Chapter 5

PREDICTION OF OUTPUT IMAGE USING MORPHING

Objective

To predict older image S_k of a child S at target age k using morphing method.

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The term morphing has been derived from the word “metamorphosis”. Metamorphosis means to change shape, appearance or form of an object to another.

In simple word, morphing is a technique of image processing which is used for the transformation of shape, appearance or form from one image to another. The three major steps involved in morphing process can be generalised as follows:

1. This process needs two input images known as source and target. In the first step, corresponding one-to-one points of source and target images has to be established.

2. In second step, a mean shape (average shape of source and target image) has to be calculated. Then with a suitable warping function both the source and target images have to be warped into the mean shape, and two warped images will be obtained.

3. Then finally one mean image will be calculated from the two warped images obtained in step 2, which will be the required morphed image of the inputs.

Two examples of morphed images are shown in Figure 5.1, where first experiment of morphing is done without warping and it produces unrealistic images as facial feature points of source and target are not aligned in the morphoed images. Whereas in second experiment, morphing is done with warping, and it shows a smooth transformation of images from source to target. In Figure 5.1, i^{th} morphed image $M_i, i = 1 \ldots n$ is found with the following equation

$$M_i = S \times (1 - \theta) + T \times \theta \tag{5.1}$$

where S and T are source and target images respectively and $\theta = i/(n+1)$ and n is number of required images in the sequence of morphed images.

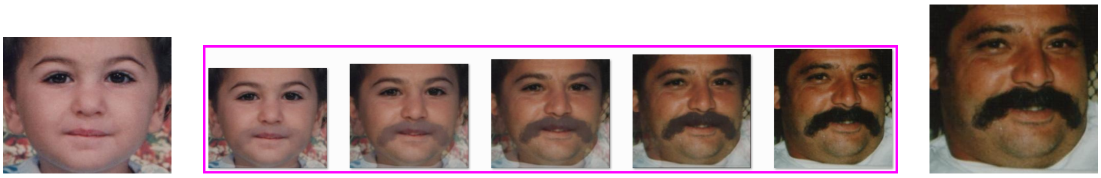
The main applications of morphing technique includes the fields of entertainment, game, multimedia *etc.*

As stated in chapter 2, we have a proposal of a morphing based technique to automatically produce synthesized age progressed face images for a childs face image. The proposed technique has been discussed in the successive sections.

5.1 Related Works of Morphing

There is a vast research in image morphing. A good survey of the morphing technique has been discussed by G. Wolberg [82], E. Wu et al. [83], R. Deepalakshmi et al. [16], and Gui B. Liberali et al. [43].

(a) Source (b) Morphed images (without warping) (c) Target



(d) Source (e) Morphed images (with warping) (f) Target

Figure 5.1: Morphing images from source to target. In first row (a) to (c), morphing without warping produces unrealistic images as facial feature points of source and target are not aligned in the morphoed images. Whether in second row (d) to (f), morphing images with warping shows a smooth transformation from source to target.

Generally morphing methods can be categorized into three major categories according to their warping approach: (a) mesh-based, (b) feature-based and (c) scattered point data interpolation based. Some more methods like field morphing, energy minimization method, multilevel free-form deformation *etc.* have been discussed by George Wolberg [81]. In the mesh-based methods [47, 80], source and target images are meshed based on specified features of the two images. Then warps the two images according to the corresponding mesh points, and blends the source and target warped images to complete the morphing. These methods are efficient and intuitive, and appear to be at most convenience in mesh-based morphing but it is difficult to specify the required features by users.

In the feature-based morphing methods [6, 7] pairs of lines are used to specify features and which simplifies the user interface in the process. The corresponding pixels are mapped according to the distance and position of a pixel to feature lines. Here sequence images of the morphing process is the result by alignment of two warped images which match together on their corresponding line features. This type of method has a disadvantage in using lines to specify features, since it is not so easy to describe a complex object by straight lines especially for an object with curve borders.

Lee et al. [40] has described another category based on scattered point data interpolation method specifying features using a set of points. This type of methods assured that the images in the sequence of morphing process does not fold and a smooth warp generated.

Urvashi et al. [8] implemented image morphing using mesh warping algorithm combined with the cross dissolving technique. The algorithms used were fast and intuitive, which efficiently computed the mapping of each pixel from the source image to the destination image. The mesh was formed of triangles obtained from the manually specified control points.

Y Guo *et.al*. [27] have presented an efficient algorithm for transforming the viewpoints of cuboid-structured images. In this algorithm the new image with high visual quality is generated by making the rest image region deform in accordance with the re-projected cuboid structure, via a triangular mesh deformation scheme and demonstrated an application of upright adjustment of photographs and a user interface which enables the user to watch the scene under new viewpoints on a viewing sphere interactively.

In all the methods described above, they usually blended images after warping to create in-between images in the sequence of morphing. The blending of warped images in each frame is not so satisfactory which produces the blurring and ghost images during the process of morphing. Some more works are also going on to improve the blending processing to minimize the blur and ghost problem. Hu et al. [32] proposed a physics-based blending method, and recently, Stich et al. [65] use an optical flow technique to refine warping and a nonlinear blending scheme to produce smoother interpolations.

