A FAST MULTI-VIEW BASED SPECULAR REMOVAL APPROACH FOR PILL EXTRACTION

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ABSTRACT

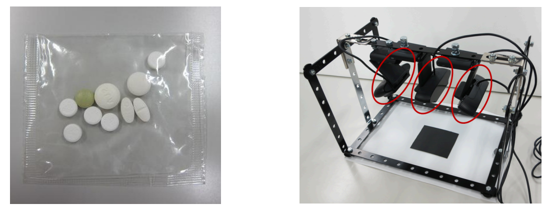
This paper presents a novel approach to remove the specular reflections on the transparent plastic medicine package and automatically extract the randomly distributed pills inside. In this approach, three cameras are employed to take images of the package from different viewpoints. And these three images are used as input image set while the output is a series of small images of a single pill. And these images can be directly applied to the traditional single pill recognition algorithms. The experimental results show the reliability of our approach by measuring correct detection rate (100%), false detection rate (0%) and pill separation accuracy (98.4%). And the proposed method processes a set of three 725×725 sized images at 0.15s averagely on a Core i5-2400 3.1GHz PC.

Index Terms— Specular reflection removal, transparent medicine package, multiple-view, pill extraction

1. INTRODUCTION

In Japanese pharmacies, transparent packages are widely used for medicine packaging because they are easy to make and human beings can see the medicines inside clearly. An example of the medicine package is shown in Fig. 1(a). After making the packages, the pharmacy staff need to check the number and the types of the pills inside twice to ensure the patients getting the correct medicines. Such kind of manual checking is a boring and tough task when there are a big number of packages, and mistakes may happen due to the human tiredness. To release the pharmacy staff from the heavy work of manual checking, we propose to automatically detect whether the pills are packaged correctly, in other words, to recognize the pills inside the package.

Traditional medicine recognition algorithms recognize single pills [1] based on size, shape, color, imprints or recognize medicine package by using symbol match [2] or other descriptors [3]. But all these methods do not work with the medicine packages of our case, because the pills are distributed randomly, specular reflections on the package may cover



(a) Medicine package (b) Image capturing device

Fig. 1. Introduction

pill surfaces, and the transparent colorless package contains no useful information for medicine package recognition.

The ultimate goal of our work is to remove specular reflections and separate the pills so that the final results can be directly used by the traditional single pill recognition algorithms. For specular removal, the existing methods can be generally classified into two categories, single image methods [4, 5, 6] and multiple images methods [7, 8, 9], according to the number of input images. Methods [4, 5, 6, 8] can only remove the specular on the chromatic objects, while methods [7, 9] take images of the objects one by one, any object movement during image capturing may cause severe errors.

In our approach, a multi-view strategy is adopted based on the phenomenon that the specular reflections will appear at different places by changing viewpoint. Fig. 1(b) is our image capturing device, it uses three cameras (surrounded by red ellipses) to take images of the package from different viewpoints at the same time. After getting three images of the package, we remove specular reflections by assuming that at least one of three corresponded pixels is not specular. And the pills are separated by calculating their accurate locations.

2. THE FRAMEWORK OF OUR APPROACH

This section introduces a novel framework to remove the specular reflections on the transparent medicine package and extract the contained pills. Fig. 2 provides an overview of our framework which includes the following contributions. (i) We designed a new image capturing device, which can assist to efficiently and accurately normalize images. (ii) We constructed a mechanism to select reliable boundary points

This research was mainly supported by Grant-in-Aid (Grant No. 24500216) for Scientific Research by the Ministry of Education, Science and Culture of Japan, and partially supported by the Key Project of National Natural Science of China (Grant No.61133009).

