# Registration and color calibration for dermoscopy images in time-course analysis

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## ABSTRACT

Since melanomas grow and metastasize rapidly, the mutation in their appearance is much larger than that of nevi. If the variation of skin tumor can be evaluated quantitatively, it is of substantial help not only for clinical diagnosis, but also for development of computer-based diagnostic systems. However, photographic conditions of skin tumor are in most cases not uniform during the follow-up. In this study, we proposed a fully automated image registration and color calibration method between dermoscopy images in the time-course analysis. Our proposed algorithm aligned the time-course images with a precision of 91.6 $\pm$ 5.1% and a recall of 95.7 $\pm$ 5.9%, respectively whereas the fully manual registrations with Exif data as a performance reference did 95.4 $\pm$ 3.2% and 92.4 $\pm$ 6.5%, respectively. Our color calibration method largely reduced the color difference between time-course images $\Delta E$ from 10.9 $\pm$ 5.6 to 3.9 $\pm$ 1.7. These results showed that the proposed method was effective to compensate both geometrical and chronological changes between dermoscopy images in the time-course analysis.

**Keywords:** image registration, color calibration, computer-aided diagnosis, dermoscopy, melanoma

## 1. INTRODUCTION

Melanoma is the worst skin cancer which has a difficulty in early detection and a high grade of malignancy. Dermoscopy, a non-invasive skin imaging technique using special magnification device consisting of magnification lens, white uniform light source and polarization filter, was introduced in clinical and it largely improved the diagnostic accuracy, however diagnosis is still subjective and has low reproducibility. Because discrimination between melanomas and nevi is often difficult even by expert dermatologists, automated discrimination system of melanoma have been developed.[1]

We have been developing an Internet-based melanoma screening system[2] and keep investigating on improvement (current URL is http://dermoscopy.k.hosei.ac.jp). Our latest system was built based on a total of 1,455 dermoscopy images with the confirmed diagnosis and supports not only usual melanocytic pigmented skin lesions, but also acral volar lesions.[3] The classification accuracy of the system is both around 86% in sensitivity (SE) and specificity (SP) for the former cases and 93% in SE and 91% in SP for the latter cases. With the advantage of the Internet-connection, everyone who has a dermoscopy can use our system. It is well known for dermatologists and researchers in this field that color information in dermoscopy images is very important in clinical as well as the computer-aided diagnosis. Dermoscopes should therefore produce accurate color images, but unfortunately this is not always true in practice. Device calibration to compensate for various imaging conditions such as magnification factors, lighting conditions, etc. is crucial for the development of a reliable system. Since hardware-based color calibration is not feasible in a web-based system, we had addressed this issue using a software-based approach.[4]

Now, we are under the consideration to add a new function to our Internet-based system. Since melanomas grow and metastasize rapidly, the mutation in their appearance is much larger than that of nevi. In clinical, investigation of shape and color of the tumor and their variation during the clinical follow-up are an important clue for diagnosis. If this variation can be evaluated quantitatively also in an automated system, it is of substantial help in the discrimination. However, as far as our best knowledge, there are no systematic studies on this topic. We think that is because, as mentioned before, the capturing condition of skin dermoscopy image were in most

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cases not uniform during the clinical follow-up and accordingly, it made the quantification of the variation of tumor difficult. In this study, we proposed a fully automated image registration and color calibration method between time-course dermoscopy images only with observed images.

## 2. MATERIAL AND METHOD

In this study, dermoscopy images obtained from 18 patients from Tokyo Women's Medical University, Medical Center East at their clinical follow-up, a total of 36 images, were used and investigated. All the cases were diagnosed as nevi (benign). In this study, we refered to tumor images photographed in initial consultation as tumorA and tumor images photographed in a certain period after tumorA as tumorB for simplicity. The proposed method performed the geometrical registration and the color calibration procedures to tumorB to make closer to the conditions of tumorA (i.e. its position, angle, size, and color).

Our image calibration algorithm consists of the registration phase and the color calibration phase. The details are described in followings.

