face recognition, face's geometrical measures,
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AUTOMATIC HUMAN FACE RECOGNITION METHOD BASED ON GEOMETRICAL FACE FEATURES

There are many ways to describe and recognize the human face. The paper shows one of them - the feature based method. It also considers usefulness of the face geometrical measurements in recognition and also the geometrical dependence on the features. The paper treats on the feature points detection and takes into consideration six of them, which are: two eyes, two eyebrows, nose and lips. It shows a detailed algorithm of the proposed method and describes its advantages and disadvantages. It also describes a filtering, feature points extraction and gives formulas for calculation of a face likeness coordinates. At the very end it concludes with experiments and examples of the proposed method.

1. INTRODUCTION

Recently there is often a common need to have automatic systems to face identification and recognition. They may be used successfully in many areas of our lives. It is well known fact, for example, that on the basis of skull, court medicine technician may fully reconstruct the face. Having such reconstruction one can compare the image of reconstructed face of the skull's owner with the ones gathered in a database to establish personal data of the owner (for example in police investigations). Moreover because each human race has its typical face geometry, also having such reconstruction, basing on the computed face geometry, one can establish the race and even origin of the skull's owner. As one can see such automatic or semi-automatic face identification and recognition systems may significantly aid investigators and anthropologists (as well as many other specialists) at their work.

There are many techniques of face recognition in wide use [3, 6, 7, 10, 15, 16]. They represent many different approaches to the face recognition problem. And in this connection some of them are better in some applications, while the other ones are better in others. The method presented in this paper is quite useful, for example, in finding the face in a database. It also may be successfully used in establishing the race (although these applications are not reported in the paper) due to computing the main geometrical parameters of the face. Moreover let us note, that in this method, what follows immediately from our experiments, the emotional state of the face has no effect on the obtained results.

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The presented method is based on some well-defined face features: eyes, eyebrows, nose and lips. These features have one main advantage – they are present on all human faces, in opposite to, for example, hair line above forehead (note, that not everybody has hair). Moreover in the presented method it is meaningless whether a face wears glasses or has a beard.

2. FEATURE POINTS DETECTION

Consideration of symmetry among face features is a very natural step in feature face detection. It takes pressure on geometric measures in the face. Very helpful in this approach is also consideration of pixels grey value distribution – places like eyes, lips, eyebrows and nose are always darker, even the darkest in their location region, which can be defined from geometric measures in the face. Geometric measures of the face are shown in Fig. 1. Reisfeld in [9, 10] presents one of such geometrical methods according to fact, that its every pixel is determined by an adequate value and is symmetrical to some based geometrical relations (such as location of eyes above lips). This relation allows us to detect interesting points, which represent feature points candidates. This method has also its disadvantages – it can be applied only to the frontal face views.

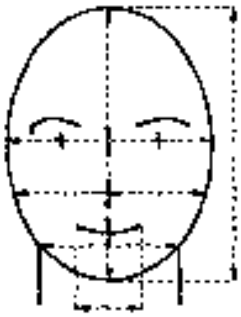


Fig.1. Geometrical measures across the human face.

As it has been said above, all six types of feature points (that is eyes, eyebrows, nose and lips), especially in low resolutions, appear as darker places in contradiction to lighter background of the face. Some examples of feature points are shown in Fig. 2. Resolution of cut fragments has been decreased to 10 dpi.

