Improving the attractiveness of faces in images

Tatiane Silvia Leite
School of Electrical and Computer Engineering - FEEC
State University of Campinas
Campinas, Brazil
Email: tatiane.leite@gmail.com

José Mario De Martino
School of Electrical and Computer Engineering - FEEC
State University of Campinas
Campinas, Brazil
Email: martino@fee.unicamp.br

***Abstract*—Advertising images increasingly require attractive faces to attract the public's attention. Several studies have been conducted to enhance facial attractiveness in images. While some researchers suggest changes in geometrical shape, others advocate modifying the appearance of the facial skin; however, there have been few attempts to explore the possibility of combining both techniques. This paper sets out a novel method of doing this: facial geometry and skin texture modifications. Our method, which is based on supervised machine learning techniques, is able to improve the attractiveness of faces in images while preserving the original features of the picture. We also demonstrate the effectiveness of this combination by carrying out two different evaluations. Accordingly, we analyze the significance of each change that is designed to improve attractiveness by comparing the original image with a) the image in which only the facial geometry has been modified, b) the image in which only the texture skin has been modified and finally c) the image with both modifications. Our results reveal that the combination of geometric and skin texture modifications results in the most significant enhancement. It also demonstrates that modifications to the skin texture can be regarded as more important to obtain an attractive face than changes to the facial geometry. Additionally, evaluations are provided to quantify the gain in facial attractiveness and it should be pointed out that our method is the first to employ these, since there are no references to such tests in the literature.**

***Keywords*-facial attractiveness; facial geometry; skin texture; machine learning**

I. Introduction

What makes a face attractive is an intriguing and fascinating question that has challenged scholars and researchers for a long time. It has been a matter of interest in different areas such as art, philosophy, and medicine. Nonetheless, only recently, with the advent of the digital image processing technology, has the enhancement of facial attractiveness through digital images gained momentum. Currently, people are constantly being exposed to a huge amount of graphics media and hence there is an increasing concern about the aesthetic appeal of facial pictures. As stated in the English proverb "First impressions are the most lasting". There are at least two areas where this proverb holds true: advertising and building social media presence. The main objective of advertising is to ensure a positive and lasting first impression is obtained and this is often carried out by using manipulated images of "beautiful" faces to attract the customers' attention. In a very similar way, social media groups strive to create a good impression. Having attractive personal images can be a means of drawing more attention, creating empathy more readily and making it easier to form interpersonal relationships. Given this growing influence of attractive faces in people's everyday lives, this paper sets out a novel method for the automated enhancement of facial attractiveness in images which can be applied in different areas, such as those mentioned above.

There is already a significant body of research on the modifications carried out by facial geometry and shown in images [1], [2], [3]. There are also research studies on modifications in facial texture [4], [5]. However, very few of theses studies combine both techniques [6], [7], since they either fail to keep the original facial features or are unable to produce realistic results. In contrast, our method combines both strategies - facial geometry and modification in skin texture - while keeping the modified face close to the original and giving a photorealistic rendering of the image.

In this paper, it is employed a method for making geometric changes to the face, based on concepts defined in [1], followed by a procedure for a modified skin texture that leads to a more attractive facial image.

Making changes in the facial geometry, involves calculating the distances between pairs of feature points marked on the face. The distances are computed both for the target image and for all the images of a training set. The training set consists of facial images and the attractiveness of which had been previously evaluated by volunteers. The distances and the attractiveness of the images of the training set are used to train the machine learning algorithms. After the learning phase, the algorithms are capable of establishing the positions of the new feature points that can increase the attractiveness of the target face. The new positions are calculated by considering the set of k images of the training set with a high attractiveness score and distance between features points closer to the target image. These new positions are used to warp the target image and change the geometry of the face accordingly.

The resulting image obtained from this first stage becomes the input for the next stage of texture modification. The skin texture changes are based on the set of faces that serve to increase the attractiveness of the target face. This set is warped so as to have the same format as the target face. The pixels of the skin region are calculated through a weighted average of the training set of faces and the target face. As a result, a new image is created with color pixels that are only modified in the skin area.

In this paper, two user studies are also evaluated. The first study compares the attractiveness of facial images by applying four different modification strategies of the degree of alteration: 1) no modification at all, 2) only a change in the geometry, 3) only a change of the facial skin texture, 4) an alteration of both the geometry and skin texture. The second study analyzes the gain in attractiveness in terms of the initial attractiveness score of the image.

The results of the first study show that combining geometric and textured modifications produces faces with higher degree of attractiveness than employing the other three strategies. The evaluation also shows that only modifying the skin texture enhances the attractiveness more than only altering the facial geometry. The results of the second study suggest that the lower the attractiveness of the original face, the greater the improvement achieved by our method.

