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DETECTION OF SELECTED FACE AREAS ON THERMOGRAMS WITH ELIMINATION OF TYPICAL PROBLEMS

The paper presents an algorithm enabling a fully automatic detection of characteristic areas on thermograms containing patients' faces in a front projection. A resolution of problems occurring at the segmentation of face images, such as a change of position, orientation and scale, has been proposed. In addition, attempts to eliminate the effect of the background and of disturbances caused by the haircut and the hairline were made. The algorithm may be used to detect selected points and areas of a face or as a preliminary component in the face recognition, as a development of optical analysis methods or in the quantitative analysis of face on thermograms.

1. INTODUCTION

The studies on the face analysis and recognition have been carried out for a few decades, numerous examples may be found in the literature [1, 2, 3]. Most of them are related to studies in the light, however, in recent years attempts have also been made to use thermograms in such areas as the medicine [5, 6] or face recognition [7, 8]. In medicine the thermograms' analysis is used in several areas, i.e. ophthalmology, dermatology, stomatology, laryngology, neurology and neurosurgery, examples have been described in the literature [9, 10].

Examples of human thermograms are presented in Fig. 1. Thermograms, which may cause problems at the segmentation and analysis, have been indicated on purpose. Disturbances caused by the background (Fig. 1 a), thick hair around the forehead (Fig. 1 c, d) and luxuriant haircut (Fig. 1 c) may be observed here. The brightness of individual pixels of the image depends on the temperature of specific point of the object studied acc. to a visual scale of temperature (Fig. 1. f).

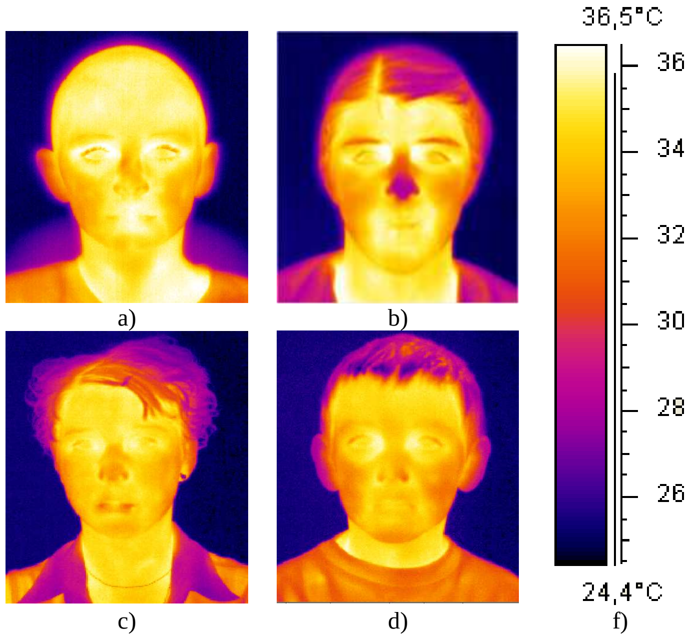

Fig. 1. Examples of thermograms with typical disturbances.

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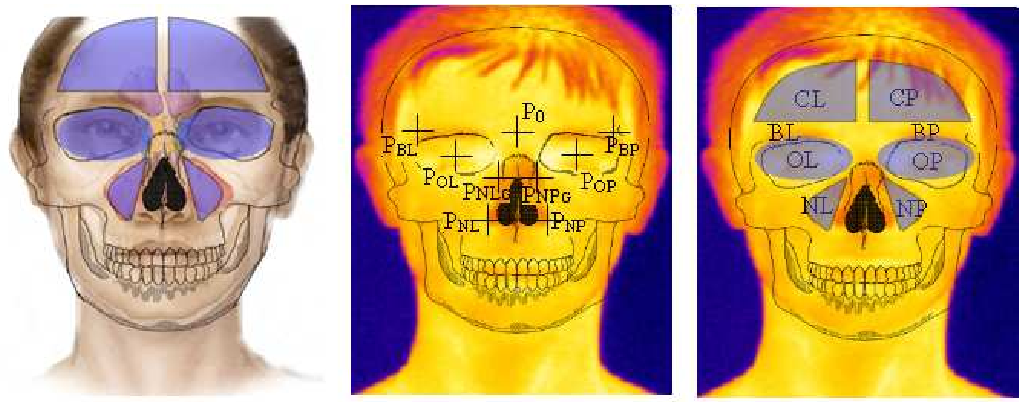
2. ASSUMPTIONS AND THE PROCESS OF PREPROCESSING

In the case of quantitative analysis it is not possible to determine precisely the temperature values or to perform a statistical analysis of the results obtained. The software delivered together with thermovision cameras does not allow automating the process of analysis. The studies described in this paper are aimed at preparing an algorithm for automatic analysis of face thermograms.

