Improving the Method of Wrist Localization Local Minimum-Based for Hand Detection

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Abstract Nowadays, hand detection and gestures recognition have become very popular in human computer interaction systems. Several methods of hand detection based on wrist localization have been proposed but the majority work only with short sleeves and they are not efficient in front of all the challenges. Hand detection based on wrist localization proposed by Grzejszczak et al. (Proceedings of the 8th International Conference on Computer Recognition Systems CORES 2013 439–449, 2013), Nelpa et al. (Man Mach Interact 3(242):123–130, 2014) [3, 4] use the property of local minima along the contour of the skin mask obtained in the first stage to detect the wrist position. Although this technique provides good results where the skin mask contains the hand and the forearm, it still sensitive to the short contour where the skin mask contains the hand region only which generate false detection of the hand. We present in this paper an assessment of this method where the skin mask contains the hand region only. The main idea is based on the 2D shape properties of the hand and its components. Using 134 color images with their ground- truth, we evaluated the method enhanced and the results obtained were very satisfactory compared to the original one.

Keywords Hand detection · Wrist localization · Skin detection · Gestures recognition

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1 Introduction

Human-computer interaction aims to provide a better communication with a computer system. Furthermore, hands are spontaneous mean for a user to communicate with his environment, they are easy to use and correspond to the human nature. The use of hands in the human computer interaction domain may greatly improve the communication between the user and the computer.

Several methods of hand detection have been proposed; we can divide them in two categories: material- and vision-based approaches. The first methods [1, 2] impose to the user to wear a device on his hand for interaction. Effectively, these methods offer high detection results, but they are unnatural and not suitable for daily applications. The second methods [3–14] apply one or more techniques of computer vision on the acquired images, the skin segmentation is usually the first step and the skin mask obtained contains the hand region only or the hand and the forearm.

Among the vision-based methods of hand detection, they exist a number of methods based on wrist localization incorporating: local minima analysis and method width-based. The method using the local minima concept [3, 4] detects the hand of the user without imposing constraints on the length sleeves or background color, but it remains sensitive where the skin mask contains the hand region only. In this paper, we propose an enhancement for this method in order to detect well the hand where the skin mask contains the hand region only.

The paper is structured as follows. Section 2 introduces the different techniques of wrist localization presented in the literature. Section 3 presents the main contribution of the paper. Section 4 illustrates the experimental results and Sect. 5 concludes the work.

2 Related Work

Hand detection based on wrist localization has been widely studied recently in order to facilitate the interaction between the user and its machine.

In [1, 15], the authors proposed a wrist localization method for hand detection where the skin-mask contains the hand and the forearm. They localized the wrist by analyzing the forearm width with respect to the mask orientation. The minimum distances between symmetric contour points will represent the wrist location, and the side which contains several value changes of width-distance will be the side of the hand region (Fig. 1). The hand is well detected in these two methods but the width property loses its efficacy with the change of gestures and it does not work where only the hand region is presented in the scene.

In [4], the authors proposed a new method of hand detection based on wrist localization that works without any constraints on the sleeves length. After rotating the skin mask horizontally (using the longest cord of contour points) (PQ Fig. 2),

Fig. 1 The method of wrist localization proposed in [1, 15]

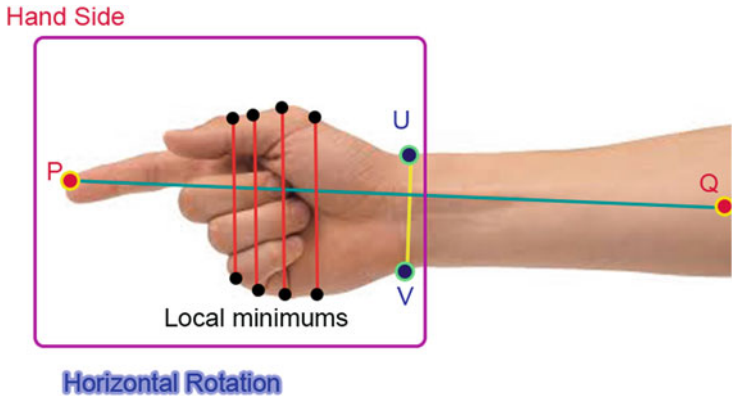

Fig. 2 The method of wrist localization proposed in [4]

they determined the position of the wrist by finding the local minimum (UV Fig. 2) of the contour of the skin mask. And the hand region is detected by finding the side which contains the high number of local minimum from the points UV of the wrist (Fig. 3).