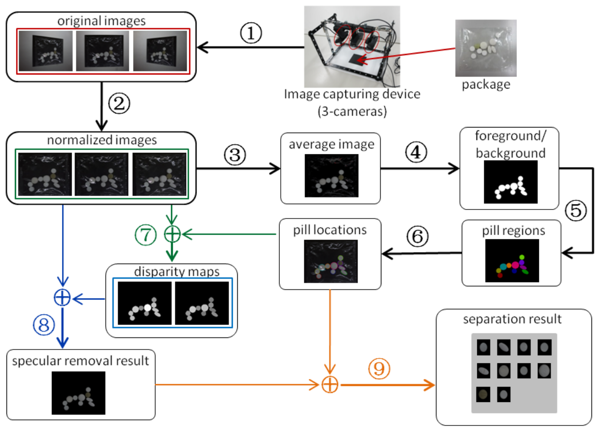


Fig. 2. Our Framework: (1) image capturing; (2) image normalization; (3) average image construction; (4) foreground extraction; (5) pill regions searching; (6) pill locations calculation; (7) specular stereo match; (8) specular removal; (9) pill separation.

of the pill, and calculated accurate pill locations by ellipse fitting algorithm using these boundary points. (iii) We presented a new algorithm of specular stereo match based on pill locations and pill boundary matching. (iv) We proposed a location-based pill separation method.

As shown in Fig. 2, our framework contains 9 steps, namely, image capturing, image normalization, average image construction, foreground extraction, pill regions searching, pill locations calculation, specular stereo match, specular removal and pill separation. The details of each step will be introduced at Section 3.

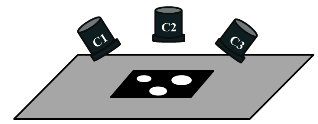
3. MULTI-VIEW BASED METHOD

3.1. Image Capturing

Fig. 3(a) is the structure diagram of our image capturing device. A black rectangular board is used as background to place the medicine package. And three cameras are fixed over the background board for taking images of the package from different viewpoints. The shooting lines of these cameras are coplanar and all perpendicular to the left and right edge of the rectangular board. And the plane which contains shooting lines passes through the center of the background board. Fig. 3(b)(c)(d) is an example set of original images. In these three images, the locations of specular reflections are different from image to image.

3.2. Image Normalization

The main idea of image normalization is doing perspective transform on the original images basing on the coordinates of black background board corners. We first detect the four



(a) Structure Diagram

(b) left view image (c) middle view image (d) right view image

Fig. 3. (a) Structure diagram of image capturing device, C1,C2,C3 are three cameras; (b),(c),(d) are original images taken by camera C1,C2,C3 respectively

corners of the black quadrilateral in each original image, and then map them to the four corners of a standard rectangle. Fig. 4(a) is the normalized image of the middle view image. In this step, there are mainly two goals. The first one is recovering the original pill shape from perspective distortion. The second goal is to degrade the pixel disparity dimensionality. In original image set, the translations of the pixels are two-dimensional. And after perspective transformation, it is degraded to one dimension (only horizontal disparity).

3.3. Average Image Construction

In normalized image, it is not easy to extract the pill regions precisely because some specular reflection region has similar size and intensity with white pills. In order to extract the pill regions correctly and robustly, we make an average image by using three normalized images to keep the intensity of pill region pixels while decrease the intensity of the background regions. In this step, we first set two thresholds to find the evident background (low intensity part) and denote strong specular (high intensity part), and the intensity of evident background pixel is set to 0. And then construct the average image by averaging the intensities of corresponded non-specular pixels. Fig. 4(b) is the average image of three normalized images.

3.4. Foreground Extraction

In this step, we first set a threshold to the average image to roughly separate foreground and background and then refine the rough foreground. The roughly extracted foreground contains not only the pill regions but also part of specular regions. Based on the pre-knowledge that the single pill region is much larger than the specular region by comparing the shortest axis, a sequence of morphological operations (dilation, erosion, dilation and intersection) is conducted to refine the foreground. Fig. 4(c) shows the extracted foreground.

3.5. Pill Regions Searching

After the foreground is extracted, we only need to apply the watershed algorithm to separate it to get each pill region. And the separated result is shown in Fig. 4(d). Different pill regions are denoted by different colors. Up to now, the rough region of each pill is found, and this information will be further used in calculating the accurate pill locations.

