Development of a New Method for Adapting a 3D Model from a Minimum Number of 2D Images

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***Abstract* – This paper describes new methods that are used to adapt a 3D polygon model of a face, which is then used in a facial recognition system. In this paper, a new method is proposed, which can adapt a 3D model of a face, while using a minimum number of 2D images of a face (full face, profile, half-turn). Control points and distances between them are used to extract eyes, nose and other fragments from a face, and to find links between them in different projections. The results of the proposed algorithm are compared with a Faceworx program.**

***Keywords* – Facial recognition, face 3D model, polygon model.**

I. INTRODUCTION

Creating a three-dimensional model of a human face from two-dimensional images is a relevant task in many different fields (medicine, forensics, security systems and video surveillance systems etc.). The purpose of creating such models is that they could later be used in a facial recognition system. For example, in forensics, many of the existing 2D facial recognition algorithms could not be used to identify a criminal from an image of a side of his face, because input information about the shape of a face consists of minimal training sample – an image of a full face, profile and a half-turn. Creating a three-dimensional model of a face based on the input images allows rotating the model at different angles, thus increasing the training sample, which allows retrieving missing information about the shape of a face, which later could be used for the further analysis and it could increase the precision of facial recognition.

There are many approaches, which could be used to reconstruct a three-dimensional model of a face:

1) Automatic approach using a 3D scanner [1] allows acquiring more precise data about the shape of the head and the proportions of a face. However, this approach requires direct contact with the analysed object (contact method). In a different approach a scanner emits directed waves at an object and detects its reflection for the further analysis (no contact method) [2][3]; the disadvantage of this approach is that it has huge material costs. Such methods as [4], [5], [6], [7], [8], [9], [10] use an approach based on parametric models of a face. The disadvantage of these methods is a high computational complexity.
2) Semi-automatic method, using specialized software, that allows creating a shape of the face by manually placing control points on input images – Looxis Faceworx [11], bioVirtual 3DMeNow Professional [12] or FaceGen Modeller [13], but models created using these programs do not always resemble input images.
3) Manual approach implies creating the 3D model of face from scratch, manually moving each vertex of an object (object consists of polygons that have vertices), which takes an enormous amount of time.

In this paper, a semi-automatic method of adapting a 3D polygon model of a face from a minimum number of input images (full face, profile and half-turn) is proposed. The proposed method adapts the 3D model of a face by using manually placed control points in several projections; it also places texture on the adapted model.

II. THE PROPOSED METHOD

a. *Creation of the 3D Polygon Model of a Face*

The input three-dimensional model of a head was created using FaceGen Modeller 3.1; it was used to create an average model of a head, which can be seen in Fig. 1, then this model was simplified (by decreasing the polygon count) in Autodesk 3Ds Max 2012 [14].

The main purpose of simplifying the model was to link the control points placed on the images of face and the polygon mesh of the model, but the mesh should not contain more than 1000 vertices, which would slow down calculations.

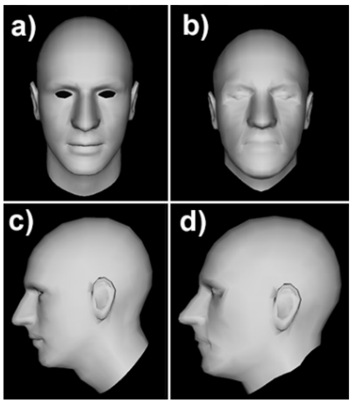

Fig. 1. Average 3D model of a head: a),c) 3D model of a head created in a FaceGen Modeller; b),d) 3D model of a head with a simplified polygonal structure.

b. *Adapting the 3D Model of a Face*

To create the algorithm, a lot of photographs of one man were taken, three of which were used as input images (full face, profile, half-turn), on the other images the face was turned at different angles to check for similarity between the adapted model and the original images of a face. A block diagram of the 3D model adaptation algorithm is shown in Fig. 2.

