Fast Texture Transfer

Using Wavelet-Based Image Fusion

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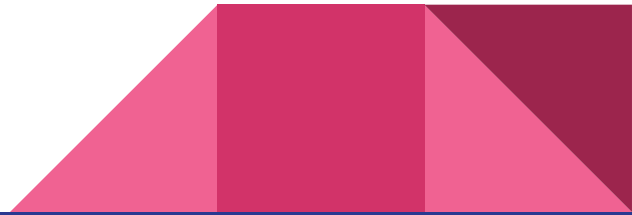
Introduction

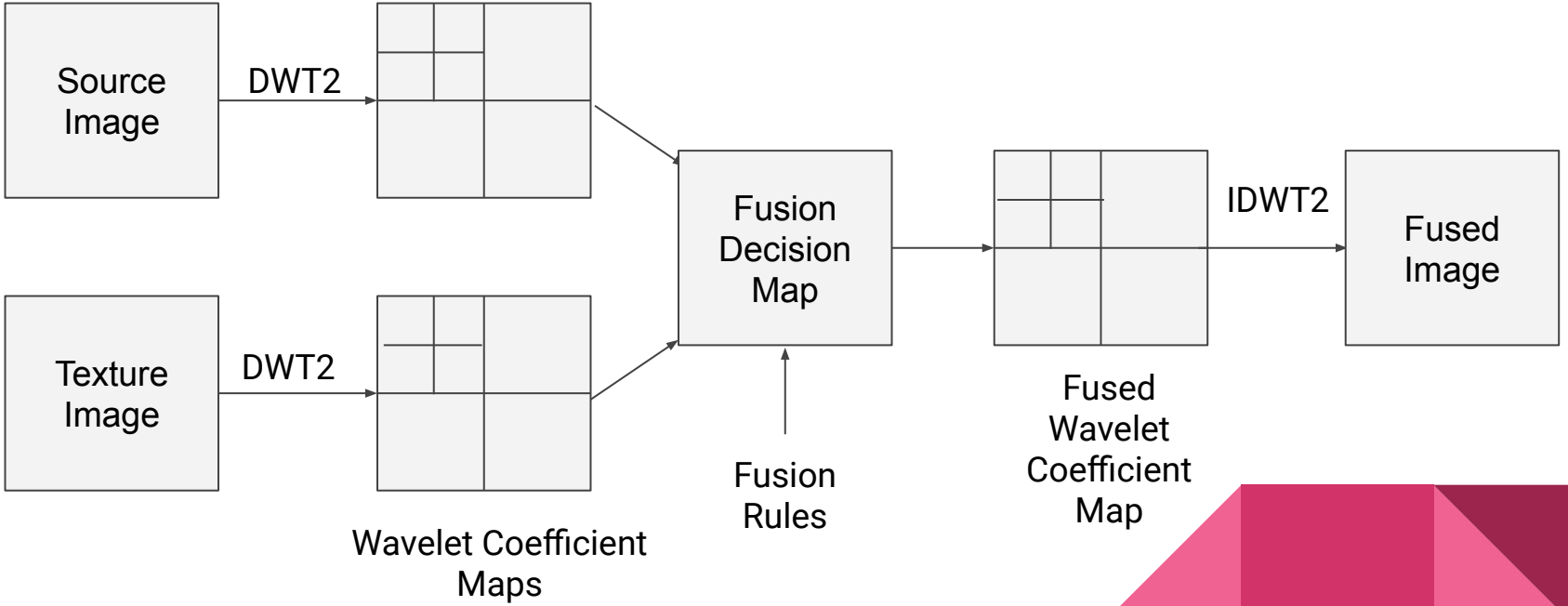
Texture transfer applies the pattern of the texture image to the source image.

While many of the methods perform texture transfer in the space domain, in this implementation we process images using image fusion in wavelet domain

Image fusion is a method to process information from multiple images and combine then into a single image.