5.2 A Morphing Based Technique to Predict Older Face Images of a Child

The block diagram of this proposed work of "Morphing Based Technique to Predict Older Face Images of a Child" is given in Figure 5.2. The main steps to achieve the results of this morphing technique are given as below:

1. Take inputs of source and target images,
2. Preprocess inputs to detect the facial part and find facial feature points,
3. Find detected face and feature points of source (shape),
4. Find detected face and feature points of target (shape),
5. Find intermediate feature points (shape),

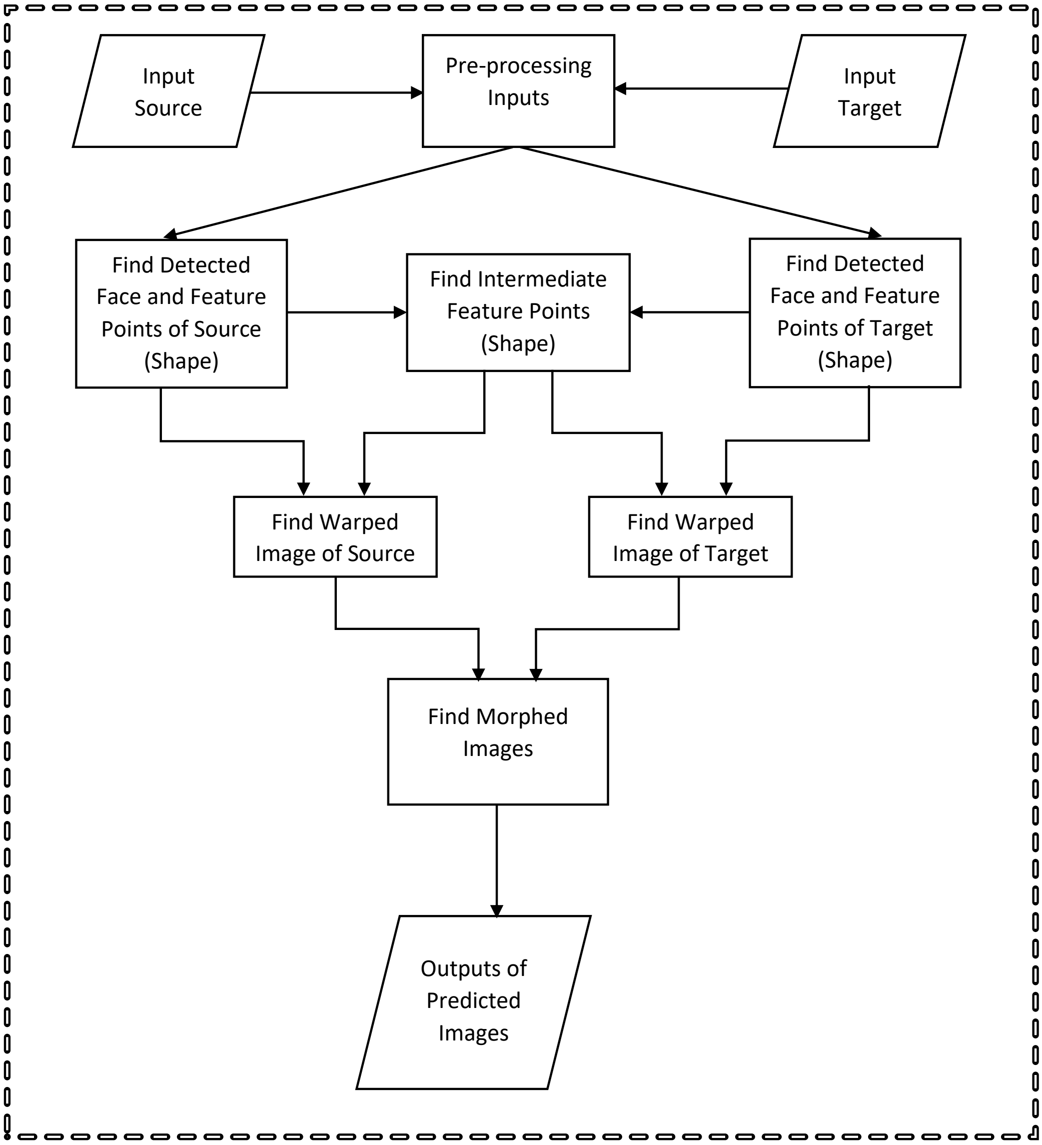


Figure 5.2: Morphing Based Technique to Predict Older Face Images of a Child

6. Find warped image of source,
7. Find warped image of target,
8. Find morph images,

5.2.1 Take inputs of source and target images

In our method of morphing process two input images are required. We call source image S which is the first input image, and target image T which is the second input image.

