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# Fingernail Detection Method from Hand Images including Palm

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## Abstract

*We think that hand pose estimation technologies with a camera should be developed for character conversion systems from sign languages with a not so high performance terminal. Fingernail positions can be used for getting finger information which can't be obtained from outline information. Therefore, we decided to construct a practical fingernail detection system. The previous fingernail detection method, using distribution density of strong nail-color pixels, was not good at removing some skin areas having gloss like finger side area. Therefore, we should use additional information to remove them. We thought that previous method didn't use boundary information and this information would be available. Color continuity information is available for getting it. In this paper, therefore, we propose a new fingernail detection method using not only distribution density but also color continuity to improve accuracy. We investigated the relationship between wrist rotation angles and percentages of correct detection. The number of users was three. As a result, we confirmed that our proposed method raised accuracy compared with previous method and could detect only fingernails with at least 85% probability from -90 to -40 degrees and from 40 to 90 degrees. Therefore, we concluded that our proposed method was effective.*

## 1 Introduction

We think that hand pose estimation technologies with a camera should be developed. Hand pose estimation means that a computer gets 3D hand pose information about each joint angle, abduction and wrist rotation angle. These technologies will enable us to construct systems such as character conversion systems from sign languages or 3D gesture interfaces with not so high performance terminal. Hand pose estimation systems using only a camera categorize as 3D model-based matching [1] and 2D appearance-based matching [2]. However, both of them often use outline information. Therefore, the estimation results will be inaccurate if some finger information cannot be obtained. Fingernail positions can be used in this case as the finger-tip information. Therefore, construction of fingernail detection system is important. We decided to construct a practical fingernail detection system which could be used even if hand images included palm side area. It is preferable not to put anything on fingernails attached. We don't use any markers.

Some researchers proposed some fingernail area extraction or detection method. They used hue information [3], the first component coordinates of color information [4], and orthogonal axis to individual skin color axis [5] and so on. They only used color information. Therefore, they could extract some skin areas which have color like fingernails. Unfortunately, hand images including palm side usually have them. Thus, it is difficult for these methods to detect only fingernails from hand images including palm area.

Fingernail detection systems have to use not only color information but also something to remove skin areas having nail-color. Before, we proposed a two-stage search method for hand images including palm side using color information and distribution density of strong nail-color pixels [6]. This method could detect only fingernails with at least 80% probability from -90 to -40 degrees and from 40 to 90 degrees, i.e. excepting that hand was not facing upward or downward. However, the previous fingernail detection method was not good at removing some skin areas which have nail-color and gloss like finger side area. Therefore, we should use additional information to remove these areas.

What information can't be obtained using distribution density information? We thought that one type was "boundary information". Color usually doesn't change rapidly unless materials are different. Vicinity area of a skin having nail-color usually doesn't have a clear boundary. Besides, vicinity area of a fingernail has it because this area includes not only fingernail area but also skin area. Therefore, this information will be available for detecting fingernail.

Color continuity information is available for getting it. In this paper, therefore, we propose a new fingernail detection method using not only distribution density of strong nail-color pixels but also color continuity and improved detection accuracy.

## 2 Capturing environment

We used the high-speed camera "Dragonfly ExpressTM (640 x 480 pixels, 120 fps)" produced by Point Gray Research Inc. Lighting was a fluorescent lamp attached to the ceiling. Color temperature was 5000K. We used a black-color fabric for making the background black because we assumed that our proposed system input a hand image which made the background area black using another algorithm.

## 3 Previous method

The previous system using the privious method[6] does a two-stage search. In the first search, it processes the whole hand area. In the second search, it processes some hand areas in each Region of Interest (ROI) area

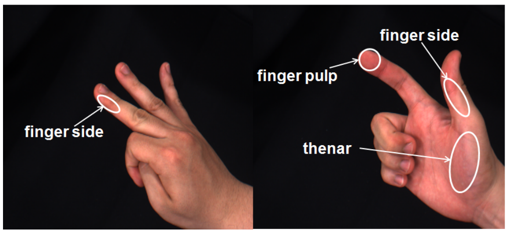



Figure 1. Skin areas having nail-color pixels.

including vicinity area of a nail-color area. We will express these processes in the following paragraph.

In the first search, The system inputs a hand image and outputs centers of gravity in nail-color areas. First, it inputs a hand image. Second, it removes a hand outline edge because outline information has a lot of color noise. Third, it extracts nail-color areas using third principal component coordinates of pixel distribution in RGB color space. Third principal component axis is used as nail-color index. This coordinate is a high value if a pixel has strong nail-color. The threshold value is usually 6.0. Finally, it creates nail-color areas using smoothing and labeling and calculates center of gravity for each area. Fingernail, thenar, finger pulp and finger side area especially tend to be extracted regardless of individual differences. Figure 1 shows these skin areas.

