Removing Shade and Specular Noise in Images of Objects and Documents Acquired with a 3D-Scanner

Rafael Dueire Lins[1], Gabriel de França Pereira e Silva[1], Ednardo Mariano[1], Jian Fan[2], Peter Majewicz[2], and Marcelo Thielo[3]

[1] Universidade Federal de Pernambuco, Recife, Brazil
[2] HP Labs., Palo Alto, USA
[3] HP Labs., Porto Alegre, Brazil

Abstract. This paper presents an efficient algorithm for removing the specular noise and undesired shades in images of objects and documents acquired with a 3D-Scanner. The basic principle of such device is to photograph objects by taking multiple images with different illumination sources.

Keywords: Specular noise, 3D-Scanner, illumination sources.

1 Introduction

The fast pace of technological evolution today opens new horizons and brings new challenges every day. Digital cameras appeared not long ago and caused the death of "traditional" over a century-old photography. Portable digital cameras are omnipresent today and even cell-phones embedded ones yield images of quality and resolution unforeseen in not distant past, widening its applicability into new domains such as digitizing documents with an ease not allowed by scanners. People now photograph documents, avoiding photocopying, and take photos of teaching boards and bill boards, instead of taking notes. A new and fast evolving research area [4] was born and claims for new algorithms, tools and processing environments that are able to provide users in general with simple ways of visualizing, printing, transcribing, compressing, storing and transmitting through networks such images. Some particular problems arise in document digitization using portable digital cameras [7]. One of them is due to non-uniform illumination. A even more complex situation is faced when the paper of the document is glossy: often the photo has areas in which the in-built strobe flash or intense lighting from the environment “erases” parts of the document presenting what is called the “specular noise” [2]. The same phenomenon may also occur with 3D-objects if it reflects part of the incident illumination.

Figure 1 presents an example of a photo with specular noise. The photo from two bound pages of a magazine printed on glossy paper exhibits at least three areas of specular noise, pointed at by red arrows. The photo was obtained with a portable digital camera with the built in strobe flash on.

The situation of taking photos of 3D-objects is even more difficult as besides the specular noise the illumination shaded areas often appear. An example of both phenomena may be observed in the image of the apple shown in Figure 2, where the red arrows point at the specular noise areas and the blue arrow to the undesired shade one.

M. Kamel and A. Campilho (Eds.): ICIAR 2013, LNCS 7950, pp. 299–307, 2013.

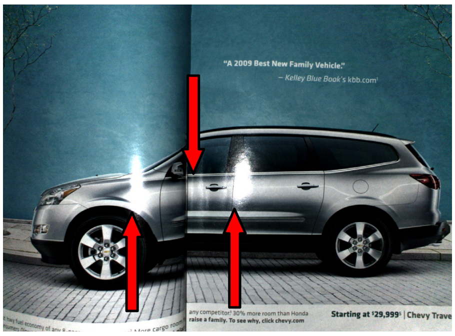


Fig. 1. Photo of a two page magazine printed on glossy paper with specular noises

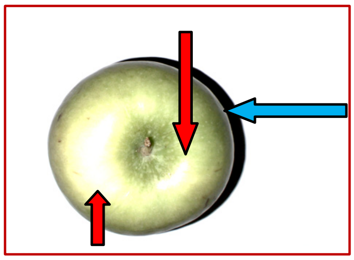


Fig. 2. Photo of an apple with areas of specular noises (red arrow) and shade (blue arrow)

2 The Multiple Image Platform

To solve such problems of filtering out the specular noise and undesired shades in 3D-object photographs the Hewlett-Packard Company developed a simple and low-cost platform, which was released as the HP TopShot laser printer with "3D scanner", which, besides targeting at removing such noises, it also allows the fast and efficient digitalization of documents, included bounded books. It is important to remark that there are situations in which the use of cameras is more adequate and easier than flat-bed scanners. Such 3D-scanner was integrated with a laser printer as an "all-in-one" device (scanner, printer and copier), thus the price for the 3D-scanner became marginal. Larger than A4 flatbed scanners have kept their high prices unchanged and are not "off-the-shelf" available to buy. Scanning larger documents, such as maps, is a difficult task. The same happens with bound books (either hard or soft) for which one either damages the volume or has to address the difficult problem of geometrical

Fig. 3. Photo of the HP TopShot laser printer with "3D-scanner"

Fig. 4. Detail of the camera and illumination set-up of the "3D-scanner"

warping and even blur in some areas. In the case of oversized old books or documents, using standard A4 flatbed scanners is unviable. The correction of the geometrical warp caused by book binding was studied in a series of papers [9] [10] with satisfactory results.