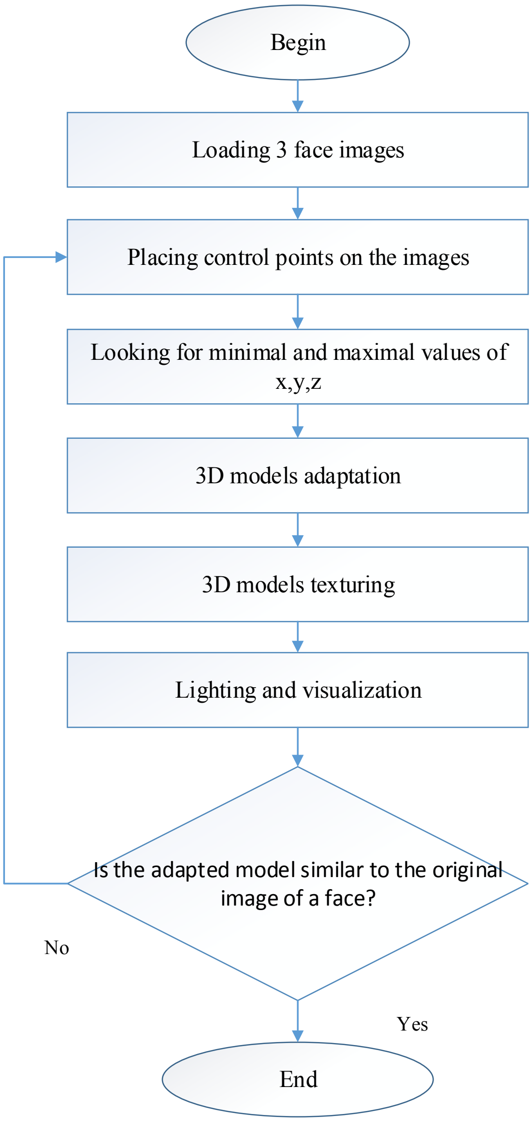

Fig. 2. Block diagram of the proposed 3D model adaptation algorithm.

<u>3D model of a face adaptation algorithm</u>

1) At the beginning of the algorithm, three base images of a face are loaded (full face, profile, half-turn); they may be seen in Fig. 3.

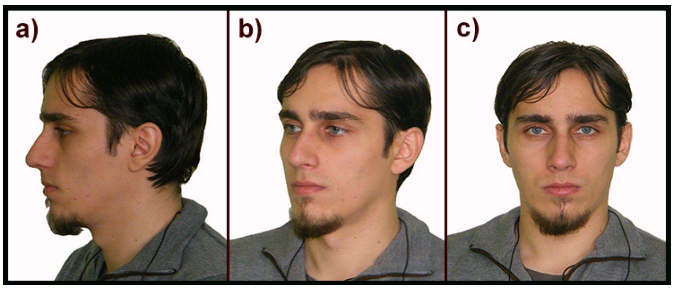

Fig. 3. The initial images of a face: a) profile; b) half-turn; c) full face.

2) Control points are manually placed on the images as seen in Fig. 4. The position of the control points is very important; they describe such features of a face as position of the pupils, edges of the lips, contour of the profile etc.

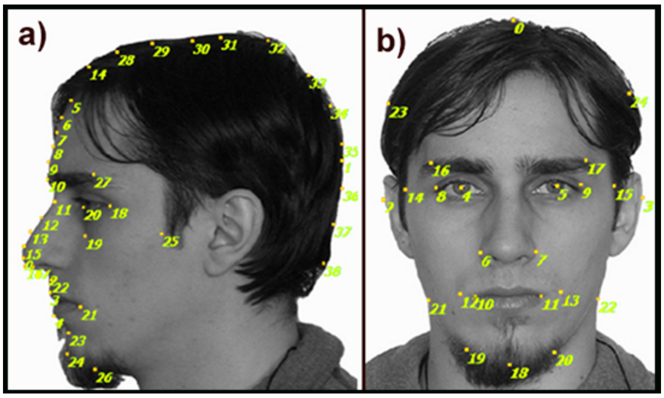

Fig. 4. Placing the control points on the face: a) profile; b) full face.