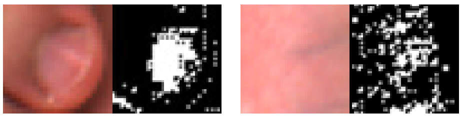
In the second search, the system inputs a hand image and centers of gravity in nail-color areas and outputs them in fingernail areas. First, it sets ROI area around centers of gravity as the rectangle shape. ROI size is set manually to become a size in which any fingernail is contained. Second, it creates ROI images. From this, it processes each ROI image. Third, it extracts high-ranking strong nail-color pixels in each ROI image and transfers them to binary images. Extracted pixels have top 15-25 percent strong nail-color in each ROI area. These pixels tend to gather closely if a fingernail is included in the ROI area. Figure 2 shows examples of extraction. Extraction rate, $Rate_{upper}$, was 20%. This figure indicates distribution density of strong nail-color pixels was different between the vicinity areas of fingernails and skin. The most difficult part to remove is the finger side. We surmise that this is because gloss by reflection of light is changing the color locally. This feature is expressed numerically. The $i^{th}$ ROI binary image is defined as "$O_i$". The system creates the images which have high density pixels using $7 \times 7$ median smoothing filters to $O_i$. This image is defined as "$C_i$". Moreover, the following image is defined as "$S_i$".

$$S_i = O_i \oplus C_i. \tag{1}$$

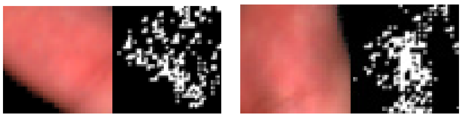
Where, "$\oplus$" means Exclusive OR. Number $i^{th}$ ROI area includes a fingernail if equation (2) is true. $Th_{CS}$ is usually 1.2:

$$\frac{N_S^i}{N_C^i} < Th_{CS}. \tag{2}$$

Where,
$N_C^i$: The number of pixels in $C_i$,
$N_S^i$: The number of pixels in $S_i$ and
$Th_{CS}$: Threshold for distinguishing fingernail.



(a) Fingernail (b) Thenar



(c) Finger pulp (d) Finger side

Figure 2. Differences of distribution density.Left: original images and Right: extracted pixels having strong nail-color.

## 4 Detection method using color continuity

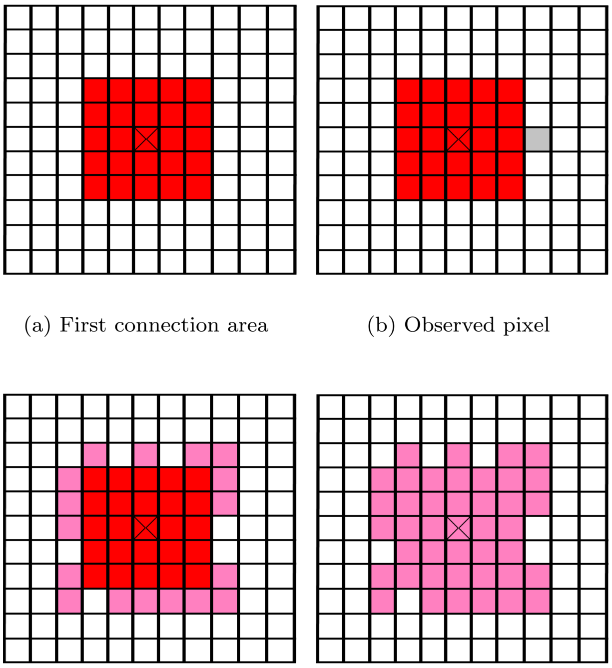
A new feature was required for removing some parts having gloss. We paid attention to boundary information. The color tends not to change rapidly if the object, fingernail or skin, is the same. Therefore, if rapid color change occurred on a large scale, there is usually a boundary between fingernail and skin. The center point in each ROI area including fingernail is usually on the fingernail area. Therefore, extraction process can stop on the boundary if the area having color continuity is extracted from the center point. Besides, the center point in each ROI not including fingernail is definitely on the skin area. Therefore, the area extracted will spread widely. This feature -"color continuity"- arises even if skin has gloss. Thus, we thought that this feature was available.

The added search is inserted after the end of the first search. In this search, proposed system inputs a hand image and centers of gravity in nail-color areas and outputs them in fingernail areas. First, the area, in less than 2 pixels from center point using 8-neighbering distance, is defined as a "connection area" (Figure 3 (a)). Second, it observes one pixel on the outside of this area and next to this area's pixels (Figure 3 (b)). This pixel is connected to the connection area if the following equation is true (Figure 3 (c)).

$$Third_j - Third_{connectionAreaMean} > Th_{connection}. \tag{3}$$

Where,
$Third_j$:
Third principal component coordinate in $j^{th}$ pixel,
$Third_{connectionAreaMean}$:
Mean value of the third principal component coordinate in coupling area, and
$Th_{connection}$: Threshold for connecting pixels.