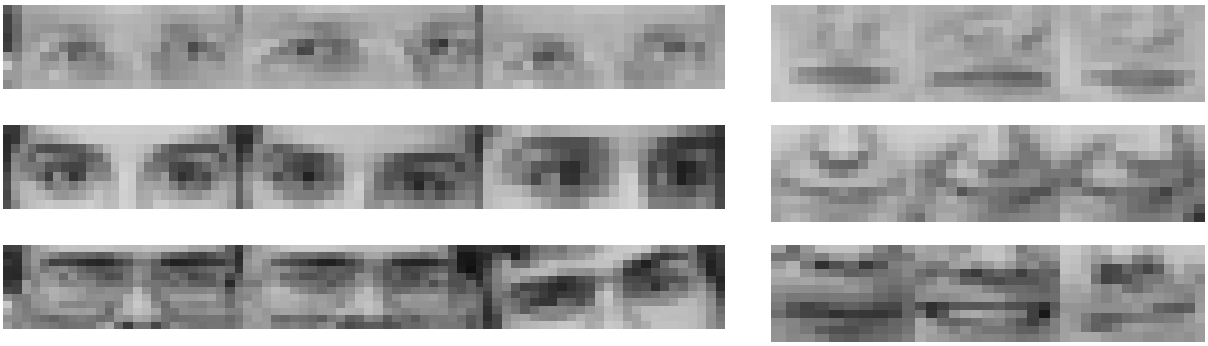


Figure 2. Feature points cut from faces at decreased resolution.

Feature points, which one can see everyday in human faces, are defined as high level objects, which are presented in our faces according to intuitive idea of human face composition. Eyes, lips, nose and ears are such points. However, feature points of the image are defined as low level objects which one can localize in digital image by finding edges, corners, gray levels of the pixels and geometric regions of the face. To easily detect feature points, the image has to be smoothed. After that operation the feature points in high resolution become the ones in the low resolution. In the method shown in this paper all the images have been smoothed with the Spacek filter [11]. To find feature points, this method also uses thresholding. To divide the feature points into groups in which they will be recognized, the authors apply the Triesman method [14]. This method consists of two stages (phases). The first one, called pre-attending perception, collects image information, that is marks interesting points and regions. The second one, the attentive stage, groups, compares, estimates and concludes major groups of objects (features) in the image. The method applied in this paper operates in the first stage on the rows of image and finds a list of interesting features in associated region. In this stage occurs likely appearance of the features and the geometry of the face is taken into consideration. The second stage classifies the features or not to the interesting group, by applying Gestalt organization rules [4, 5]. Gestalt organization rules, taken from psychology, formulate basic principles, according to which the Human Visual System groups information. They consider such qualities as neighborhood, resemblance, continuity and closeness.

3. IMPLEMENTATION OF THE METHOD

The proposed method finds six feature points, that is eyes, eyebrows, nose and lips. It marks them with black dots. These features are chosen because of its evident advantages: the features are “interior” points of the face (opposite to “exterior” points, that are laying on the edge of the face and are the most dependent on the background, the same causing disturbances). Chosen features are, above all, also the most “absolute”, so their geometry cannot be easily changed (this mean their relations, e.g. distance) by personal human face expressions like sadness, confusion, etc. There are also some disadvantages of choosing these features. The feature points cover only small region of the face, so it could provide a large error during recognizing.

General algorithm of the described method is made up of three stages. Firstly, we have to filter image using different filters to pre-process it to better finding searched features. Secondly, the main feature points of the face must be found and verified in the image (that is all six ones mentioned earlier). And finally, we compute some geometrical coefficients, which allow us to identify the face. Detailed scheme of the method is shown in Fig. 3. In the upper left there is the scheme of filtering (the first stage), in the upper right there is the scheme of feature points acquisition algorithm (the second stage) and in the bottom there is the scheme of the final stage – face likeness determination algorithm. Also more detailed description of this method is presented in the following subsections.

3.1. FILTERING

In the first stage of the described method two filters were applied: the Sobel [7, 12] filter and the Spacek [11] one. The Sobel filtering consists of two directional Sobel gradients put one to

another and is used to edge finding. The Spacek filter is more complicated. It is called a SPN – Spacek Noise Suppression filter and it has been chosen as a smoothing filter before finding edges process (the Sobel filter). The mask of SPN filter is 5x5 pixels and is formed according to

$$SPN(r(i,j)) = \frac{1}{2} + \frac{1}{2}\cos(\pi r(i,j)) - \frac{\pi}{4}\sin(\pi r(i,j)) - \frac{\pi^2}{4}(r(i,j))^2 + \frac{\pi^2}{4}r(i,j), \qquad (1)$$