3) The next step is converting the coordinates of the control points from 2D space into 3D space. It is important to note that the control points were placed in 2D space, but since there were several images, the information about the x, y coordinates of the adapted 3D model was taken from the full face image, and the z coordinate was calculated from the profile image, where the x coordinate represented the depth and the z coordinate in the 3D model.
4) The width and height of the face is calculated based on specific control points.
5) The next step is finding the minimum and maximum values of the x, y, z coordinates out of all the vertices of the simplified 3D model. The ratio between the sizes of the 3D model and width and height of the face is calculated to find a coefficient, which is multiplied with each vertex of the 3D model to scale the simplified model.
6) The 3D model of a face is divided into several zones (forehead, eyes, nose, lips, chin, cheeks). If the position of the manually placed control points matched the position of the vertices of the 3D model, the coordinates of the vertices did not change, otherwise the coordinates were multiplied with the specific values of the coefficient, which were in an interval $k \in [0.5, 1]$. An example of the placement of the weight coefficient may be seen in Fig. 5.

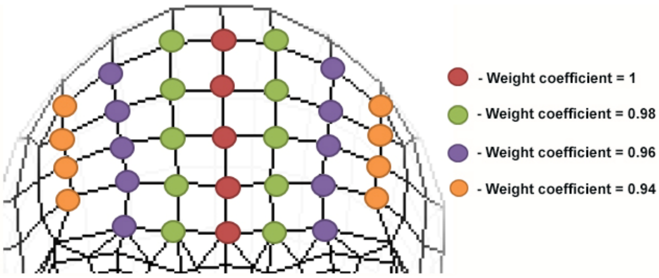

Fig. 5. Putting the weight coefficients on the polygonal 3D model mesh.

7) Next, it is necessary to apply two textures on the adapted model (the first texture for the full face, and the second for the profile). Before the textures can be applied, they are processed to remove the noise and background, which otherwise will be visible on the final model. A short process of the texture preprocessing may be seen in Fig. 6.

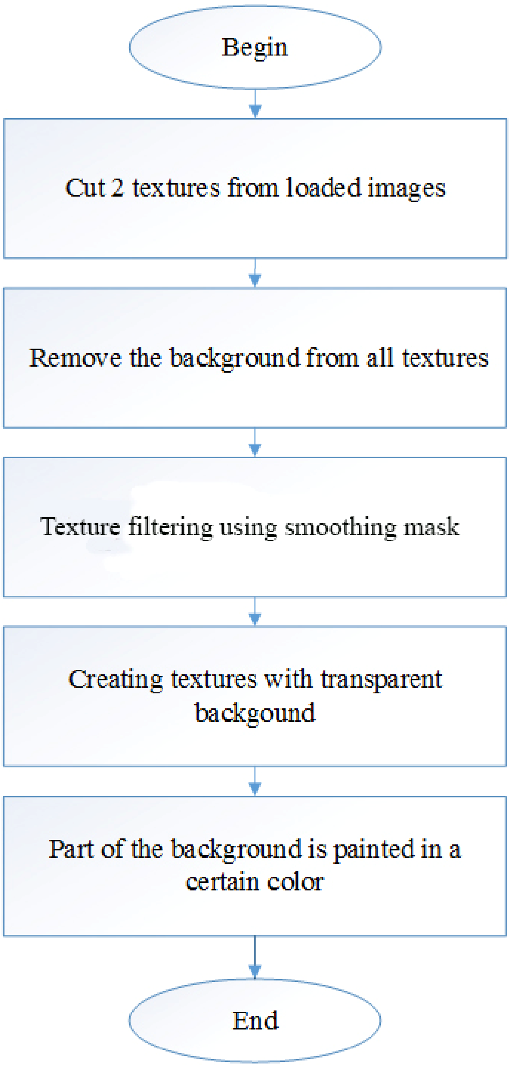

Fig. 6. Texture preprocessing before placing on the 3D model.

Textures were extracted from the input images of a full face and profile, and were cropped at the coordinates of control points. Example of extracted textures may be seen in Fig. 7.