Figure 3 presents a photo of the HP TopShot laser printer with "3D scanner" and Figure 4 zooms into the camera and illumination part. The experiments reported here made use of a slightly different platform from the one already released as a product by HP. The platform takes three pictures of documents or 3D-objects with a fixed camera and varying the position of the light sources. The platform used here has the following technical features:

- Camera: 8 Mpixels with fixed resolution and zoom. Lens distortion is negligible; True color RGB 24-bits.
- Camera height (lens) to support plan: 21 cm;
- Lamp: high-power phosphor-converted white LEDs;
- The center lamp is positioned as close to the lens as possible.
- Lamp offset (left and right):7.5 cm

In the platform under study a total of three frames of the scene with different setups are obtained. Figure 5 provides an example of an image of a 3D-object acquired with the platform, in which one may clearly observe shaded areas and specular noises. The transparency of the object (bottle) highly increases the complexity of the image filtering.

Left lamp on, right lamp off, center lamp off; | Left lamp off, right lamp off, center lamp on. | Left lamp off, right lamp on, center lamp off;

Fig. 5. Example of images of a 3D-object obtained with the 3D-Scanner

Two problems are addressed in this paper: the removal shades and filtering-out the specular noise. The first one is attacked by using the multiple images for developing a mask that contains only the area of the object. The second processing step is performed to find the areas “erased” by the specular noise and filtering it out. The two strategies are presented in the next sessions.

3 Removing Shades

The removal of shades of 3D-objects is performed by using the three images obtained with the HP-Platform. The key idea here is to obtain an image “mask” which is restricted to the object area. The three images are enhanced, binarized, composed in a special way to generate a final image which yields the final mask.

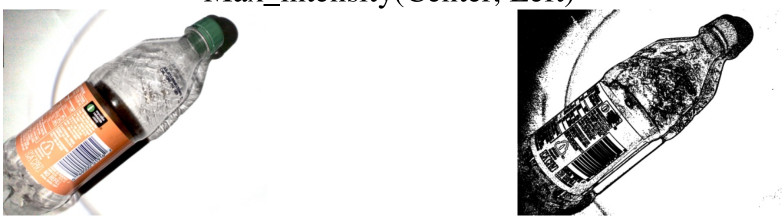
Center image: Left lamp off, right lamp off, center lamp on;

Left image: Left lamp on, right lamp off, center lamp off;

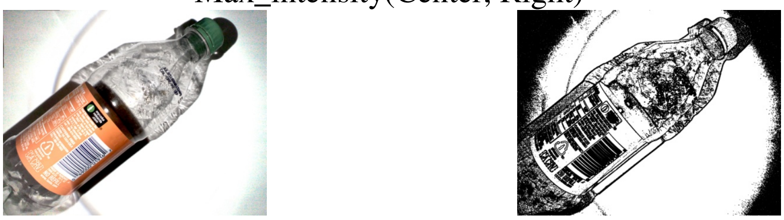
Right image: Left lamp off, right lamp on, center lamp off;

Fig. 6. Images of a 3D-object shown in Figure 5 and corresponding edge enhanced images with Canny filter

Max_intensity(Center, Left)



Max_intensity(Center, Right)



Max_intensity(Left, Right)

Fig. 7. Composition of the images in Figure 6 using "highest intensity" pixels and corresponding binarized image using Otsu algorithm

The first step is to enhance the image borders by using a Canny edge detector [1] and then performing histogram equalization, both implemented in ImageJ [13]. The application of the filter to the images shown in Figure 5 may be seen in Figure 6 The next step is to stress the contour of the object by adding the images obtained by edge enhancement. Several different possibilities were tested and the best results obtained are shown in Figure 7, where the resulting image is obtained by getting the pixels of the highest intensity from the two input images. Then, the image is made monochromatic by using Otsu [11] binarization algorithm. Figure 8 presents the composed images and the result of binarization.

The three masks obtained in Figure 7 are now combined into a single mask through “majority voting” to find an image that serves as the "contour" of the final mask that is obtained through the “fill holes” algorithm implemented in the ImageJ [13] open-source tool. The majority voting image and the final mask obtained through fill holes may be found in Figure 8.

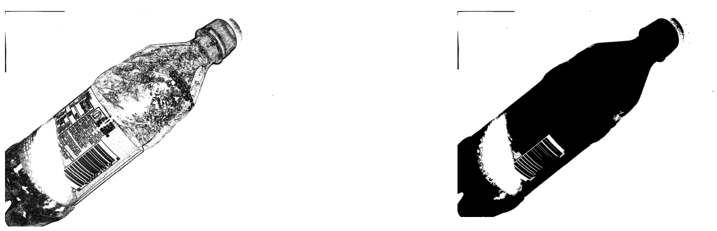


Fig. 8. Left: Result of applying the “majority vote” algorithm to the three images in Figure 5 – Right column. **Right:** Final mask obtained by the application of the “fill holes” algorithm to the image to its left.

