $f(W)$ pixel values of general image shading will not be changed. It permits to obtain n images with corrected highlighted and shadowed regions while remaining shading aspects (illumination particularities) of each initial image important for further analysis. Unlike a gamma correction procedure [11], Eq.(3) allows only correction of outlier intensity values, the coefficient of correction is adaptive to each pixels value and depends on the proper pixel intensity value and pre-defined parameters of function Eq.(2). The proposed correcting function is necessary to get smooth transition between corrected and not corrected zones.

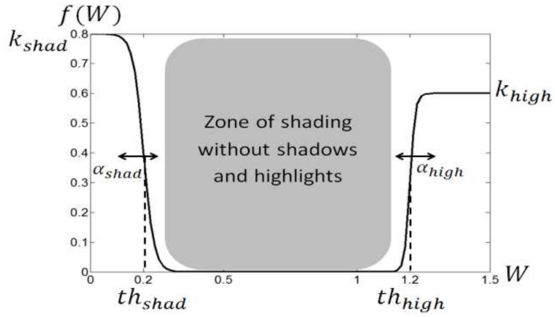
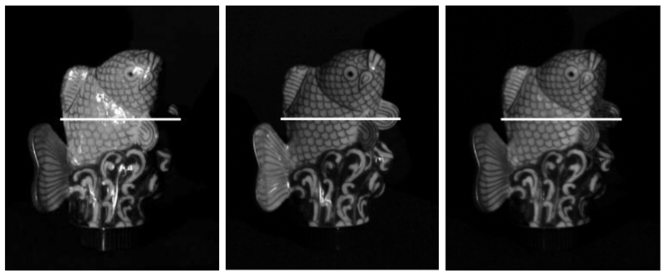
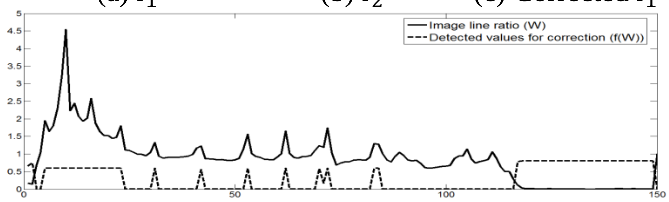


Figure 2: Correction function $f(W)$ depending on the ratio value W

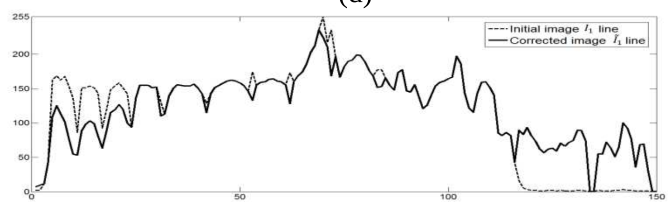
Let us have only two initial gray-scales images, Fig.3(a)-(b). We aim at correcting highlighted and shadowed pixels of I_1, Fig.3(a), using image I_2, Fig.3(b), as reference image for correction. For simplification and more evident demonstration we can choose only a line of image (is shown in white) to correct. Image line ratio values W and values of $f(W)$ function are shown on Fig.3(d). Values of $f(W)$ different from zeros indicate pixels to be corrected.



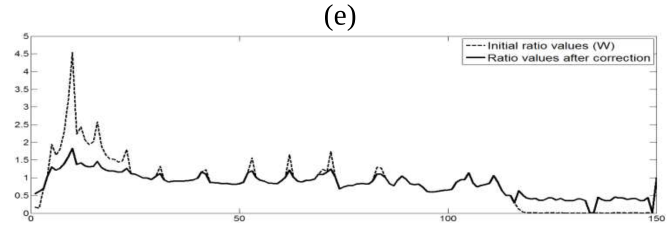
(a) I_1 (b) I_2 (c) Corrected $\tilde{I}_1$



(d)



(e)



(f)

Figure 3: (a) – (b) Two gray-scaled images (I_1, I_2) with chosen (white) line to be corrected in image (a); (c) Corrected image $\tilde{I}_1$ using image I_2 as referenced image; (d) Initial image line and appropriate f(W) function; (e) Initial and corrected image lines; (f) Values of pixel ratio W for initial and corrected images line

In accordance to this, on Fig.3(e) there are values of intensities of initial and corrected pixels. Finally, to confirm the results of correction we plot pixels ratio of the initial I_1 and corrected $\tilde{I}_1$ images with referenced image on Fig.3(f). After the entire image correction $\tilde{I}_1$, Fig.3(c), we can observe intensity decreasing for highlighted zones, and intensity increasing for shadowed zones. Image regions which were highlighted on both initial images are not detected, thus intensity of these regions is remained abnormally elevated. To overcome this deficiency, we need either more initial images or reference images without outliers.

2.2 Limitations for usage

The limitation of the proposed method consists in an absence of total artifacts regions overlapping, Fig.4. For the case of overlapping it becomes impossible to define if the region of the selected image has outlier intensity values or not because values of the referenced images (all rest images) also correspond to values with artifacts.

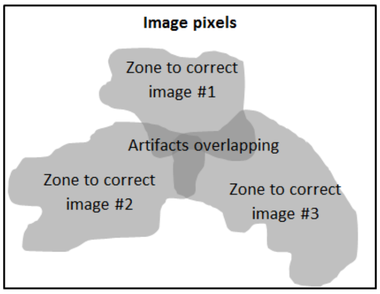


Figure 4: Artifacts overlapping demonstration

For the image of an object the location of highlights and shadows is predetermined by the principal direction of illumination used during image acquisition. For the same object, the closer positions of lighting sources are chosen for different acquisitions, the more likely we obtain the same artifacts for the same region of different images. Thus, not only the number of images is important for qualitative correction, but also the spacial distribution of light sources used during images acquisition. Even with the minimum required number of images ($n = 2$) made with sufficiently spaced illumination directions, we can obtain better results than with dozen images made with spatially close lighting directions.

