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Sketch generation from photo to create test databases

Streszczenie. *Artykuł przedstawia stan wiedzy z zadań porównania portretów pamięciowych (szkic) i odpowiednich im portretów fotograficznych. Zaproponowano nowatorskie metody automatycznego generowania szkicu z portretów fotograficznych popularnych baz obrazów twarzy. Przedstawiono, że wysoką jakość rozpoznawania szkiców można osiągnąc w ramach prostych systemów rozpoznawania. (**Porównanie portretów pamięciowych (szkic) i odpowiadających im fotograficznych**)*

***Abstract**. Article proposed novel method of automatic sketch synthesis, that can be used for creating test databases and sketch recognition tasks research and retrieval of corresponding photo. These methods were applied to two popular benchmark face databases. It was shown that for recognition of sketches very simple systems can be used.*

Słowa kluczowe: portrety pamięciowe (szkic), generowanie szkiców, porównanie szkiców z portretami fotograficznymi.
Keywords:sketch synthesis, face photo-sketch comparison, sketch recognition system, two-dimensional principal component analysis.

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Introduction

In recent years are observed increased interest to problem of matching original photo-image with its forensic sketch. We are presenting the scope of related problems and the state of the art of proposed approaches and solutions. Discussed are proposed solutions of relevant problems, such as retrieval the original face image in big database based on given sketch, prepared according to oral descriptions of witnesses or participants of some events (including the criminal ones); relations between sketches and corresponding images of faces, solution to the problem of mutual recognition: face image ↔ sketch.

Problems of face image – sketch matching

Five variants of sketches were used, as presented in Fig. 1, taken from different papers about sketch synthesis and recognition [1 – 7].

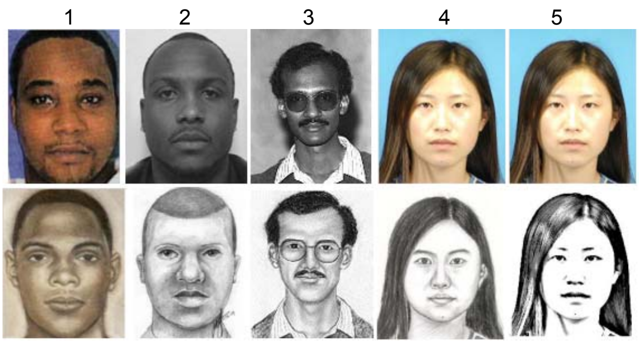


Fig.1. Examples of face images and corresponding sketches

Here in first row are represented five original photo and in second row – accordantly sketches: 1 – forensic sketch; 2 – composite sketch; 3 – art sketch, 4 – result of automatic generation from data base (viewed sketch) and manually preprocessing by artist; sketch, 5 - viewed sketch.

Analysis presented in papers [6, 7] shown that stable recognition results using two first variants (forensic face sketches and composite face sketches) and steady retrieval of corresponding photo in databases is unattainable.

This bad result is a consequence of three basic reasons:

1) bad quality of used sketches;

2) lack of image databases adequate for such applications;

3) imperfect methods of photo-sketch recognition

First and second reasons are presented and partially investigated in [5, 6].

Sketch quality depends on technique of oral portrait descriptions transformation into corresponding image. Here we have to do with witness subjectivity, usually the ordinary people, having no crime detection knowledge, their specific observation and description ability, influencing the translation of their perpetrator description into corresponding sketch.

Second reason is connected with inadequacy of „old face databases" (mug shot images gallery) to modern computer technology of image processing as used in face biometric applications.

Third reason is connected with underdeveloped technology of comparing photo – sketch, causing with lack of simple and effective method of matching, lack of appropriate benchmark bases of the pairs photo – sketch, and consequently lack of experience in such comparison.

Approaches and solutions analysis

Above was the reason of attempts to create bases of sketches and extensions of existing benchmark face databases [1, 2], development of comparison methods photos – sketches, and modeling the task of retrieving the photos based on given sketches [3-10].

