UDC 004.93’12:57.089(045)

D. M. Fedorov, post-graduate student

THE IMPROVEMENT OF ASM-ALGORITHM FOR AUTOMATIC PLACEMENT OF THE FACE CONTROL POINTS

National aviation university, e-mail: vorodef@ukr.net

Abstrakt. *There was analysed the operation of the active shape model algorithm. It is described the application of this algorithm in systems for determining the characteristics of the face in its pictures. There was proposed an improvement of active shape model algorithm, which consists in replacing learning step by stage of computation of minimax area and using it for limitation of search area of the face checkpoints. The results of the pilot study the speed of the improved algorithm. There were shown the speed results of the experimental study of the improved algorithm.*

Keywords: image recognition, face control points, active shape model, minimax area, person’s identification, artificial intelligence.

Introduction. The interest in the processes of person’s recognition and identification, has always been significant, especially due to the ever-increasing practical needs: security systems, verification of credit cards, forensic examination, newsgroups, etc. Despite the clarity of the vital fact that the person is well identify people's faces, it is not obvious how to teach computer, including how to allocate faces in digital images of specific points and areas of their elements. Most of the work in this area has been devoted to the obtaining of an image with a photo or video. Only in the United States and Germany on technology identification by facial features worked hundreds of companies that have been allocated government grants. Originally intended for the development of intelligence, but with time these knowledges were allowed to be used for commercial purposes. As a result, the market appeared a number of pattern recognition systems (though not all of them were suitable in practice). The problem of optimal identification of weakly contrasting objects, which are considered to be the human face on the basis of cybernetic systems can be seen in the aspect of the classical problems of perception, and in the aspect of new approaches.

Many existing approaches of face recognition is based on algorithms that automatically detect facial features. One of the most successful of these algorithms is developed in 1995 by Tim Cutes and Chris Taylor – active shape model (ASM) algorithm [1]. Possible practical application of the algorithm – the mood detectors, lie detectors, which are based on automatic analysis of facial expressions, and of course the simple classification of persons by facial photo. Despite the potential opportunities of the ASM-algorithm, quality of its work greatly depends on the parameters of image angle and other factors. Also, it depends on the algorithms of automatic placement of face control points. Automatic placement of control points can be used not only in electronic facial recognition systems, but also in the emotional state assessment systems by face image, recognition of articulation, recognition of race, nationality and others [2].

Face recognition systems have the advantage of including other systems of identification, as some of the passive recognition systems. They can be divided into two categories:

– Searching for a person in a large database, such as passport database. These systems usually give a list of the most similar people in the database. Usually only one image is available for one person and often it is not necessary that the recognition was carried out in real time.

– Identification of a specific person in real-time, such as in security systems or access control systems when you need to access a certain group of people and deny it to everyone else. Often it uses multiple images for a single person and recognition is performed in real time.

In both categories of recognition the algorithm of the active shape model are used for automated detection of facial features. This paper focuses on the improvement of this algorithm.

The analysis of the latest researches and publications. Currently algorithms using active shape models are the most common algorithms of placement control points. Form in the context of this paper – a geometric description of the area occupied by the object and which limited by its external borders. In other words, we abstract from the position of the object, its size, color and other characteristics. The shape of the object forms a set of points. The task of the active shape model algorithm – is to compare this model with the new image.

The algorithm is based on obtaining the statistical model of face for the most informative of its elements (eyebrows, eyes, nose, ears, mouth and shape of the face). It features derived local control points, which are then used to find the most similar points in the new image. Building a statistical shape model of the object by a set of training images was first proposed in [3]. It is encoded by face shape vector composed of the coordinates of the control points. Shape of the face is represented as the sum of "average" for the study sample form with a set of linear increments that define non-rigid (not preserving the distance between points) converting the average shape and a set of parameters that define the rigid transformation forms – rotate, zoom and parallel transfer. To find directions increments that correspond to non-rigid transformations to vectors form the training set is applied alignment procedure that avoids rigid transformation model forms contained in the training sample. Directions linear increases in average shape, which correspond to non-rigid transformations are defined as major components of the matrix kovariatsiy aligned vectors form the training set. At the stage of training received information about the properties of its image texture. To do this, in the vicinity of the *i*-th control point model for the *j*-th training sample is extracted image texture profile, which is a vector g_{ij}, consisting of n_p values of the difference image intensity at points along the normal to the boundary model [4].