II. Related Work

Facial attractiveness has been studied in many different areas, such as psychology, anthropometry, medicine, and computing. It is hard to precisely classify the facial features that define an attractive face, since it depends on many different factors. Nonetheless, considerable research has been carried out in an attempt to explain, identify, and define the features that make a beautiful/attractive face.

Some studies argue that facial attractiveness is universal, multicultural and is not affected by gender factors or ethnicity. With regard to this, [8], [9], and [10] describe evaluation tests conducted with young children. The selection of children for the experiments is based on the assumption that they have been less exposed to social, cultural and media influences than adults. The results of the studies show that babies look longer at attractive faces (as evaluated by adults), which suggests that infants are able to discriminate between attractive and unattractive faces and that, in principle, facial attractiveness is not defined by factors like race, gender or social background.

[11] employs an automatic method for classifying faces with regard to attractiveness, and takes account of their geometric and textural features. On the basis of this study, Leyvand [1] devises a system to enhance facial attractiveness in images. The approach is based on supervised machine learning algorithms that are trained by a database of images of faces, each being given an attractiveness rating. The core algorithm of the approach calculates a modified distance vector that predicts higher attractiveness scores than the original one. The resulting new position of the feature points is used to warp the original image and change the geometry of the face. Similarly, [2] outlines a system for attractiveness enhancement, which uses an image database of celebrities as a reference for the geometric enhancement of faces.

Conceptually, both approaches [1] [2] are similar to ours; however, they only deal with geometric modifications while our strategy combines geometric and textured modifications to obtain a better result. Moreover, we use a database of ordinary people instead of using a celebrity database. In our view, pictures of celebrities may convey more than simply information about attractiveness and include factors such as the empathy and charisma of the celebrity.

Alternatively, [3] employs a method that is also based on making geometric modifications and takes into account the shape of an average face. The original image is altered so that it is close to the average. The results show the averageness hypothesis is in general effective, which means the closer the face is to an average face, the more attractive it can be considered. Unfortunately, the approach may lead to an outcome where final facial image has little or no resemblance to the original.

A smooth skin texture plays an important role in facial attractiveness as in general it is associated with health, attentiveness and, beauty. [4] states that men consider women who have homogeneous skin to be more attractive. [5] provides results to show that facial skin color distribution significantly influences the perception of attractiveness of female faces as well.

[12] analyzes the influence of symmetry as a factor in facial attractiveness. A case study employs a strategy that combines geometry - remapping some of the feature points to symmetrical positions - and texture - replacing the original texture with an average skin texture - modifications. The authors conclude that symmetrical faces are more attractive than non-symmetrical ones, especially when the skin texture is uniform. This study shows that symmetry is one feature that can improve the attractiveness of the face, but it is not the only one. Moreover, the images that emerge from this approach have unrealistic blurred facial contours that are clear signs that the images have been manipulated. In contrast, our method considers a wider set of characteristics to change the geometry of the face and reduce the problem of undesirable visual artifacts by employing an error decorrelation strategy during the transformation of the colors of the pixels in the skin region.

Additionally, other studies also suggest that finding the average of a set of faces usually produces a more attractive face than the original one. Langlois et al. [6], [13] establish an arithmetic average of the faces. A new image is produced by averaging grayscale pixel values. The authors state that the average faces are preferred to the original ones. Likewise, [7], [14] also consider average faces, but use colored images. Again, the average faces are considered to be more attractive than the original ones. Unfortunately, all these approaches lead to blurred facial outlines.

III. Proposed Approach

The overall schema of our method is shown in Figure 1. The input for our system is an image of a face in a frontal view, where there is a need to enhance the facial attractiveness. Our method consists of two key stages: Geometric Modification and Skin Texture Modification.

The first main stage entails altering the geometry of the input face. This can be achieved by first extracting the feature points of the input face. Then, it's calculated a set of distances between these feature points. These distances will be used

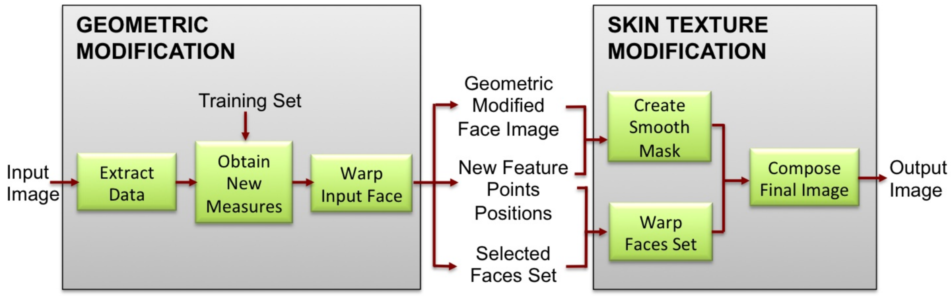


Fig. 1: The overall schema of our method.

by machine learning algorithms and they come up with a new distance set for the input face. It should be mentioned that these algorithms were previously trained with distance sets and their associated attractiveness. In this way, they learn whether the proportions are considered to be attractive or not. The new proportion shaped for the input face is used to warp the original image. The output of geometric modification are as follows: 1) the modified geometric warped image, 2) the new positions of the feature points in the face, and 3) the list of images of the training set that led to the positions of the features points being altered. All the output data are used in the next stage.