In results bases of sketches has been created – CUHK Face Sketch database (CUFS) and the base CUHK Face Sketch FERET Database (CUFSF), containing 606 and 1194 pairs of photo – sketches [1, 2], respectively. Some instances of such pairs presented in Fig. 1 in column 3 (base CUFSF) and 4 (base CUHK).

Besides, new ideas concerning automatic sketch synthesis from face photo, were developed. In majority of cases these development were made using the base CUHK.

CUHK base contains sketches generated automatically from original images and corrected by artists, having 188 pairs photo-sketch. CUFSF base contains sketches, that are drawn while viewing an original photos from the base FERET, retaining basic face features of imaged people, but having some artefacts (elements of caricature or exaggeration) that are made by artist.

In summary of performed analysis we can note as follows: application of various rather complicated processing methods to the bases CUHK and CUFSF is not justified. It is possible that important role played "fashion" on the methods CMM, CITE, CITP, LBP, rather than strong arguments for their selection; result for base CUFSF was not fully correct presented, and were repeated many times in the papers of different authors.

We can also mention that in applications involving processing of the pairs of images (photo and sketch), implementation of projections onto subspaces should be made using 2D methods, presented detail in, e.g. [8]. These give substantial reduction of computation costs for all transformations mentioned above, improve stability of solutions of eigen-problems, additionally solved the small sample problem accompanying image processing problems.

Express - method of photo-sketch generation

We are given the input color image in color space RGB. Viewed sketch generation process has two stages: first stage involve preparation operations, and operation of global sketch structure formation; second stage – local sketch structure formation using simple geometrical transformations of face area (it is particularly important when modeling sketches, in case of not full or inexact parameters of «input photo»).

Fig. 2 illustrated all operations of first stage. Here: 1 - blurring of the input image; 2 – difference between blured image 1 and input image; 3 - negative of result 2; 4 - is result 2×input image (regions are selected containing hair); 5 – sum images 3 and 4; 6 - is result of transform image 5 to GRAY scale.

As we can see express-method are very simple, easy implementable, allowing to synthesis sketches for any benchmark face databases.

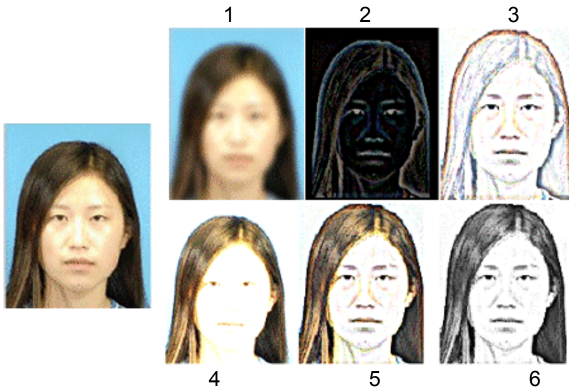


Fig. 2. First stage of sketch generation

In Fig. 3 illustrated two set of images each containing: input image, corresponding sketch from the base CUHK and sketch obtained by proposed express–method. Please note that sketch obtained with express-method is exact anthropometric copy of input image, and includes all necessary shadows in the hair area and face area (nose, chin, area around lips, neck…), but not contains original texture. Here «viewed sketch» can be treated as first approximation to drafted face images.

Fig. 3. Input image, corresponding sketch from [1] and sketch obtained by proposed express–method

Before we go to the second step of sketch synthesis, we consider Fig. 4 for answering the following questions: how we can evaluate the similarity measure of input image and corresponding sketch? And how the visible similarity (visible to human) should correspond to some formal index? And what is more important to evaluate: similarity visible by human observer of input image and its sketch, or some formal index of similarity? This question is particularly important is situation «witness → verbal face description → artists → sketch» and «sketch → photo retrieved based on this sketch».