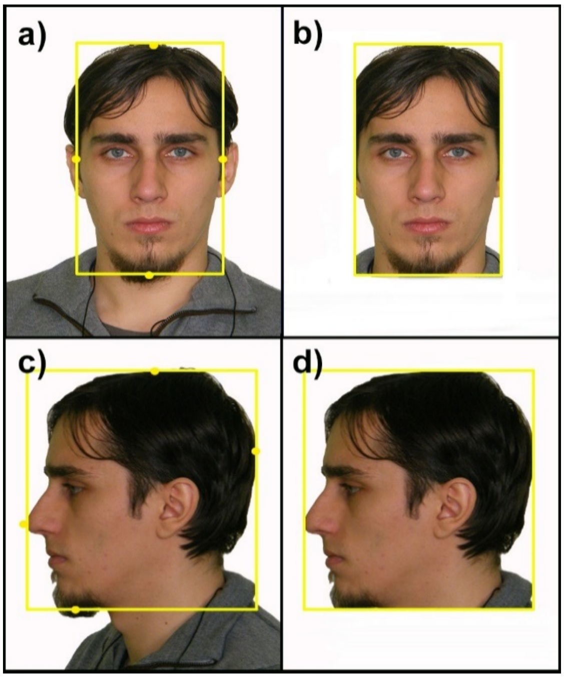

Fig. 7. Texture cutting based on control point coordinates: a), c) original images; b), d) output textures.

7.1) Background is removed from the texture using the region growing algorithm [15].
7.2) To remove the noise and aliasing effect, texture is processed with a smoothing mask [16].
7.3) An alpha channel is added to the texture to make the background transparent.
7.4) For the hair zone, the texture is painted in a colour of one pixel located in a specific control point. An example of the final texture may be seen in Fig. 8.

Fig. 8. Final texture after merging two textures together.

After the textures are applied to the model, two light sources are added to scene, and the adapted 3D model is compared with the input images of a face, if the adapted 3D model is similar to the input images, then the algorithm stops, if it is not the same then the algorithm returns to step 3.

III. EXPERIMENTS

The proposed method was tested on the images of a face of one person. Photographs were taken at different times. The resolution of all photographs was reduced; the photographs were also cropped using Adobe Photoshop CS6 program. The resulting images were then loaded into the developed program. The results of the proposed method may be seen in Fig. 9.

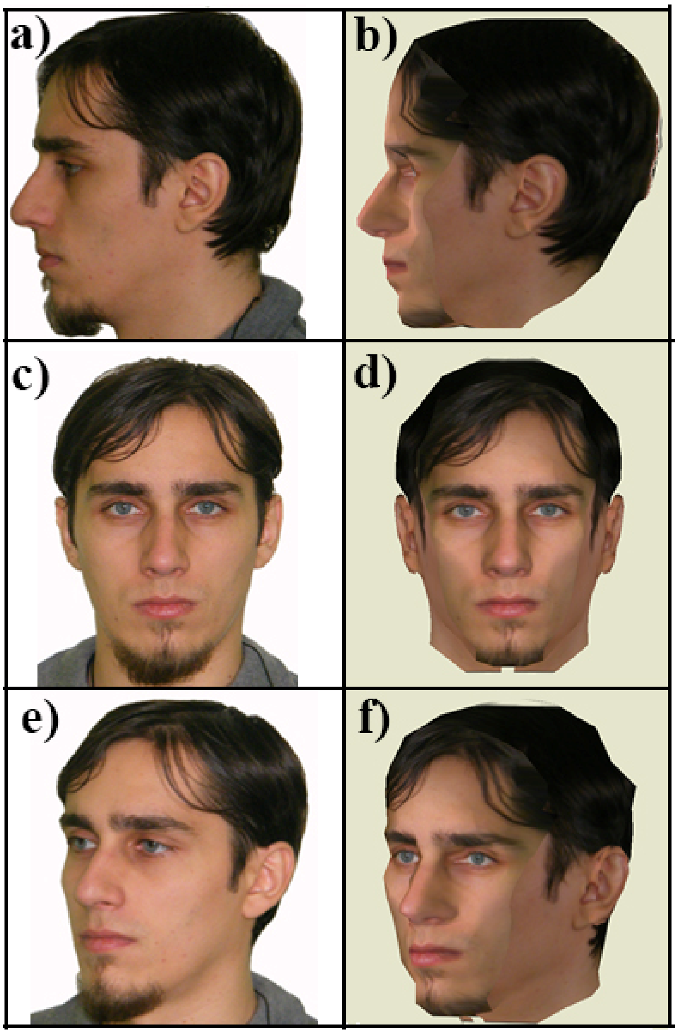

Fig. 9. Comparison of a),c),e) input image profile, full face, half-turn; b),d),f) the proposed method.