Although this method detects the hand well where the skin mask contains the hand and the forearm, it still sensitive to the case of hand region only.

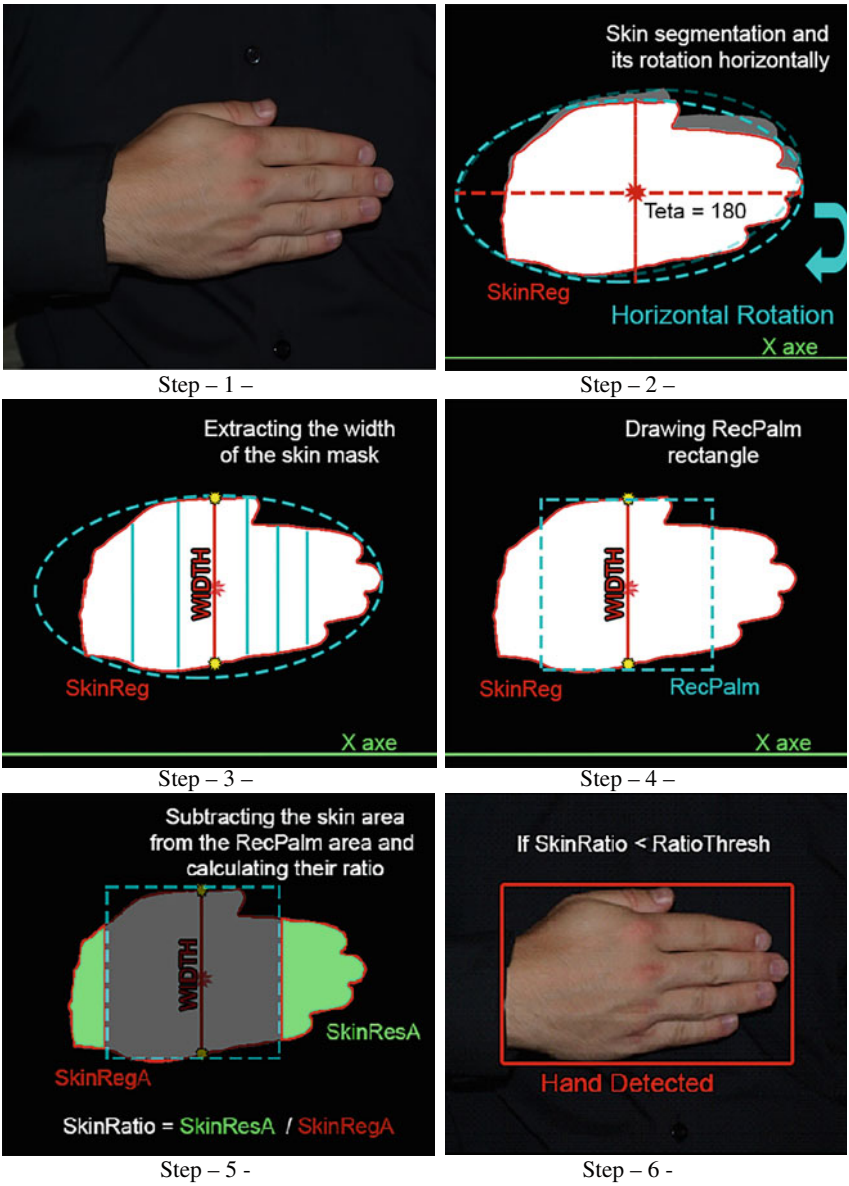

Fig. 3 Different steps used by the enhanced method for hand detection

3 Enhancement Proposed

The main idea of our proposed method is inspired from the 2D shape properties of the hand. A hand is a deformable object composed of fingertips, wrist and a hand palm that represents the majority of the hand area. This last property was used for the enhancement of the wrist localization local minima-based method where the skin mask contains the hand region only.

After the skin region segmentation and its rotation horizontally, we used the area property of hand palm to verify if this skin mask contains the hand with or without the forearm. The algorithm of the hand region verification is presented as follow:

Begin

1 – Skin region segmentation **SkinReg**.

2 – Rotate the skin mask **SkinReg** horizontally.

3 – Get out the width **SkinWidth** of the skin mask **SkinReg**.

4 – Draw a rectangle **RecPalm** with a length = **SkinWidth** and with same center as the skin mask **SkinReg.**

5 – Remove the skin mask **SkinReg** from the rectangle **RecPalm** and save the result in **SkinRes.**

SkinRes = SkinReg - RecPalm.