Overview of Implementation



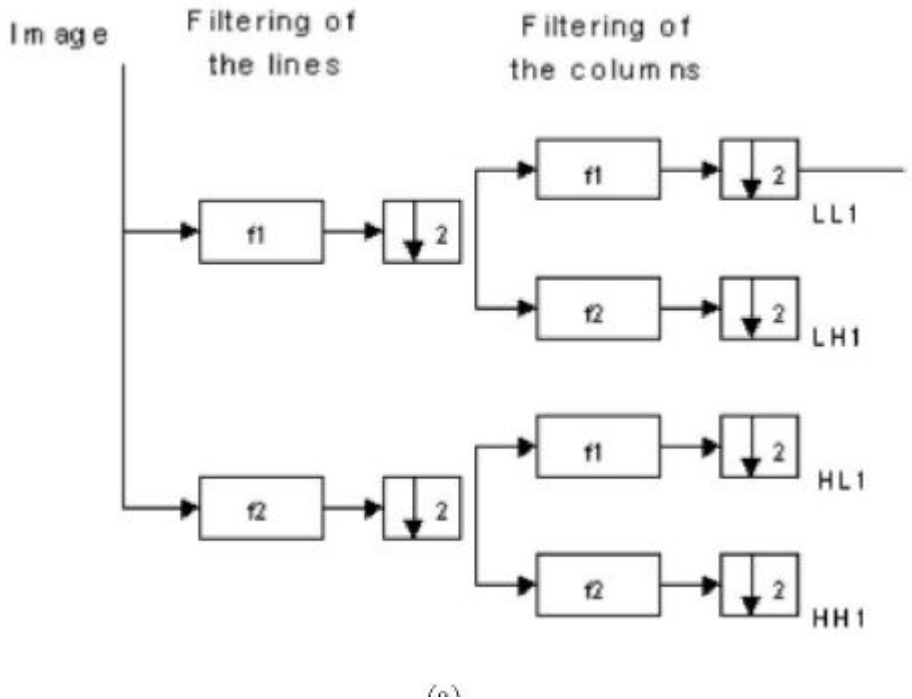
Overview of Implementation

- Wavelet decomposition of the source and texture image is taken
- Then we use a fusion decision map which has the wavelet coefficients as the input and the fused wavelet coefficients are constructed from the input according to the fusion decision rules. The decision is thus made on pixel wise basis for each coefficient
- Fused image is then obtained by performing the inverse wavelet decomposition

2D - Discrete Wavelet Transform

Using CDF 9/7 wavelet obtained via Matlab file exchange

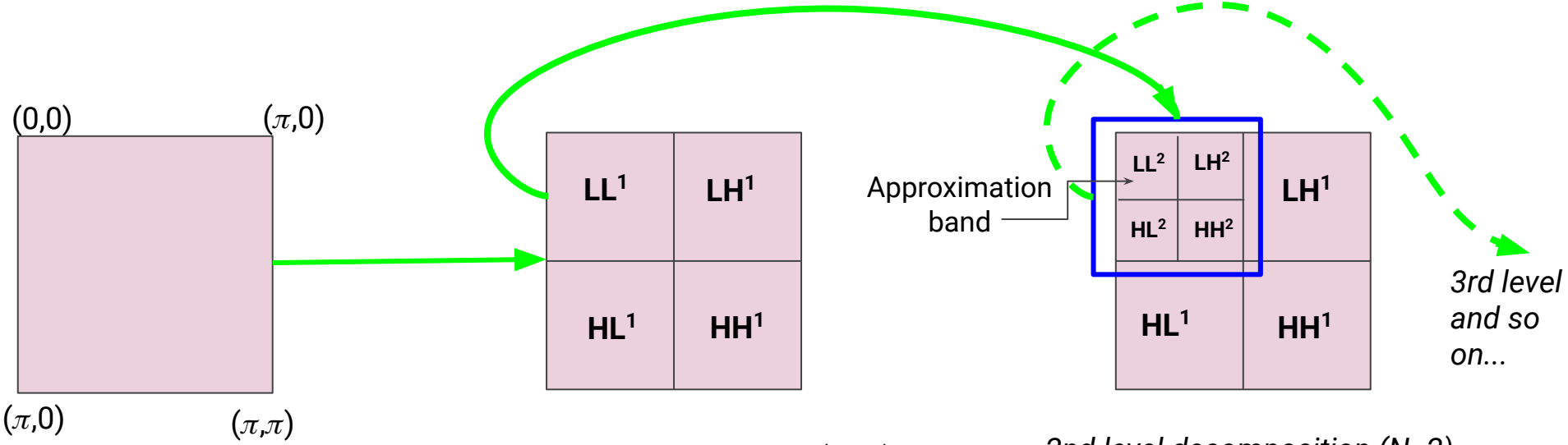
One-level decomposition of 2-D wavelet transform