The mask obtained is used to select the “Region of Interest” in the three original images.

4 Filtering-Out the Specular Noise

In the case of 3D-objects such as the ones shown in Figure 2 and 5, after the shade areas were removed by applying the mask developed in the previous section, now the problem of removing the specular noise is addressed. The case of the image shown in Figure 1 has no shade area, thus the “region of interest” encompasses the whole image. In any case, removing the specular noise from images such as the one presented in Figure 1, Figure 2 and Figure 5 is a difficult task. The basic idea is to try to “reassemble” a new image replacing the parts "erased" by the specular noise from one image with the “information” from another shot. The solution presented here was found after an exhaustive number of attempts of many different strategies and techniques because to automatically extract the information from each component image and yield a result that reaches a reasonable quality standard is a complex task. The unsuccessful attempts made ranged from local ones such as splitting the image into small blocks and using a neural classifier [6] to spot where the specular noise could be found in each of them, to global ones such as the functor analysis of color variation on each image. The algorithm that is presented below was the one that yielded the best and most consistent results in image quality and, besides that, is also fast in processing time, which is an aspect of paramount importance as it must be executed in an embedded device with an acceptable response-time and throughput.

A. The algorithm.

The main idea of the algorithm proposed is to compare the intensity of the pixels of the image between components. Each image is split in its RGB components, which corresponds to an 8-bit grayscale image (*Left-R*, *Left-G*, *left-B*; *Center-R*, *Center-G*, *Center-B*; *Right-R*, *Right-G*, *Right-B*).

The final image with the specular noise filtered out is assembled by choosing the lowest intensity of the same RGB-component of the three images for each pixel, as depicted in Figure 9.

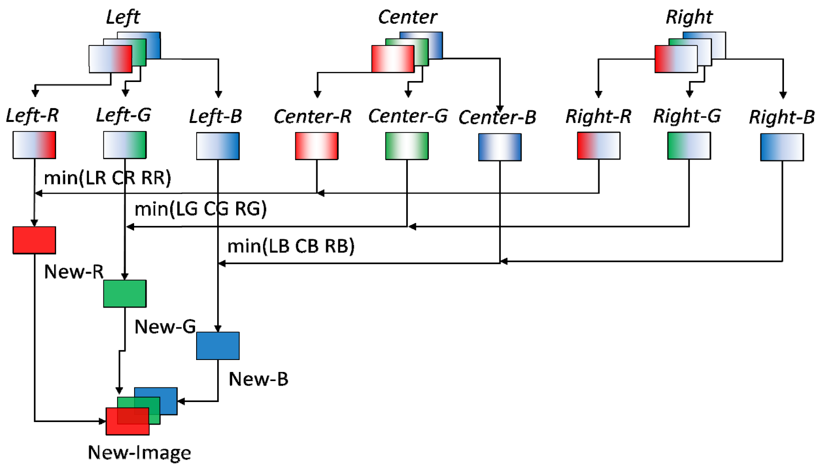


Fig. 9. Removing the specular noise by simultaneous analysis of the RGB components of the three images obtained with the HP-Platform

A circular halo may be found in the images illuminated by the right and left hand strobe flashes (LED lamps) as they appear at the opposite sides to the lamp position, causing the pixel intensities to vary widely and covering a large part of the image area. The equalization of the global histogram of each RGB component both of the left and right illuminated images causes an increase [1] in the contrast of such halo. The resulting image presents a significant reduction of the specular noise as may be observed in Figures 10 and 11.

Fig. 10. Figure 1 after processing

Fig. 11. Figure 2 after processing

As the algorithm presented chooses the pixels in each component with the lowest intensity, the resulting image has its brightness reduced in relation to the original ones. All the information, colors and shapes are recovered, making possible the application of techniques of histogram correction to enhance the brightness and contrast of the resulting image [1]. If one closely observes Figure 10, one may see that the filtered image is slightly darker than the original one and that there appeared a brownish area to the left of the soft bound area, not present in the original picture. This problem is addressed further on.

The image of the apple presented in Figure 11 minimizes the shade area leaving only some residual pixels in the contour. The specular noise was attenuated but is still present in the final image, as the three images obtained with the HP-Platform exhibit specular noises in the same areas.

B. Enhancing the Results Obtained

The removal of the specular noise may be made faster and yield better quality images both in 3D-objects and in document images acquired with the HP Platform if instead of applying the algorithm presented above to the whole image, one applied it only to the regions where the specular noise is found in the image. This can be done by

Fig. 12. Image of Figure 1 with the specular noise removed by the application of the algorithm proposed in the areas affected by the specular noise only

Fig. 13. Image of Figure 1 with the specular noise removed by the application of the algorithm proposed in the areas affected by the specular noise only

looking for areas within a 3D-object or an image where the intensity of pixels saturate, the area is surrounded by lower intensity pixels and the saturated pixels are not so in the other two images. This allows one to find the regions “erased” by the specular noise to which the algorithm presented is applied to replace such pixels with the information received from the other images.

