Non-positive Face Chin Detection Method Based on Curve Fitting

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Abstract. The head recognition system needs precise contours of the face area, whereas the non-positive face color contours often contain neck areas, which will seriously affect the extraction of contour features. Therefore, the neck area in the outline of the human face needs to be removed to obtain the final facial contour. In this paper, the chin curve is fitted based on the extremum of the contour features of the left and right sides of the human chin region, and then the neck area can be removed. The experimental results show that the method proposed in this paper can obtain the non-positive face profile without the neck.

1. Introduction
Head pose estimation [1-2] is to estimate the pose parameters of the user's head from the captured video image. This is a typical and complex pattern recognition problem. In head pose estimation, an accurate face area is required to recognize the posture of the head. However, when the face is non-frontal, the detected face often contains a neck area. Therefore, the skin color area must be further processed to eliminate the neck area. The method that is widely used today is the chin contour detection method. At present, there are many methods for chin contour detection [3], but most of these methods are used for frontal faces. For example, a literature [4] first determine the intersection point of the neck and cheek, and then the chin contour is fitted by Sobel gradient operator; a literature [5] uses Snake algorithm to extract the chin contour by the depth map of the image; in literature [6], the outline of the face is determined and the outline of the chin is obtained through the positional information and geometric relations of the facial features. However, these methods are for positive faces. In non-positive situations, there are no fixed patterns for the position of the neck, the intersection with the cheeks, etc. Therefore, the chin detection is very difficult. As in the case of the frontal face, the chin area in the non-positive face still has certain contour features. But it is the uncertain contour rather than the contour of the quadratic curve in the positive case. In this paper, a line segment chin fitting method is proposed to determine the position of the chin according to the contour features of the skin color region based on the positive face curve fitting chin method.
2. Chin fitting algorithm

2.1. Skin area contour features
As shown in Fig. 1, a non-positive face obtained by shooting in an indoor environment, and the skin color area shown in Fig.2 is obtained by performing skin color detection [7] through a skin color detection model.

![Figure 1. a non-positive face](image1)

![Figure 2. The skin color](image2)

After the skin color region is obtained, the contour image of the skin region binary image is extracted to obtain the contour curve shown in the following figure. It can be known that the neck area is generally in the lower half of the entire color profile.

![Figure 3. Face area contour curve](image3)

After comparing several groups of skin contour curves, it is found that there is a turning point at the intersection of the cheek and the neck in the curves on the right and left sides of the neck. The turning point is very close to the starting point of the chin, so this method approximates that point is the chin start point.
2.2. Neck curve extraction
For the facial skin area contour, the left and right neck curves can be extracted based on geometric features. Figure 4 shows the neck curve extraction process. In the figure, Min X is the highest point of the contour, Mid X is the midpoint, Max X is the lowest, X Width is the X-coordinate difference between the lowest point and the highest point of the curve at the bottom of the contour, Mid Y is the mid-point Y value of the contour in the Y-axis direction.

![Figure 4. Neck curve extraction process](image)

After getting the neck curve, firstly, here we only need to obtain the vertical curve of the Mid Y to the left half of the curve. Secondly, cut the curve of the lower half horizontally by the Mid X, and then cut the curve of the upper part by the Max X-X Width transversely. Finally, the left curve can be obtained as shown in Figure 5 below. The right curve extraction method is the same as above.

![Figure 5. Left curve of neck area](image)

The resulting curve of the neck approximates a quadratic curve that contains an extreme point, which can be approximated as the left starting point of the chin. For calculating the extreme points, the left curve needs to be fitted.

2.3. Curve fitting [8] and chin starting point calculation
After the neck curve is extracted, the left and right neck curves need to be fitted respectively to obtain a fitted curve equation, and then an extreme point of the curve is calculated through the equation. The neck curve in the figure is stored in the computer as a set of point coordinates. The equation of this irregular curve cannot be calculated directly. Only by getting an approximate curve equation by fitting can the extreme points be calculated. There are many methods for curve fitting, such as least squares fitting [9], steepest gradient method [10], smooth spline fitting [11], and sine curve fitting [12], etc.

In this paper, the neck curve itself is close to a curve with only one extremum in the interval. Therefore, it is hoped that the fitted curve is as smooth as possible and contains only one inflection point
or extremum point. In the experiment, a fitting experiment was performed on the curve of the left neck. The smooth spline method and the sinusoidal curve method were used.

The fitting result of the smooth spline method is shown in Fig. 6. The fitting result is excellent, and the fitting curve basically completely smooths the original curve. However, there is a serious problem here. There are more than one inflection point of the smooth curve, the curve equation is too complicated, and the calculation of the inflection point is too large, which is very unfavorable to the chin fitting.