In the second stage, the color of the pixels inside the facial skin area is modified to create a more homogeneous skin tone. In this process, a mask is created which determines the facial skin area that will be modified. This mask has its edges smoothed out, to ensure that the facial contours will not be rough. Moreover, during this phase, the subset of facial images selected in the previous stage must be warped to fit the new geometry of the input face. In this way, our method ensures that the masked area will only contain skin tone values. Thus, for each valid pixel of the mask, its color is calculated by a weight average between the warped faces and the geometrically-modified input face. Our method was employed for an extensive set of images, and the results were evaluated by two different tests. The first analyzed the effectiveness of the processes by making a comparison between the following: the original image, the image which only had facial geometrical modifications, the image which only had modifications of the facial skin texture and, the image which included both changes. The second test measured the level of attractiveness enhancement achieved by our method. In this test, the faces were awarded an attractiveness score for both the original and modified image. The difference between the modified image and the original image scores defines the gain in attractiveness achieved by our method.

A. Geometric Modification

The facial proportion and arrangement of its features (the nose, mouth, eyes, etc.) are the basis for the recognition of a human face. Furthermore, this data also includes information related to facial attractiveness. The geometric factor is, thus, of great importance to the work outlined in this paper.

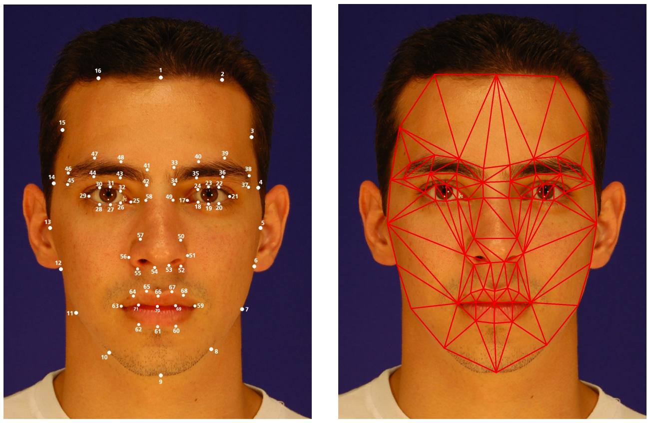
Making geometric alterations is the first phase of our method. This phase follows the general approach adopted by previous work, namely Data-Driven Enhancement of Facial Attractiveness [1]. In this section, there is a brief account of how the method introduced in [1] is applied to our work. More details can be found in the reference mentioned.

This phase can be divided into four important steps: construction of the training set, extraction of data from the input image, obtaining new measures for the input face based on supervised learning algorithms, and finally the warping of the original image to a new geometrically modified face.

1) Training Set: This work was carried out by creating a standardized database of images with 156 pictures of men and 111 pictures of women, taken from university students. All the pictures were taken in the same environment, in a frontal position, and the subjects were aged 18 to 30. All the images have the same proportion - 2000 pixels by 3008 pixels. They also keep the same distance between the photographed and the camera. This means that the input image that will be enhanced needs to be normalized accordingly. All the images had 71 located feature points, as well as 194 distances calculated between them (both shown in Figure 2).

In addition, each image was awarded an attractiveness score. This score was obtained on the basis of an evaluation carried out by 40 volunteers. All the volunteers gave a facial attractiveness score for all the images in the database. The men's and women's faces were evaluated separately. The evaluation consisted of 3 phases: in the first, all the faces were shown in thumbnails, so the volunteers could have an idea of all the faces that they would have to assess; in the second phase, all the pictures were shown individually and in high resolution, so the volunteer could award an attractiveness score for each face more effectively; finally, in the last phase, all the faces were shown in thumbnails again but now grouped by different scores, so the volunteers could check if the groups were consistent. During this phase, it was also possible to adjust the scores linked to each image. All the pictures were randomly shown to the volunteers. The attractiveness score for each face was calculated by finding the average of all 40 evaluations. All this data information is important to build our training set. Our training set was formed by the distances between the feature points of each face, and the attractiveness scores associated with each set of distances.

2) Extraction of Data: This activity consists of obtaining information of interest from the input image. Essentially, it is



(a) (b)

Fig. 2: (a) 71 Locations of feature points; (b) 194 Measured distances.

necessary to locate the same feature points identified in the training set, as well as the same distances between them for the input face. It should be noted that the input image does not belong to the training set. All feature points were manually determined.