Fig. 2 presents selected points and areas (detected automatically by the algorithm) and their position on an optical image and on a thermogram.

When developing the method proposed an attempt was made to automate the temperature normalisation threshold to distinguish a silhouette from the image and to fulfil the assumptions made previously, i.e.:

- elimination of the background disturbances and of the haircut effect;
- determination of characteristic points of a face, i.e. the point of the face symmetry axis and eyebrows axis intersection (*P0*), centres of the left and right orbit (*POL*, *POP*), extreme points of the nose (*PNL*, *PNP*), extreme points of eyebrows (*PBL*, *PBP*), points of the upper end of sinuses (*PNLG*, *PNPG*);
- determination of areas, i.e.: eyebrows line (*BL*, *BP*), eyes area (*OL*, *OP*), nasal (maxillary) sinuses (*NL*, *NP*), forehead (*CL*, *CP*);
- automatic performance of the detections and measurements mentioned without operator's intervention;
- quantitative analysis of the image, i.e. the measurement of areas surface and temperature properties.



a) b) c)

Fig. 2. Selected face areas subject to the temperature measurement.

In the studies published so far [11, 12, 13], a preliminary image normalisation and the elimination of the background disturbances by means of the algorithm presented was carried out based on the temperature threshold adopted as a result of experiments and observations. In the studied group of images a value of T_U = 28.3 °C was set, which allowed eliminating properly most of the problems related to the background and haircut. However, in single cases there were problems with the determination of proper outline of the head, with the determination of its size and with the determination of the temperature threshold in such a way as to avoid the haircut effect.

Attempts to apply the Otsu method used in the literature [6] also were not fully satisfactory for the studied group of images. Therefore attempts were made to automate the process of temperature selection taking into account the results obtained and the properties of areas determined after the operation of threshold setting. The range of temperature analysis was determined based on observations:

$$Range \cdot T = T_{\min T} : T_U \qquad (1)$$

where:

$T_{\min T}$ –minimum temperature on the thermogram; T_U = 28.3 °C – set temperature.

An assumption was made that the best area of patient's silhouette for further segmentation should be as small area as possible obtained as a result of threshold setting with automatically set threshold, should not contain "holes" and should not significantly deform the silhouette. To determine such area the relationship has been determined:

$$Wsp_{(index)} = (P_0 - P_{Max(index)}) / \left|(E_{(index)})\right| / N_{(index)} \tag{2}$$

where:

P_0 –area of image studied of M rows, N columns dimension;
$P_{\mathrm{Max}(index)}$ –surface of the largest area created after the threshold setting $t_{(index)}$;
$E_{(index)}$ –Euler number for consecutive images created after the threshold setting;
$N_{(index)}$ –number of areas in the image studied after the threshold setting operation.

In the process of temperature value determination, the algorithm analyses the set temperature range ($T_{\mathrm{min}T}$ to T_U). The range is analysed with an iteration step of ΔT=0.25 ºC. The operation of threshold setting is carried out for each value of temperature. For the binary image determined in this way, $L_{Bin(index)}$, coefficient ($Wsp_{(index)}$) is determined – for the largest area obtained as a result of the "threshold setting". As a result, the algorithm determines the area of patient's silhouette, being the smallest area without "holes".

Fig. 3 a) b) present results for thermograms from Fig. 1 a),d). It is characteristic that these disturbances are eliminated and at the same time the silhouette is not subject to major deformations, which could affect further segmentation.

A proper determination of the examined person silhouette has a positive impact on the precision of operation of further algorithm blocks. It allows determining properly a potential centre and shape of the head and its approximate height, using an active contour.