### 2.1 Registration phase

In the registration phase, our algorithm firstly searches corresponding points (CPs), namely several pairs of geometrically "same" points between tumorA and tumorB with the scale-invariant feature transform (SIFT).[5] Although SIFT is robust and polished descriptor, obtained CPs sometimes include some outliers. These outliers make serious effects for accuracy of the image registration. We therefore introduced the bi-weight method[6] is to eliminate these inappropriate CPs. Fig.1 shows an example of selected and eliminated CPs. They are dermoscopy images under the clinical time-course. The left and right images are tumorA and tumorB, respectively. Each line indicates the estimated geometrical correspondence between images by SIFT. It is namely the ends of each line indicates the location of corresponding point (CP) between the images. The x markers in the images are the eliminated CPs by the bi-weight method. The bi-weight method firstly assigns a weight for each CP as an accuracy index based on positional relationship among all CPs. Then, this algorithm finds erroneous CPs using linear regression analysis. After the elimination of outliers, we perform the similarity transform from the geometry of tumorB to that of tumorA based on the positional relation of remaining CPs. With this process, our algorithm calibrates differences of position, angle and magnification between target images.

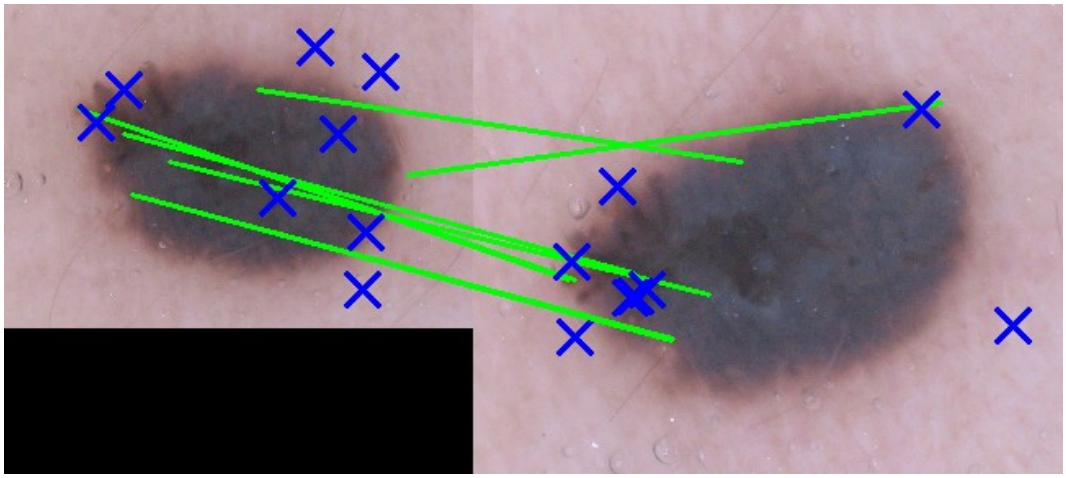

Figure 1. Example of selected corresponding points (CPs) in the registration phase

### 2.2 Color calibration phase

In color calibration of dermoscopy image, there are several issues need to be addressed. Firstly, we have to pay careful consideration for the cause of color difference between the images. That is, the reason of color difference between the images were usually happened with both reasons: (i) images were taken by different photographic

conditions and (ii) tumor color has actually varied during the time-course. Secondary, we have to perform color calibration with only given dermoscopy images (i.e. blind estimation problem). Accordingly, a commonly used basic color calibration method, such as histogram equalization, cannot be applied for this task. The proposed color calibration algorithm stands on the idea that the areas with few appearance changes during the time-course should have originally an almost same color. The diagram of the proposed color calibration process is shown in Fig.2. Here, we also call tumorA as the base image and tumorB as the calibration target for convenience.

We searched all the remaining CPs from the previous phase and selected several CPs having high similarity, CPs*, between tumorA and tumorB with the Euclidean distance of SIFT descriptors. We considered that the internal skin structures around the selected CPs* had stayed constant, namely the shape and color had nearly unchanged in the time-course. Therefore, we defined the rectangle areas as the basis regions (BRs) for color calibration (See Fig.2 upper half) each of which contains the CP* with its gravity center. Then, the cumulative density histogram was formed by accumulating each histogram obtained from each BR. The obtained histogram is called the cumulative brightness transfer function (CBTF).[7] Using the CBTF, color space of the tumorB can be calibrated to that of tumorA with the consideration of abovementioned issues. Note that the CBTF was developed by several BRs and hence it was capable of wide range of color calibration.