The same strategy applied to the image in Figure 5, after shade removal using the mask presented in Figure 8 (right) is shown in Figure 13, where one may observe that the results obtained are very satisfactory, despite the very high degree of complexity of the original image due to the transparency of the object (plastic bottle).

5 Conclusions

The strategy of using multiple illuminated images photographed with a single camera is a simple way to develop a low-cost 3D-scanner for objects and documents. There are some problems that arise from such set-up, however. Shaded areas and specular noises may arise in the digitalization of documents printed on glossy paper or of 3D-objects, due to uneven illumination sources and the short distance between the camera and the photographed object [7][10][8].

This paper presents an efficient method to remove the shaded areas and the specular noise in such kind of platform. It was tested in images obtained in the HP-Platform and performed well. In some document images, besides the specular noise, the intensity of the strobe flash lamps also gave rise to chroma noises, also known as confetti [2]. The removal of chroma noise may be perfomed by using the scheme presented in reference [12].

The implementation of the algorithm presented here was done in Java, running on Microsoft Windows Seven Professional® in a platform Intel quad core 2.5 with 4 Gb RAM. The average processing time per image set (3 images with the illumination patterns described) was originally of 10 seconds. The enhancement strategy presented above of applying the specular noise removal algorithm only to the areas "erased" by the noise yielded a reduction of processing time to 1.8 seconds per image set.

References

[1] Canny, J.: A Computational Approach To Edge Detection. IEEE Trans. Pattern Analysis and Machine Intelligence 8(6), 679–698 (1986)

[2] Gonzalez, R., Woods, R.: Digital Image Processing, 3rd edn., pp. 68–102, 259–300. Prentice Hall (2008)

[3] Landon, G.V., Lin, Y., Seales, W.B.: Towards Automatic Photometric Correction of Casually Illuminated Documents. In: IEEE Conference on Computer Vision and Pattern Recognition (2007)

[4] Liang, J., Doermann, D., Li, H.: Camera-Based Analysis of Text and Documents: A Survey. International Journal on Document Analysis and Recognition (2005)

[5] Liang, J., DeMenthon, D., Doermann, D.: Geometric Rectification of Camera-Captured Document Images. IEEE Transactions on Pattern Analysis and Machine Intelligence 30(4), 591–605

[6] Lins, R.D., Pereira e Silva, G.F., Banergee, S., Kuchibhotla, S., Thielo, M.: Automatically Detecting and Classifying Noises in Document Images. In: ACM-SAC 2010, vol. 1, pp. 33–39. ACM Press (2010)

[7] Lins, R.D., Gomes e Silva, A.R., Pereira e Silva, G.: Enhancing Document Images Acquired Using Portable Digital Cameras. In: Kamel, M.S., Campilho, A. (eds.) ICIAR 2007. LNCS, vol. 4633, pp. 1229–1241. Springer, Heidelberg (2007)

[8] Saint-Pierre, C.-A., Boisvert, J., Grimard, G., Cheriet, F.: Detection and correction of specular reflections for automatic surgical tool segmentation in thoracoscopic images. In: Machine Vision and Applications, vol. V22(1), pp. 171–180. Springer (2007)

[9] de Oliveira, D.M., Lins, R.D.: Improving the Border Detection and Image Enhancement Algorithms in Tableau. In: Campilho, A., Kamel, M.S. (eds.) ICIAR 2008. LNCS, vol. 5112, pp. 1111–1121. Springer, Heidelberg (2008)

[10] Oliveira, D.M., Lins, R.D., Torreão, G., Fan, J., Thielo, M.: A New Method for Text-line Segmentation for Warped Documents. In: Campilho, A., Kamel, M. (eds.) ICIAR 2010. LNCS, vol. 6112, pp. 398–408. Springer, Heidelberg (2010)

[11] Otsu, N.: A threshold selection method from gray level histograms. IEEE Trans. Syst. Man Cybern. v(9), 62–66 (1979)

[12] Mariano, E., Lins, R.D., Pereira e Silva, G.F., Fan, J., Majewicz, P., Thielo, M.: Correcting Specular Noise in Multiple Images of Photographed Documents. In: ICDAR 2011 - International Conference on Document Analysis and Recognition, pp. 111–116. IEEE Press, Pequim (2011)

[13] ImageJ: `http://rsbweb.nih.gov/ij/` (accessed March 20, 2013)