A preliminary determined, as a result of erosion, centre of head area is used to initiate an active contour. After the segmentation using the active contour the head height is determined as well as its preliminary orientation based on the shape obtained. Fig. 4 presents examples of this operation – the segmentation using the active contour (balloon type), the automatically determined head height and the detection with TSzablon (TTemplate).

3. DETERMINATION OF HEAD ORIENTATION

Based on the data on the head size and anthropometric relationships of the face as well as analysing examples in the literature [6, 14, 15, 16] a detector (hereinafter referred to as the TSzablon) – Fig. 3 c). Analysing the information on the brightness (temperature) distribution taking into consideration the data on the face symmetry, it determines characteristic points (P_0, P_{BL}, P_{BP} – Fig. 2 b) on the thermogram. In addition, the detector determines precisely the face orientation by determining the eyebrows line and the axis of nose symmetry.

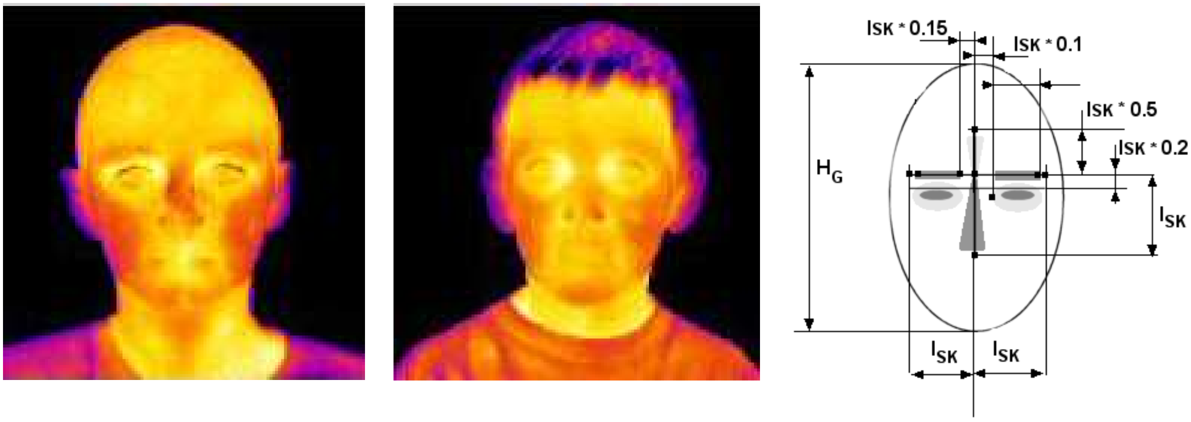
The basic magnitude of the TSzablon consists of its height (arm) – I_{SK}. It is determined based on automatically determined head height – H_G. Numerous tests have shown that even despite making pictures from the same distance to the face no constant value of the magnitude may be assumed for the detector. The head size changed depending on the person examined. Therefore an attempt was made to select automatically the TSzablon magnitude (I_{SK}) based on the head size and shape. The best efficiency was achieved at the set value of:

$$I_{SK} = 0.3 \cdot H_G \tag{3}$$

where:

I_{SK} – basic magnitude of the Template;
H_G – approximate head size (height).

The determination of orientation and eyebrows line substantially simplifies further analysis of the image, allowing extracting the head area from the image and determining the vertical position of the face.



a) b) c)

Fig. 3. Schematic presentation of the detector – TSzablon.

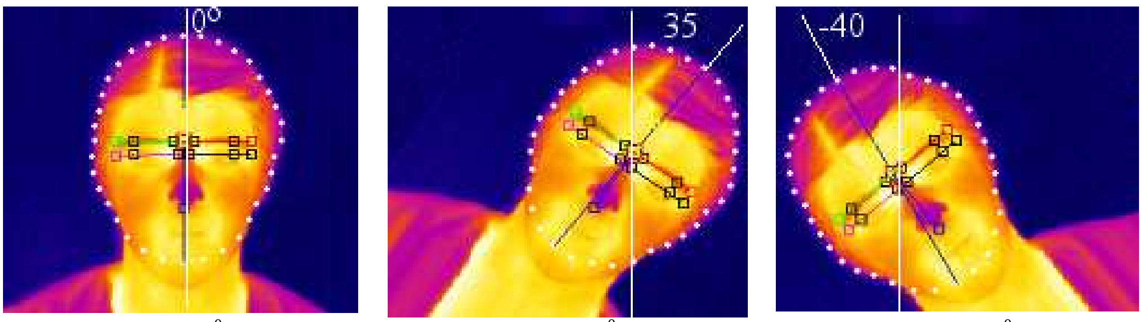
Fig. 3 c) presents a visual model of the TSzablon. When designing the detector it was assumed that the characteristic areas fulfil certain defined relationships:

- the brightness of the eyebrows area is lower than of the upper part of orbits area;
- there is a symmetry in the distribution of brightness of the eyebrows line area and of orbits;
- the brightness of the nose area is lower than the temperature in the orbits area.

Precisely determined eyebrows line and the nose symmetry axis allows then narrowing the area of searching in the process of orbits and nose detection.

During numerous tests the optimal values and relationships between significant characteristic areas of the face have been determined, marked in Fig. 3 c).

Fig. 4 a, b and c present proper detections, at a varying head orientation, and axis 0Y in relation to which the orientation is determined. A proper detection of the head outline using the active contour allows determining automatically height H_G. Based on the orientation of section H_G and its length the TSzablon takes preliminary values for further analysis – I_{SK} and angle α_G.



a) $\alpha = 0^0$ b) $\alpha = 35^0$ c) $\alpha = -40^0$

Fig. 4. Examples of detection by means of TSzablon for a varying orientation of the head.

The analysis with the use of the TSzablon is carried out in two ranges:

- in scale 1:2 - preliminary $\alpha G\text{-}10 \leq \alpha Tsz_{1:2} \leq \alpha G+10$ with a step $\Delta\ \alpha tsz_{1:2} = 2°$.
- in scale 1:1 - verification step - $\alpha Tsz_{1:2}\text{-}5 \leq \alpha Tsz_{1:1} \leq \alpha Tsz_{1:2}+5$ with a step $\Delta\ \alpha tsz_{1:1} = 1°$

where:

αG –the orientation of head determined based on the section being the head height;
$\alpha Tsz_{1:2}$ –the orientation angle of the TSzablon in 1:2 scale – preliminary stage;
$\alpha Tsz_{1:1}$ –the orientation angle of the TSzablon in 1:1 scale – verification stage;

In certain cases in the case of selecting smaller ranges the TSzablon could not determine correctly the proper orientation. The division of process into two stages substantially increased the speed of this algorithm's block operations. Fig. 4 b, Fig. 4 c it is also possible to observe that the preliminary determined head height is not always consistent with its actual symmetry axis. Therefore a precise verification using the TSzablon allows accurate determination of the orientation.

4. DETECTION OF ORBITS AREA

After a proper detection of the eyebrows line, nose and head orientation, the next step consists of the orbits area and their centres detection. Because of a warmer interior of orbits as compared with their vicinity, the edge detection method may be used to determine their outline. The best results were achieved using the Canny method. The information obtained earlier on the head size and on the position of the eyebrows line allowed defining a potential area for orbits searching. The Hough transform has been applied to their detection, which is used in such tasks, most often for the light [17, 18, 19, 20].

However, in the solution proposed the greatest drawbacks of this method have been eliminated, i.e. problems with the selection of the ellipses size and with the ellipses analysis in the case of rotation. This was possible due to the automatic detection of the head size, using the active contour, and to the head orientation determination by means of the TSzablon. In the calculations the following ranges of orbits ellipses sizes have been assumed:

Longer semi-axis in the *RXOka* range:

$$0.2 \cdot Isk \leq RXOka \leq 0.4 \cdot Isk \tag{4}$$

Shorter semi-axis in the *RYOka* range:

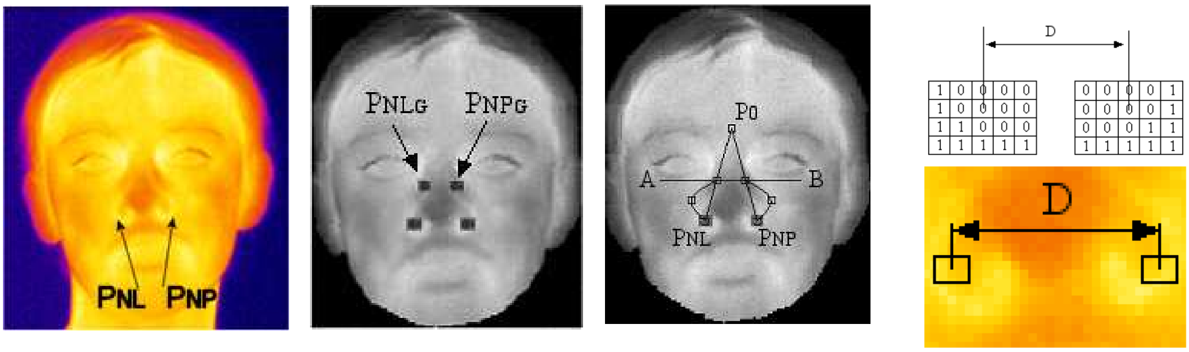
$$0.1 \cdot Isk \leq RYOka \leq 0.2 \cdot Isk \tag{5}$$

As a result of segmentation of a potential area the algorithm determines the orbits centres and the maximum size of ellipses. Based on this the outline and position of areas (O_L, O_P) – presented in Fig. 2 c are then marked

5. DETECTION OF NOSE

In the case of thermograms the detection of characteristic points of the nose turned out to be a bit more complex. The methods proposed for the light such as detection methods for the nostrils centre [21] or the symmetry axis could not be used [22]. The examples of detection used in the thermovision based on the brightness (temperature) in the nose surroundings also were not an ideal solution [23]. Characteristic points of the nose are not always well visible and easy to detect. Therefore it was necessary to determine other invariants on the image, which localisation will be possible for each of the images examined. Because of the TSzablon application, the preliminary determined position of the nose is precise. Therefore the nose height and symmetry axis (Fig. 4 a, b, c) and hence the searching area may be determined relatively easily. The extreme left and right points of the nose were taken as the characteristic ones – Fig. 5 a. Fig. 5 b shows these points (determined by the algorithm) and another two allowing marking the upper scope of nasal sinuses (P_{NLG}, P_{NPG}). The next image Fig. 5 c presents the detection of characteristic points including the marking of sinuses area.

Especially prepared structural element SE_N (Fig. 5 d), is used for the detection of point pairs (P_{NL}, P_{NP}). The standard of brightness (temperature) distribution is considered as well as the mutual position of the left and right element – distance D. The analysed ranges are determined based on the position and distance of orbits centres.



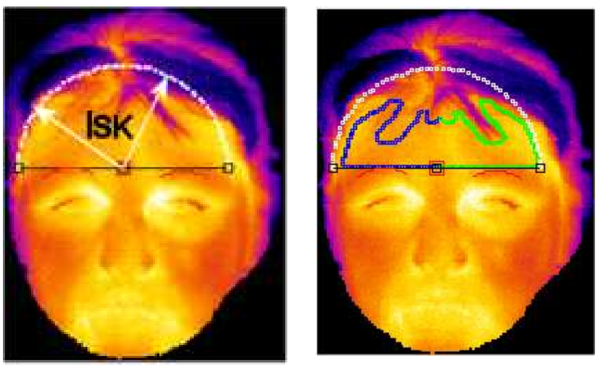
a) b) c) d)

Fig. 5. Assumptions and an example of detection of the nose points including the SE_N element.

To detect the other points necessary to mark the sinuses the algorithm also determines points (P_{NLG}, P_{NPG}), which are the intersections of section AB (coinciding with the lowest situated point of orbits) with side axes of the nose – connecting points P_0 with P_{NL} and P_0 with P_{NP} (Fig. 5 c). The outline of sinuses is determined by a spline. A proper detection of nose points (P_{NL}, P_{NP}) position enables determination of the nasal sinuses area. In addition, it allows verifying the symmetry axis of the face, preliminary determined by means of the TSzablon.

