

# Warping and Morphing

## Warping

Warping of images [2] is an image-based technique used in computer graphics. The warping equation makes it possible to view the image from a different point of view. The procedure is real-time capable, but produces some artefacts such as detection or masking errors. In contrast to morphing, warping usually provides transformations between images from the same object but from different perspectives.

The currently most commonly used warping algorithm has been developed by Beier and Neeley at the end of the 1980s [1]. It uses user-defined feature points and line pairs to facilitate linear interpolation. The Algorithm is outlined in Algorithm 1.

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**Algorithm 1** Beier-Neeley warping algorithm.

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1: for each destination pixel  $p$  do
2:    $p_{sum} = (0, 0)$ 
3:    $w_{sum} = (0, 0)$ 
4:   for each feature line  $L[i]$  in destination do
5:      $p'[i] = p$  transformed by  $(L[i], L'[i])$ 
6:      $p_{sum} = p_{sum} + p'[i] * weight[i]$ 
7:      $w_{sum} += weight[i]$ 
8:   end for
9:    $p' = \frac{p_{sum}}{w_{sum}}$ 
10:  destination( $p$ ) = source( $p'$ )
11: end for
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possible artefacts:

- Occlusion errors: Image areas that were originally hidden by objects may be visible in the new perspective, but cannot be displayed correctly due to missing information.
- Uncovering errors: Similar to the concealment errors, for example, back sides of the object can become visible here, which are also not displayed correctly.
- External detection error: Objects and scene areas that were outside the image can get into the image. These are also not displayed.

## Morphing

Intermediate transitions are calculated between two single images using morphing. In contrast to warping, morphing usually provides continuous transformations between images from *different* objects.

The aim is to create a realistic transition from a source image to a target image. The typical morphing process is therefore to select distinctive image features (e.g. facial features such as mouth and eyes or object edges) in the source and target image and to distort them in such a way that their contours can be brought into agreement. In order to achieve the most realistic effects possible, it is important that the source and target image do not differ too much from each other; for example, it is easier to transform a human face into another human face than an stone. Played as a series of frames, these images create the impression of a constant transformation.

Morphing is mainly used in the film industry. In 1985 the music videos 'Cry' by the band Godley & Creme made this technique known to a wide audience for the first time. The first film in which the technique was used was The Navigator's Flight, 1986, which became famous in 1991 with the video clip on Black or White by Michael Jackson, in which people of different origins, skin colour and appearance were transformed into each other in a continuous movement.

In the past, transitions of films had to be created by frequently creating and photographing a scene (slow-motion capturing) in connection with complex film cuts. Due to the constant increase in computing power, the film industry has increasingly begun to develop films using digital technology (computers and digital image processing programs). Transitions of images are no longer realized with slow-motion methods, but with morphing. In the early days of morphing, simple and unrealistic effects such as blending (slow blending of RGB values from source to target) and fading (slow blending of RGB values) were used.

Other areas of application for image morphing outside the film industry include the use of morphing in biology and chemistry to change models or in criminal investigation to search for missing persons. In the latter case, old photos of these people are modified by morphing in order to adapt the appearance of these people to their age (e.g., <https://www.youtube.com/watch?v=Df41G7r5tMY>)

A morphing process consists of three steps:

1. Warping (distortion)
2. Tweening (interpolation, interim images)
3. Cross dissolving (cross-fading)

Warping is the transformation and distortion (stretching) of an image. A new position is assigned to each position of a point in the source image. This new position is dependent on the manual selected, distinctive pictorial elements, which are later referred to as reference line pairs.

The second part of the morphing algorithm uses tweening. This is a simple linear interpolation that transfers the position of each point in the original image to its new position. Warping assigns a new position in the target image to each point of the original image. Tweening transfers each point in the original image to the new position calculated by warping. An animation can be generated by linear interpolation. A calculated interval size is used to steer step by step to the new position.

The third and last part of the morphing process consists of so-called cross-dissolving. Cross-dissolving is executed in parallel to tweening. The individual RGB values of each pixel are interpolated and mixed linearly. The interpolation is carried out depending on the source and target image, i.e. during the first interpolation steps, the proportion of the source image is significantly higher than that of the target image. Then, the proportion of the target image increases more and more until the last interpolation step only contains the RGB values of the target image and thus the morphing is finished.

The whole morphing process is outlined in Algorithm 2 and an example for the music video 'Black and White' and the corresponding Beier-Neeley paper [1] is shown in Figure 1.

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**Algorithm 2** Basic morphing algorithm.