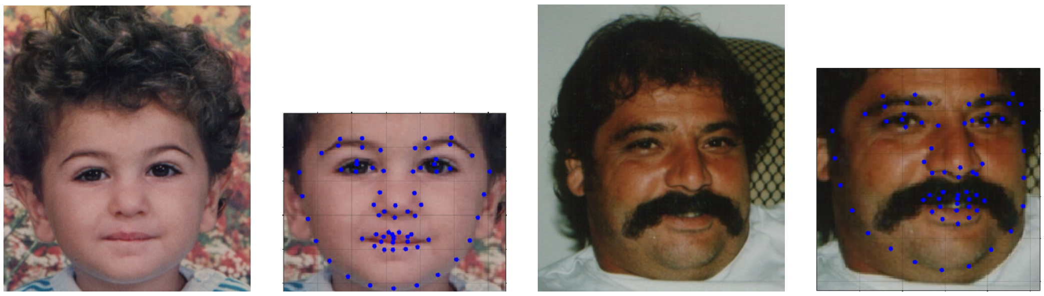
5.2.1.1 Model or Target Image Selection

In morphing technique we need two input images source image S and target image T as mentioned in previous section. The target image T can be a prototype or a mean image of several face images, or a matching older image of source S or an older familial face image. To select an older familial face image we suggest the following options, the choices are shown below in order of preference.

1. Brother/sister, or
2. Father/mother, or
3. Grandfather/grandmother, or
4. Close relative

5.2.2 Preprocess Inputs

The input images S and T are preprocessed to extract the face according to the steps given in Section 3.3.2 in Chapter 3, and find the corresponding feature point sets SS and TS of the source and target images S and T respectively by the method described in Section 3.3.3 of Chapter 3. The formation of these two sets are given by Equation 5.2 in Section 5.2.5.



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

Figure 5.3: Inputs and preprocessing to get face detection and feature points. (a) Input of a child, (b) Detected face and feature points of (a), (c) Input of target old face image, (d) Detected face and feature points of (c)

5.2.3 Find Detected Face and Feature Points of Source (Shape)

Detect the face image from the first raw input image using the technique described in section 3.3.3 of Chapter 3, which will be considered as the source image S, *i.e* child's face image. Then localize the facial feature points SS from this source image S as described in the mentioned Chapter (Figure 5.3(a), (b)).

5.2.4 Find Detected Face and Feature Points of Target (Shape)

Similarly, detect the face image from the second raw input image using the technique described in section 3.3.3 of chapter 3, which will be considered as the target image T, *i.e* older face image. Then localize the facial feature points TS from this target image T as described in the mentioned Chapter (Figure 5.3 (c), (d)).

5.2.5 Find Intermediate Feature Points (Shape)

The shape SS and TS, obtained in the previous step, are denoted by the following two given sets,

$$\begin{aligned} SS &= \{P_1^S, P_2^S \dots P_{68}^S\} \\ TS &= \{P_1^T, P_2^T \dots P_{68}^T\} \end{aligned} \tag{5.2}$$

where $(P_i^S, P_i^T), i = 1 \dots 68$ are set of feature points (dots in the images of (b) and (d) in Figure 5.3) of source and target images S and T respectively. These feature points or land mark points are calculated using the technique of localization of feature points described in Chapter 3.

To find out the intermediate feature points or shapes (Figure 5.4) of source

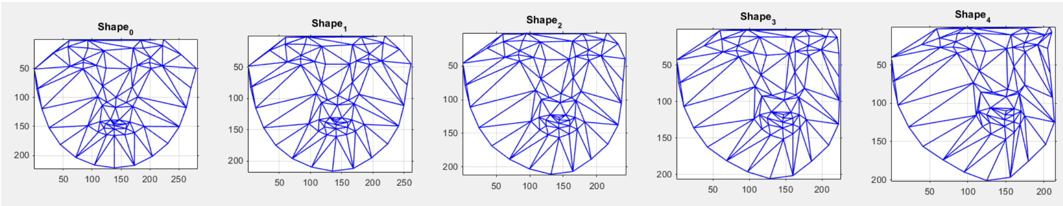


Figure 5.4: Intermediate shapes in the sequence of morphing, the first shape is of source and last shape is of target images respectively.

and target images in morphing technique, we calculate the set of feature point locations of k^{th} shape $Shape_k = \{(Shape_k^{xi}, Shape_k^{yi}) \mid i = 1 \ldots 68\}$ with the following Equation 5.3.

$$\begin{aligned} Shape_k^{xi} &= SS^{xi} \times (1-\theta) + TS^{xi} \times \theta \\ Shape_k^{yi} &= SS^{yi} \times (1-\theta) + TS^{yi} \times \theta \end{aligned} \tag{5.3}$$

where (SS^{xi}, SS^{yi}) and (TS^{xi}, TS^{yi}) are the coordinates of i^{th} feature point of source and target shapes SS, TS respectively, $\theta = k/(n+1)$, n is number of required shapes in the sequence.