3.6. Pill Locations Calculation

The method of calculating accurate locations of pills in middle image is based on the assumption that all the pills have an approximate ellipse shape (this assumption holds for almost all of the ordinary pills because the elliptical pills are easy for patients to swallow). In this step, we first calculate ROI (region of interest: the annular region near the pill region boundary) of each pill region, and then use Canny edge detector to find boundaries in the ROI, finally the points belongs to the long edges in the ROI are selected as reliable pill boundary points to fit an ellipse. The calculated pill locations are shown in Fig. 4(e), denoted by colorized ellipses.

3.7. Specular Stereo Match

Different from traditional window based specular stereo matching methods [10, 11, 12], our proposed matching method is based on pill boundary match with the preknowledge, namely the inside objects all have an approximate ellipse shape and pixels in whole region of the pill have same disparity. To do stereo match between right image and middle image, we first find reliable left boundary points of a pill in right image, and calculate the horizontal distance between each points and the standard ellipse fitted in "*Pill Location Calculation*" step, and finally *winner-takes-all* principle is used to obtain the disparity for the pill. Stereo match between left image and middle image is processed in a similar way.

3.8. Specular Removal

After stereo match, a pill region pixel in middle image is paired with two pixels, one from left image and the other one from right image. In specular removal process, pill regions and background are processed separately. For a pill region pixel, we use the minimum r,g,b value of three corresponded pixels, while for a background pixel, using pure black. Specular removed image is shown in Fig. 5(a). In this image, the specular reflections are all removed, and the color and the boundary of the pill are well preserved.

3.9. Pill Separation

With the calculated accurate pill locations, we can extract the pills from the specular removed result one by one. Fig. 4(f) shows the extracted pills, and they can be directly applied to the traditional single pill recognition algorithms.

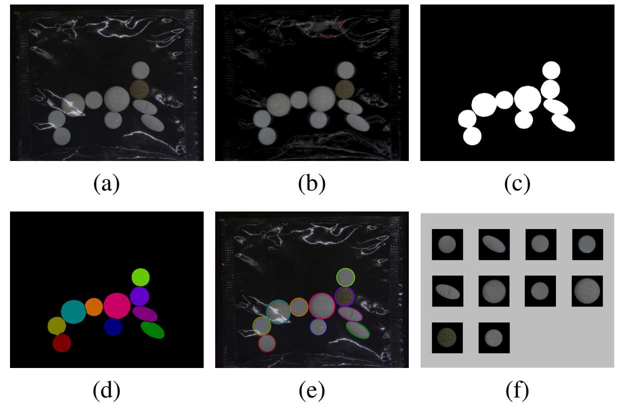


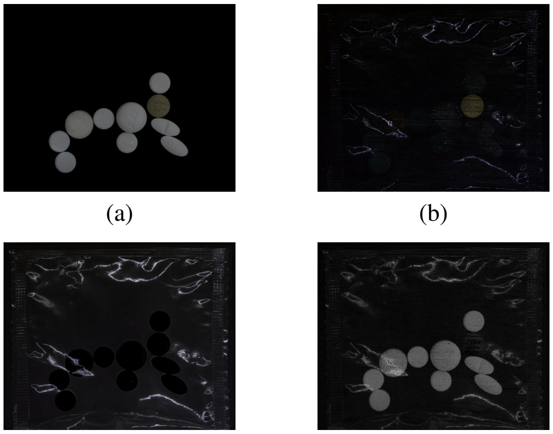
Fig. 4. Multiple view based method. (a) normalized middle image; (b) average image; (c) extracted foreground; (d) rough pill regions; (e) accurate pill locations; (f) separated pills.

4. EXPERIMENTS AND RESULTS

To evaluate our approach, 32 sets of images (one set contains three images) are tested in aspects of specular removal performance, pill extraction performance and running speed. In Section 4.1, a comparison of specular removal results is made between our approach and others'. And the pill extraction performance is measured in Section 4.2. Finally, Section 4.3 describes the implementation and its running speed.