6 – Calculate the ratio **SkinARatio** between the initial area **SkinRegA** of the skin mask and the skin area **SkinResA** resulted after subtraction.

SkinARatio = SkinResA / SkinRegA.

7 – If **SkinARatio** < **RatioThresh**, then the **SkinReg** contains the hand region only, hand detected.

Elsewhere, the **SkinReg** contains the hand and the forearm region; apply the original algorithm of hand detection based on wrist localization (local minimum)

End.

4 Implementation Test and Results

Our experimental results are conducted on HP G62 notebook equipped with an Intel processor Core ™ i3 CPU 2.27 GHz, 4G of RAM and windows 7 OS. The method of wrist localization based on local minima was re-implemented on Matlab2013a and assessed using the database1 of hand gesture recognition created by [4].

We defined the threshold **`RatioThresh = 0.4`**, the corresponding results of hand detection are showed in the Figs. 4 and 5 the results of the original method are presented.

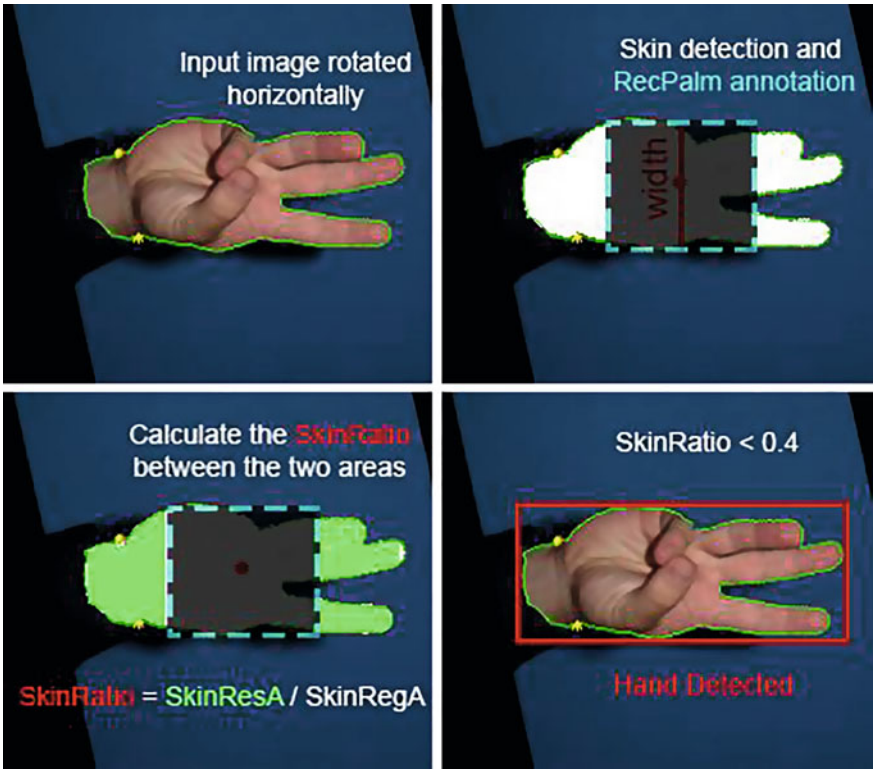

Fig. 4 Hand detection result by the enhanced method

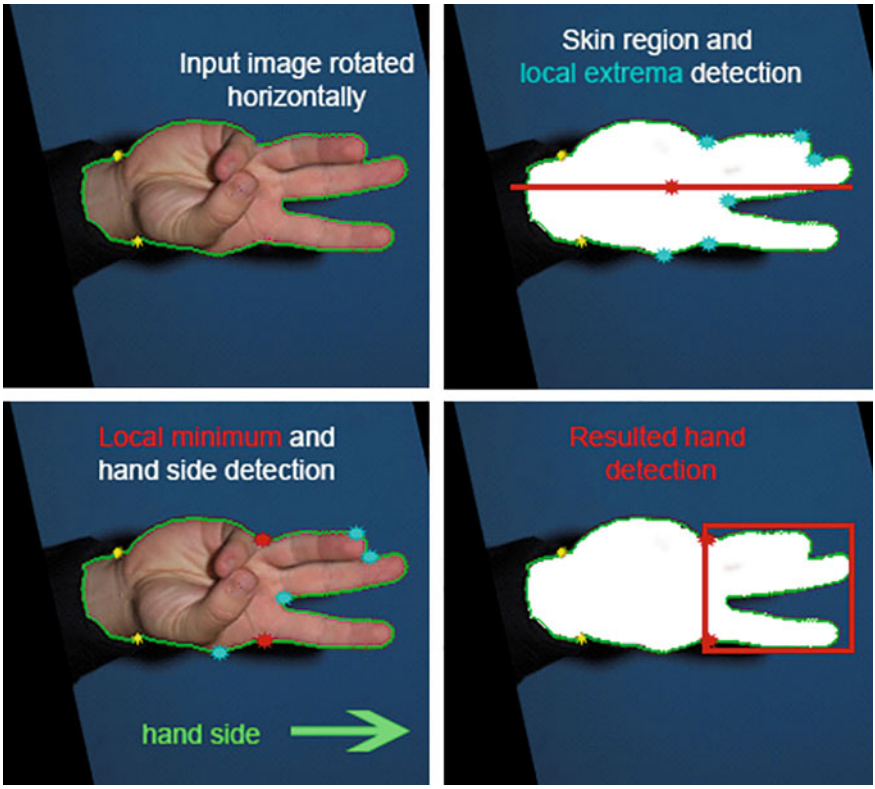