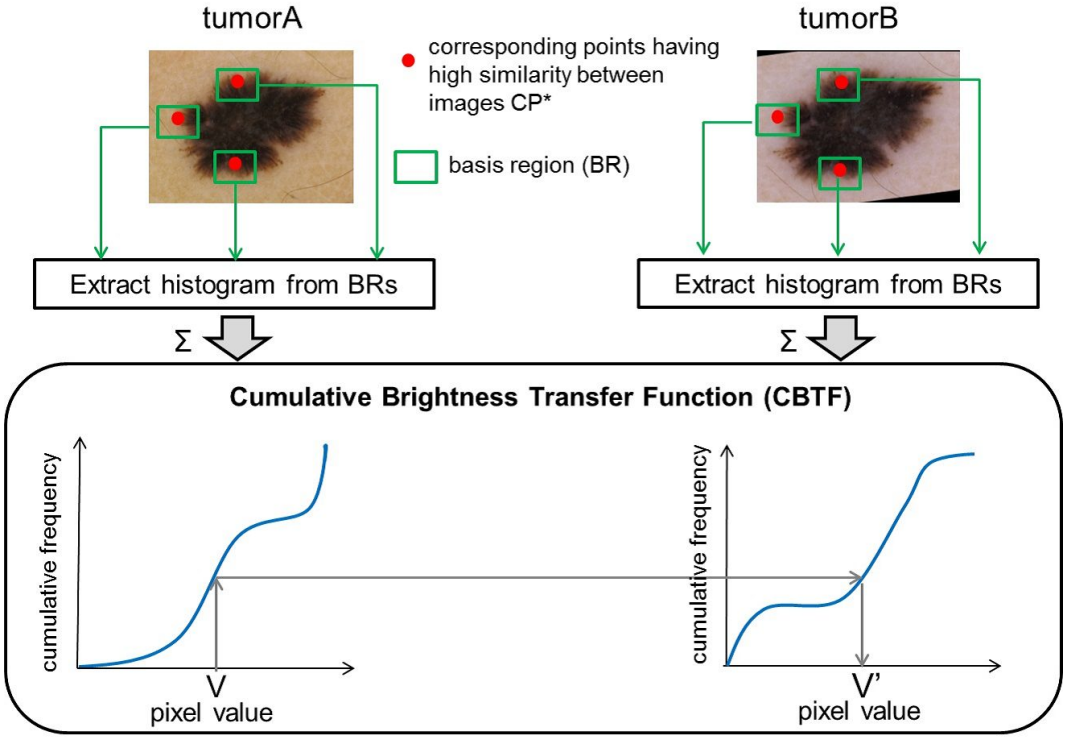


Figure 2. Schematics of color calibration process

## 2.3 Evaluation criteria

In this study, we cannot define absolute evaluation criteria for the tumor registration task because no one knows the " correct " registration. Alternatively, we defined a precision and recall measures as follows to evaluate registration performance:

$$precision = \frac{S(\text{tumorA} \cap \text{registrated tumorB})}{S(\text{tumorA})} \tag{1}$$

$$recall = \frac{S(\text{tumorA} \cap \text{registrated tumorB})}{S(\text{registrated tumorB})}, \tag{2}$$

where $S$(X) indicates the size of X. Here, when we need to detect tumor area from the image (i.e. in cases when we calculates the size of tumor in the equations (1)-(2), and color difference inside the tumor $\Delta E$ in the equation (3), mentioned later), we used our " dermatologist like " tumor area extraction algorithm.[8] This algorithm was shown to be highly accurate[9] and has been used successfully in our previous studies.[2–4]

With this measure, if both tumorA and registrated tumorB are completely unchanged and completely overlapped, both indices become 100(%). We agree this measure may become not adequate especially when the tumor appearances has largely varied during the time-course (i.e. in cases there are large differences betwen tumorA and tumorB). However, all cases used in this experiment are benign tumor and therefore the effects of this issue can be considered to be limited. As for a comparable reference, we manually registrated tumorB with tumorA in the best possible manner with the Exif data (it records photographic conditions such as magnification ratio) and evaluated the performance using same criteria.

As the evaluation measure for the color calibration, we calculated the mean of color difference between the tumorA and tumorB as follows.

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}. \tag{3}$$

Here, $\Delta L$, $\Delta a$, $\Delta b$ in the equation indicates the color differences between inside of the tumor areas in L, a* and b* channels in CIE L*a*b* color system, respectively.

