1. Hybrid Image Algorithm

1.1 Introduction

Hybrid images are static images that change in interpretation as a function of the viewing distance.

Hybrid image can be created by blending the high frequency portion of one image with the low frequency portion of another image, which leads to different interpretations at different distances. Quality of hybrid image depends on different factors such as a gap between low and high frequencies, appropriate alignment between images, using color for high frequency component.

1.2 Algorithm

```
% DESCRIPTION: Algorithm to create a Hybrid image by blending low frequency component
%              of one image with high frequency component of another image.
% INPUT:       %imgPath1    Path of first image
%              %imgPath2    Path of second image
% OUTPUT:      Create and save Hybrid image along with its Gaussian and Laplacian
%              Pyramid.
```

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1. Initialize algorithm's tuning parameters such as,
    a. Standard Resolution for input images e.g. [640 480]
    b. Total number of levels to be created in 'Gaussian' and 'Laplacian' pyramids of input images e.g. 10
    c. Cutoff Frequency for creating frequency components from input images using levels in their respective pyramids e.g. 8
    d. Down sampling factor for pyramid generation e.g. 0.8
    e. Up sampling factor for reconstructing frequency component using pyramid e.g. (1/Down sampling factor)
2. Read both input images from the disk.
3. Resize both images to a given standard resolution.
4. Use both images in RGB color space and normalize them.
   Reason:
   Using color for both Low and High frequency components enhances Hybrid image effect and both frequency components can easily be distinguished from each other when viewed from different distances.
5. Increase the contrast of RGB image that contributes High frequency component (second image).
   Reason:
   Increasing contrast of RGB image that contributes High frequency component enhances Hybrid image effect. It enhances visual quality of High frequency component over Low frequency component when viewed up close.
6. Align both images together if required.
   Reason:
   If aligned appropriately, algorithm produces better results. Under proper alignment, the residual frequency band does not manage to build a percept. When viewed up-close, it is difficult to see the Low frequency component, which is perfectly masked by the High frequency component. From far away, the High frequency component's edges are

assimilated to the Low frequency component.

7. Generate 'Gaussian' Pyramid for the first image (Low frequency component) with specified number of levels and down sampling factor.
   Note: For pyramid generation algorithm, please refer section 1.3.
8. Reconstruct Low frequency component using 'Gaussian' pyramid of the first image with specified cutoff frequency i.e. total number of levels from pyramid to be considered for merging, up sampling factor, etc.
   Note: For an algorithm to reconstruct a frequency component using pyramid, please refer section 1.4.
9. Generate 'Laplacian' Pyramid for the second image (High frequency component) with specified number of levels and down sampling factor.
   Note: For pyramid generation algorithm, please refer section 1.3.
10. Reconstruct High frequency component using 'Laplacian' pyramid of the second image with specified cutoff frequency i.e. total number of levels from pyramid to be considered for merging, up sampling factor, etc.
    Note: For an algorithm to reconstruct a frequency component using pyramid, please refer section 1.4.
11. Combine Low frequency component of the first image with High frequency component of the second image for creating a Hybrid image.
12. Generate 'Gaussian' and 'Laplacian' pyramids for a Hybrid image.
13. Stop.

1.3 Pyramid Generation

% DESCRIPTION:	Generate either 'Gaussian' or 'Laplacian' pyramid for the given image with specified tuning parameters.	
% INPUT:	%img	Image for which pyramid is to be generated
%	%levels	Number of frequency levels to be generated
%	%downsamplingFactor	Down sampling factor
%	%pyramidType	Type of pyramid to be generated
% OUTPUT:	Either 'Gaussian' or 'Laplacian' pyramid.	

1. Create a 'Gaussian' filter with sufficiently large kernel size [25 25] and standard deviation 5.
   Reason:
   Picking sufficiently large Gaussian kernel, so that Low frequency component can be blurred appropriately and it will not be visible up close after blending with High frequency component.
2. FOR specified number of levels,
   a. IF 'Gaussian' pyramid is to be generated,
      Then,
      I. Apply 'Gaussian' filter on current image and get a filtered image.
      ELSEIF 'Laplacian' pyramid is to be generated,
      Then,
      I. Apply 'Gaussian' filter on current image and subtract filtered image from current image.
      ENDIF
   b. Store the filtered image into pyramid.
   c. Down sample filtered image with the specified down sampling factor and set it to

next current image.