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1: for each intermediate frame time  $t$  do
2:    $Warp_0 = WarpImage(Image_0, t)$ 
3:    $Warp_1 = WarpImage(Image_1, t)$ 
4:   for each pixel  $p$  in final Image do
5:      $Result(p) = (1 - t) \cdot Warp_0 + t \cdot Warp_1$ 
6:   end for
7: end for
```

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## References

- [1] Thaddeus Beier and Shawn Neely. Feature-based image metamorphosis. *SIGGRAPH Comput. Graph.*, 26(2):35–42, July 1992.

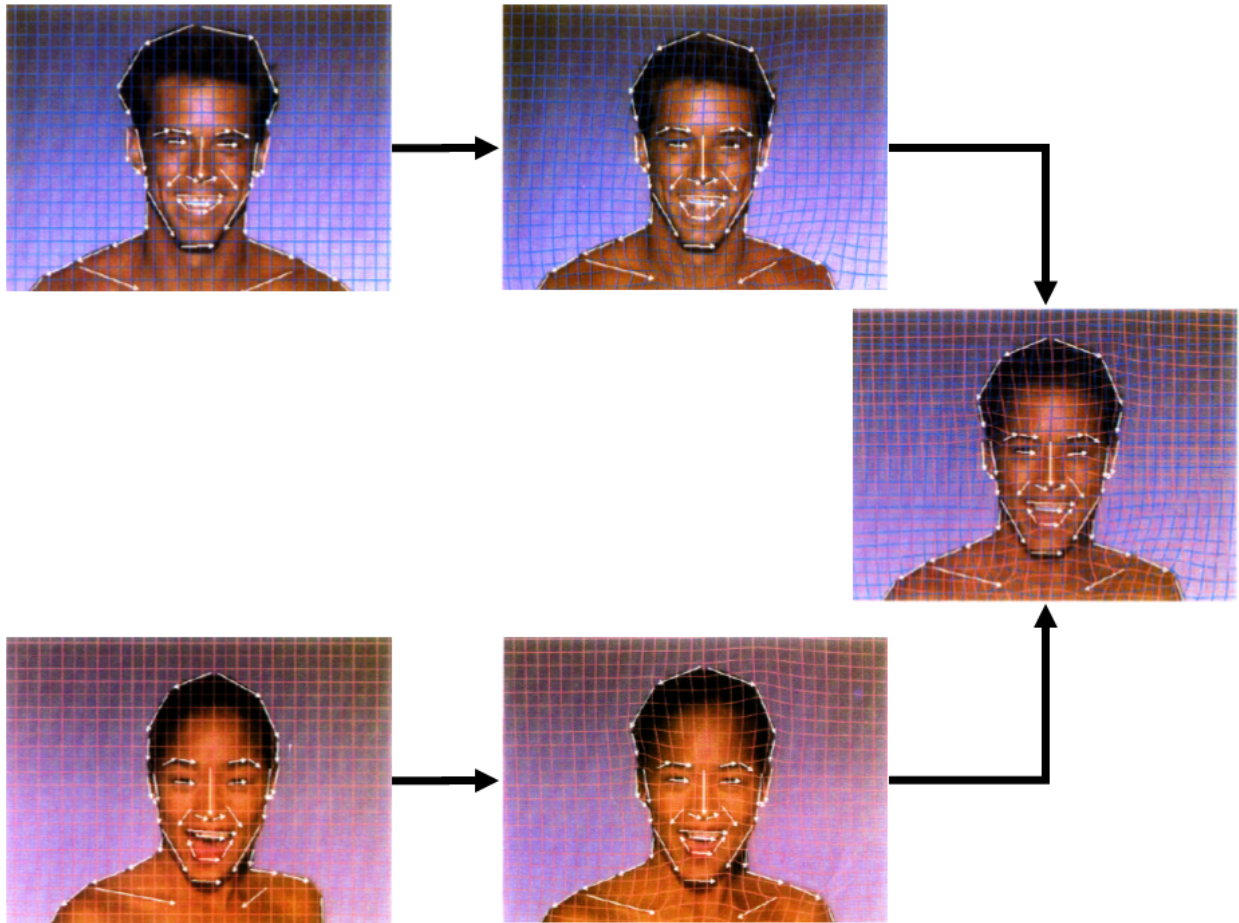


Figure 1: Example from [1] for morphing between faces. This method has been used for the music video 'Black and White' by Michael Jackson (<https://www.youtube.com/watch?v=3ZHtL7CirJA>)

[2] Leonard McMillan and Jr. An image-based approach to three-dimensional computer graphics. Technical report, 1997.