During the process of searching the predictable movement points around each control point of the model with test images, it is obtained value of profile g (normal to the boundary model) of length $l > n_p$. Further on this profile point d_{best} is selected in such way, that the profile of the test image centered at this point most similar to the reference profile [4]. As a similarity measure the Mahalanobis distance is used

$$f_{prof}(d) = (h(d) - \overline{g})^T S_g^{-1} (h(d) - \overline{g}),$$

where $h(d)$ – a subset of g of length n_p profile centered at d, S_g – covariation matrix of training set of profiles. Point d_{best} is selected as the new proposed provisions appropriate reference point. The set of coordinates of points $d_{best,i}$ specifies approximation model form s^k at k-th iteration [5].

The described process is repeated iteratively until the next condition become true

$$\left| s^{k+1} - s^k \right| < \varepsilon,$$

or would exceed the maximum number of iterations [5]. Procedures for training and search conducted on the pyramid of the image of arbitrary depth. Unlike source [5], in the source [6] is proposed a somewhat different statistical model of face and its elements, in which each point is known identity rectangular region within which the point can be located. This region in [6] called minimax because its coordinates are the minimum and maximum values of the x, y points of identification. That is, all possible positions of these points are inside this area. The average probability of a point belonging to the boundary of her face image is computed using the following recurrence formula

$$\overline{P}_{ij}(x_1, y_1, x_2, y_2) = \frac{C_{ij}(x_2 - N_p, y_2 - M_p) + C_{ij}(x_2, y_2 - M_p) + C_{ij}(x_2 - N_p, y_2) + \Delta KS_p}{(x_2 - x_1 + N_p)(y_2 - y_1 + M_p)},$$

where

$$C_{ij}(x_2 - N_p, y_2 - M_p) = (x_2 - x_1)(y_2 - y_1)\overline{P}_{ij}(x_1, y_1, x_2 - N_p, y_2 - M_p);$$

$$C_{ij}(x_2, y_2 - M_p) = (x_2 - x_1 + N_p)(y_2 - y_1)\overline{P}_{ij}(x_1, y_1, x_2, y_2 - M_p);$$

$$C_{ij}(x_2 - N_p, y_2) = (y_2 - y_1 + M_p)(x_2 - x_1)\overline{P}_{ij}(x_1, y_1, x_2 - N_p, y_2),$$

x_1, y_1, x_2, y_2 – coordinates of minimx area, N_p i M_p – width and height of area, S_p – square of area, ΔK – quantity of points, where x or y coordinate is maximal for their sub-area. When $x_1 = x_2$, $y_1 = y_2$ and $i = 1$, $j = 1$, then

$$\overline{P}_{11}(x_1, y_1, x_2, y_2) = \frac{1}{q}\sum_{j=1}^{q}\frac{kS_p}{(x_2 - x_1 + N_p)(y_2 - y_1 + M_p)},$$

where k – quantity of points in sub-area (x_1, y_1, x_2, y_2), – quantity of images in training set and probability $P(x_1, y_2, x_2, y_2)$ can take value “1” or “0” depending on either border goes through the point (x_1, y_1). If it goes through, then $P(x_1, y_1, x_2, y_2) = 1$, else $P(x_1, y_1, x_2, y_2) = 0$.

Task statement. Recognition algorithm, which searches checkpoints faces have a complicated structure and often their individual stages are issued in the form of libraries. As recognition algorithms with different complexity, it makes sense to compare the performance of different libraries search checkpoints faces used in these algorithms. The following table (table 1) The time algorithms for placing control points from the library Visionopen, a standard algorithm for ASM, ASM-optimized algorithm library ASM Lib algorithm and ASM +, described in [6].