ENDFOR

3. Stop.

1.4 Reconstructing Frequency Component Using Pyramid

```
% DESCRIPTION: Reconstruct either 'Low' or 'High' frequency component from the given
%               pyramid with specified tuning parameters.
% INPUT:        %pyramid              Pyramid from which frequency component is to be
%                                     constructed
%               %cutoffFrequency      Cutoff frequency
%               %upsamplingFactor     Upsampling factor
%               %frequencyType        Frequency type
% OUTPUT:       Returns reconstructed frequency component.
```

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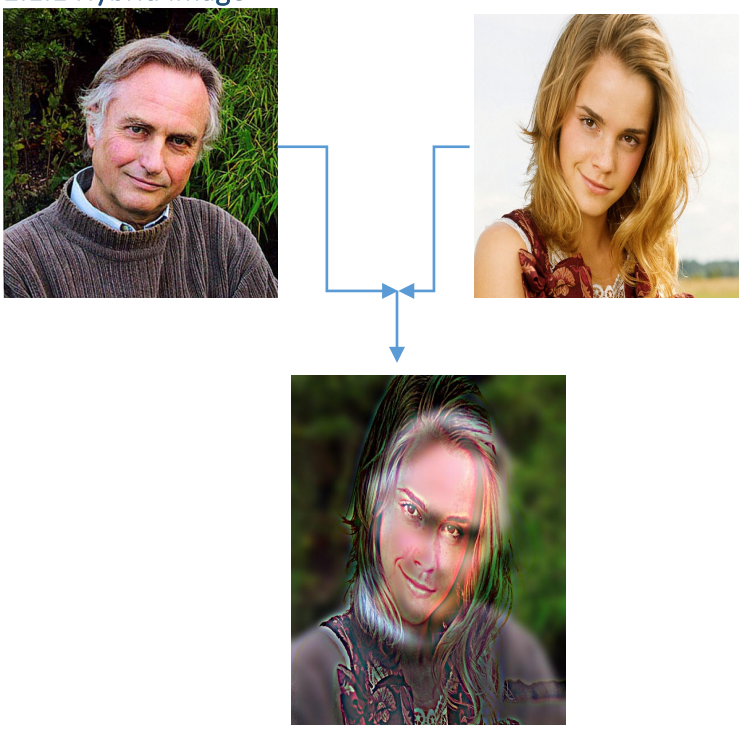
1. Determine frequency levels to be picked from pyramid based on cutoff frequency and frequency type.
   a. For Low frequency component, merge specified number of levels starting from the end of ‘Gaussian’ pyramid (including last low frequency level).
   b. For High frequency component, merge specified number of levels starting from the beginning of ‘Laplacian’ pyramid.
2. For reconstructing frequency component, follow procedure exactly reverse to pyramid generation i.e. up sample each level instead down sampling it.
3. Return final reconstructed frequency component.

2. Experiments

Below are few examples of Hybrid images and its relevant Gaussian and Laplacian pyramids.