Fig. 5 Hand detection result by the original method of wrist localization

5 Evaluation

The database used for the evaluation contains 899 color images of hand gestures with both cases (hand, hand and forearm). However, as our method improve the detection of the hand where the skin mask contains the hand region only, we chosen from this database only the images containing the case studied. In result, we obtained 134 images with their ground-truth (Figs. 6, 7 and 8).

We compared the results of the original method of hand detection by wrist localization with the enhanced one using these 134 color images in measures of time processing, wrist error statistics and rate of correct hand detection (Table 1).

The time-processing results obtained by the method of wrist localization before and after the enhancement are very close. From the corresponding graphs, we can notice that the majority of the images in the original method have been executed in 0.2 s only, and in the enhanced method, the majorities are distributed between 0.2 and 0.3 s.

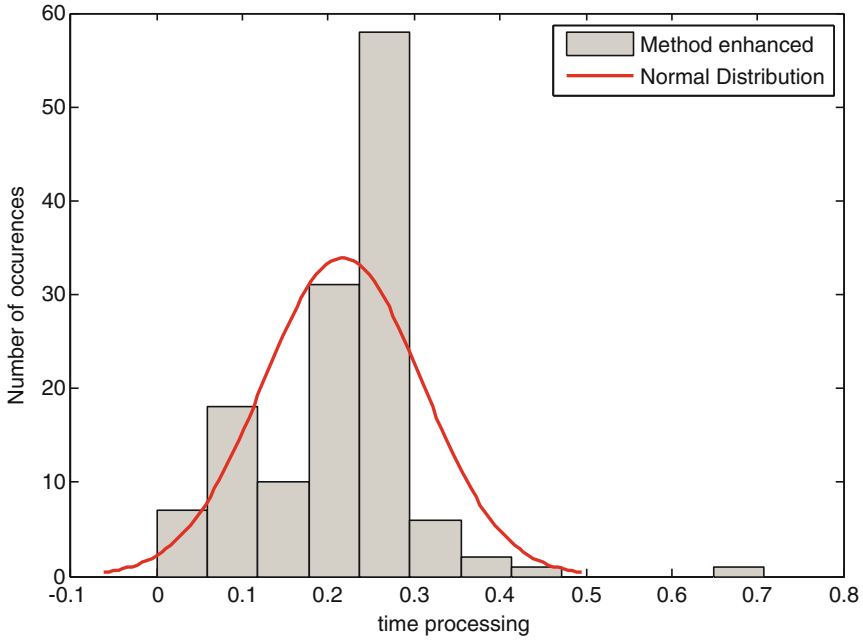

Fig. 6 Histogram of time processing for the 134 color images of the database using the enhanced method