Fig. 4. Photo and sketches based on verbal description by the witnesses

In our opinion pairs photo-sketch have a visible similarity, but there is a problem how to measure it. We start with universal quality index [11] for evaluation of similarity between original photo and its corresponding sketch. Index Q measures the similarity of two images as combination of three factors - luminance distortion, contrast distortion and correlation lost:

$$Q = \frac{4\sigma_P \sigma_S \overline{P}\,\overline{S}}{(\sigma_P^2+\sigma_S^2)[(\overline{P})^2+(\overline{S})^2]} = \frac{2\sigma_P \sigma_S}{\sigma_P^2+\sigma_S^2} \times \frac{2\overline{P}\,\overline{S}}{(\overline{P})^2+(\overline{S})^2} \times \frac{\sigma_{PS}}{\sigma_P \sigma_S},$$

where: $\overline{P}, \overline{S}$ - luminance averages of input image and corresponding sketch; σ_P^2, σ_S^2 - luminance variance of input image and its sketch; $\sigma_{PS}/(\sigma_P \sigma_S)$ - amplitude correlation between input image and its sketch.

Additionally we use phase correlation, which unlike amplitude correlation responds sharply to local image changes.

Fig. 5 illustrate: 1 and 2 – original photo and its «Art Sketch» from the base CUHK; 3 – sketch obtained on first stage of express-method; 4 – sketch 3 modification by forming a new local structure of face in stage 2.

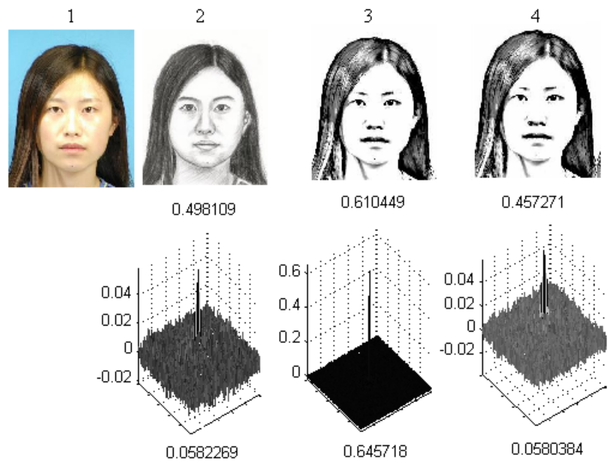


Fig. 5. Result of comparing photo with its sketches

Below images are shown: quality index Q, photo-sketch phase correlation function and its maximal values r_{max}. We can comment as follows: visual similarity means values of Q≈0.5, and r_{max}≈0.06. This means global (holistic) similarity of photo and «Art Sketch», but are not similar at local level.

For sketch obtained at first step of express-method we get $Q \approx 0.7$, and $r_{max}= 0.62$!

It means that photo and its sketch are similar on both level (it is the result of the way we form the sketch, what we comment earlier).

For third sketch (with parametric changes of geometry of local segments of face area), parameters Q=0,457 and r_{max} = 0,058 are like in the case of «Artist Sketch». Such changes are visible in all sketches generated for the base CUHK, leading to the conclusion: local changes in face geometry we obtain new sketches, with similar parameters as for «Artist Sketch».

In fig. 6 presented all second stage express–method operations.

Here is: 1 and 2 – input for initial sketch and input for parameter d – scale changes of face areas. Using a random number generator we can formed parameter p, which values are scaled in the range ± d such that:

$$p = sign(R_n)\, fix(dR_u),$$

where: d - maximum change the boundaries face area and $d \geq 2$; R_n - normally and R_u uniformly distributed random numbers, and *sign* – sign of parameter p.