2.1 Richard Dawkins (Low Frequency) and Emma Watson (High Frequency)

2.1.1 Hybrid Image

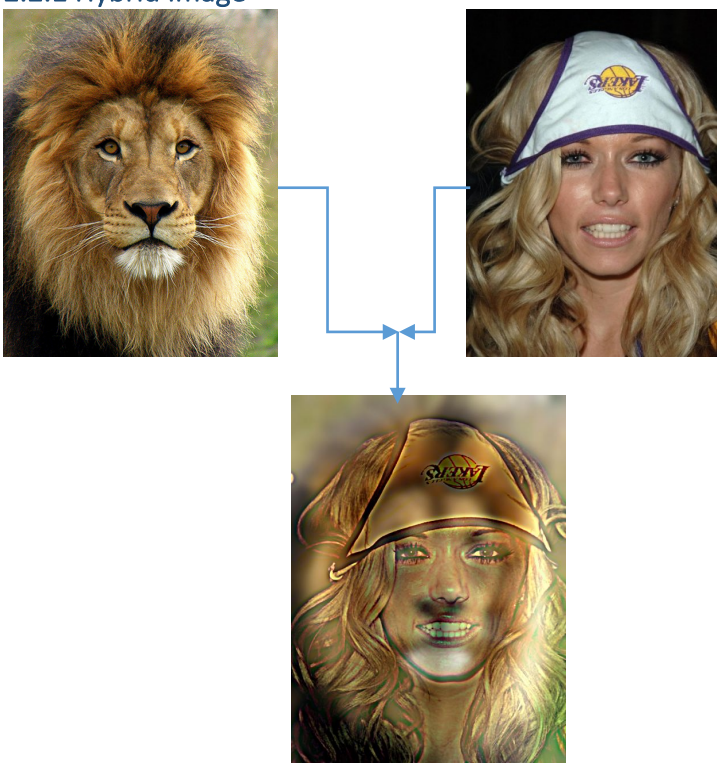


2.1.2 Gaussian Pyramid

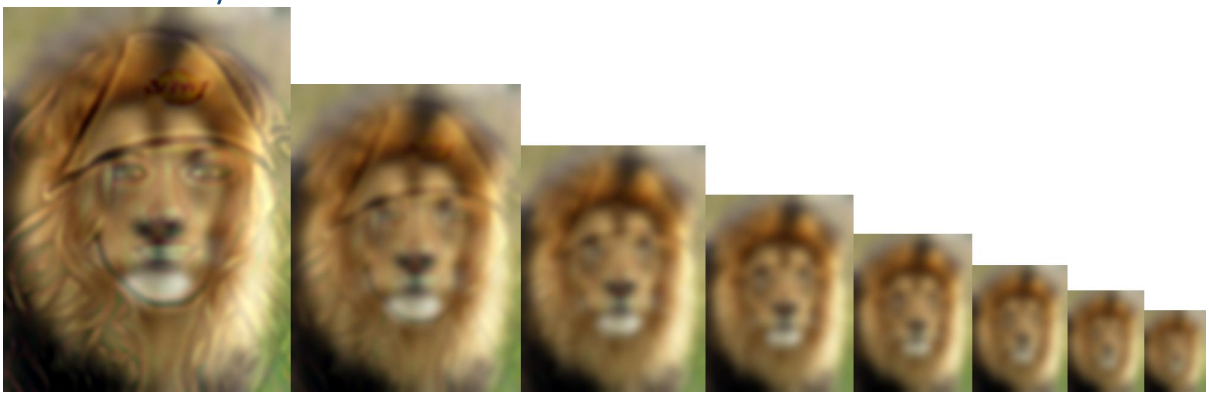
2.1.3 Laplacian Pyramid

2.2 Lion (Low Frequency) and Laker Girl (High Frequency)

2.2.1 Hybrid Image



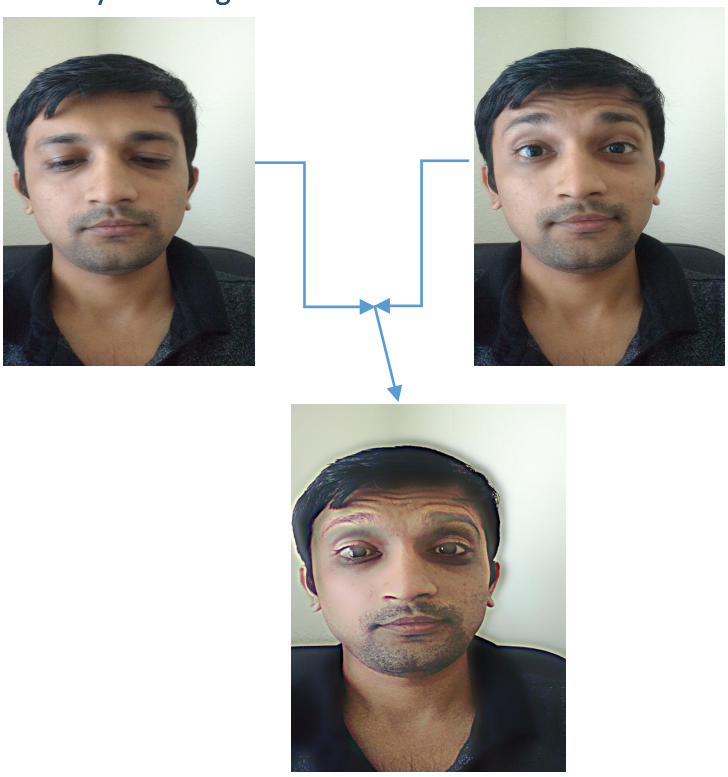
2.2.2 Gaussian Pyramid



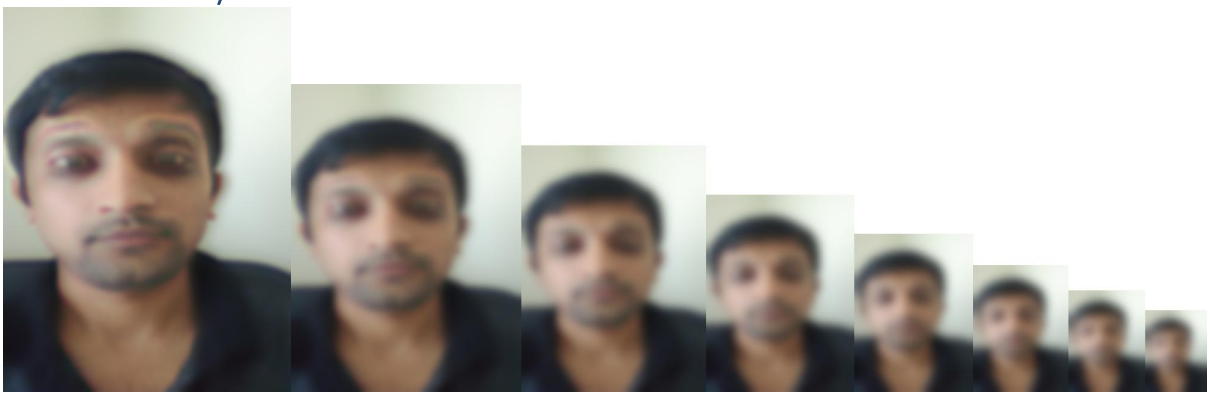
2.2.3 Laplacian Pyramid

2.3 Sad (Low Frequency) and Surprise (High Frequency)

2.3.1 Hybrid Image



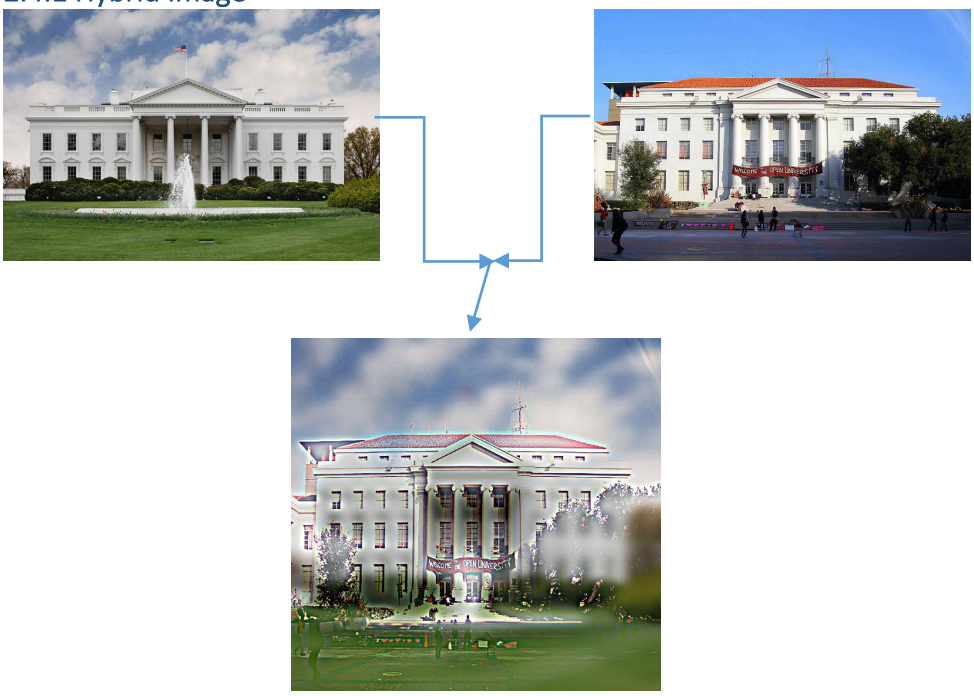
2.3.2 Gaussian Pyramid



2.3.3 Laplacian Pyramid

2.4 Whitehouse (Low Frequency) and Sproul (High Frequency)

2.4.1 Hybrid Image

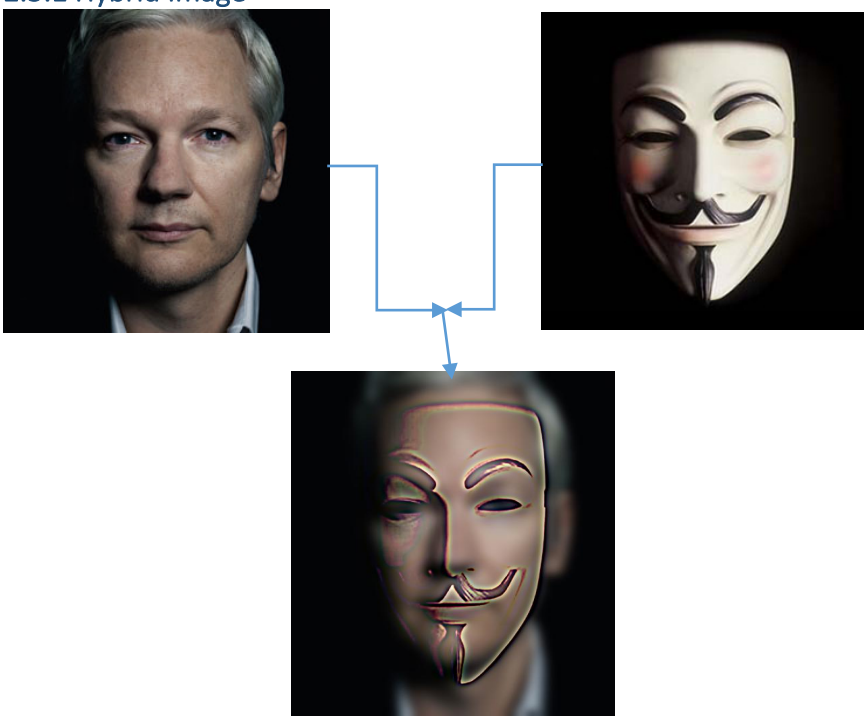


2.4.2 Gaussian Pyramid

2.4.3 Laplacian Pyramid

2.5 Assange (Low Frequency) and Fawkes (High Frequency)

