# Hybrid Image using Image Morphing


Jinsuk Yang
Dept. of Media, Soongsil University
Sangdo 1-dong, Dongjak-gu,
Seoul, Republic of Korea
+82-2-822-3924
ispio@ssu.ac.kr

Haoxu Zheng
Dept. of Media, Soongsil University
Sangdo 1-dong, Dongjak-gu,
Seoul, Republic of Korea
+82-2-822-3924
tidus-zheng@ssu.ac.kr

Kyoungsu Oh
Dept. of Media, Soongsil University
Sangdo 1-dong, Dongjak-gu,
Seoul, Republic of Korea
+82-2-822-3924
oks@ssu.ac.kr



## ABSTRACT

Hybrid image refers to an image that is viewed in two different ways, depending on the distance of a viewer. This optical illusion comes from human perception of concentrating on the specific spatial frequency band information with regard to the observation distance, and it makes one excited and amazed. However, the existing hybrid image synthesis method has limited application to making diverse contents since two input images have to have similar shape and alignment for synthesis and sometimes the image is not easily perceived from certain distances. This paper suggests a new hybrid image synthesis method that improves the shortcomings of the existing method. By using the image morphing method, multiple morphed images are created, in which two images smoothly transform. Based on those, hybrid image is created. Our method can be used to create an excellent quality hybrid image without using images of similar shape or alignment, and the produced image is easily perceived at different viewing distances. In addition, we expect that these hybrid image contents, which are created in many different and easier ways, will be applied to diverse fields such as advertisement and exhibition.


## CCS Concepts

• **Computing methodologies→Image processing;**


## Keywords

Hybrid image; dual image; human perception; scale space; image morphing


## 1. INTRODUCTION

"Double-meaning image" refers to an image that has different ways of recognition and interpretation depending on the viewing method and the viewer, and has been of increasing interest in academia and in practice in recent years [6, 7, 10, 11, 12]. Some of the most representative examples include optical illusion image like Rubin's vase [3], lenticular image [15], hybrid image [8], and so on. In Figure 1, perceptions of the Einstein–Monroe hybrid image [9] from a close distance and far distance are shown.




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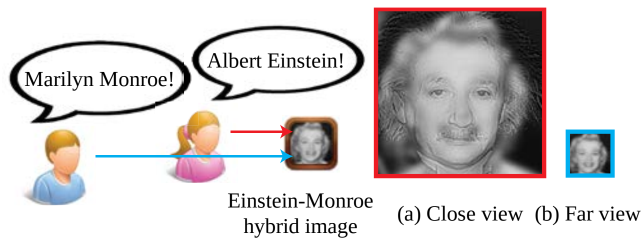


**Figure 1. Einstein-Monroe hybrid image: A girl recognizes an image as Albert Einstein up close. However, a man recognizes it as Marilyn Monroe from far away.**

As shown, the image is perceived as Einstein (a), when viewing from the close distance, but as Marilyn Monroe (b) from far away. This kind of illusion occurs due to the multi-scale processing of the human visual system, which concentrates on the specific spatial frequency band depending on the viewing distance [1, 4, 13].

The compelling characteristic of this kind of hybrid image is that it provides surprising and exciting experiences to its audience. One of the examples is the private font, which can be read a certain distance away, or sign board, in which different images are seen depending on the distance between the viewer and image. Furthermore, the applicability to various areas, such as media art, advertisements, and computer vision application, makes it a highly valuable research subject.

Existing hybrid images [8] are, in general, created by synthesizing two different images into one. One image is a blur image filtered through a low-pass filter, and the other is an edge image filtered through a high-pass filter. However, there are largely two limitations in this existing hybrid image production method. Firstly, the shape and alignment of the two input images need to be very similar in order to make a clear hybrid image. For example, if the locations of the eyes in the two images are different, then the hybrid image could produce an image with four eyes. Secondly, if the cut-off frequencies for the low-pass and high-pass filters are improperly selected, then the produced hybrid image becomes hard to recognize. If that is the case, then the two filtered images could have a large area of overlapping frequencies, and, thus, transition of recognition between two images would become ambiguous. In addition, if the band information were damaged too much, then the recognition would be impossible. Therefore, in order to create a high quality hybrid image, extensive testing is required.

We suggest a new hybrid image synthesis method, which improves the shortcomings of the existing method. The suggested method uses image morphing, so that input images with little similarity can be used to generate easily recognizable hybrid images, with band information loss minimized. The main contributions to this paper are as follows:

· Using image morphing method, two input images are produced as multiple morphed images. Since the hybrid image is produced based on the morphed images, two input images of dissimilar shape or alignment can produce an easily recognizable hybrid image.