After one level of wavelet decomposition there will be 4 frequency bands -

- Low Low(LL)
- Low-High(LH)
- High-Low(HL)
- High-High(HH)

2D-DWT in Action : Filters with BP Characteristics

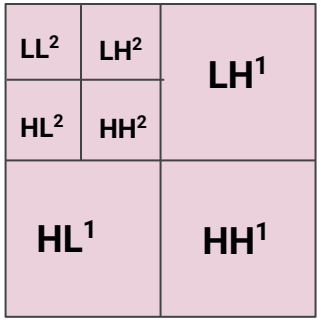


2d DTFT of image

1st level decomposition (N=1)
→Three detail filters (3N)
→One approximation filter

2nd level decomposition (N=2)
→Six detail filters (3N)
→One approximation filter

2D DWT



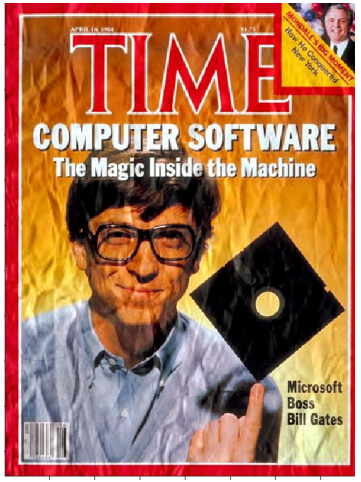
- Pyramid structure of wavelet decomposition
- N level decomposition results in 3N+1 different frequency bands
- Lower most band ----- ***Approximation of the image***
- Other 3N High frequency bands ----- ***Details of the Image***
- Approximation band contains overall characteristics of an image
    - ***Power law*** *of natural images*

Fusion Rules

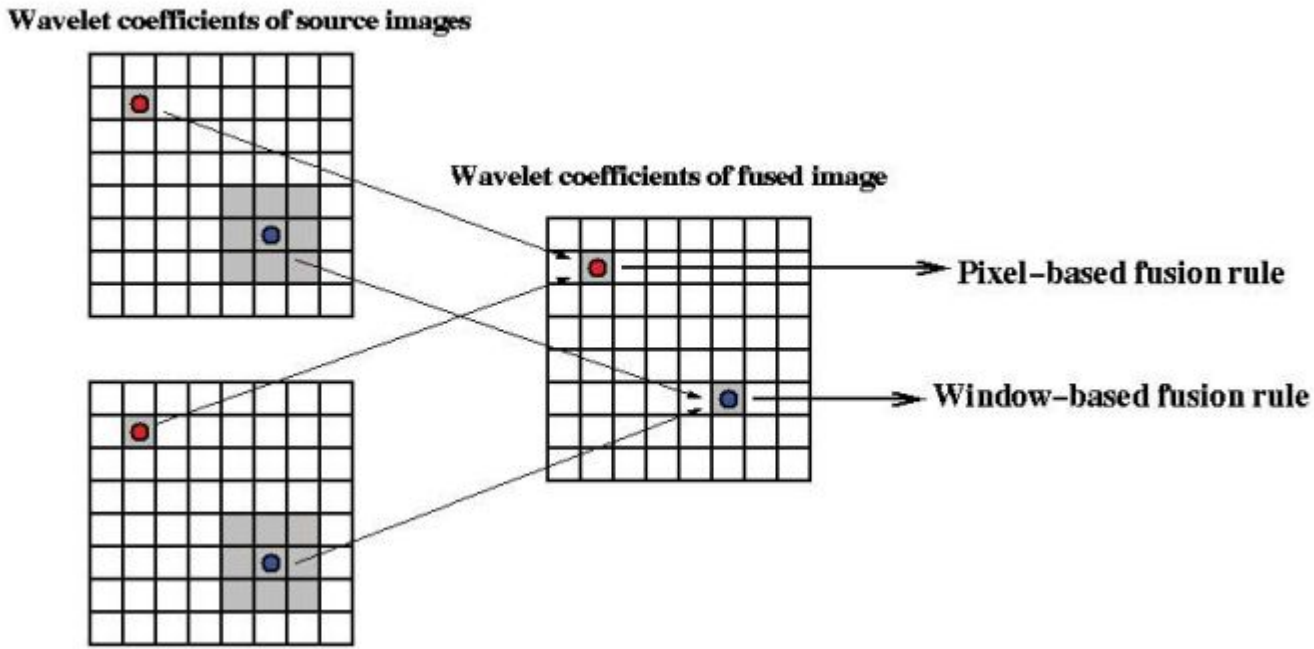
To perform texture transfer , we want to transfer characteristics of only the luminescence and not colors. So we transfer image from RGB to YCbCr coordinates and take 2d wavelet transform of the Y channel.