2.5.1 Hybrid Image



2.5.2 Gaussian Pyramid

2.5.3 Laplacian Pyramid

3. Extra Credit

Color provides very strong grouping cue, which we can use to create more compelling illusions.

3.1 Using color for High frequency component

If color is used only with High frequency component, it enhances Hybrid image and reinforces the interpretation of the Low frequency component as shadows when Hybrid image is viewed up close.

e.g.

3.2 Using color for Low frequency component

If color is used only with Low frequency component, it dominates over High frequency component even when viewed up close. So, there is no significant improvement in Hybrid image quality when color is used only for Low frequency component.

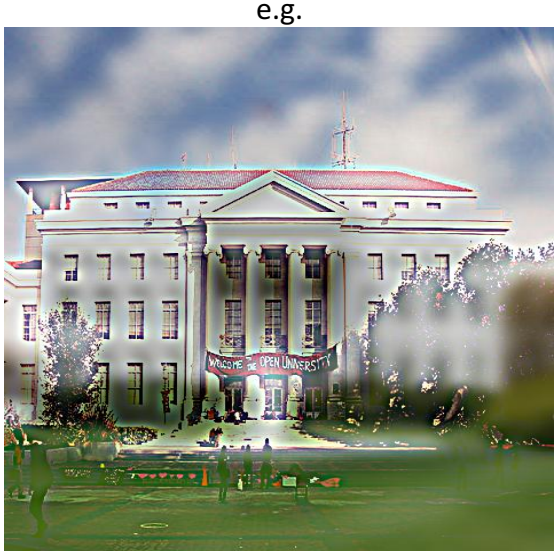
e.g.

3.3 Using color for both Low and High frequency components

If color is used for both Low and High frequency components, it significantly enhances Hybrid image effect. Additionally, if color contrast of High frequency component is increased, it enhances visual quality of High frequency component over Low frequency component when viewed up close. Using color for both frequencies often gives better results in generating Hybrid images.

Note: All the above Hybrid images from experiments section are generated using color for both Low and High frequency components.

e.g.



4. References

1. http://cvcl.mit.edu/hybrid/OlivaTorralb_Hybrid_Siggraph06.pdf
2. http://cvcl.mit.edu/hybrid_gallery/gallery.html
3. https://en.wikipedia.org/wiki/Hybrid_image
4. http://cvcl.mit.edu/publications/Talk_Hybrid_Siggraph06.pdf

5. Repository

https://github.com/chetanborse007/HybridImage