· Applying various cut-off frequencies to the morphed images, many images of high and low frequencies are produced. A hybrid image is produced by synthesizing a few selected images. Therefore, the frequency band information loss is reduced compared to the existing method, and it is possible to create an image that changes smoothly with respect to diverse perspectives.

The remainder of this paper is organized as follows. It presents previous work and the details of the proposed algorithm, in Chapters 2 and 3, respectively. Finally, in Chapter 4, the experimental result and conclusion are given.

## 2. RELATED WORKS

According to the study of psychophysics, human visual system analyzes images based on a multi-scale (in a coarse-to-fine frequency analysis). That is to say, the low spatial frequency components are carried by the fast magnocellular pathway, while dominate early visual processing. [8] introduced hybrid stimulus associated with multi-scale perception process. Hybrid stimulus were created by blending a fine information (high spatial frequency) with a coarse information (low spatial frequency). Using recognition tasks on hybrid stimulus, Oliva tested the role that spatial frequency bands play for the image interpretation. When the task required identifying a scene image quickly, human observes interpreted the low spatial frequency band before the high spatial frequency band.

Oliva proposed the use of hybrid stimulus as image that can be perceived differently depending on viewing distance. They tested the perception of different frequency bands with hybrid images. When showed hybrid images from far away, observers identified the low spatial scale. On the other hand, they identified the high spatial scale up close. Also participants were unaware that the visual stimuli had two interpretations. In practice, hybrid images require following some rule. They explain that similar shapes and alignment provide a very strong grouping cue that could be used for more compelling visual illusion.

Since [8] introduction, some extended hybrid images have been proposed. [14] attempted to improve this limitation. They insert noise and color into the high frequency image, so that the hybrid image recognition is better than original. [2] proposes the multi-scale perception model. They use the results of computing multi-scale Gabor feature similarities between the hybrid image and its original picture. [5] makes hybrid image based on wavelet transform. Their results remain full band of frequency information with compelling visual effect.

## 3. OUR PROPOSED METHOD

The existing method creates a hybrid image ($H$) from different two images ($I_1$, $I_2$), by following equation (1) as below.

$$H = I_1 \cdot G_1 + I_2 \cdot (1 - G_2), \quad (1)$$

where $G_1$ is low-pass filter, and $(1 – G_2)$ is high-pass filter. The cut-off frequency of each filter is set at 1/2 of the filter amplitude gain, and the distance of best recognition corresponds with the cut-off frequency of filter.

In this chapter, the new hybrid image synthesis method, based on the existing method, is proposed and explained. In the proposed method, morphed images are created by using the image morphing technique, and the hybrid image is produced based on this. An overview of the suggested method is as shown in Figure 2. In section 3.1 and 3.2, the morphing process of creating a morphed image (a) and high and low frequency image generation processes through frequency decomposition (b) are described, respectively. Lastly, in section 3.3, the hybrid image generation process (c) from synthesis of high and low frequency images is described.