6. DETECTION OF FOREHEAD

The detection of forehead is based on the information obtained in previous steps of the algorithm. The input parameters received by the forehead detection block comprise the determined eyebrows line and the preliminary determined upper outline of the forehead area defined acc. to the TSzablon magnitude data I_{SK}. Fig. 6 a presents a potential area of the forehead, which is then analysed from the haircut disturbances elimination point of view. Examples of the forehead area detection and analysis in the light and in the infrared radiation are presented in papers [6, 24, 25, 26]. In the method proposed, to detect the forehead area and the hairline, a preliminary verification of the area was applied on the basis of [5 x 5] sample standard deviation for each pixel of the potential forehead area. Because of a high diversity in the set of thermograms studied this solution was not universal. Therefore attempts were made to analyse the histogram, the preliminary determined forehead area (Fig. 6 a) and to determine the condition of pixels selection based on the results obtained in this way.



a) b)

Fig. 6. Assumptions and an example of detection of the forehead area.

After correctly detection of hairline, very important is also definition of symmetrical areas of forehead, to compare each other. Symmetry axis of forehead is computed precisely, based on coordinates of points P_{NL}, P_{NP} – Fig. 5 a. Next, in result of AND operation between images right and left part of forehead, properly shape of forehead is detected Fig. 6 a).

7. QUANTITATIVE ANALYSIS OF THERMOGRAMS

The properly determined points and areas provide a possibility to use a computer in the process of thermograms analysis. Because of that it is possible to carry out faster the entire process of measurements and to obtain finished measurement results of temperature and of required areas surface without the need for user's intervention. The results repeatability is also important, which is simply unachievable by the manual marking of required areas. Thanks to the prepared user interface it selects only the image and starts the function of analysis. The finished results are presented in a graphical form with a possibility of saving the data in a file.

Table 1 presents the results of average temperature measurements of the determined areas for the selected thermogram. A change of orientation was introduced so as to verify its influence on the results of measurements – values as in Fig. 7. The areas were marked as in Fig. 2 c). It has been observed that despite the introduction of rotation and position change the measured values are nearly identical, what confirms the detection efficiency of the proposed algorithm as well as its independence of the orientation and translation. This also shows a possibility of the presented method application to a computer analysis of the face temperature on thermograms.

Table 1. Results of temperature measurements from the thermogram in Fig. 7.

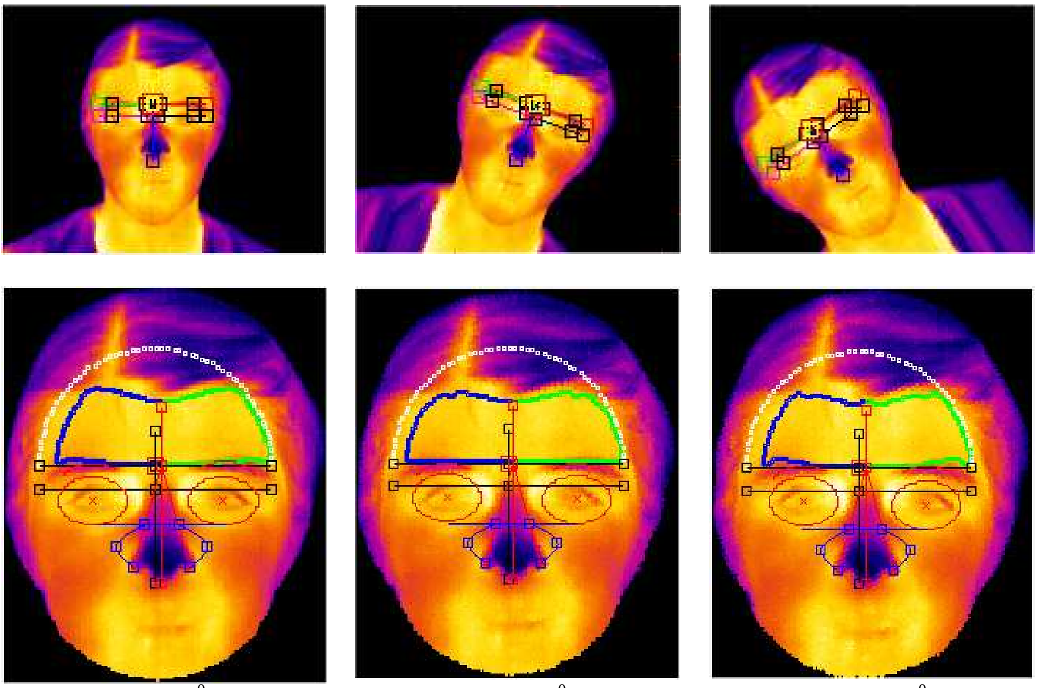
Area	Average temperature in areas for rotation [ºC]		
	-35º	0º	+20º
O_L	34.26	34.26	34.26
O_P	34.46	34.40	34.42
C_L	34.02	33.93	33.98
C_P	33.81	33.79	33.74
N_L	32.22	32.04	32.05
N_P	32.09	32.21	32.22