## 3. RESULTS AND DICCUSSION

Figs.3-8 show some examples of our registration and color calibration results. In each figure, (a: left) dermoscopy image at initial consultation (tumorA), (b: middle) dermoscopy images at 2-4 weeks later (tumorB), and (c: right) the result of our proposed method (results of geometrical registration and color calibration of tumorB).

Our registration algorithm aligned time-course images with a precision of 91.6 $\pm$ 5.1% and a recall of 95.7 $\pm$ 5.9% (mean $\pm$ SD), respectively, whereas the fully manual registrations with Exif data as a performance reference did 95.4 $\pm$ 3.2% and 92.4 $\pm$ 6.5%, respectively. Note that all tumors slightly vary in size and therefore that the precision and recall cannot reach 100%. We confirmed that our automated method attained equivalent calibration performance to the best manual results with the Exif data (i.e. available magnification information). It is namely, our method registrated images without any other additional information such as the Exif data, but attained excellent results.

Our color calibration algorithm largely reduces the color difference between the time-course images $\Delta$E from 10.9 $\pm$ 5.6 to 3.9 $\pm$ 1.7. Also from visual assessment, we confirmed the calibration results are quite natural and appropriate. These results show that the proposed method is effective to compensate both geometrical and chronological changes between time-course dermoscopy images.

## 4. CONCLUSIONS

In this paper, we proposed a fully automated method for registration and color calibration for dermoscopy images during the time-course based on only given images. We confirmed our method attained excellent performance in both purpose. Appropriate quantification of variation of tumor appearance should help both for clinical and computer-based diagnoses. We will mount this function to our web-based melanoma screening system (http://dermoscopy.k.hosei.ac.jp) in near future.

## ACKNOWLEDGMENTS

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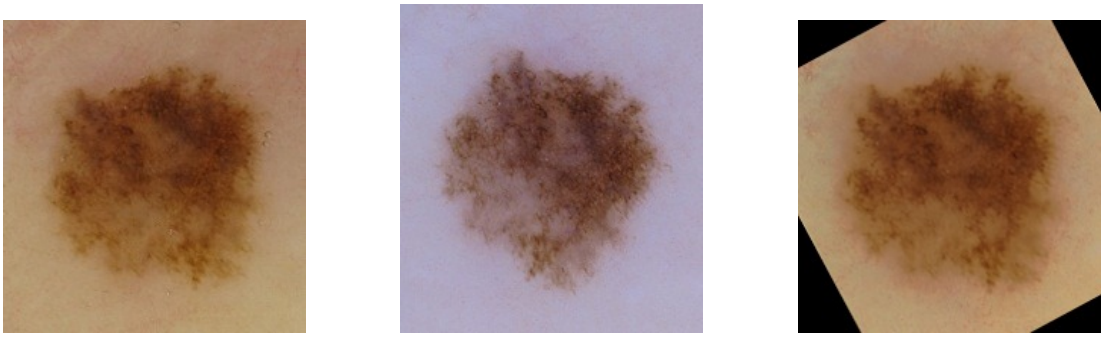
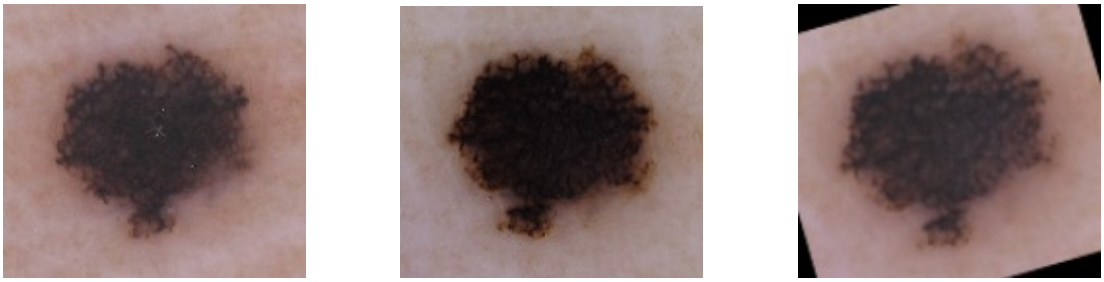