Why only luminescence and not color?

- Since we believe texture transformation can be achieved by simply by physically distorting surface of a real object.
- Consider the Times cover here, if I ask you to physically transform it to the fusion image, you can simply crumple it with hands, this would distort the surface, causing change in the reflection from, orientation and intensity of different parts thus achieving the texture transformation.



Fusion Rules



Fusion rules

We do fusion decision pixel-wise

1. Since the low frequency components are very critical to define the image , we transfer the DWT coefficients of the LL(lowest band) of the source image directly. In this way, the synthesized image will look like the source overall
2. For other filter outputs i.e for the details, we choose the larger of the source‘s and texture image’s coefficients for the fusion image. By taking the maximum, the fusion preserves local characteristics of both source and texture. The edges of source and texture still remain sharp after fusing.
3. To control extent of transfer, the coefficients of texture image can be attenuated by a factor between 0 and 1 (if 0 is chosen, no transfer occurs)

Decomposition levels - depth

How many decomposition levels of the wavelet transformation should be used?

- With one, two, or three levels, texture is not correctly transferred. As most of wavelet decomposition applications to images uses four or five levels, texture transfer also looks reasonable starting from four levels.
- From four to ten levels, the results look very similar even though there exist slight differences between results of four and five levels.
- Therefore, five levels are chosen to be used for the fusion scheme.
- We will see further the results of using different decomposition levels while the filter and fusion rule remain unchanged.

Complete Algorithm

Pseudo Code

1. Adjust the source (s) and texture (t) image to same size
2. Convert the source and texture images into YCrCb scale (s_Y and t_Y)
3. Apply DWT2 (N = 4) to the Y channels of source and texture image (S_Y and T_Y)
4. Use the Fusion rule to create a fused wavelet coefficient map (J_Y)
5. Take IDWT2 of the fused wavelet map to get Y channel of fused image (j_Y)
6. Two options to determine the other channels
    a. Use s_{Cr} and s_{cb}
    b. Use t_{Cr} and t_{cb}
7. Optional Histogram Matching for further enhancement

Time Complexity

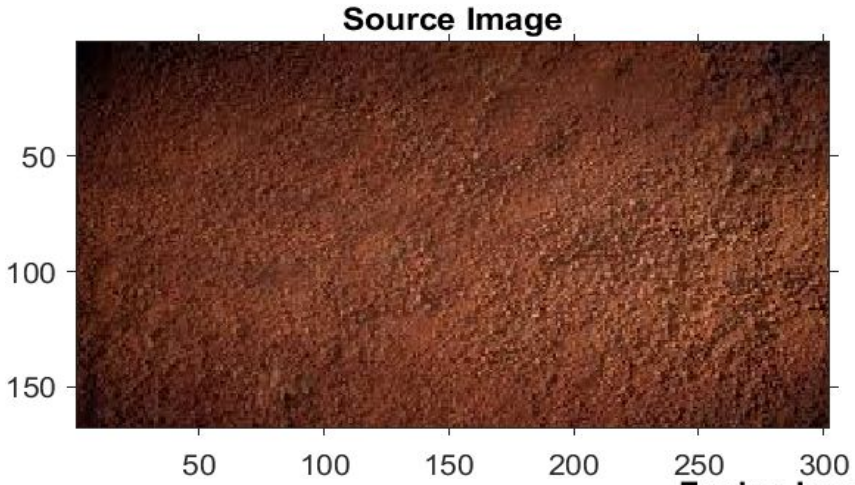
- RGB to YCrCb -- **2 x O(N^2)**
- 2D - DWT -- **2 x O(N^2)**
- Fusion Decision Map - Pixel Wise Fusion Rule -- **O(N^2)**
- 2D - IDWT -- **O(N^2)**
- YCrCb to RGB -- **O(N^2)**