8. CONCLUSIONS

Fig. 7 presents the final results of thermograms segmentation. The method's efficiency may be observed at a change of the examined person silhouette position and orientation. The method for temperature threshold detection in this group of images described at the beginning allowed a proper selection of the threshold at the normalisation of examined images. The head and its outline detection was more precise than in the studies so far and allowed eliminating at this stage the problems with a thick hairline (of too low temperature). An automatic detection of the head size using an active contour enabled the normalisation of the head size, allowing additionally a preliminary determination of the angle of its symmetry axis orientation. The application of the TSzablon described as a precise detector for the orientation and eyebrows line enabled determining the position and angle of head orientation in relation to 0Y axis. Fig. 7 presents the results of segmentation of the required areas and face characteristic points with the normalisation of the position, scale and rotation for the thermogram in Fig. 1 b in 3 variants. When the head was in a position close to the vertical Fig. 7 a. At the rotation by $\alpha = 20^0$ –Fig. 7 b, and $\alpha = - 35^0$ Fig. 7 c. The presented mechanism for face elements detection and localisation may be used not only as a tool for temperature measurements on thermograms. Its application in related fields also seems possible, e.g.:

- as the first stage of the face recognition process in biometric systems,
- at the designing of man-machine interface,
- as a development of optical face analysis methods,
- 3D face modelling.

Based on the analysis of results obtained the next stage of work on the algorithm may comprise increasing its precision and optimisation.



a) $\alpha = 0^0$ b) $\alpha = 20^0$ c) $\alpha = -35^0$

Fig. 7. The source image and results of segmentation for selected cases.

BIBLIOGRAPHY

[1] STAM Z. Li., JAIN A. K., Handbook of Face Recognition, Springer Science+Business Media, 2005, pp. 13–61.

[2] YANG M., KRIEGMAN D J., AHUJA N., Detecting Faces In Images: A Survey, IEEE, Pattern Analysis and Machine Intelligence, 2002, pp. 34–58.

[3] HJELMAS E., Face detection: a survey, Computer Vision and Image Understanding 83, 2001, pp. 236–274.

[4] KONG S.G., HEO J., ABIDI B.R., PAIK J., ABIDI M.A., Recent Advances in Visual and Infrared Face Recognition A Review, The Journal of Computer Vision and Image Understanding, Vol. 97, 2005, pp. 103–135.

[5] KOPROWSKI R., WOJACZYŃSKA–STANEK K., WRÓBEL Z., Diagnostyka Bólów Głowy Na Podstawie Sekwencji Obrazów Termowizyjnych, XIV Konferencja pt. „Biocybernetyka i Inżynieria Biomedyczna”, Komitet Biocybernetyki i Inżynierii Biomedycznej PAN, KBIB–2005, Wyd. Pol. Częstochowskiej, 2005, pp. 279–284, (in Polish).

[6] KOPROWSKI R., WOJACZYŃSKA STANEK K., WRÓBEL. Z., Automatic Segmentation Of Characteristic Areas of the Human Head on Thermographic Images, Machine Graphics & Vision, Vol. 16, 2007, pp. 251–273.

[7] KOBEL J., SUCHWAŁKO A., PODBIELSKA H., Application of Thermal Imaging for Human Face Recognition, Opt. Appl., Vol. 32(4), 2002, pp. 653–664.

[8] BAUER J., MAZURKIEWICZ J., PODBIELSKA H., Thermovision in biometrics face recognition based on thermal imaging, Termowizja w biometrii rozpoznawanie twarzy na podstawie obrazu termicznego, Inżynieria Biomedyczna Acta Bio–Optica et Informatica Medica, Vol. 12(2), 2006, pp. 85–88. (in Polish)

[9] Praca zbiorowa pod. red. NAŁĘCZA Z., Biocybernetyka i Inżynieria Biomedyczna, Tom 8, Obrazowanie Biomedyczne, Exit, Warszawa 2000, pp. 475–508, (in Polish).