3) Obtaining New Measures: The next step consists of weighting the faces belonging to the training set on the basis of the set of distances extracted from the input image. This weighting is based on the attractiveness scores and the proximity of the set of distances of the faces in the training set are from the set of distances of the input face. This is illustrated in Equation 1 where A_n is the attractive score of the compared face, v is the distance vector of the input face and v_n the distance vector of the compared face.

$$w_n = \frac{A_n}{\sum |v - v_n|} \quad (1)$$

Thus, the faces in the training set are considered to be more important, the more attractive and closer they are to the target face. All the faces are arranged in descending order of weights. After that, two supervised learning algorithms are employed: KNN (K Nearest Neighbor) and SVR (Support Vector Regression). The KNN algorithm is responsible for calculating new sets of distances for the input face. The new sets of distances are calculated for different values of K using an arithmetic average. After taking account of all the new sets of distances created by KNN, it's necessary to know which of them is the best choice. The SVR technique, which was previously trained to use our training set, was employed for this and is able to assign an attractiveness score for all the new sets of distances produced by the KNN technique. The joint performance of KNN and SVR allows the value of K to be determined according to the highest score of attractiveness. Thus, the set that resulted in the highest rating is used for the geometric transformation of the input face.

4) Warp Input Face: This is the last step of geometric alterations. At this point, it is necessary to convert the set of distances that have been chosen into feature point locations. As a result of the original and new locations of the feature points, the image of the target face is distorted by employing the warping technique with radial basis function [15]. Thus, a new face geometrically modified image is created.

B. Modification of Skin Texture

Facial skin plays an important role in attractiveness since it occupies the largest area of the face and its color and texture are usually associated with health, cleanliness and care.

We decided to change the colors of the pixels in the facial skin region on the basis of the faces that led to geometric alterations. This choice is based on two factors. First, the faces that were chosen for alteration in the input face geometry are those that have a similar structure to this face. Second, as the images evaluated by volunteers were colored images, we assumed that they would convey more than geometric attractiveness, and can reveal other information about the nature of attractiveness. It is important to mention that our training set is composed of faces from only one ethnic group - Caucasian in our case. The handling of facial images from a variety of ethnic groups is not addressed in our work and remains an open issue.

The process of modifying the skin texture can be divided into three stages, as shown in Figure 1: the creation of a smooth mask, the warping of face set and, finally, the composition of the final image.

1) Creating a Smooth Mask: As input, this stage receives the new positions of the feature points and the image generated by the geometric modification procedure.

The smooth mask is in fact a composition of some other partial masks that treat different aspects of the face and try to accurately isolate the skin region. This is necessary because some input images may have hair covering the facial skin area, which means that the new locations of the feature points are not enough to determine the actual skin region (see Figure 3).

(a) (b)

Fig. 3: (a) Contour elements established by the feature points; (b) Skin texture modified in the area determined by the feature points results a problem in the hair region.

The first partial mask created is the contour mask formed by the location of the new feature points, see Figure 4(a). The second partial mask created is called the threshold mask. At first, a hair region is selected int the geometrically modified face (the hair region is determined by the area of a square of 15x15 pixels, 50 pixels above the top facial feature point). Then, it is calculated the average of the pixel colors of this region. This average represents the average pixel color of the hair and it will be used as our threshold value. Pixel values below this average are considered skin tone and those above are not.

In addition, all the internal facial features left by the threshold are eliminated by removing the pixels that cannot be reached by filling in the background from the edge of the image. An average filter, 30x30, is also applied to obtain smooth edges. Finally, the image is binarized, see Figure 4(b).

The next stage consists of an intersection operation between both masks - the contour mask and the threshold mask (Figure 4(c)). This new created mask shows us the skin area by removing hair region when it is covering the skin area. We created two images on the basis of this last mask: one dilated and another eroded, so that after subtracting them, we were able to obtain an image with the contour of the skin, see Figure 4(d).

Now facial elements are added to the mask, such as the mouth, with the aid of the locations of its feature points, see Figure 4(e). On the basis of this image , it is finally possible to create the final smooth mask. A smooth mask is necessary to ensure that the edges between the skin and the rest of the image are not going to be rough in the contour. Our algorithm defines a graduated contour for each facial element, except for the eyes, since the points are defined around the eyeball, which differs significantly from the skin region. However, this situation does arise in the contours of the eyebrows and mouth, where the region of the contour skin is mingled with these elements.

A seed point is established closer to the center of each element: one for the face contour, one for each eyebrow and one for the mouth. The main idea here is that the closer the pixel is to the edge, the less likely it is to be changed, and the closer the pixel is to the seed, the more likely it is to be changed.

The following algorithm was employed for each facial element. The first stage consists of checking if the pixel belongs to the element contour where the graduation is being calculated. If it belongs to the element, the Euclidean distance is calculated between this pixel and the seed of the element, which is called the ”general distance”. The graduation will be applied only on the pixels that are close to the contour edge. The percentage, p, defines the width of the border that will have graduation. For example, in the case of the face contour, the width of the graduated border is broader, with p=80%, while the width of the graduated border on the internal elements, such as the mouth, has p=20%.