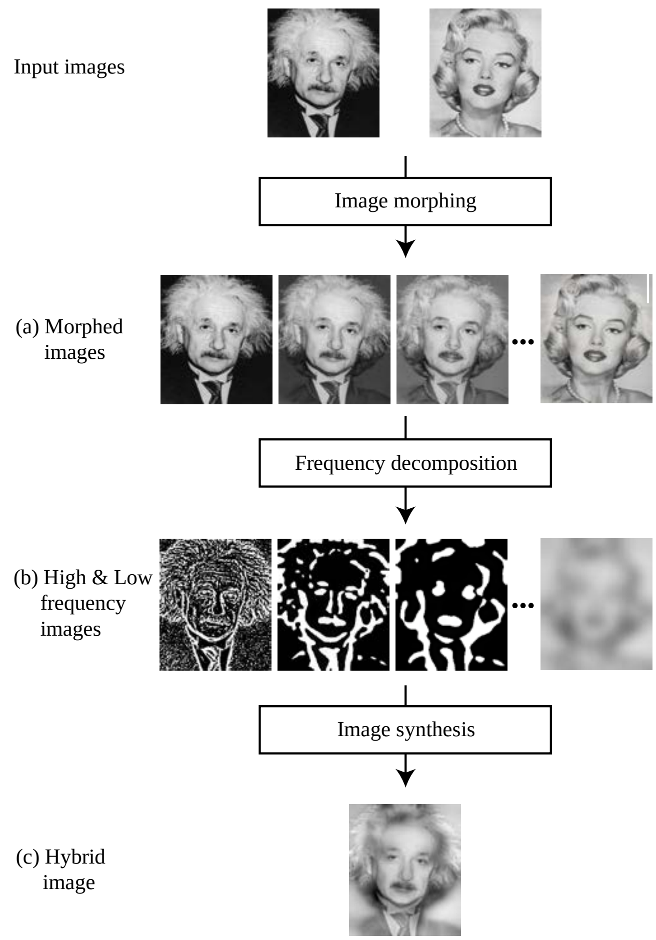


**Figure 2. Overview of the proposed method: (a) Firstly, Create morphed image from two input images by using image morphing technique. (b) Create high and low frequency images from each morphed image using frequency decomposition. (c) Lastly, select a few high and low frequency images and synthesize to create hybrid image.**

### 3.1 Generating Morphed Images

Image morphing [16] is an image processing technique, which transforms one image from another. The result of transformation is the morphed images shown in Figure 3-(e). The existing method of generating hybrid image is restricted in that it can only use two images of similar shape and alignment. However, using morphed images, which interpolate the shape and alignment of two images, it will be possible to create a hybrid image that overcomes this limitation of the existing method.

In this section, the morphed image generating process using image morphing as shown in Figure 3. Firstly, the corresponding control point is inserted at a location where the user thinks the features of the two images are similar. The inserted point defines the spatial feature relationship between two images. Then, each point is connected to generate a triangular mesh. Through interpolation of generated triangular meshes, *N* number of warped meshes is created. Finally, through cross-dissolving of two input images, morphed images are generated. *N*, the number of morphed image, is determined by the user.

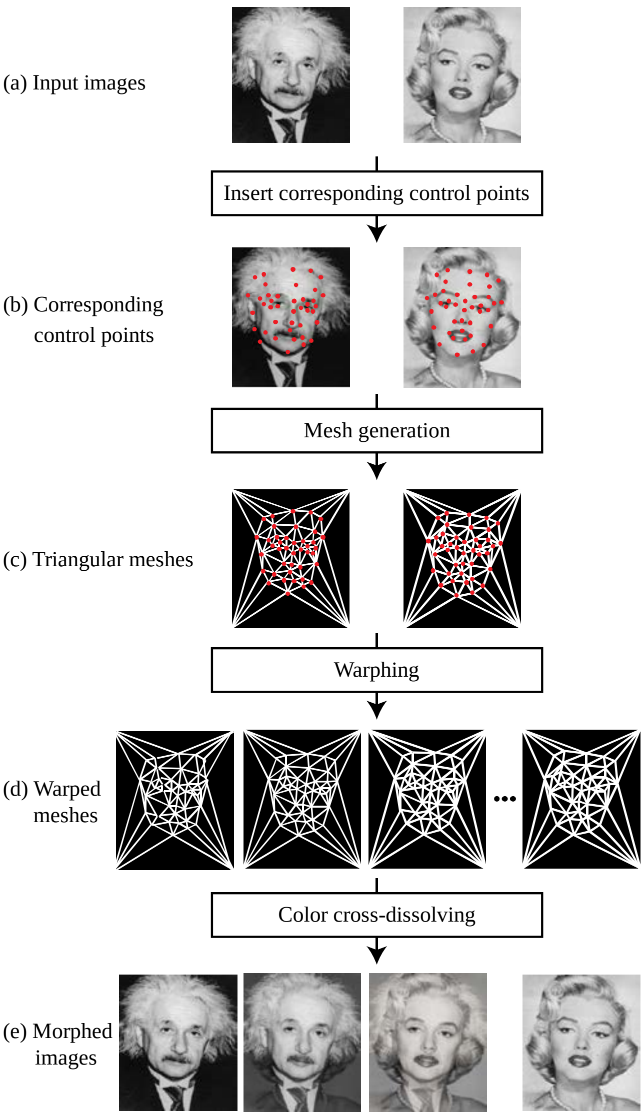


**Figure 3. Example of generating low and high frequency images from morphed image**

## 3.2 Generating High and Low Frequency Images

According to research on human perception, when a person views a random object, each person takes different characteristics of frequency channels depending on the viewing distance. For example, at close distances, high spatial frequency band information is received, as compared to low spatial frequency band information from far away. The existing hybrid image uses this characteristic of frequency channel for image recognition. However, since it uses a fixed cut-off frequency, the two filtered images can lose frequency band information to the extent that it might be difficult to recognize the image.

