

The active contours method analysis in solving cephalometry problems

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Abstract

The task of automating the process of determining a face profile cephalometric features was solved using the active contours method. A method for automatic detection of key cephalometric points and automatic classification of images by profile types and profile harmony was proposed. The analysis of automatic data markup results was performed.

Results of experimental studies

A set of 120 profile images was used for experimental studies.

A preprocessing of images: cropping of images (according to a rectangular area, found with the Haar model); converting all images to grayscale; scaling images to one size $N \times N$ (in this paper $N = 900$); noise removal using morphological operations (erosion, dilation, opening, closing, logic filters); increasing the contrast of the original image; image blurring using Inverse Gaussian Gradient.

To verify the results obtained, all images were also marked up by a medical specialist manually. In both cases, three types of data markup were carried out: detection of the profile key cephalometric points; multiclass markup (three possible classes according to the certain type of profile); binary markup (profile harmony).

To analyze the detection accuracy of $m=7$ key cephalometric profile points, the average distance between the points $M_i(x_i, y_i)$ marked manually and the points $M_j(x_j, y_j)$ obtained automatically was used as a metric:

$$\sigma = \frac{1}{N \cdot m} \sum_{i,j=1}^m \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}.$$

The ratio of incorrectly detected profile types to the total number of images in the sample was used as an estimation of erroneous probability to analyze the obtained results in the case of multiclass and binary data markup.

Active contours method for cephalometric tasks

The active contours method is a variational method for finding boundaries on a given image. The initial contour is initialized as some simple line consisting of n points. The contour is deformed iteratively until its shape is close enough to the shape of the object being studied. The energy value for each point v_i of the variable contour is found from the equation:

$$\begin{aligned} E_i(v_i) &= a \cdot E_{int}(v_i) + b \cdot E_{ext}(v_i) \\ a \cdot E_{int}(v_i) &= c \cdot E_{con}(v_i) + d \cdot E_{bal}(v_i) \\ b \cdot E_{ext}(v_i) &= g \cdot E_{mag}(v_i) + h \cdot E_{grad}(v_i) \end{aligned}$$

Correctly selected weight coefficients of the corresponding energies allow us to get the contour closest to the contour of the object: at higher values of the coefficient "c" with the smoothing energy of the contour $E_{con}(v_i)$, the curve will shrink faster, at higher values of the coefficient "d" with the bursting energy $E_{bal}(v_i)$, the curve will be smoother, the coefficient "g" at $E_{mag}(v_i)$ is responsible for the attraction of the contour to darker in brightness areas, the coefficient "h" with the gradient energy function $E_{grad}(v_i)$ is responsible for changing the brightness of the image.

The profile contour function was studied for extremes to find the key cephalometric points of the face. To do this, the detected closed contour of the profile was unfolded (by switching from polar coordinates to Cartesian coordinates) after applying the active contours method.

$$x_1 = \arctg(\varphi); \quad y_1 = \sqrt{x^2 + y^2}$$

To find the coordinates of the closed contour extremum points, a reverse transition to polar coordinates was required, taking into account the initial contour center coordinates $C(x_c, y_c)$:

$$x_2 = y_1 \cos(x_1) + x_c; \quad y_2 = y_1 \sin(x_1) + y_c$$

When analyzing the obtained values, the profile type and harmony of the face profile was determined:

Three types of the profile are distinguished in anthropometric analysis:

- straight profile – the angle between the straight lines is 180° ;
- convex profile – the angle between straight lines is less than 180° ;
- concave profile – the angle between straight lines is more than 180° .

The aesthetic line of the face profile according to Ricketts is the line connecting the nose tip and the most protruding point of the chin. The profile is considered to be harmoniously developed if this line does not cross the lip border, while the upper lip lags behind this line by 2-3 mm, the lower lip lags by 1-2 mm.

Analysis of the automatic detection results

values of coefficients corresponding to energy functions			the value of the quality metric σ	the probability of erroneous automatic classification	
E_{con}	E_{bal}	E_{grad}		profile type	profile harmony
0,01	0,01	0,01	29,76	0,64	0,12
0,02	0,01	0,01	25,27	0,11	0,97
0,05	0,01	0,01	37,41	0,08	0,86
0,01	0,01	0,01	26,83	0,48	0,09
0,001	0,001	0,005	74,35	0,98	0,23
0,001	0,001	0,001	03,66	0,02	0,03

Conclusion

Analysis of the automatic data markup results showed that the proposed method of profile contour selection based on the active contours method does not provide an exact match of cephalometric points selected automatically and manually. However, if the weight coefficients are set correctly, the probability of an erroneous classification of the profile type and harmony can be reduced to 0.03.

The proposed method of profile contour selection based on the active contours method allows to mark up the main profile anthropometric points and cephalometric characteristics automatically.

The data marked up this way is planned to be used in the future when training a neural network to determine the main cephalometric features. This will automate the process of filling out mandatory medical documentation. The developed software module can become part of an automated decision support system for identifying the need for orthodontic treatment.

Active contours method for facial contour

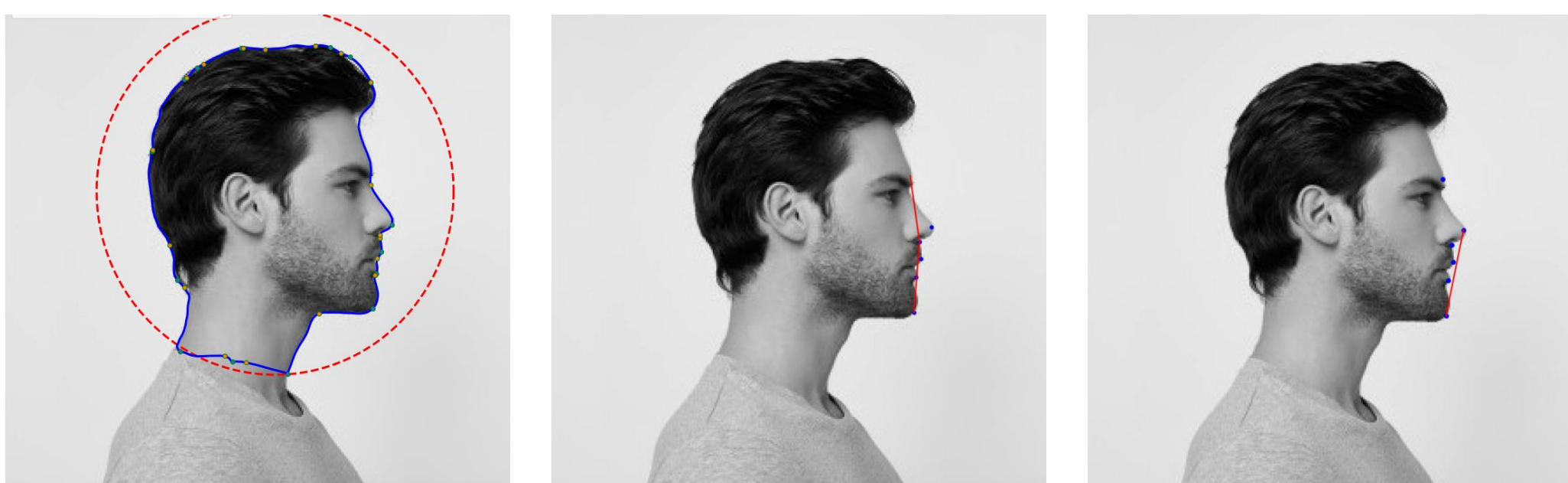


Figure 1. Closed contour. Locating the extrema of the face profile contour function. Determining the profile type and profile harmony.

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