A line is established for all the contour pixels by connecting the pixel to the seed of that element. This line can be established by different algorithms such as DDA (Digital Differential Analyzer) [16], which is responsible for identifying

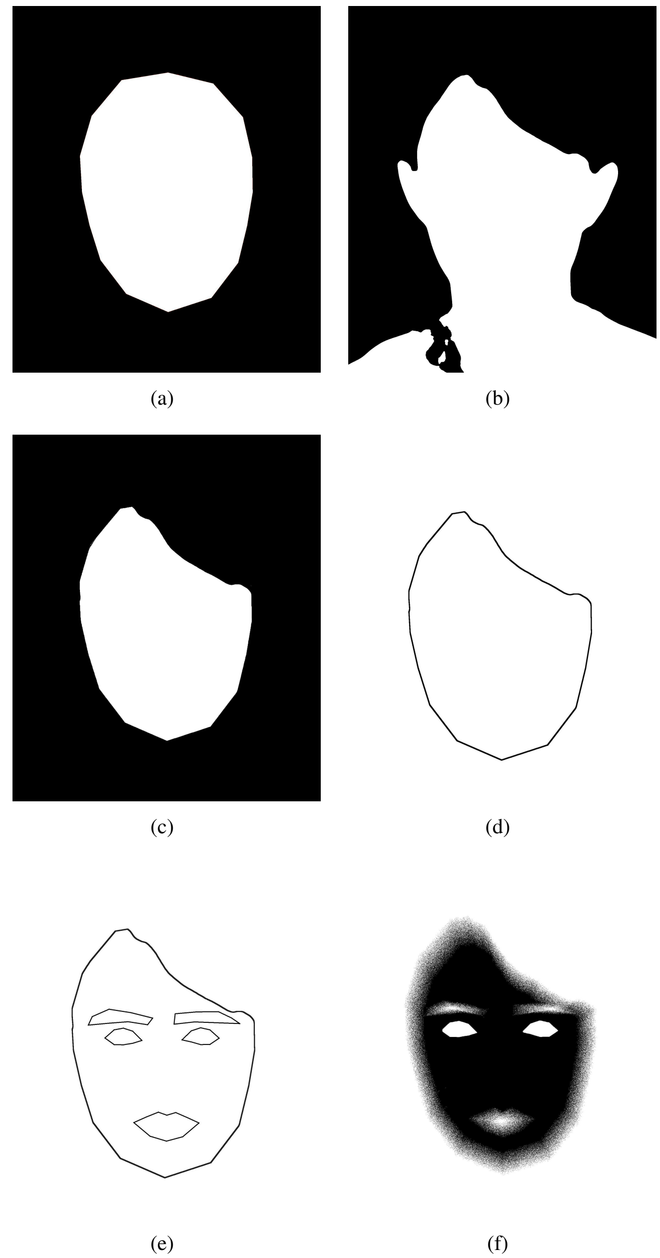


Fig. 4: (a) Contour mask established by feature points; (b) Threshold mask; (c) Intersection operation of (a) and (b); (d) Facial skin area; (e) All elements of the contour; (f) Smooth mask.

the pixels that form a straight boundary-line between the pixel and the seed point.

The Euclidean distance from the seed of each pixel identified is also calculated and called as the ”local distance”. With the local distance, it is possible to identify whether the pixel is below the percentage that will be changed, or if it is above the percentage in the region that will undergo graduation. For this reason, It is necessary to calculate the ratio of the local distance using the general distance. If the resulting value is below the percentage established, the pixel must be changed;

otherwise it is necessary to calculate the relative distance shown in Equation 2.

$$d_{Relative} = \frac{d_{Local} - p * d_{General}}{(1-p) * d_{General}} \quad (2)$$

The relative distance must be calculated to create a graduation closer to the edge. This is to enable us to know how close the pixel is from the edge or from the percentage limit; moreover, a random number between 0 and 1 must also be generated. The random number is necessary to avoid creating tracks of graduation since a more natural smoothness is needed. Thus, if the random number is greater then the relative distance calculated, the pixel is changed; otherwise it is not.

When this algorithm is applied to all the facial elements (except the eyes), a smooth mask is obtained, as shown in Figure 4(f), where only the dark pixels will have their pixel value modified to ensure that the edges will not be roughly marked.

2) Warp face set: In this stage the following are received as input: the new locations of the feature points and the subset of facial images that led to modifications in the facial geometry. Each facial image of the subset is warped to fit the new locations of the feature points that have been found for the input image. The skin texture of the input image is modified in accordance with the pixel values assigned to the skin region of the subset of warped images.