4.1. Specular Removal Results

To evaluate the specular removal performance, a comparison is made between the proposed method and Tan's method [4]. Fig. 5(a) is our specular removal result of the running example. In this figure, all the pills are well preserved while the reflections are removed. Fig. 6(c) is the reflection component (subtract the specular removal result from the original image) removed by our method. On the other hand, Fig. 6(b) is the specular removal result by Tan's method, the pills in this image are blurred or disappeared and the saturated reflection still exists. The reflection component by Tan's method is shown in Fig. 5(d). As we see in this image, the white pills are removed as a part of reflection component. And more comparisons are shown in Fig. 6. Single image based methods like [5, 6] will generate similar result with Tan's, because all these methods cannot distinguish the white pill surfaces from specular reflections. And Yang's method [8] cannot solve this problem either although it is a multi-view based method, because it also needs an assumption of chromatic object surface. Another shortcoming of these previous methods is destroying of chromatic pill surface. The reason is that their methods are all based on dichromatic reflection model [13] which does not work with transparent plastic film.



(a) (b)

(c) (d)

Fig. 5. Specular removal result comparison.(a) specular removal result by the proposed method; (b) specular removal result by Tan's method [4]; (c) reflection component by proposed method; (d) reflection component by Tan's method [4].

Table 1. Pill Extraction Performance

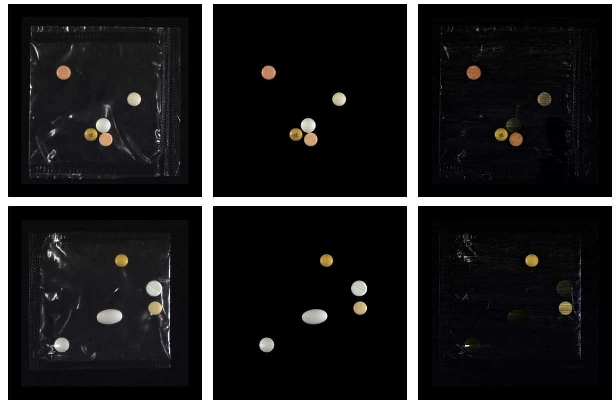
	Manually Labeled	Correctly Detected	Falsely Detected	Correctly Separated
number	124	124	0	122
rate		100%	0%	98.4%

4.2. Pill Extraction Results

Pill Extraction performance is measured by correct detection rate, false detection rate and separation accuracy rate. If the extracted region is a pill, then it is treated as a correct detection, otherwise, as a false one. And the criterion of judging pill separation correctness is defined as follows. The long axis length (a) and short axis length (b) of the extracted pill are compared with manually labeled ground truth ($\bar{a}$) and ($\bar{b}$), if $|a - \bar{a}|/\bar{a} < 0.03$ and $|b - \bar{b}|/\bar{b} < 0.03$, the separation is treated as a correct one. The pill extraction performance of the proposed method is shown in Table. 1. Totally 124 pills in the test image sets are labeled manually, and 124 pills are correctly detected without false detection by using the proposed method, the correct detection rate is 100% (correctly detected pill number / total pill number) and the false detection rate is 0% (falsely extracted pills number / totally extracted pills number). Among 124 correctly detected pills, 122 pills are separated correctly, the accuracy is 98.4%. And Fig. 7 shows some extraction results.

4.3. Implementation

The proposed method is implemented by C++. And on a Core i5-2400 3.1GHz PC, the speed for processing one image set



(a) middle image (b) our results (c) Tan's results [4]

Fig. 6. More comparisons of specular removal results.

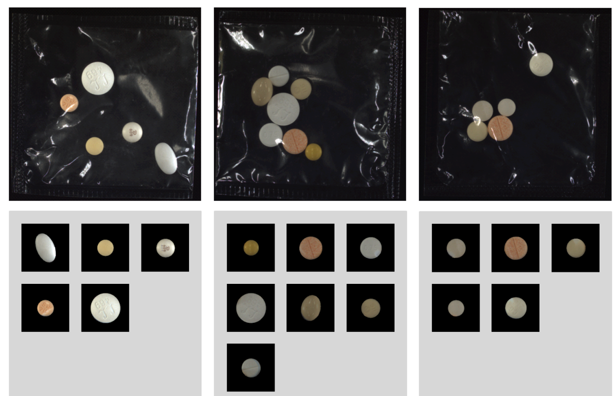


Fig. 7. Pill extraction results. first row: middle images (normalized); second row: final results.