![Figure 6. Smooth spline fitting](image)

The result of fitting by the sine function method is shown in Fig. 7. This method approximates the neck curve through a sine function. Although the sine function method is not as close to the original curve as the smooth spline method, the purpose of fitting is to calculate the inflection point. The sine function equation here is simple, the inflection point calculation is very easy, and it can approximate the approximate position of the extreme point.

Therefore, this paper uses the sine function method to fit the neck curve. Taking Fig. 7. As an example, the equation expression of the sine function curve can be calculated after the curve is fitted. The general expression of a sine curve is:

\[ f(x) = a \sin(b_1x + c_1) \] (1)

For the sine function in Figure 7, \( a_1 = 214.4 \), \( b_1 = 0.007222 \), and \( c_1 = 5.599 \). Therefore, the sine curve equation is:

\[ f(x) = 214.4 \sin(0.007222x + 5.599) \] (2)

After obtaining the sine curve equation, the extreme point calculation is performed. For a general quadratic curve, the extreme point is the point where the first derivative is zero. The curve in this article is a sine-fitting curve, and the fitted curve contains only one extreme point in the interval. The calculation of the point where the derivative of the sine function is zero is required.

For Equation 2-2, the coordinates of the extreme point in the interval \( x \in (250,400) \) can be calculated. The result is (312.24, 214.45), and the left starting point of the chin can be obtained finally.

![Figure 7. Sine function fitting](image)
2.4. Chin fit
When the face in the image is face up, the neck will be located directly below the face through a series of facial skin color outlines. Therefore, the chin position can be fitted to find the neck area by using the lower half of the skin color profile in the above figure. This paper designed a chin fitting algorithm. The basic steps are as follows:

1. The binarized skin area image is contoured to obtain a skin color profile.
2. Cut the skin color profile curve. According to the common knowledge of human face structure, the position of the chin is generally 1/2 to 1/3 of the height of the contour, so the lower half of the contour curve is intercepted to obtain left and right contour curves.
3. Smooth the two curves separately. It was found through observation that the chin generally extends from the inflection point of the left curve to the inflection point of the right curve.
4. Fit the two curves and find the position of the inflection point of the two curves. Because for the quadratic curve, the point where the second derivative is zero is the curve inflection point. Therefore, the point where the derivative is zero can be found by calculating the second derivative of the curve, which is the starting point of the chin.
5. After step 4, if the posture of the face is looking forward, then both left and right curves will have inflection points. If the face rotates to the left or right, there may be cases where there is no obvious inflection point on one side of the curve. If you get two inflection points in step 4, connecting the left and right inflection points with a line segment; if you only get one inflection point, starting a straight line from this inflection point and performing the horizontal straight line fitting process. The chin fitting results under different conditions are shown in the figure below.

3. Experiments and analysis
3.1. Results of chin curve fitting
After a lot of experiments, this paper proposes a chin fitting method based on the characteristics of the skin color area contour curve. The starting points on both sides of the chin are obtained by calculating the inflection points of the left and right sides of the neck, and the final chin curve is obtained after connecting the two starting points. The basic flow of chin fitting is shown in the flow chart below.
Since the chin curve fitting is based on the result of the skin color detection, the chin curve fitting can only be performed after obtaining the skin color profile curve. When the correct skin color area contour is obtained after the skin color detection process, the chin curve fitting can be performed. Because of the length of this paper, the chin fitting will be performed on the contours of some of the skin color areas, including up, down, left and right directions, and the results are shown in Figure 10.

From part of the curve fitting results the chin in Figure 10, the chin fitting method based on the inflection point feature of the skin color region contour curve proposed in this paper can achieve good results. Therefore, so long as the skin color region can be detected, the chin curve fitting will generally successful.

3.2. Results of neck removal
After the region of the chin curve fitted image is grown, a non-frontal face contour that does not include a neck region can be obtained. According to the geometric relationship of the proportion of the human face, it can be known that the center point of the skin color region contour must be in the upper part of the human face rather than the neck region. As a result, the skin color region contour center is selected as the region growth point [13]. The results are shown in Figure 11.
Figure 11. Results of neck removal (results of face contour extraction)

It can be seen from the results of Fig. 11 that the final non-frontal face contour can be obtained after removing the neck by region growth, and the results of neck removal are successful.

4. Conclusion
In this paper, a neck region is excluded from the skin color profile obtained by skin color detection. When the face is non-positive, the resulting contour after skin color detection must include the neck region. After a lot of experiments and researches, this paper proposes a method of fitting the chin through the inflection point of the skin color region contour curve. The results of simulation experiments show that the proposed method can approximate the approximate position of the chin and eliminate the neck to obtain the non-positive face contour.

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