$Th_{connection}$ is usually -3.0. After observing all pixels on the outline of the former connection area, it updates $Third_{connectionAreaMean}$ (Figure 3 (d)). It repeats this processing until pixels are no longer extracted. Proposed system concludes that fingernail is included in the ROI image in this search if any pixels on the most outer line aren't extracted. Figure 4 shows an example



(a) First connection area (b) Observed pixel

(c) Result of extraction (d) Update of mean value

Figure 3. Making a connection area.

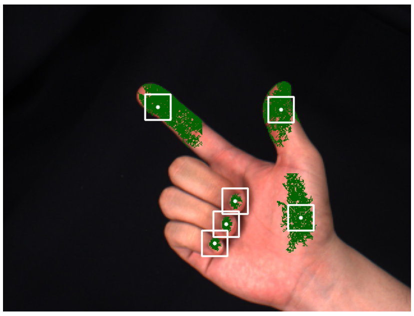


Figure 4. Final connection areas.

of the final connection areas when all hand area was used.

## 5 Experiments

We investigated the relationship between wrist rotation angles and percentages of correct detection in evaluation experiments. Correct detection means that all fingernails are detected and all skin areas are removed. At this point, we targeted fingers except for the thumb because it had different influence of wrist rotation compared with other fingers. There were 19 angle patterns.We used 500 pictures for each angle. These pictures had from 0 to 4 fingernails. The number of fingernails increased by one every 100 pictures. The angle was -90 degree if palm areas turned to the front. The angle was 90 degree if back side areas did. The fingernail was extracted when fingers ware bent between -90 and 0 degree and lengthened them between 10 and 90 degree. The number of user was three. Figure 5 shows used hands. Table 1 shows their RGB mean color and

(a) User 1 (b) User 2 (c) User 3

Figure 5. Hands used in experiments.

Table 1. User's information and parameter.

| User number | 1 | 2 | 3 |
|---|---|---|---|
| Gender | Man | Man | Woman |
| Back side | (199,126,105) | (193,113,98) | (229,151,119) |
| Palm side | (227,129,120) | (231,133,122) | (244,156,123) |
| Fingernail | (229,126,126) | (248,130,129) | (246,134,125) |
| ROI size | $41 \times 41$ | $51 \times 51$ | $41 \times 41$ |
| $Rate_{upper}$ | 20.0 | 15.0 | 20.0 |

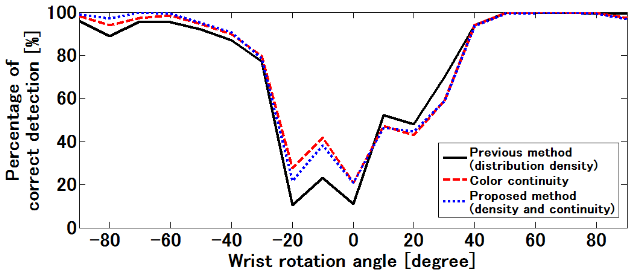
system parameters. We compared systems using only distribution density of strong nail-color pixels (previous method), only color continuity and both of them (proposed method).

Figure 6 shows the experimental results. This figure indicates that our proposed method was superior to the others from -90 to -40 degrees and from 40 to 90 degrees. Then, our proposed method achieved fingernail detection with at least 85 percent probability. Therefore, we concluded that our proposed method was effective. All method couldn't detect only fingernail from -30 to 30 degrees. This was because some fingernail areas were too small to detect them or shadow caused problems. We want to solve these problems and improve accuracy more in the future.

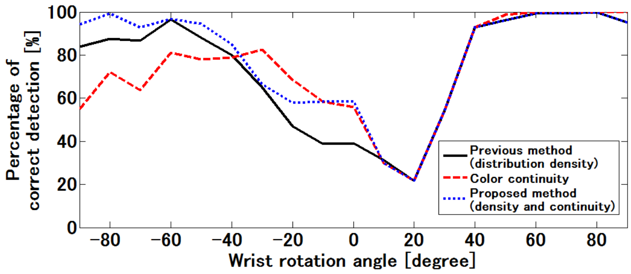
From this point on, discussion about accuracy will begin. Differences between distribution density and color continuity will be discussed. First difference was elimination probability of the finger side. Table 2 shows the results of elimination probability. This figure indicates that color continuity was effective to remove finger side. We think that the range of gloss caused this result. Gloss is a phenomenon that depends on how the lighting hits the fingernail. A lighting ingredient generally changes gradually. Therefore, the area of gloss tends to be wide range. Thus, color continuity is available to remove the finger side area.