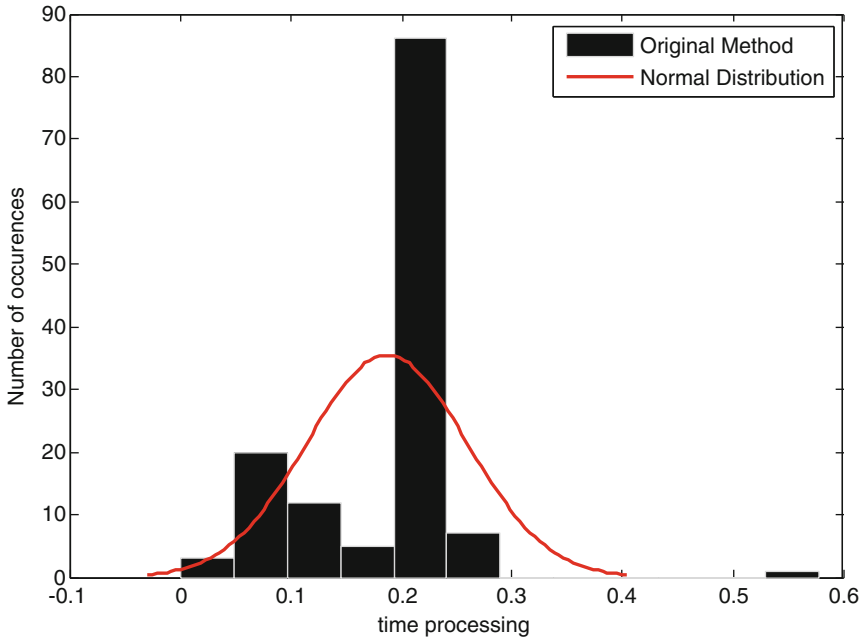

Fig. 7 Histogram of time processing on the 134 color images of the database using the original method

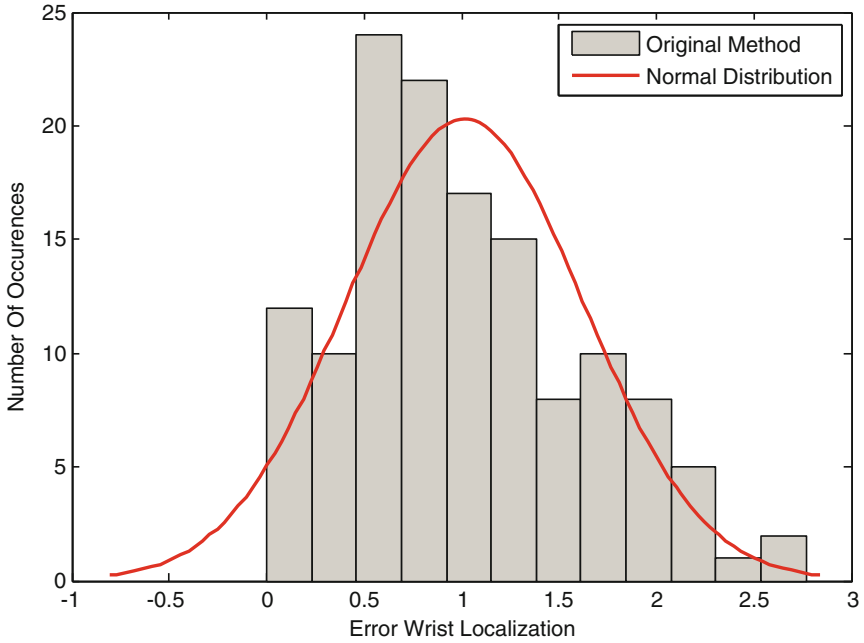

Fig. 8 Error statistics of wrist localization resulted by the original method

Table 1 Time processing comparison between the original method of hand detection and the enhanced method

		The original method of wrist localization [4] (s)	The original method after enhancement (s)
Processing Time	time_avg	0.1786 ± 0.0716	0.2192 ± 0. 0934
	time_max	0.6103	0.7206

Table 2 The rate of the successful hand detection and error statistic for the original and the enhanced methods of hand detection

	The original method of wrist localization [4]	The original method after enhancement
Correct hand detection	46	**86**
	34.41 %	*64.17 %*
Error statistic	88	**48**
	65.67 %	*35.82 %*

The Table 2 shows the rate of the correct hand detection obtained by both methods. For the original method, we consider a correct hand detection if the error wrist localization E compared to the annotated ones are inferior to E < 0.8. For the second method, we consider a correct hand detection if the **`RatioThresh < 0.4.`**

We can notice from the results obtained that the enhanced method recovers 30 % of the misclassified hand images from the original one.

6 Conclusion

We presented in this paper an enhancement of the method of hand detection by wrist localization based on local minimum. We confirmed in the experiments that the proposed method performs in short times and recovers 30 % of the misclassified hand images of the original method. We conclude form the results obtained that there is no need to localize the wrist where the hand region is presented in the scene only.

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