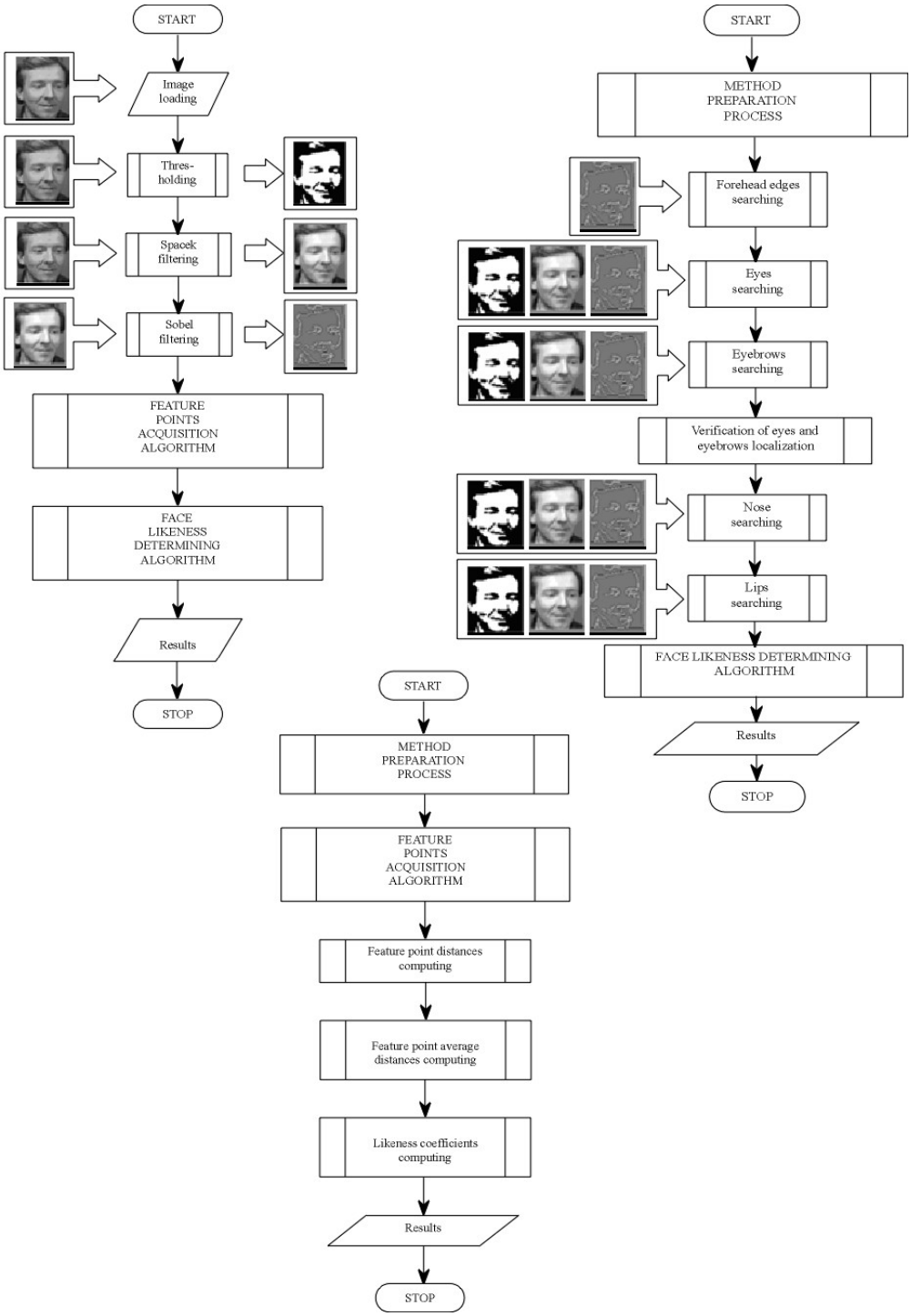


Fig.3. The schemes of three successive stages of the algorithm.