3 Experiments

We apply the proposed technique for shadowed and highlighted regions correction to images made by authors of [12]. These images were taken for the purpose of photometric stereo. There are 14 images of specular object made with the fixed camera position and varying illumination. Light source position for each image acquisition are distributed enough to obtain information about object shading hidden with shadows and specularities in one or several images and present in the rest ones. Fig.5(a)-(c) show three of 14 initial images with highlights and shadows. On Fig.5(d)-(f) there are the results of simultaneous highlight and shadow regions correction with the proposed technique. To correct each initial image, all rest images were used as reference ones. The parameters of correcting function $f(W)$ were empirically chosen. The correction rate was chosen the same for highlighted and shadowed zones, $k_{high} = k_{shad} = 0.75$. Thresholds values were chosen with 0.2 margins ($th_{high} = 1.2$, $th_{shad} = 0.2$). Due to more gradual passage between shadowed and non-shadowed zones comparing with highlighted and non-highlighted ones the value of $\alpha_{shad} = 50$ was chosen two times smaller than the value of $\alpha_{high} = 100$. the automated choice depending on the ratio values is a question for further research.

On Fig.5(g) there is the result of median image of 14 initial images. Though median filtering allowed the discussed optical effects avoiding, it does not remain all general shading information which could be important for further processing and analysis. Moreover, after this procedure we obtain only one image that makes photometric stereo application impossible. One of the existing possibilities is to use the obtained median image as a reference and provide highlights and shadows detection or correction by the means of ratio with the median image intensities values.

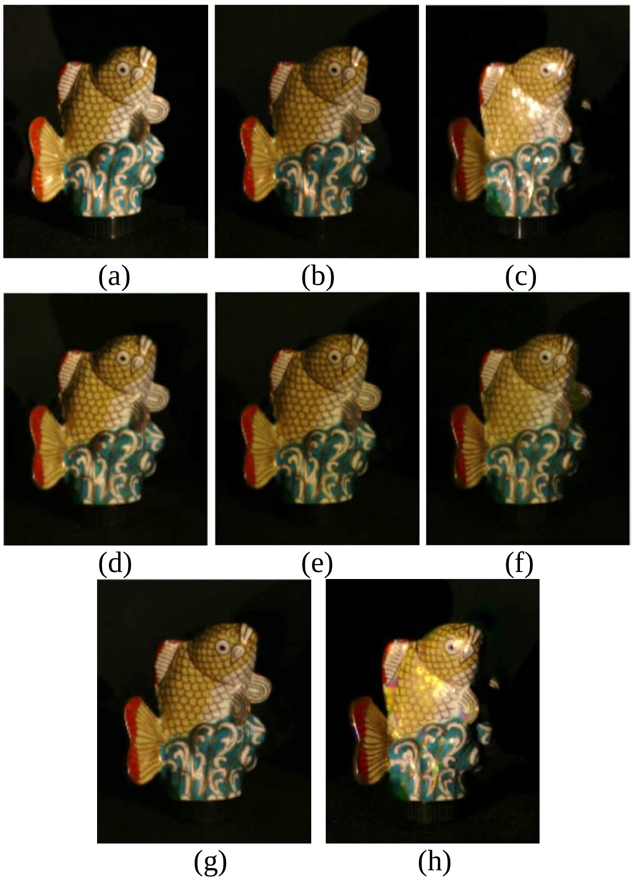


Figure 5: (a) – (c) three initial images with different illumination directions and optical effects such as highlights and shadows; (d) – (f) images (a) – (c) with corrected highlight and shadow regions; (g) median image of 14 initial images; (h) image (c) with detected highlights and shadows correction using inpainting technique

Fig.5(h) demonstrates results of highlights and shadows correction by inpainting [13]. Zones for correction were chosen on the base of th_{high} and th_{shad} values respectively. Zones hidden by highlights are of complex textural structure and they were not well corrected with the inpainting technique. Surroundings of shadowed region do not provide enough information for good shadowed zone restoration as well. However the main advantage of the inpainting technique consists in only one input image need.

General shading remaining is better visible for images of one-colored large object, when we can watch slight pixels intensities values changes from one object part to another depending on lighting direction. For results demonstration we apply the proposed method to one of image sequences also from [12]. The processed images do not contain shadows or complex highlighted textures, but they are demonstrative for shading remaining. On Fig. 6(a),(c) there are two of eight RGB images of painted bottle with highlights differently located on each image. Fig.6(b),(d) shows corresponding images with corrected specular zones. The parameters used for correcting function are the same as for the previous example. Before as well as after correction with the proposed method we are able to estimate direction of illumination used during each image acquisition.

(a) (b) (c) (d)

Figure 6: (a), (c) Initial images with different object shading depending on illumination directions; (b), (d) Corrected images of Fig.6(a) and Fig.6(c) respectively with shading remaining

4 Conclusions

The method of images fusion to correct highlighted and shadowed zones was proposed. Highlights and shadows are presented as abnormally bright or dark pixel intensities comparing images made with the fixed camera position and varying illumination directions. The elaborated function permits to regulate parameters of highlight and shadow zones such as correction rate and transition between corrected and non-corrected zones. The described technique makes the fusion of only regions of interest which need changes and remains all other shading particularities of the initial images which could be important for the further processing and scene analysis such as photometric stereo. Usage of all images of the sequence for shadowed or highlighted zones restoration allows efficient application of the proposed method even for images with large texturally complex zones. Automatic correcting function parameters choice depending on initial images is in perspectives of this work.

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6 References

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