Table 1

Execution time of algorithms of placement control points (s)

Area	ASM	ASM+	Visionopen	ASM Lib
Whole face	10,3	8,1	8,8	6,9
Mouth	8,6	7,9	10,0	7,5
Eyes	8,5	5,3	4,6	4,8
Eyebrows	8,3	4,9	5,0	4,8

The best results, both in performance and the accuracy of the algorithm showed the library ASMLib. Accuracy ASM algorithm is satisfactory, but slightly lower than that of other algorithms, ASM + shows precision, superior algorithm for ASM and close the library ASMLib, but a non-trivial way to compute texture features it runs much slower. The test was performed on a computer with a processor Intel Core i3 3,1 GHz and RAM 4 GB. Given that the identification of persons in devices for face recognition process should take as little time, the task of this work is to modify the ASM-algorithm in which the time of the improved algorithm is less than the corresponding parameters are listed in table 1. As will be shown below, the work of the above algorithms can be reduced, which will certainly be useful for the identification of face and computer vision systems.

Task solution. To reduce the running time of the algorithm is proposed to use ASM Minimax field to limit the search scope of each breakpoint face. In the algorithms in the above libraries under study face shape is encoded by a vector composed of the coordinates of control points and is represented as the sum of “average” for the study sample form with a set of linear increments. In the improved algorithm under study minimax values calculated fields for each control point face and its elements. Then, with a test image, the coordinates of the control points are computed face and its components. To do this, you need to find the value of (x, y), which satisfy the following set of conditions:

$$\begin{cases} \dfrac{C_{ij}(x_2 - N_p, y_2 - M_p) + C_{ij}(x_2, y_2 - M_p) + C_{ij}(x_2 - N_p, y_2) + \Delta KS_p}{(x_2 - x_1 + N_p)(y_2 - y_1 + M_p)} \to \max \\ F(x, y) = 0, \quad x_1 \le x \le x_2,\ y_1 \le y \le y_2 \end{cases},$$

where $F(x, y)$ – function contours in the image face. If $F(x_0, y_0) = 0$, the point (x_0, y_0) belongs to the contour of the face or element.

On the other hand, the average probability of a point belonging to the boundary face image whether it is an element minimax region size $N_p \times M_p$. In this case, the probability is “1”. That is:

$$\begin{cases} \dfrac{C_{ij}(x_2-N_p, y_2-M_p)+C_{ij}(x_2, y_2-M_p)+C_{ij}(x_2-N_p, y_2)+\Delta KS_p}{(x_2-x_1+N_p)(y_2-y_1+M_p)}=1; \\ F(x,y)=0, \quad x_1 \le x \le x_2, \quad y_1 \le y \le y_2, \quad x_2-x_1=N_p, \quad y_2-y_1=M_p; \end{cases} \Leftrightarrow$$

$$\Leftrightarrow \begin{cases} \dfrac{C_{ij}(x_2-N_p, y_2-M_p)+C_{ij}(x_2, y_2-M_p)+C_{ij}(x_2-N_p, y_2)+\Delta KS_p}{4N_pM_p}=1; \\ F(x,y)=0, \quad x_1 \le x \le x_2, \quad y_1 \le y \le y_2, \end{cases}$$

where

$$C_{ij}(x_2-N_p, y_2-M_p)=N_pM_p\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2-N_p, y_2-M_p)=N_pM_p;$$
$$C_{ij}(x_2, y_2-M_p)=2N_pM_p\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2, y_2-M_p);$$
$$C_{ij}(x_2-N_p, y_2)=2N_pM_p\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2-N_p, y_2),$$

so

$$\begin{cases} \dfrac{1}{4N_pM_p}\Big(N_pM_p+2N_pM_p\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2, y_2-M_p)+ \\ +2N_pM_p\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2-N_p, y_2)+\Delta KS_p\Big)=1; \qquad \Leftrightarrow \\ F(x,y)=0, \quad x_2-N_p \le x \le x_2, \quad y_2-M_p \le y \le y_2 \end{cases}$$

$$\Leftrightarrow \begin{cases} \dfrac{1+2\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2, y_2-M_p)+2\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2-N_p, y_2)+\Delta KS_p}{4}=1 \\ F(x,y)=0, \quad x_2-N_p \le x \le x_2, \quad y_2-M_p \le y \le y_2 \end{cases} \Leftrightarrow$$

$$\Leftrightarrow \begin{cases} 2\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2, y_2-M_p)+2\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2-N_p, y_2)+\Delta KS_p=3; \\ F(x,y)=0, \quad x_2-N_p \le x \le x_2, \quad y_2-M_p \le y \le y_2, \end{cases}$$