The model was then rotated at different angles to compare the adapted model with the photographs that were taken at similar angles. The results may be seen in Fig. 10.

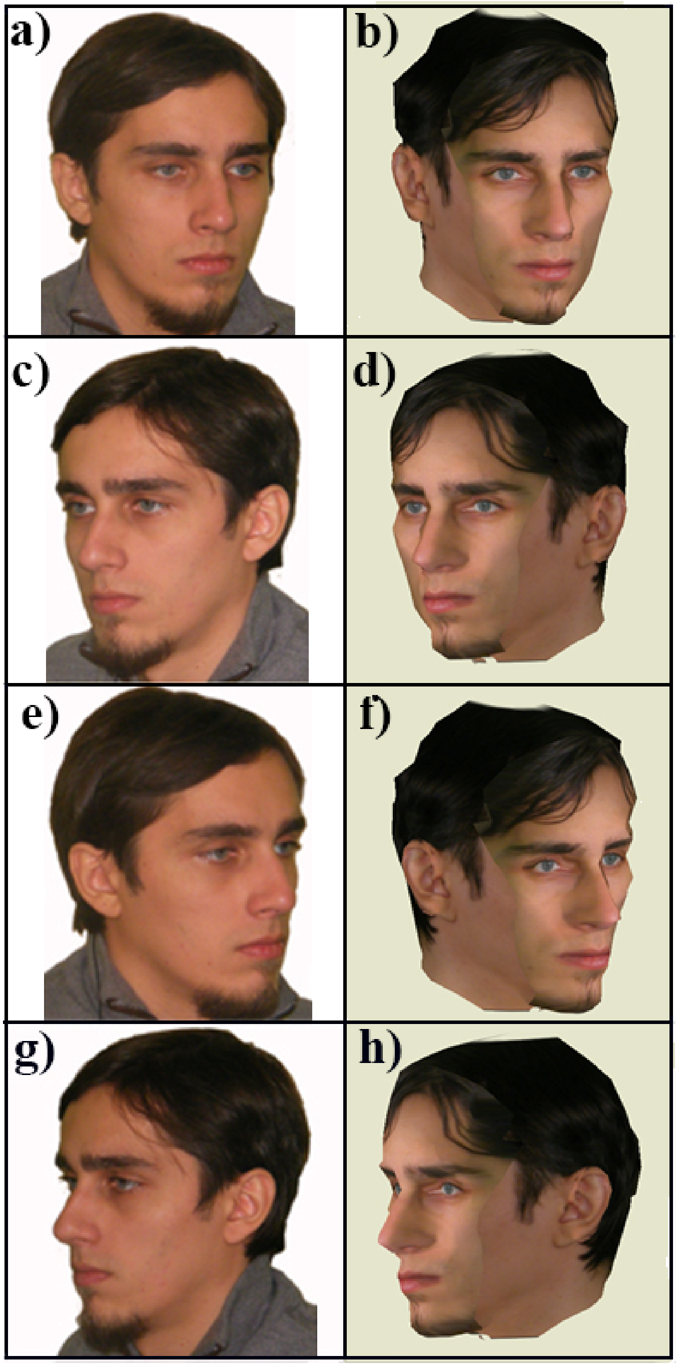

Fig. 10. Comparison of a), c), e), g) input images; b),d),f),h) the proposed method.

The proposed method was also compared with the several existing methods. The same input images were used in different programs to create 3D models. The comparison of the proposed method with 3D models may be seen in Fig. 11.