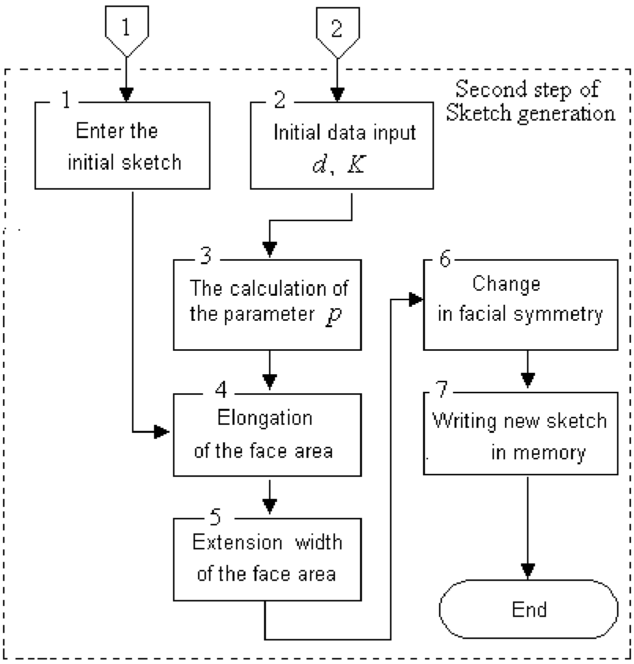


Fig. 6. Second stage of express–method

Fig. 7 illustrate nine «Art Sketches» and nine «Viewed sketch» with local changes of face area generated at second stage of express-method. Parameter Q changed in the range 0.41 – 0.5, and it is worth noted these sketches are closer to real life applications.

On fig. 8 in first row are represented art sketch for original foto base FERET (CUFSF) and below – sketches modify by proposed method.

Simple sketch recognition system

We can show that practically satisfying solution to the task of sketch recognition is achievable with simple FaReS (Face Recognition System [9]), not requiring any of the processing methods mentioned in [3-7]. For FaReS implementing we use the base CUFS, containing K=100 pairs of test images (pair photo – sketch). In the base of templates we place all 100 photos, and as test images using sketches «Artist Sketch» and sketches formed with proposed express-method.

Let the images-templates $I(k)$, $\forall$ k=1,2,..., K, be contained base FaReS. Besides each template is represented in FaReS as feature vector $V(k)$, $\forall$ k=1,2,..., K.

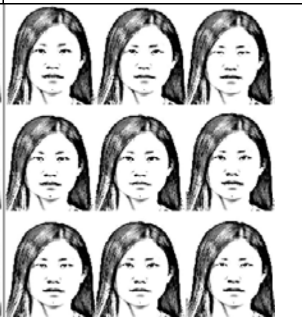
Sketches generated at second step	
«Art sketch»	«Viewed sketch»
	
Value of Q	Value of Q
0.4181 0.4433 0.4734	0.4157 0.4905 0.4721
0.4172 0.4689 0.4696	0.4795 0.4812 0.4792
0.4567 0.4689 0.4037	0.4396 0.4184 0.4456

Fig.7. Local changes of sketch face area

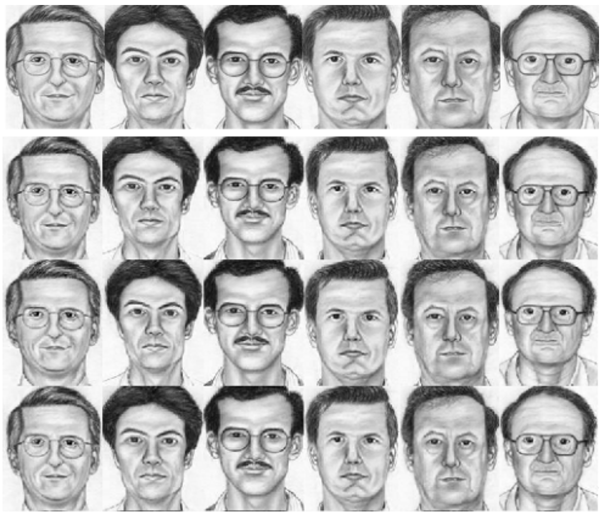


Fig.8. Input skeches and modify skeches

Every test-sketch S is also represented as feature vector Vs. Using this way of data representation in FaReS, classification problem (recognition) of all test images S could be treated as search of nearest image $I(k)$, $\forall$ k from the base FaReS, using certain similarity measure. Similarity measure of two images is taken as minimal distance between their feature vectors:

$$d(k) = \text{distance}(Vs, V(k)), \forall k.$$

In this case classification problem of test image S is reduced to calculation of distance $d(k)$, $\forall$ k=1,2,..., K. Index k coresponding to minimal distance will define nearness of test image S to image $I(k)$ from the base FaReS.

In the frame of supervised classification, when we have information about category (class) of image S, final result of recognition can be reported as the fraction of correctly classified test images from the set of all test images. This fraction will be given in percentage.

FaReS model

No special method of images or sketches preprocessing will be not performed. In original feature space the input image and corresponding sketch will be represented by their values of pixel in gray-level scale. For input images and sketches sizes of $M \times N$, dimension of feature space is

MN. Photo is transformed into spectrum through discrete 2D principiale component analysis (2D PCA) [8]. Size of spectrum matrix is also $M \times N$. Spectrum magnitude fall rapidly in the direction of main diagonal of spectral matrix. Therefore we build feature vector using only from the left upper corner of spectral matrix. Each feature vector contains only $d(d+1)/2$ spectral components laying symmetrically on both sides of main diagonal, selected so that it contains components with coordinates (1,1), (2,1), (1,2), (3,1), (2,2), (1,3), (4,1), (3,2), (2,3), (1,4), etc. Parameter d – is a length of square side located in left upper corner of spectral matrix.

We perform minimum distance classification using metrics L1 and result rank=1. Based on above procedure, the model [10] of computer experiment is:

(1) **CUFS(100/1/1){2DPCA:*M*×*N*→*d*}[KMP/L1/r=1]**,

where: M = 250; N = 200: d = 30 and parameter «d» is defined by solving the variational problem. Result obtained is 71% with rank=1. Including the preprocessing operation of selecting the central face area (**Cr**opping) from the whole image, result obtained was 97% with rank=1.

Model of computer experiment in this case is:

(2) **CUFS(100/1/1){Cr/2DPCA:*M*×*N*→*d*}[KMP/L1/r=1]**.

Performing the same experiments with the data set «training» from the base CUFS the amount of correctly classified sketches (rank = 1) was 85 out of 88, it is 96.9%.

For «Art Sketch», modified in second step of express-method, average outcome in the frame of model (2) was in the range 89% to 81% at rank=1, depending on selected modification parameters. Reduction in recognition rate can be justified by changes in local structure of these sketches. Two times of 5 groups of experiments with 9 changes of modification parameters in each experiment – total 90 of experiments was conducted. Analogous experiments were conducted with sketches synthetised with express-method. Some better results amounted on average 88.6667% for «Art Sketches» and nine «Viewed sketch» 98.689% respectively .

In Fig. 9 presented original data and recognition results concerning our base of sketches, obtained with above described express-method in stage 1. All experiments was conducted according to models (1) and (2). Results obtained in both cases amounted to 100% at rank=1.

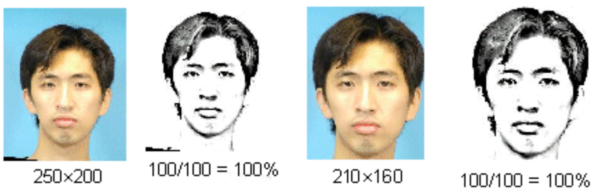


Fig. 9. Input data and results for own sketch base

For own sketch base, obtained in stage 2, average results for 90 experiments for models (1) and (2) amounted from 98.7% to 99.8% at rank=1.

Fig. 10 presents structure of modeled FaReS, used in all experiment. FaReS consists of: 1- block of selecting ROI; 2 and 3 – 2DPCA blocks; 4 – base of templates (original images and their vector representations); 5 – classifier.