where

$$r(i,j)=\frac{\sqrt{(i-i_0)^2+(j-j_0)^2}}{2\sqrt{2}},\qquad \mathrm{i,j}=1,2,\ldots,5,\quad \mathrm{i_0,\ j_0}=3. \tag{2}$$

Note that r(i,j) has been normalized. After Spacek filtering, two Sobel gradients of various angles are put on the image. They are linked with the formula

$$I=\sqrt{I_1^2+I_2^2}, \tag{3}$$

where I denotes the number expressing brightness of the pixel in adequate Sobel mask.

3.2. FEATURE POINTS EXTRACTION

After appropriate filtering in the first stage of the method, feature points acquisition is performed according to Reisfeld method [9, 10]. It is based on the face geometry and, like in Triesman method [14], has two stages. The first one determines regions and feature points candidates, the second one approximates clear location of the features. The first stage is applied on the filtered image. Regions, which are located, are determined to eyes and eyebrows by vertical lines lying on the forehead's edges (it is a width between left and right temple). According to the algorithm requirements it is also taken into account that eyes should be found in the upper half of the transformed image. The second region, that is the one with nose and lips, is determined by vertical and parallel lines passing by eyes, and the region is the place between these two lines and above the eyes. The second stage, exactly approximating the features location, considers pixels brightness and the edges of the face. The darkest pixels are found in every region (from Spacek filtered image). These points are eyes, eyebrows, lips and nose. Then, the cuttings with features (from the Sobel filtered image) are considered for verification.

3.3. FACE LIKENESS COORDINATES

In the final stage of our algorithm we compute the face likeness coordinates. Let us denote the values d_1 and d_2 as the face likeness coordinates. They are counted from the formulas

$$d_1=\frac{1}{6}\sum_{i=1}^{6}d_{1i}\ ,\quad d_2=\frac{1}{6}\sum_{i=1}^{6}d_{2i} \tag{4}$$

where

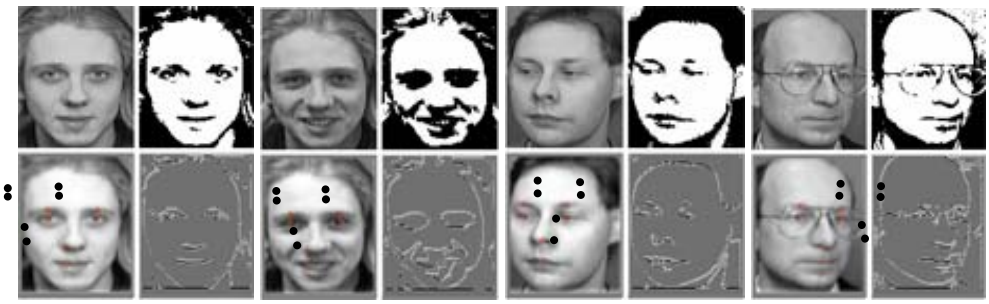
$$d_{1i}=\begin{cases}1 & ,\ x_i=0,\ y_i\neq 0\ \text{ or }\ x_i\neq 0,\ y_i=0\\ \dfrac{|x_i-y_i|}{\sqrt{|x_iy_i|}} & ,\ x_i\neq 0,\ y_i\neq 0\\ 0 & ,\ x_i=y_i=0\end{cases} \tag{5}$$

$$d_{2i} = \begin{cases} 0 & , \ x_i = y_i = 0 \\ 1 & , \ x_i = 0, \ y_i \neq 0 \ \text{ or } \ x_i \neq 0, \ y_i = 0 \\ \left| \dfrac{x_i - y_i}{x_i + y_i} \right| & , \ x_i y_i > 0 \\ 1 + \left| \dfrac{x_i + y_i}{x_i - y_i} \right| & , \ x_i y_i < 0 \end{cases} \qquad (6)$$

for $i = 1,...,6$. In formulas (5), (6) x_i and y_i, $i = 1,...,6$ denote numbers representing one of six feature points of faces from X and Y images, respectively. The d_1 coordinate prominences large differences in face, and d_2 omits it, giving them weights similar to these, given to small differences. Also d_2 gives greater difference between x_i and y_i, $i = 1,...,6$, when they have opposite signs. The d_1 and d_2 coordinates are normalized and take values in [0, 1] interval. The less coordinate means the larger likeness, but in the method a completion of coordinates is computed just to represent these values in more natural way. From these coordinates there is computed the one more value – that is a percentage value of likeness.