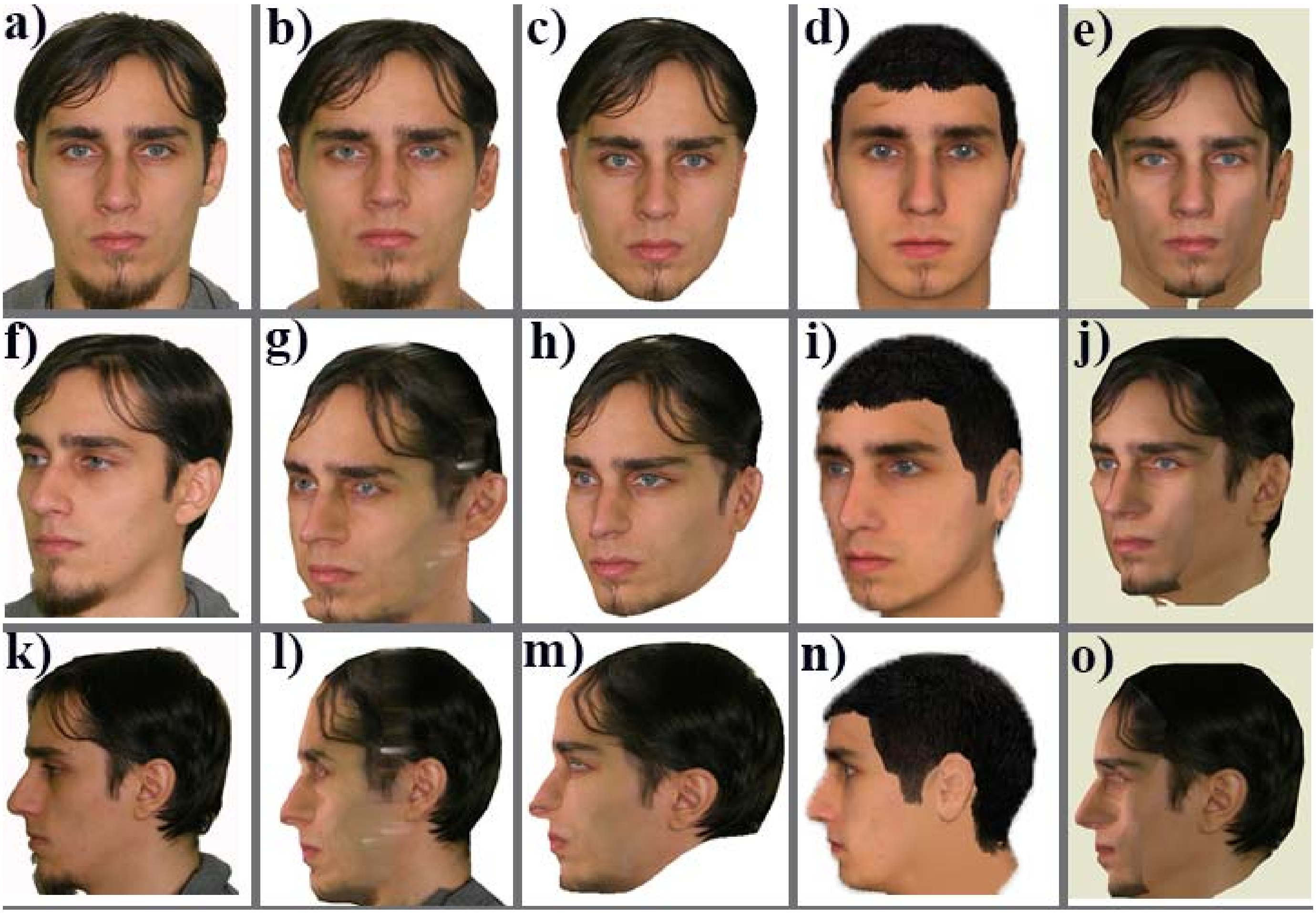

Fig. 11. Comparison of the results of 3D model creation in different programs: a),f),k) input images; b),g),l) results in 3DMeNow Professional program; c),h),m) results in Looxis Faceworx program; d),i),n) results in bioVirtual FaceGen Modeller 3.1; e), j), o) the proposed method.

IV. Conclusions

A semi-automatic method was developed for adapting an average 3D model from three 2D images of a face, and an algorithm of placing a face texture on a polygonal model. As results show, the proposed method manages to adapt the model of a face to the real images of a face, where the initial model was created using FaceGen Modeller 3.1 and the initial model was simplified using Autodesk 3Ds Max 2012. The drawback of the proposed method is that it is sensitive to light, and it produces a few artifacts.