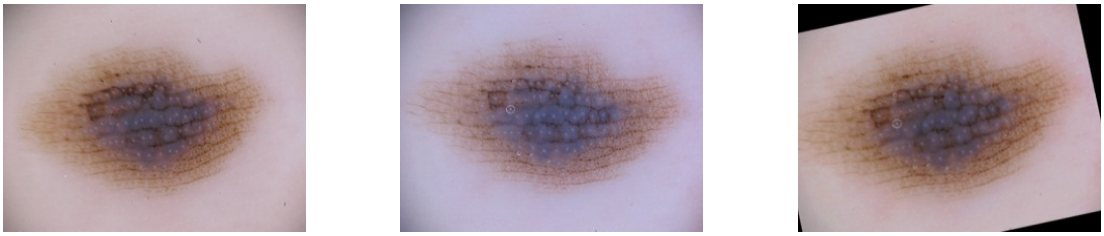
(a) tumorA (b) tumorB (c) Calibrated tumorB

Figure 3. Example 1 (precision=98.7%, recall=96.0%, average of color difference ΔE: 20.28→3.07)



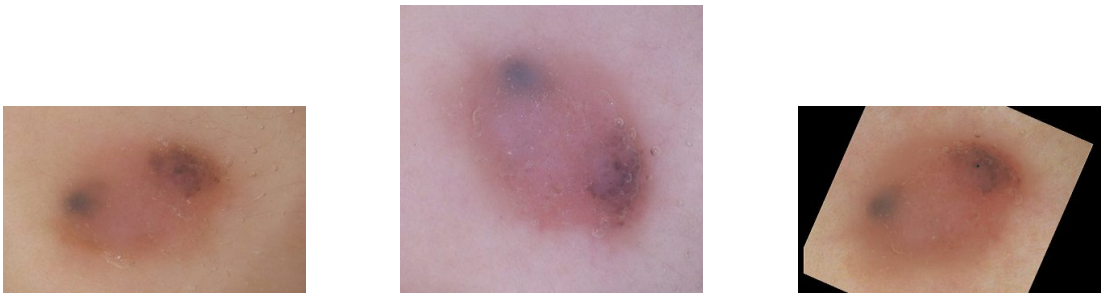
(a) tumorA (b) tumorB (c) Calibrated tumorB

Figure 4. Example 2 (precision=95.7%, recall=97.7%, average of color difference ΔE: 15.00→3.59)



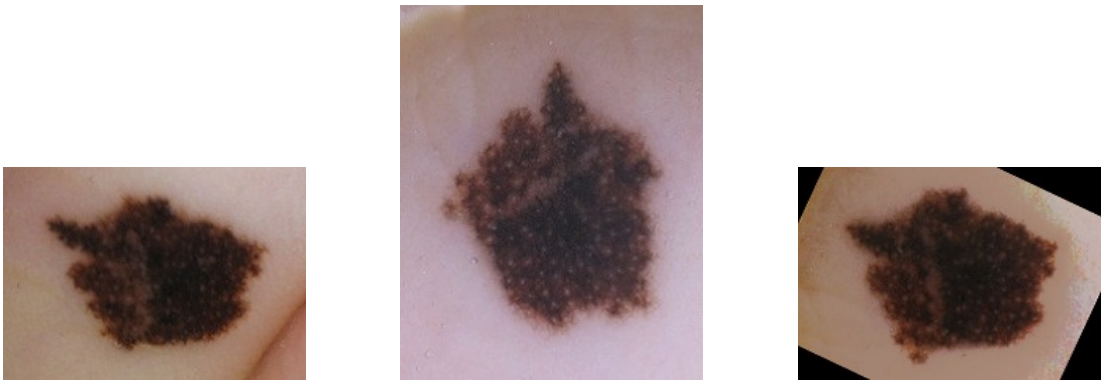
(a) tumorA (b) tumorB (c) Calibrated tumorB

Figure 5. Example 3 (precision=96.5%, recall=89.7%, average of color difference ΔE: 12.85→4.63)



(a) tumorA (b) tumorB (c) Calibrated tumorB

Figure 6. Example 4 (precision=95.5%, recall=85.7%, average of color difference ΔE: 17.17→3.00)



(a) tumorA (b) tumorB (c) Calibrated tumorB

Figure 7. Example 5 (precision=93.85%, recall=98.04%, average of color difference ΔE: 10.35→3.32)

(a) tumorA (b) tumorB (c) Calibrated tumorB

Figure 8. Example 6 (precision=96.87%, recall=96.76%, average of color difference ΔE: 6.26→3.07)