3) Compose final image: In this stage, the final image is composed by using the smooth mask created and all the warped facial images. In the case of all the dark pixels belonging to the smooth mask (Figure 4(f)), the color of the pixels will be calculated by a weighted average, where 50% is given to the original pixel values and 50% is given to the arithmetic average of the pixels of all the faces from the subset, (see schema in Figure 5). We decided to give a high weight to the original face, to keep the resulting image similar to the original, but other alternatives can be explored, depending on the scope of the modification.

IV. Results and Discussion

Our method has been tested with different input images for male and female faces. Figure 6 and Figure 7 show examples of our results for a man and for a woman, respectively. Four pictures are shown for each example: the original one, the picture with only facial geometrical modifications, the picture with only skin texture modifications, and finally, the picture with both modifications at the same time.

The effects of each of the alterations on enhancing facial attractiveness were analyzed by carrying out evaluations with volunteers. We asked university students to evaluate the pictures according to their attractiveness. In this evaluation four pictures of the same person were shown to them at random, (as shown in Figures 6 and 7). They were instructed to look at the pictures and arrange them according to their attractiveness, by ordering them from the least attractive to the most attractive. There was no time limit. 50 volunteers evaluated 42 sets of

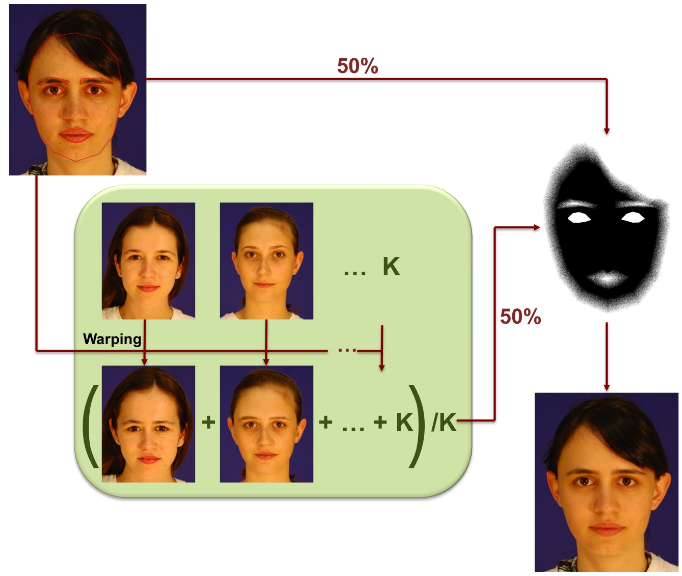


Fig. 5: Schema that represents the composition of the final image.

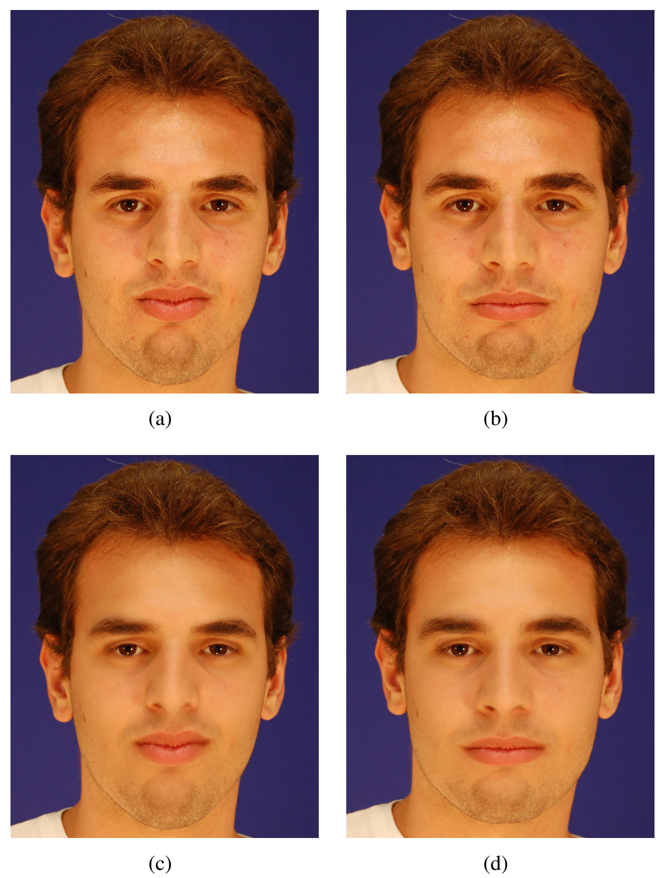


Fig. 6: (a) Original picture; (b) Geometrically modified; (c) Skin Texture modified; (d) Modified both Geometrically and for the Skin Texture.

pictures, all using the same equipment (screen and machine),

(a) (b) (c) (d)

Fig. 7: (a) Original picture; (b) Geometrically modified; (c) Skin Texture modified; (d) Modified both Geometrically and for the Skin Texture.

in a separate room, which ensured that there was no outside interference, or difference in the quality of the vizualization during the evaluation.