The values of θ represents the amount of contribution of shape which has to be taken form source shape SS and target shape TS. Lower values of θ indicates higher contribution of source shape and less contribution of target shape. Again in reverse, higher values of θ indicates less contribution of source shape and higher contribution of target shape.

5.2.6 Find Warped Image of Source and Target

To perform the morphing method for two given images S and T (Figure 5.3), source and target respectively, we have to find n pairs of in-between warped images of S and T in the sequence of n morphed images. To find the k^{th} warped images ($k = 1 \ldots n$) $Warp_k^S$ and $Warp_k^T$ (1^{st} and 3^{rd} row of Figure 5.5) of source and target images we use the following Equation 5.4. Here $Warp_k^S$ and $Warp_k^T$ are the transformed images of S and T whose shapes and sizes are unique as of $Shape_k$ (4^{th} row of Figure 5.5).

$$\begin{aligned} Warp_k^S &= Warp(S, Shape_k) \\ Warp_k^T &= Warp(T, Shape_k) \end{aligned} \tag{5.4}$$

where $Shape_k$ is the k^{th} shape in source S and target T that have been warped, function $Warp$ is calculated using the technique of image warping described in the

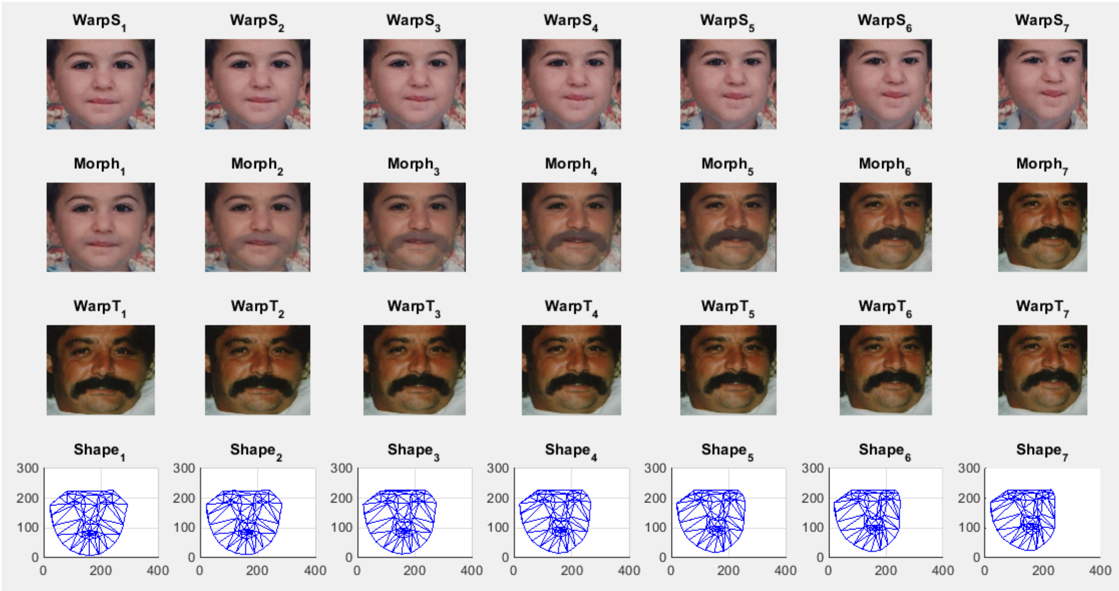


Figure 5.5: Sequence of shapes, warped and morphed images of morphing technique. Input and target images are chosen from the Figure 5.3.

previous Chapter 4.

5.2.7 Find Morph images

In this step we will get a sequence of morphing images which are obtained using cross dissolving of warped images of source and target found in previous step. The k^{th} morphed image $Morph_k$ (2^{nd} row of Figure 5.5, $k = 1 \dots n$, n is number of morphed images) is the cross-dissolved image of two images which are called as source $Warp_k^S$ and target $Warp_k^T$ warped images respectively. Here warped images $Warp_k^S$ and $Warp_k^T$ are computed by Equation 5.4, which are reformed from the two given images source S and target T images respectively. By cross dissolving these two warped images k^{th} morphed image $Morph_k$ is computed with the given Equation 5.5,

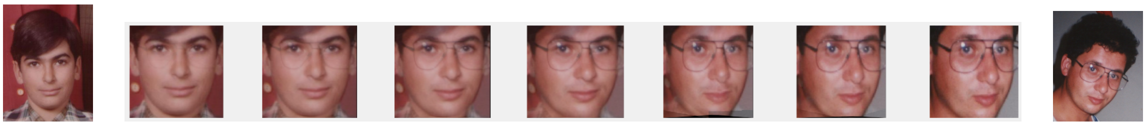
$$Morph_k = Warp_k^S \times (1 - \theta) + Warp_k^T \times \theta \tag{5.5}$$

where $\theta = k/(n+1), k = 1 \dots n$, n is number of required intermediate morphed images in the sequence.

