Sketch generation from photo to create test databases

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.

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

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 (CUFFS) 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. CUF SF 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.

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.

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].
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 blurred 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](image)

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](image)

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](image)

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:

\[
Q = \frac{4\sigma P\sigma S}{(2\sigma_{P}^{2} + \sigma_{S}^{2})} = \frac{2\sigma P\sigma S}{(\sigma_{P}^{2} + \sigma_{S}^{2})} \times \frac{2\sigma P\sigma S}{(\sigma_{P}^{2} + \sigma_{S}^{2})} \times \frac{2\sigma P\sigma S}{(\sigma_{P}^{2} + \sigma_{S}^{2})}
\]

where: \(\bar{P}, \bar{S}\) - luminance averages of input image and corresponding sketch; \(\sigma_{P}^{2}, \sigma_{S}^{2}\) - 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](image)

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 
\[ f_{\text{max}} \approx 0.62! \]
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
\[ Q=0.457 \quad \text{and} \quad r_{\text{max}}=0.058 \]
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:
\[
p = \text{sign}(R_n) \cdot \text{fix}(dR_u),
\]
where: \( d \) - maximum change the boundaries face area and
\( d \geq 2 \); \( R_n \) - normally and \( R_u \) uniformly distributed random
numbers, and \( \text{sign} \) – sign of parameter \( p \).

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 \( V(k), \forall k=1,2,..., K \).

<table>
<thead>
<tr>
<th>Sketches generated at second step</th>
<th>Value of Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>«Art sketch»</td>
<td>0.4181 0.4433 0.4734</td>
</tr>
<tr>
<td>«Viewed sketch»</td>
<td>0.4172 0.4689 0.4696</td>
</tr>
<tr>
<td></td>
<td>0.4567 0.4689 0.4037</td>
</tr>
<tr>
<td></td>
<td>0.4157 0.4905 0.4721</td>
</tr>
<tr>
<td></td>
<td>0.4795 0.4812 0.4792</td>
</tr>
<tr>
<td></td>
<td>0.4396 0.4184 0.4456</td>
</tr>
</tbody>
</table>

Every test-sketch \( S \) is also represented as feature vector
\( V_s \). 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:
\[
d(k) = \text{distance}(V_s, V(k)), \forall k.
\]

In this case classification problem of test image \( S \) is
reduced to calculation of distance \( d(k), \forall k=1,2,..., K \). Index
\( k \) corresponding 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.

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**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.

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**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 principale component analysis (2D PCA) [8]. Size of spectrum matrix is also M×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:

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

where: \( M = 250; N = 200; d = 30 \) and parameter \( d \) is defined by solving the variational problem. Reduction in recognition rate can be 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 synthesised with express-method. Some better results amounted on average 88.6667% for «Art Sketch» and nine «Viewed sketch» 98.689% concerning our base of sketches, obtained with above procedure.

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.

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 Database: http://mmlab.ie.cuhk.edu.hk/facesketch.html

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