The Second difference was an influence of the wrinkle at the joint. This tends to have a discontinuous color compared with the surroundings. Therefore, this contributes to stopping the expanse of the connection area. Thus, it is difficult to remove the finger pulp using color continuity if some wrinkles are included in the ROI area. Actually, Table 2 indicates it. Many finger pulps couldn't be removed using color continuity on user 2 because ROI size was big and some wrinkles were included. Besides, distribution density was strong for this situation because this feature didn't use skin-color pixel information.

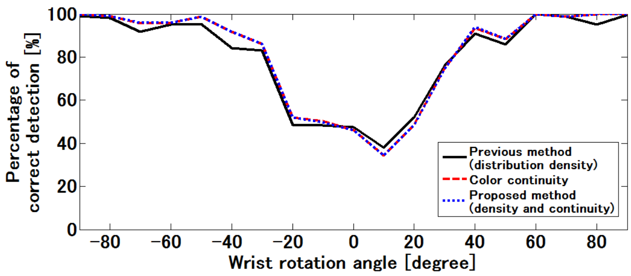
In light of the aforementioned result, we can understand why the fingernail detection accuracy was the




(a) Fingernail detection results for user 1




(b) Fingernail detection results for user 2




(c) Fingernail detection results for user 3

Figure 6. Relationship between wrist rotation angles and percentages of correct detection.

Table 2. Percentage of finger side elimination between -90 to -40 degrees.

| Percentage of skin elimination [%] | | | |
|---|---|---|---|
| Distribution density (Previous method) | | | |
| ROI size | Thenar | Finger pulp | Finger side |
| 41 × 41 | 99.43 | 92.75 | 45.57 |
| 51 × 51 | 100.0 | 91.70 | 88.53 |
| Color continuity | | | |
| ROI size | Thenar | Finger pulp | Finger side |
| 41 × 41 | 100.0 | 95.88 | 100.0 |
| 51 × 51 | 100.0 | 68.62 | 99.69 |
| Proposed method | | | |
| ROI size | Thenar | Finger pulp | Finger side |
| 41 × 41 | 100.0 | 99.02 | 100.0 |
| 51 × 51 | 100.0 | 95.64 | 99.88 |

best using color continuity and distribution density. Actually, these features have a complementary relationship. The method using color continuity works well when the skin part is not a finger pulp area or ROI size is small. Besides, the method using distribution density of strong nail-color pixels works well when the skin part is not finger side area or ROI size is big. Therefore, the method using both of them works well to remove various skin parts.

## 6 Conclusion

In this study, we talked about new information ”color continuity” and proposed a new fingernail detection method using color continuity and distribution density of strong nail-color pixels. In the experiments, we investigated the relationship between wrist rotation angles and percentages of correct detection for three users. As a result, we confirmed that our proposed system could detect only fingernails with at least 85 percent probability from -90 to -40 degrees and from 40 to 90 degrees and was superior to the previous method. Therefore, we concluded that our proposed method was effective.

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## References

[1] J. M. Rehg and T. Kanade: ”Visual Tracking of High-DOF Articulated Structures: an Application to Human Hand Tracking” *Proc. of Third European Conference on Computer Vision (ECCV'94)*, pp.35–46, 1994.

[2] K. Hoshino and T. Tanimoto: ”Realtime Hand Posture Estimation with Self-Organizing Map for Stable Robot Control”, *IEICE transactions on information and systems*, Vol.6, no.R89-D, pp.1813–1819, 2006.

[3] A. Tsuda, H .Kato, A. Yoneyama and S. Hangai: ”Nail Art Simulation by Hue Difference Feature with Light”, *Proc. of the 2009 IEICE General Conference*, p.290, 2009 . (in Japanese)

[4] Y. Chou and P. Bajcsy: ”Toward face detection, pose estimation and human recognition from hyperspectral imagery”, *National Center for Supercomputing Applications*, Technical report TR. 20041108-1, 2004.

[5] E. Tamaki and K. Hoshino: ”Personalized color system for robust extraction of skin-color”, *The Virtual Reality Society of Japan*, Vol.12, no.4, pp.471–478, 2007. (in Japanese)

[6] N. Fujishima and K. Hoshino: ”Fingernail Detection in Hand Images using Difference of Nail-color Pixels' Density between Vicinity Areas of Fingernails and Skin”, *Proc. of the 1st IEEE Global Conference of Consumer Electronics (GCCE2012)*, pp.238–242, 2012.