The roles of θ is same as stated in earlier section of “Find Intermediate Feature Points (Shape)”. The difference is of shape and color informations of source and target images. So, similar to the shape transformation, values of θ represents the amount of color contribution of k^{th} morph image $Morph_k$ which has to be taken form source image S and target image T. Lower values of θ indicates higher

Source Morphed images- transition from female to male Target

Figure 5.6: Sequence of morphing images from female to male image



Source Morphed images- transition from child to adult Target

Figure 5.7: Sequence of morphing images from child to adult image.

contribution of source image and less contribution of target image. Again in reverse, higher values of θ indicates less contribution of source image and higher contribution of target image. Some experimental results of this process to find morph images are shown in second row of Figure 5.5, and in Figure 5.6 and 5.7.

5.3 Find Predicted Face Image of Age k of a Child using Morphing

Given a child image S of age a, and a adult image T of age b, find the predicted image S_k which is synthesized face image of age k of the child, $a < k < b$.

To solve this problem, find the value of θ at age k for the Equations 5.3 and 5.5. As shown in Figure 5.12, we have,
$n = b - a$

$\delta = \frac{1}{n}$

At age a, value of $\theta = \delta = \frac{1}{n}$

At age b, value of $\theta = n \times \delta = 1$

At age k, value of $\theta = (k - a) \times \delta$

Using this value of θ, we get $Warp^S$ and $Warp^T$ for S and T from Equation 5.3. Then from Equation 5.5, we get our predicted image S_k by

$$S_k = Warp^S \times (1 - \theta) + Warp^T \times \theta \tag{5.6}$$

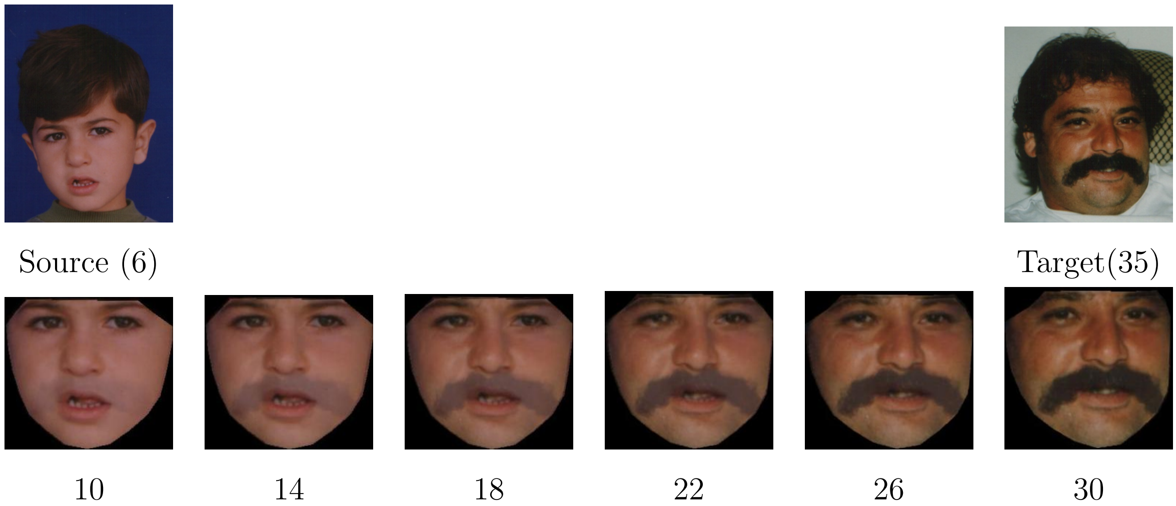


Figure 5.8: **Problem-** muchee has been appeared in early aged predicted images of ages 10,14 *etc*, this problem arises because of high age difference of source and target images (> 15). Solution of this problem has been shown in Figure 5.10.

5.4 Prediction of Older Images for which Age Difference of Source and Target is High

Some time if we want to get predicted face images of higher age group, i.e age difference of source and target is more than 15, then we might have some unexpected predicted images as shown in Figure 5.8. In the said figure a sequence of predicted images have been shown from age 10 to 30, where the ages of source and target images are 06 and 35 years respectively. In this result of normal prediction technique, muchee has been appeared in early aged predicted images of ages like 10 and 14 years, which result is not acceptable. Similarly same problematic result may arise in the cases when target images are having beard or target images are very old *i.e.* age difference of source and target image is > 15. We have solved this issue using the proposed model as shown in Figure 5.9 and solution of the above mentioned figure has been shown in Figure 5.10. We find two intermediate real images A and B of age $m = (a + b)/2$, where a and b are the given ages of source and target images respectively. Here A and B can be found by the face recognizer tool described in Section 6.1.2 in next chapter. If we try to recognize source and target images in the dataset of age group of m, then the recognizer will return two images A and B with maximum confidence score for source and target images. Then we find synthesized intermediate image $M = (A + B)/2$ using our normal proposed prediction technique. Now we have two pair of inputs $(source, M)$ and