The results are shown in Figure 8. Each pie chart represents a different modification: the original picture that has no modifications; pictures with facial geometrical modifications; pictures with skin texture modifications and pictures with facial geometrical and skin texture modifications. These charts classify each modification given from the average of the volunteers, and rage from not attractive at all (red), unattractive (yellow), attractive (blue) and very attractive (green).

It is worth noting that with regard to the original pictures, with no modification (Figure 8(a)), in most cases (93%) were classified in the two lowest attractiveness categories: not attractive at all or unattractive. In contrast, with regard to pictures where our method was employed (i.e. with both modifications) (Figure 8(d)), in most cases (92%) were classified in the two highest attractiveness categories - attractive and very attractive. In addition, compared with the isolated modifications, our method (which combines both modifications) obtained the highest attractiveness scores. It is clear that the proposed methodology succeeded in enhancing the facial attractiveness of the images.

The results also show that pictures with only facial geometrical alterations (Figure 8(b)) were awarded the highest percentage rating (75%) in the two lowest attractiveness categories, while, pictures with only skin texture modifications (Figure 8(c)) received the highest percentage rating (77%) in the two highest attractiveness categories. These results suggest that skin texture modification is more important for facial attractiveness than facial geometry modification.

A second type of evaluation was also conducted which, only took account of the pictures where our method was employed. Our aim was to check the gain in attractiveness obtained by each face. This evaluation was similar to the one carried out during the geometric modification procedure, when all the original pictures were evaluated by volunteers that formed the training set (as described in Section III-A1). The only difference was that 42 modified pictures replaced the original ones in the set of 267 pictures of the database. This new evaluation also relied on 40 volunteers. The attractiveness score is given in the same way, by the average number of evaluations. Figure 9 shows the result obtained by this evaluation. The horizontal axis represents the 42 faces that were altered, and the vertical axis represents the attractiveness scores. The faces were sorted according to the original score from the lowest to the highest score. The red bars represent the new attractiveness scores obtained by the modified pictures; the blue bars represent the original scores, obtained by the original pictures; the blue bars are overlap the red ones. The results show that all the faces had their scores increased (as shown in the red area). Another interesting piece of information revealed by this graphic is that there is a downward trend in gain of attractiveness when the original score is greater. In other words, the less attractive the face is in the input image, the higher will be the gain of attractiveness that it will have after our method has been employed. The more attractive the face is in the input image, the lower will be the gain in attractiveness.

V. Conclusion

This study has provided a detailed account of an automated system for enhancing facial attractiveness in images. To the best of our knowledge, our work is the first to combine facial geometric alterations with facial skin texture modification in a single unified system for improving attractiveness, while seeking to ensure the pictures remained photorealistic. The results produced by our technique were analyzed by evaluations that showed that it is effective and really leads to an improvement in image attractiveness. Although our method makes a significant step forward, we discovered several challenging issues for future research in the area of enhancement of attractiveness in visual media. For example, this work could be extended to increase the attractiveness of 2D video presenters, which can involve virtual sellers, virtual tutors, game characters, news presenters, and other kinds of situations. Our method, however, has a limited database image with faces in frontal position, with subjects between 18 and 30 years old. It might be worth extending this database to include other facial positions and

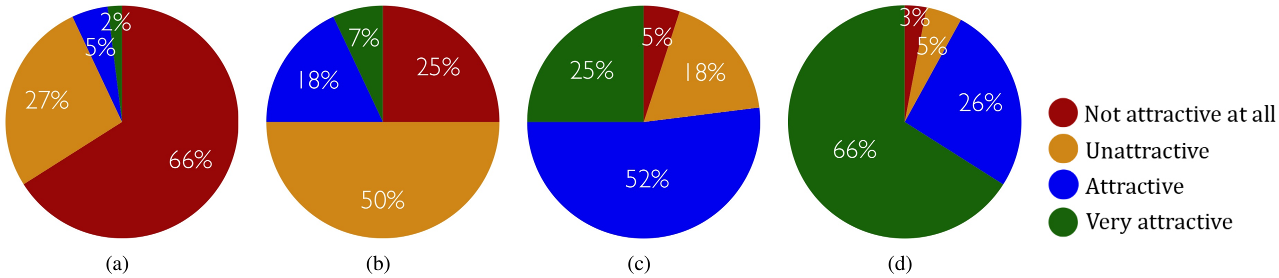


Fig. 8: (a) Original picture; (b) Geometrically modified; (c) Skin Texture modified; (d) Modified both Geometrically and for the Skin Texture.