[10] NOWAKOWSKI A., Postępy Termografii – Aplikacje Medyczne, Wydawnictwo Gdańskie 2001, (in Polish).

[11] MARZEC M., KOPROWSKI R., WRÓBEL Z., Wyznaczanie charakterystycznych obszarów twarzy na zdjęciach termowizyjnych., Inżynieria Biomedyczna. Vol.15, 2/2009, pp. 149–152, (in Polish).

[12] MARZEC M., KOPROWSKI R., WRÓBEL Z., Automatyczny pomiar temperatury na termogramach w diagnostyce bólów głowy, Pomiary Automatyka Kontrola, nr 2009, Vol. 55, No 11, 2009, pp. 923–926, (in Polish).

[13] MARZEC M., KOPROWSKI R., WRÓBEL Z., Badanie właściwości algorytmu detekcji cech twarzy na obrazach termowizyjnych, Informatyzacja Ochrony Zdrowia. Wybrane zagadnienia Wyd. Polskie Tow. Informatyczne, 2008, pp.135–151, (in Polish).

[14] SOHAIL A.S., BHATTACHACHARYA P., Detection of facial feature point using anthropometric face model, SITIS, 2006, pp. 656–665.

[15] GUANGDA H., CHENG S. Du., Feature Points Extraction from Faces, Research Institute of Image and Graphics, Department of Electronic Engineering, Tsinghua University, Beijing, China, 2003, pp. 154–158.

[16] CHAN Y.H., ABU–BAKAR S.A.R., Face Detection System Based on Feature–Based Chrominance Color Information, Proceedings of the International Conference on Computer Graphics, Imaging and Visualization (CGIV'04), 2004, pp. 153–158.

[17] KAWAGUCHI T., RIZON, M., HIDAKA D., Detection of Eyes From Human Faces By Hough Transform And Separability Filter, Electronics and Communications in Japan (Part II Electronics) , Vol. 88, No. 5, 2005, pp. 29–39.

[18] RAJPATHAK T., KUMAR R., SCHWARTZ E., Eye Detection Using Morphological and Color Image Processing, 2009 Florida Conference on Recent Advances in Robotics, FCRAR 2009, pp. 1–6.

[19] TOENNIES K.D., BEHRENS F., AURNHAMMER M., Feasibility Of Hough–Transform–Based Iris Localisation For Real–Time–Application, Proceedings of International Conference on Pattern Recognition (ICPR'02), Vol. II, 2002, pp. 1053–1056.

[20] RIZON M., YAZID H., SAAD P., SHAKAFF Y. A., Object Detection Using Circular Hough Transform, American Journal Of Applied Sciences 2 (12), 2005, pp. 1606–1609.

[21] SOHAIL A.S.M. BHATTACHARYA P., Detection of Facial Feature Points Using Anthropometric Face Model, IEEE International Conference on Signal–Image Technology and Internet–Based Systems, Springer Lecture Note Series in Computer Science (LNCS), Tunisia, December, 2006, pp. 656–665.

[22] SZLAVIK Z., SZIRANYI T., Face Analysis Using CNN–UM, Proceedings IEEE International Workshop on Cellular Neural Networks and their Applications (CNNA 2004), pp. 190–195.

[23] TRUJILLO L., OLAGUE G., HAMMOUD R., HERNANDEZ B., Automatic Feature Localization In Thermal Images For Facial Expression Recognition, IEEE, Computer Vision and Pattern Recognition Workshops, 2005, pp. 14–21.

[24] ZHU Z., TSIAMYRTIS P., PAVLIDIS I., Forehead Thermal Signature Extraction In Lie Detection, Engineering In Medicine and Biology Society, 2007, EMBS 2007, 29th Annual International Conference of the IEEE , Lyon, pp. 243–246.

[25] YACOOB Y., DAVIS L., Detection, Analysis and Matching of Hair, Computer Vision, 2005, ICCV 2005. Tenth IEEE International Conference on, Vol .1, 2005, pp. 741 – 748.

[26] JI Z., LIAN X.C., LU B.L., Gender Classification by Information Fusion of Hair and Face, State of the Art in Face Recognition, INTEH 2009, pp. 215–230.