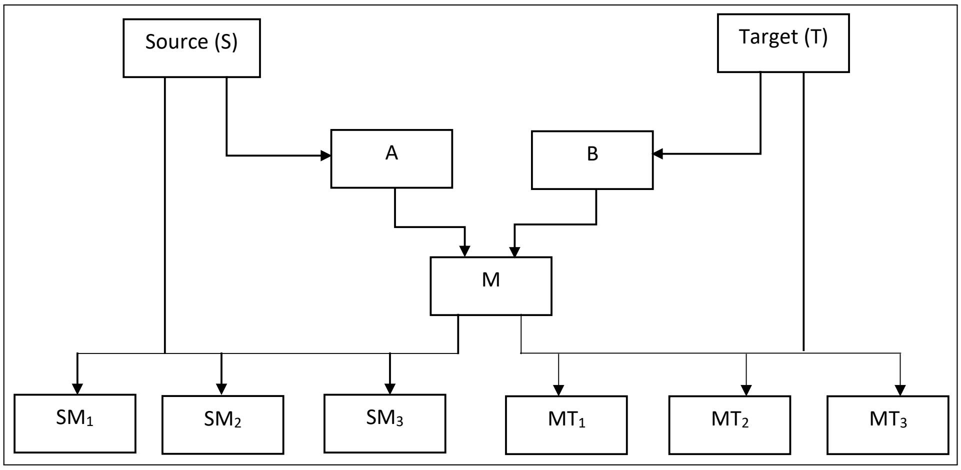


Figure 5.9: Prediction of older images for which age difference of source and target is high. A and B are intermediate real images, M is the mid image of A and B, $SM_1, SM_2 \ldots$ are synthesized images of S and M and similarly, $MT_1, MT_2 \ldots$ are synthesized images of M and T.

$(M, target)$, where age pairs will be (a, m) and (m, b). Finally, re-applying the proposed technique of prediction, we will get two groups of synthesized images of age a to m and m to b which solves our problem. The predicted images from younger age (21) to older ages (66) are shown in Figure 5.11, where age difference of target and source image is very high, which is 69-16=53 years.

Some experiments which find predicted images for given child images are shown in Figures 5.13 to 5.16.

Experiment and evaluation of predicted older and ground truth face images are discussed in Chapter 6.

5.5 Conclusion

In this morphing technique two images are taken as inputs, one is child image, and another one is older model image which are also known as source and target images respectively. The model image (target) is selected based on the nearest relationship of the input with the familial face images. These source and target images have been sufficiently preprocessed with the method of face alignment and face extraction. Then facial feature points have been extracted from the input images by which mapping is done for these pair of images. With this necessary mapping information a warping technique has been applied, and these two input images have been being linearly warped into a series of in-between linear shapes of the source and target images. In every step of morphing process, two number

Figure 5.10: Solution of problem Figure 5.8. A, B are real images, which are used to get M the model image (mean of A and B) to predict younger aged images $SM_1, SM_2, \ldots$ and older images $MT_1, MT_2, \ldots$. The terms A, B, M, SM and TM are described in Section 5.4 and Figure 5.9. The respective ages are shown below of the each images.

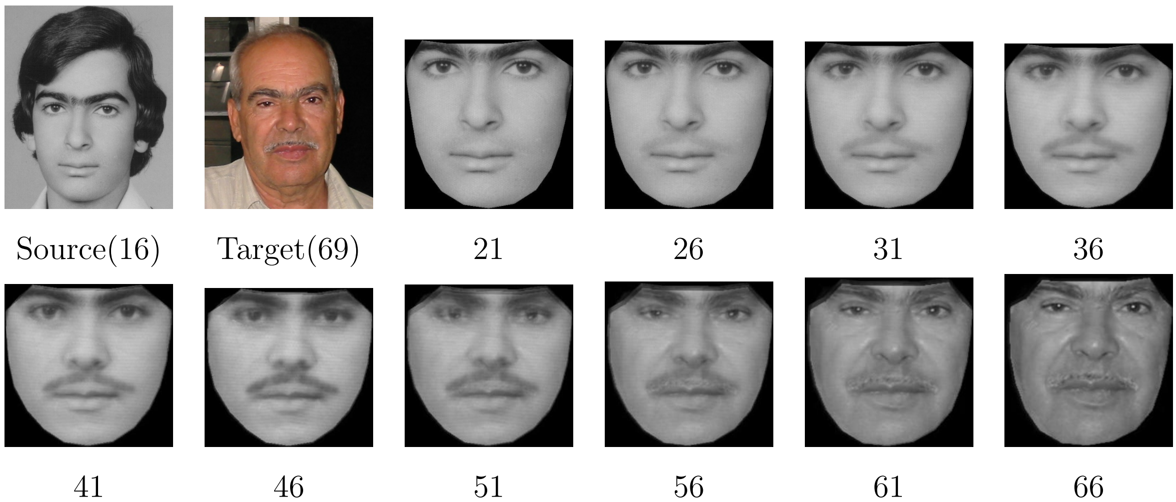


Figure 5.11: Intermediate predicted images from age 21 to 66, where ages of source and target images are 16 and 69 respectively.