ΔK (number of points where the coordinate x or y is the maximum for their sub-area) for the resulting system of equations is equal 2, because in the first equation is computed probabilities sum for areas that have a common sub-area and two sub-areas that are at the left and bottom of it. Therefore, the last set of equations can be rewritten as

$$\begin{cases} \overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2, y_2-M_p)+\overline{P}_{ij}(x_2-N_p, y_2-M_p, x_2-N_p, y_2)+S_p=1{,}5; \\ F(x,y)=0, \quad x_2-N_p \le x \le x_2, \quad y_2-M_p \le y \le y_2. \end{cases}$$

The function $F(x, y) = 0$, as was said above, is a function of facial contours in the image and so it is built in tabular form. To find the control points in the face image, we need for face minimax region with coordinates $(x_2 - N_p, y_2 - M_p, x_2, y_2)$ to find a point (x, y) such that $F(x, y) = 0$, and certainly $x_2 - N_p \le x \le x_2$ and $y_2 - M_p \le y \le y_2$. The complexity of this algorithm will be approximately $O(n^2)$, because speed of finding each of the control points depending on the size of the image and the algorithm itself – is nothing like the full search of the points on the image and checking their affiliation to the minimax area.

In the experimental verification of modified ASM-time algorithm for finding the control points decreased, as shown in table 2.

Table 2

Execution time of modified algorithms of placement control points (s)

Area	ASM	ASM+	Visionopen	ASM Lib
Whole face	6,7	5,3	7,5	4,8
Mouth	6,2	5,8	5,1	6,4
Eyes	7,7	3,9	3,2	3,5
Brows	6,5	3,7	4,4	3,6

The modified algorithm is faster than the existing as average for 25,6 %. That is, if such model use in face identification points search algorithm, it allows to accelerate its performance by 25,6 %.

Conclusions. So, in this article the analysis of the algorithm has made and the active shape model algorithm improvement has proposed. It consists in calculating the coordinates of minimax areas for each face control point instead of training stage, which was in the original algorithm, but using the same training set of face images. As a result of the experimental research of the working speed of the improved algorithm, it is turned up that it is greater than the existing algorithm for 25,6 %.

References

1. *Cootes T. F., Taylor C. J., Cooper D. H., Graham J.* 1995. Active shape models – their training and application. P. 38–59.
2. *Proyaev P. O., Zhidenko M. V.* June 2012. Development and analysis of algorithms of the control points localization using an active shape model. Pub. Youth Science and Technology Bulletin of MSTU of N. E. Bauman. No.7.
3. *Taylor C. J., Cooper D. H., Graham G.* 1992. Training models of shape from sets of examples. In Proc. British Machine Vision Conference. P. 9–18.
4. *Stan Z. Li, Anil K. J.* Sept. 2005. Handbook of face recognition. Springer Science. P. 39–63.
5. *Hill A., Cootes T. F., Taylor C. J.* 1995. Active shape models and the shape approximation problem. – In Proc. British Machine Vision Conference, BMVA Press, UK. P. 157–166.
6. *Fedorov D. M.* 2013. Mathematical model of placement face elements on its photo. Pub. NAU. – Problems of Informatization and Control.

Д. М. Федоров

Удосконалення ASM-алгоритму для автоматичного розміщення контрольних точок обличчя

Проаналізовано роботу алгоритму активної моделі форми. Описано застосування даного алгоритму в системах визначення особливостей обличчя за його фотознімком. Запропоновано удосконалення алгоритму активної моделі форми, яке полягає у заміні стадії навчання стадією обчислення мінімаксної області і використання її для обмеження області пошуку контрольних точок обличчя. Наведено результати експериментального дослідження швидкості роботи удосконаленого алгоритму.

Д. М. Федоров

Усовершенствование ASM-алгоритма для автоматического размещения контрольных точек лица

Проанализирована работа алгоритма активной модели формы. Описано применение данного алгоритма в системах определения особенностей лица по его фотоснимку. Предложено усовершенствование алгоритма активной модели формы, которое заключается в замене стадии обучения стадией вычисления минимаксной области и использования ее для ограничения области поиска точек лица. Приведены результаты экспериментального исследования скорости работы усовершенствованного алгоритма.