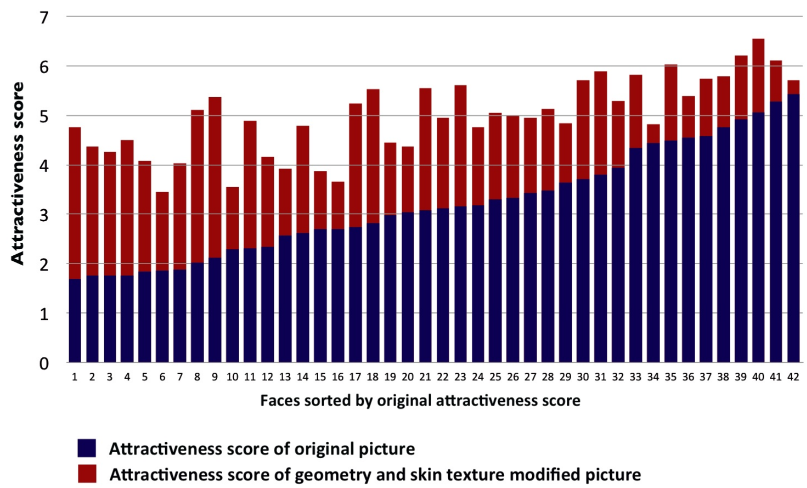


Fig. 9: Comparison of the attractiveness score between the original and modified pictures.

widen the age limit. The database extension can enable our method to be used for video as well. Furthermore, our method does not allow changes in 3D facial meshes, since it is limited to 2D images. Moreover, in the next stage in this area the same ideas used in 2D should be adapted to 3D, since 3D is becoming increasingly important.

Lastly, the feature points data used in this work are available online for public use at http://www.dca.fee.unicamp.br/~martino/face_attractiveness.

References

[1] T. Leyvand, D. Cohen-Or, G. Dror, and D. Lischinski, "Data-driven enhancement of facial attractiveness," *ACM Transactions on Graphics*, vol. 27, no. 3, pp. 38:1–38:9, 2008.

[2] S. Melacci, L. Sarti, M. Maggini, and M. Gori, "A template-based approach to automatic face enhancement," *Pattern Analysis and Applications*, vol. 13, no. 3, pp. 289–300, 2010.

[3] D. Zhang, Q. Zhao, and F. Chen, "Quantitative analysis of human facial beauty using geometric features," *Pattern Recognition*, vol. 44, no. 4, pp. 940–950, 2011.

[4] B. Fink, K. Grammer, and R. Thornhill, "Human (homo sapiens) facial attractiveness in relation to skin texture and color," *Journal of Comparative Psychology*, vol. 115, no. 1, pp. 92–99, 2001.

[5] B. Finka, K. Grammerb, and P. J. Mattsc, "Visible skin color distribution plays a role in the perception of age, attractiveness, and health in female faces," *Evolution and Human Behavior*, vol. 27, no. 6, pp. 433–442, 2006.

[6] J. H. Langlois and L. A. Roggman, "Attractive faces are only average," *Psychological Science*, vol. 1, no. 2, pp. 115–121, 1990.

[7] D. I. Perrett, K. A. May, and S. Yoshikawa, "Facial shape and judgements of female attractiveness," *Nature*, vol. 368, no. 6468, pp. 239–242, 1994.

[8] J. H. Langlois, J. M. Ritter, L. A. Roggman, and L. S. Vaughn, "Facial diversity and infant preferences for attractive faces," *Developmental Psychology*, vol. 27, no. 1, pp. 79–84, 1991.

[9] J. H. Langlois, L. A. Roggman, R. J. Casey, and J. M. Ritter, "Infant preferences for attractive faces: Rudiments of a stereotype?" *Developmental Psychology*, vol. 23, no. 3, pp. 363–369, 1987.

[10] A. Slater, G. Bremner, S. P. Johnson, P. Sherwood, R. Hayes, and E. Brown, "Newborn infants' preference for attractive faces: The role of internal and external facial features," *Infancy*, vol. 1, no. 2, pp. 265–274, 2000.

[11] Y. Eisenthal, G. Dror, and E. Ruppin, "Facial attractiveness: Beauty and the machine," *Neural Computation*, vol. 18, no. 1, pp. 119–142, 2006.

[12] D. I. Perrett, D. M. Burt, I. S. Penton-Voak, K. J. Lee, D. A. Rowland, and R. Edwards, "Symmetry and human facial attractiveness," *Evolution and Human Behavior*, vol. 20, no. 5, pp. 295–307, 1999.

[13] J. H. Langlois, L. A. Roggman, and L. Musselman, "What is average and what is not average about attractive faces?" *Psychological Science*, vol. 5, no. 4, pp. 214–220, 1994.

[14] B. Tiddeman, M. Burt, and D. Perrett, "Prototyping and transforming facial textures for perception research," *IEEE Computer Graphics and Applications*, vol. 21, no. 4, pp. 42–50, 2001.

[15] D. Ruprecht and H. Muller, "Image warping with scattered data interpolation," *IEEE Computer Graphics and Applications*, vol. 15, no. 2, pp. 37–43, 1995.

[16] D. F. Rogers, *Procedural Elements for Computer Graphics*. Mc Graw Hill, 1985.