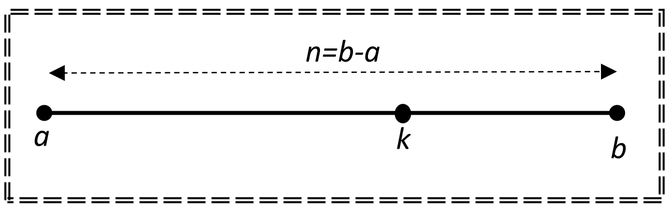


Figure 5.12: Relation of three ages a, b and k.

(a) Source(08) (b) Target(34) (c) Predicted(21) (d) Actual(21)

Figure 5.13: Predicted Face Image at targeted age of a Child-1. (a) Source(08): Child image of age 08 years, (b) Target(34): an adult image of age 34 years, (c) Predicted(21): predicted image of age 21, and (d) Actual(21): actual image of age 21 years. Images are taken from FG-NET database [57]

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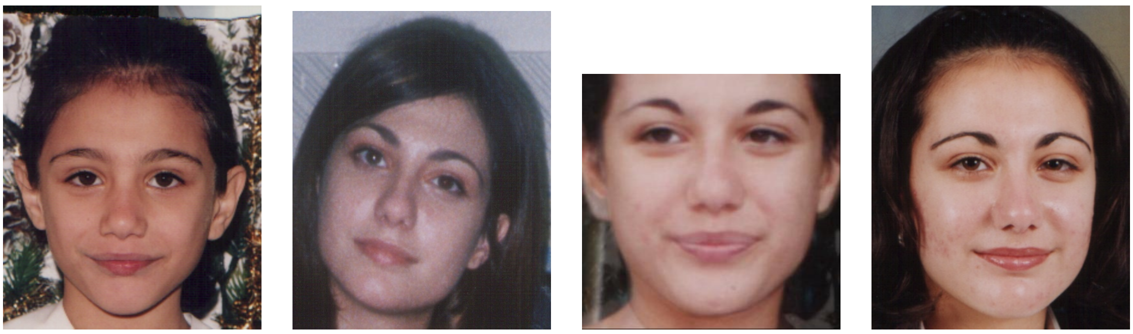

(a) Source(07) (b) Target(20) (c) Predicted(14) (d) Actual(14)

Figure 5.14: Predicted Face Image at targeted age of a Child-2. For a child image of age 07 years in (a), and a adult image of age 20 years in (b), the predicted image of age 14, and in (d)original of the child of age 14 years. Images are taken from FG-NET database [57].

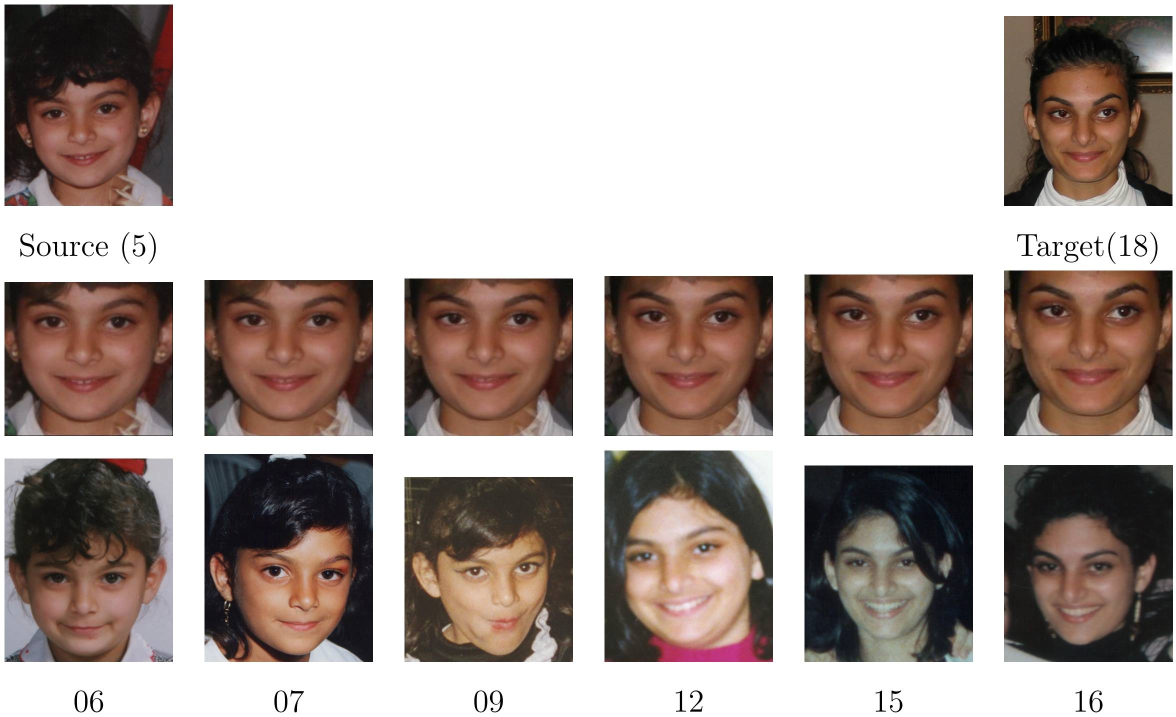

Figure 5.15: Predicted Face Image at targeted age of a Child-3. For a child image of age 05 years and a young image of age 18 years in first row, the predicted images of ages 6, 7, 9, 12, 15 and 16 years in the middle row, and the actual images of same ages are in third row. Images are taken from FG-NET database [57].