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Olga Krutikova, Aleksandrs Glazs. Jaunas metodes izstrāde cilvēka sejas 3D modeļa adaptācijā ar pieejamu minimālu 2D attēlu skaitu
Cilvēka sejas 3D modeļa veidošana, balstoties uz 2D attēliem, ir aktuāls uzdevums dažādās sfērās (medicīna, kriminālistika, apsardzes sistēmas un video novērošanas sistēmas u.c.). Šāda tipa modeļa veidošana ir saistīta ar to, lai nākotnē to varētu lietot seju atpazīšanas sistēmās. Piemēram, kriminālistikā, lai identificētu noziedznieka sejas attēlu, kurš atšķiras no pretskata attēla, turklāt daudzus esošos 2D atpazīšanas algoritmus nevar pielietot, jo tas ir saistīts ar to, ka vairākos gadījumos sākotnējā informācija par sejas formu sastāv no minimālas vispārīgas datu atlases – pretskata, sānskata un puspagrieziena attēliem. Gadījumā, kad tiek veidots trīsdimensiju modelis pēc sākotnējiem datiem, rodas iespēja pagriezt modeli dažādā leņķī, tādējādi palielinot vispārīgo datu atlasi un iegūstot trūkstošo informāciju par sejas formu nākamai sejas analīzei, kā arī paaugstināt atpazīšanas algoritma darbības precizitāti.
Šajā rakstā tiek piedāvāta pusautomātiskā metode, kura ļauj adaptēt sejas poligonālo trīsdimensiju modeli, balstoties uz minimālo ieejas attēlu skaitu (sānskats, pretskats un puspagrieziens). Piedāvātajā metodē notiek trīsdimensiju modeļa adaptācija, izmantojot ar roku uz attēliem dažādās projekcijās izvietotus kontrolpunktus, kā arī tekstūru, kura tika uzklāta uz adaptētā modeļa.
Piedāvātā metode tika testēta, izmantojot konkrēta cilvēka attēlus, kuri tika uzņemti dažādos laikos. Kā parādīja eksperimenta rezultāti, piedāvātā metode spēj sekmīgi paveikt uzdevumu un adaptēt sejas poligonālo trīsdimensiju modeli. Šīs metodes galvenā priekšrocība ir – tā neprasa dārgu aparatūru, lai adaptētu sejas trīsdimensiju modeli.

Олга Крутикова, Александр Глаз. Создание нового метода адаптации 3D модели лица при минимальном наличии 2D изображений.
Создание трехмерной модели человеческого лица по двумерным изображениям является актуальной задачей во многих отраслях (медицина, криминалистика, охранные системы и системы видеонаблюдения и т.д.). Целью создания такой модели является дальнейшее её применение в системе распознавания лиц. Например, в криминалистике, для идентификации изображения лица преступника, которое отличается от фронтального вида, многие существующие 2D алгоритмы распознавания лиц не могут быть использованы, это обусловлено тем, что в большинстве случаев исходная информация о форме лица состоит из минимальной обучающей выборки – изображения анфаса, профиля и полуоборота лица. В случае построения трехмерной модели лица по исходным изображениям, появляется возможность поворота модели под разными углами, соответственно увеличить обучающую выборку что дает возможность получить недостающую информацию о форме лица для дальнейшего анализа, а также повысить точность работы алгоритма распознавания.
В данной статье предлагается полуавтоматический метод адаптации полигональной трехмерной модели лица, основываясь на минимальном количестве исходных изображений (профиль, анфас и полуоборот лица). В предложенном методе происходит адаптация трехмерной модели лица с использованием для этого расставленных вручную на изображениях в различных проекциях контрольных точек, а так же текстуры, накладываемой на адаптированную модель.
Предложенный метод тестировался на изображениях лица конкретного человека, которые были сделаны в разные периоды времени. Как показали результаты экспериментов, предложенный метод помог успешно справиться с задачей и адаптировать полигональную трехмерную модель головы. Главное преимущество предложенного метода заключается в том, что он не требует дорогого оборудования для адаптации 3Д модели лица.