4. EXPERIMENTAL RESULTS

In our experiments, based on the described method, we have investigated many images of faces. Some sample ones are presented in Fig. 4. In the top left of each group of images there is the original image, in the top right there is the thresholded copy, in the bottom left there is the Spacek filtered one (in it also the found six features has been marked in black dots) and in the bottom right there is the Sobel filtered one.



IMG1 IMG2 IMG3 IMG4

IMG5 IMG6 IMG7 IMG8

Figure 4. Some samples of faces.

In Tab. 1 there are presented appropriate geometrical measures concerning the faces from Fig. 4. In Tab. 2 there are depicted results of comparing of the arbitrary chosen images of faces. From Tab. 2 follows immediately that the emotional states (images IMG1 and IMG7 versus IMG2 and IMG8, respectively) do not affect the results of comparing – the likeness is nearly 100%. Between the other images of faces there are some differences, so their numerical likeness is also slightly less, as one can expect. However note that wearing glasses has not disturbed proper feature extraction in the image IMG4, though in the IMG6 the points were not detected properly.

Tab.1. Geometrical characteristics of faces.

Images / Features	IMG1	IMG2	IMG3	IMG4	IMG5	IMG6	IMG7	IMG8
Eyes:	**40,05**	**39,05**	**34,02**	**33,02**	**28,16**	**18,18**	**32,00**	**32,02**
Eyebrows:	**40,00**	**39,01**	**34,02**	**33,14**	**28,16**	**10,70**	**32,02**	**32,00**
Right eye – eyebrow:	5,00	6,00	10,00	7,00	5,00	5,00	10,00	11,00
Left eye – eyebrow:	7,00	7,00	10,00	9,00	5,00	10,70	11,00	10,00
Eyes – eyebrows (average):	**6,00**	**6,50**	**10,00**	**8,00**	**5,00**	**5,36**	**10,50**	**10,50**
Right eye – lips:	44,65	44,10	27,59	36,40	43,97	354,02	165,31	164,00
Left eye – lips:	38,08	38,08	24,01	40,31	41,79	359,27	155,34	153,38
Eyes – lips (average):	**41,37**	**41,09**	**26,00**	**38,36**	**42,88**	**356,65**	**160,43**	**158,69**
Nose – lips:	**11,18**	**11,18**	**17,09**	**11,18**	**14,14**	**10,70**	**14,14**	**14,14**

Tab.2. Likeness between faces of compared images.

Compared images	$\mathbf{d_1}$	$\mathbf{d_2}$	%
IMG1 – IMG1	1,000	1,000	100,000
IMG 1 – IMG 2	0,973	0,986	97,945
IMG 3 – IMG 1	0,681	0,844	76,231
IMG 4 – IMG 5	0,771	0,887	82,926
IMG 7 – IMG 8	0,998	0,999	99,822

5. CONCLUSIONS

From the performed experiments follows that the method proposed by the authors gives quite good efficiency in feature points extraction as well as in effectiveness of comparing of the images of different faces. The examined method is efficient in reference to various groups of exactly defined images. The results of experiments allow us to formulate some remarks concerning effectiveness of our method:

- In case of examining of the same image, the face likeness coordinate is equal to 100%, which proofs correct working of the method.
- In case of examining of different images of the same person, the face likeness coordinate is almost equal to 100%.
- In case of examining of images of the same person, but expressing different emotions, the face likeness coordinate is almost equal to 100%. This proofs correct working of the method and its usefulness in experiments of this type. Moreover, experiments confirm correct selection of the feature points to the face recognizing problem and large method's dependence on face position in the image.
- In case of examining of images of different persons, the face likeness coordinate is mostly higher than 50%, but lower than 90%.
- In case of examining of images in which the features have been incorrectly extracted, the values of computed distances are incorrect and the face likeness coordinate is very low, even lower than 10%.
- Generally high values of the face likeness coordinates are caused by very little differences among computed distances of the features. This little difference arises from geometrical dependences among elements of human faces. In general it could be concluded that every human face is to some extent similar one to another.
- The method is very sensitive to noise in the image.

From these remarks (as well as from performed experiments) follows that the method presented in this paper may be successfully used in wide range of different applications. It may aid some specialists in their work, that is investigators or anthropologists, as we mentioned earlier. After some enhancements it even may be used to automatic recognition of the faces from crowd.

BIBLIOGRAPHY

[1] BARAN R., MAZUREK M., Opracowanie w języku wysokiego poziomu programu konturowania obrazu czarno-białego dla wybranych fragmentów analizowanej sceny, Praca Dyplomowa, Instytut Informatyki, Uniwersytet Śląski, Sosnowiec, 1999.
[2] COMPUTER VISION HOMEPAGE http://www2.cs.cmu.edu/afs/cs/project/cil/ftp/html/v-demos.html .
[3] JIA X., NIXON M., S., Extending the Feature Vector for Automatic Face Recognition, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 17, No. 12, December 1995.
[4] KOFKA K., Principles of Gestalt Psychology, Brace and World, Harcourt, 1935.
[5] KOHLER W., Gestalt Psychology, Liveright, New York, 1947.
[6] LEUNG T., BURL M., PERONA P., Finding faces in cluttered scenes using labelled random graph matching, Proc. 5th Int. Conf. on Comp. Vision, pp. 637–644, MIT, Cambridge, 1995.
[7] MAKIEŁA M., Metody identyfikacji obrazów twarzy na podstawie punktów charakterystycznych, Praca Magisterska, Instytut Informatyki, Uniwersytet Śląski, Sosnowiec 2002.

[8] PIGHIN F., HECKER J., LISCHINSKI D., SZELISKI R., SALESIN D. H., Synthesizing Realistic Facial Expressions from Photographs, pp. 75-84, SIGGRAPH Proceedings, 1998.
[9] REISFELD D., WOLFSON H., YESHURUN Y., Context Free Attentional Operators: the Generalized Symmetry Transform, Int. Journal of Computer Vision: Special Issue on Qualitative Vision, No. 14(2), pp. 119-130, 1995.
[10] REISFELD D., YESHURUN Y., Robust Detection of Facial Features by Generalized Symmetry, Proc. Int. Conf. On Pattern Recognition, Vol. A, pp. 117-120, IEEE Comp. Soc. Press, Denmark, 1992.
[11] SPACEK L., Edge Detection and Motion Detection, Image and Vision Computing, Vol. 4, No. 1, pp. 43-56, 1986.
[12] TADEUSIEWICZ R., KOROHODA P., Komputerowa analiza i przetwarzanie obrazów, Wydawnictwo Fundacji Postępu Telekomunikacji, Kraków, 1997.
[13] TECHNOLOGIES OF FACE RECOGNITION SYSTEMS http://www.technologie.pl .
[14] TRIESMAN A., Perceptual Grouping and Attention in Visual Search for Features and Objects, Journal of Experimental Psychology; Human Perception and Performance, No. 8(2), pp. 194-214, 1982.
[15] YOW K. CH., Automatic Human Face Detection and Localization, Downing College, Ph.D. Thesis, University of Cambridge, Department of Engineering, 1998.
[16] YOW K. CH., CIPOLLA R., Towards an Automatic Human Face Localization System, Proc. British Machine Vision Conference, Vol. 2, pp. 701-710, Springer-Verlag, Birmingham, 1995.