of warped images have been formed from the source and target images which are warped into intermediate shape of source and target. Finally these two warped images have been processed to get the morphed images, which is the cross-dissolve images of these two warped images in a particular iteration. Using this technique, a series of intermediate morphed images have been founded which have been treated as the final outputs of our technique, which are also called synthesized predicted older images of the child.

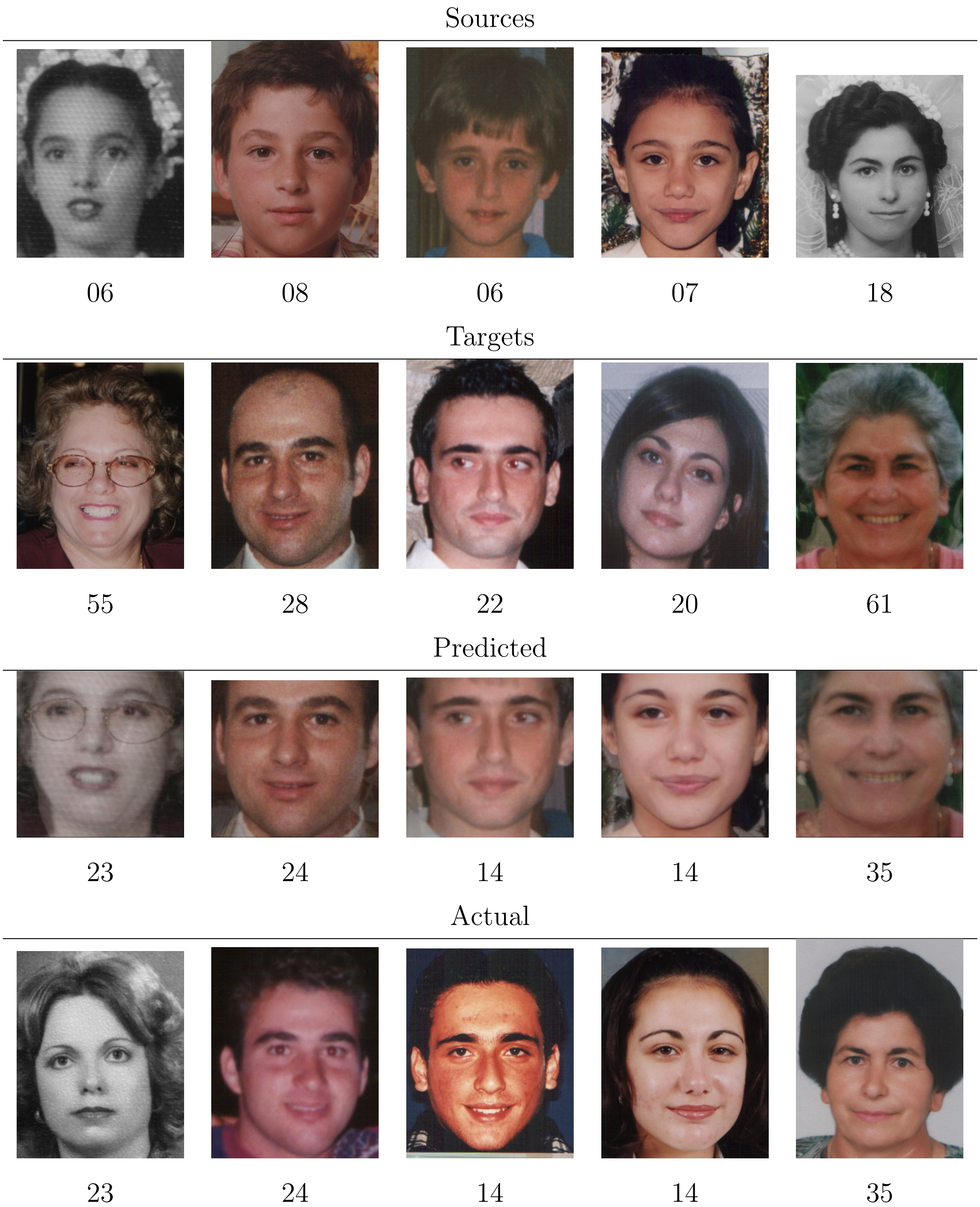

Figure 5.16: Prediction of Child's Future Images: In the first row, Child's images and their respective ages are shown; in second row target model images and corresponding ages are shown; in third row predicted images of targeted ages are shown and in forth row ground truth actual images whose ages are same as predicted images are shown.