To improve this shortcoming, the proposed method decomposes morphed images (e.g., as obtained in section 3.1) into many frequencies, as shown in this section. Figure 4 shows the process of generating N number of high and low frequency images from one morphed image. Firstly, a morphed image is filtered through a low pass filter to create a low freq.1 image of level 1. The high freq.1 image is created by subtracting the low freq.1 image from the morphed image. The low and high frequency images of level 2 can be obtained similarly. By low-pass filtering the high freq.1 image of level 1, the low freq.2 image of level 2 is generated. Similarly, the high freq.2 image can be obtained by subtracting the low freq.2 image from the high freq.1 image. By repeating these process *N* times, we can create *N* number of high and low frequency images. In this process, we used Gaussian filters for the low-pass filter.

Figure 4 is an example of multiple morphed image application. To prevent unnecessary calculation, the first morphed image was applied once, the second morphed image was applied twice, and the Nth morphed image was applied N times (refer to section 3.3 for more detail). The high and low frequency images obtained in this way were used for hybrid image synthesis in section 3.3.

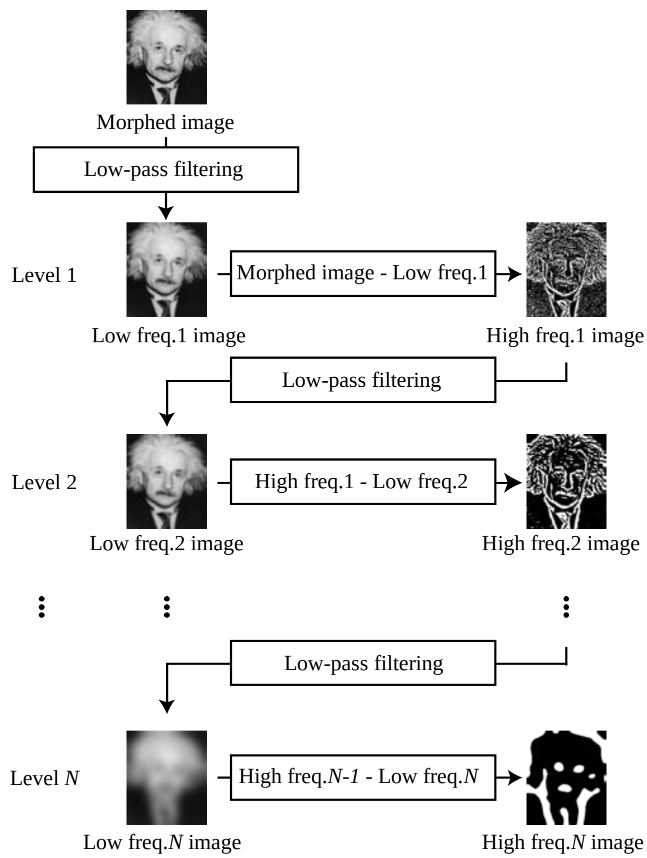


**Figure 4. Example of generating low and high frequency images from morphed image**

## 3.3 Generating Hybrid Images

In this section, a synthesis process of frequency decomposed images into one hybrid image will be explained. From the processes described in sections 3.1 and 3.2, we have frequency band information, which is not only similar in shape and alignment but has even broader frequency band information. Thus, it is possible to show a smoothly changing image even at different viewing distances.

First, images for synthesis are selected among the frequency decomposed images, as shown in Figure 4. A high freq.1 image of level 1 is selected from the first morphed image, followed by the high freq.2 image of level 2 from the second morphed image. Following the same pattern, the high freq.*N-1* image of level *N-1* is selected from the *N-1*th morphed image, and, lastly, the low freq.*N* image is selected from the *N*th morphed image. Finally, the hybrid image is produced by synthesizing selected N-1 high frequency images and one low frequency image.

## 4. RESULT AND CONCLUSION

In this section, we will explain to compare our hybrid image with existing hybrid image. In our experiments, 15 morphed images are used for synthesis of hybrid image.

Figure 5 shows the comparison of proposed method and existing method. Albert Einstein and Marilyn Monroe image is used for synthesis of hybrid image (a). Comparing (b) and (c), there is conclusion that (b) changes smoothly than (c).

In this paper, we have described a new hybrid image synthesis using image morphing. It is based on multiple morphed images which have broader frequency band information. Despite the simplicity of the technique, the image has compelling visual effects. Also, the hybrid image makes smoothly changing at different viewing distance without the need to carefully pick the two input images. We hope our work has laid the foundation for a range of future application.


**Figure 5. Comparison of the results: (b) changes smoothly than (c).**

## 5. ACKNOWLEDGMENTS

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