(three 725×725 sized images) is about 0.15s. The source code of Tan's method [4] is freely available on the author's web site. Under the same test environment, Tan's method takes more than 1 minute to process a 725×725 sized image.

5. CONCLUSIONS

In this paper, we have presented a fast multi-view based approach to remove specular reflections on the transparent medicine package and extract the randomly distributed pills inside. Our approach achieves a good performance by measuring correct detection rate (100%), false detection rate (0%) and separation accuracy (98.4%). And the separated results can be directly applied to the traditional single pill recognition algorithms. To process a set of three 725×725 sized image, the proposed method takes about 0.15s.

6. REFERENCES

[1] Young-Beom Lee, Unsang Park, and A.K. Jain, "Pill-id: Matching and retrieval of drug pill imprint images," in *Pattern Recognition (ICPR), 2010 20th International Conference on*, aug. 2010, pp. 2632 –2635.

[2] Dengsheng Zhang and Guojun Lu, "Review of shape representation and description techniques," *Pattern Recognition*, vol. 37, no. 1, pp. 1 – 19, 2004.

[3] K. Sugimoto and S. Kamata, "Color distribution matching using a weighted subspace descriptor," in *Image Processing (ICIP), 2011 18th IEEE International Conference on*, sept. 2011, pp. 1697 –1700.

[4] R.T. Tan and K. Ikeuchi, "Separating reflection components of textured surfaces using a single image," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, vol. 27, no. 2, pp. 178 –193, feb. 2005.

[5] Huiliang Shen, Honggang Zhang, Sijie Shao, and John H. Xin, "Chromaticity-based separation of reflection components in a single image," *Pattern Recognition*, vol. 41, no. 8, pp. 2461 – 2469, 2008.

[6] Qingxiong Yang, Shengnan Wang, and Narendra Ahuja, "Real-time specular highlight removal using bilateral filtering," in *Computer Vision ECCV 2010*, vol. 6314, pp. 87–100. 2010.

[7] R. Feris, R. Raskar, Kar-Han Tan, and M. Turk, "Specular reflection reduction with multi-flash imaging," in *Computer Graphics and Image Processing, 2004. Proceedings. 17th Brazilian Symposium on*, oct. 2004, pp. 316 – 321.

[8] Qingxiong Yang, Shengnan Wang, N. Ahuja, and Ruigang Yang, "A uniform framework for estimating illumination chromaticity, correspondence, and specular reflection," *Image Processing, IEEE Transactions on*, vol. 20, no. 1, pp. 53 – 63, jan. 2011.

[9] Chengjie Wang and S. Kamata, "Removal of transparent plastic film specular reflection based on multi-light sources," in *Photonics and Optoelectronics (SOPO), 2012 Symposium on*, may 2012.

[10] Yuanzhen Li, Stephen Lin, Hanqing Lu, Sing Bing Kang, and Heung-Yeung Shum, "Multibaseline stereo in the presence of specular reflections," in *Proceedings of the 16 th International Conference on Pattern Recognition (ICPR'02) Volume 3 - Volume 3*. 2002, IEEE Computer Society.

[11] Stephen Lin, Yuanzhen Li, Sing Kang, Xin Tong, and Heung-Yeung Shum, "Diffuse-specular separation and depth recovery from image sequences," in *Computer Vision ECCV 2002*, vol. 2352, pp. 89–103. Springer, 2002.

[12] Kuk-Jin Yoon and In-So Kweon, "Correspondence search in the presence of specular highlights using specular-free two-band images," in *Computer Vision C ACCV 2006*, vol. 3852 of *Lecture Notes in Computer Science*, pp. 761–770. Springer, 2006.

[13] S. Shafer, "Simple and efficient method for specularity removal in an image," *Color Research and Application*, vol. 10, pp. 210 – 218, 1985.