Summary

Proposed novel method of automatic sketch synthesis, that can be used for creating test Databases and sketch recognition tasks research and retrieval of corresponding photo. These methods were applied to two popular benchmark face databases and obtained results were discussed. It was shown that for recognition of sketches very simple systems can be used. Presented application example is one of possible variant of such system. It has many clearly visible advantages compared to systems presented in [3 - 7], in particular simple implementation and accuracy of sketches recognition.

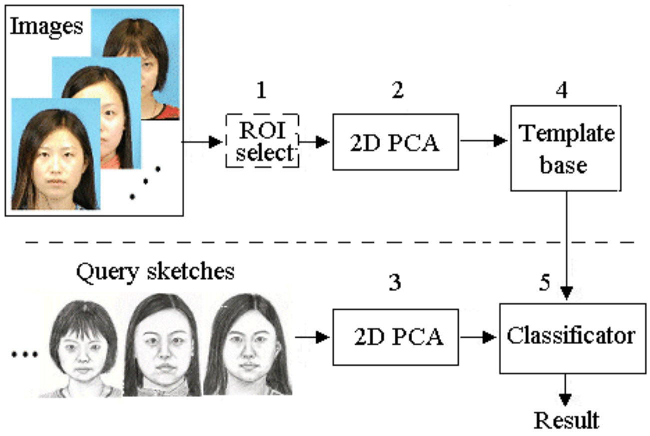


Fig. 10. FaReS structure

It seems that methods of matching sketch with corresponding photo should be directed by specific application scenario. Therefore future investigation shall be connected with analysis of different scenarios, taken from real situations. We are going to apply new variants of sketch synthesis and methods of recognition, including sketches for database FERET.

REFERENCES

[1]. Student Sketch Databse: http://mmlab.ie.cuhk.edu.hk/facesketch.html
[2]. Face Sketch FERET Database: http://mmlab.ie.cuhk.edu.hk/cufsf/
[3]. Tang X. and Wang X. “Face Photo-Sketch Synthesis and Recognition” – Ninth IEEE International Conference on Computer Vision, 2003, Proceedings, Vol. 1, pp. 687 - 694
[4]. X. Wang and X. Tang, “Face Photo-Sketch Synthesis and Recognition” - IEEE Transactions on PAMI, 2009, Vol. 31, no. 11, pp. 1955-1967.
[5]. W. Zhang, X. Wang and X. Tang. “Coupled Information-Theoretic Encoding for Face Photo-Sketch Recognition” - Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2011.
[6]. Brendan F. Klare, Zhifeng Li, Anil K. Jain. “Matching Forensic Sketches to Mug Shot Photos” - IEEE Transactions on PAMI, 2011, Vol. 33, no. 3, pp. 639-646.
[7]. Hu Han, Brendan Klare, Kathryn Bonnen, and Anil K. Jain. „Matching Composite Sketches to Face Photos: A Component-Based Approach” - IEEE Transactions on Information Forensics and Security, Vol. 8, no. 3, Jan. 2013, pp. 191 – 204.
[8]. Kukharev G., Forczmanski P. „Facial Images Dimensionality Reduction and Recognition by Means of 2DKLT”. Journal Machine GRAPHICS & VISION, Vol.16, No. 3/4, 2007, pp. 401-425.
[9]. Forczmanski P., Kukharev G.. “Comparative analysis of simple facial features extractors” - Journal REAL-TIME IMAGE PROCESSING, 2007, No.1, pp. 239–255.
[10]. Kukharev G., Shchegoleva N., People recognition based on face images (in Russian), 2006, Printed in Saint Petersburg Electrotechnical University "LETI", 176 p.
[11]. Wang Z., Bovik A. C „A Universal Image Quality Index” - EEE Signal Processing Letters, March 2002, vol. 9, no. 3, pp. 81-84.

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