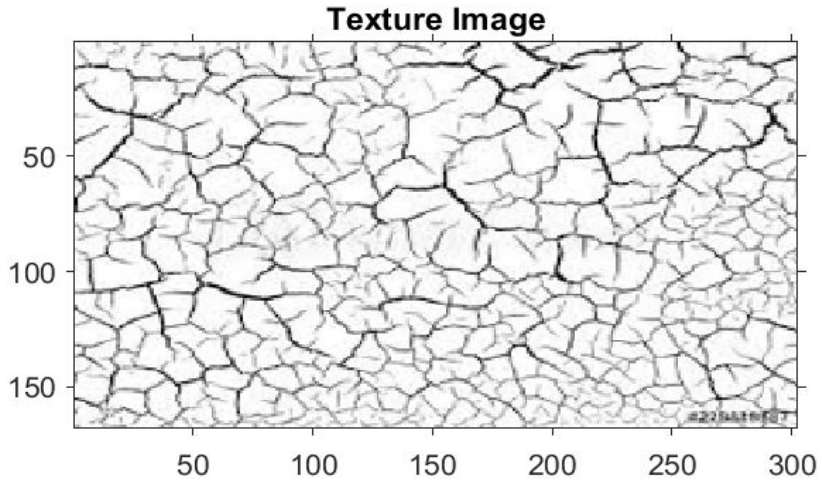
Linear time complexity in size of images

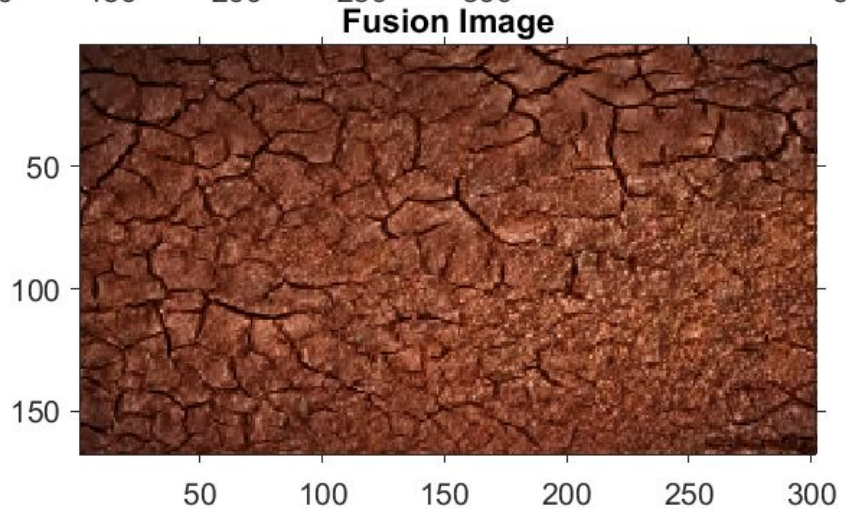
Note

- FWT has lesser time complexity than FFT
- Wavelet transform assists in multiresolution analysis and localising in both time and frequency domain
- Source and Texture images can be combined in different proportions to generate different fusion images

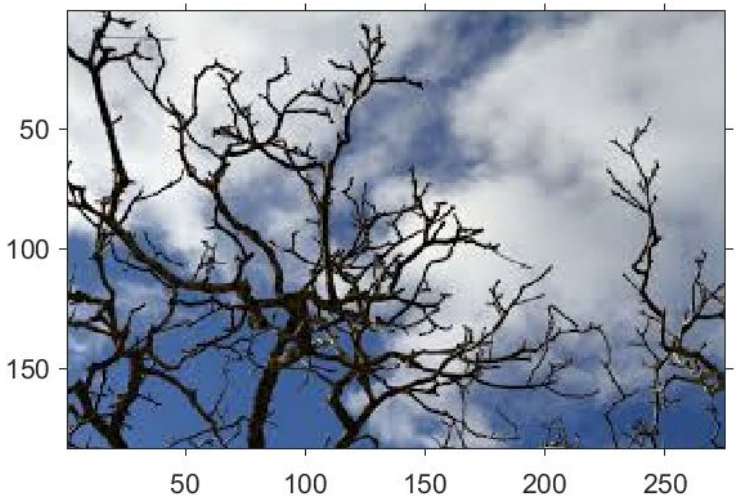
Some Results


Source Image
50
100
150
50
100
150
200
250
300

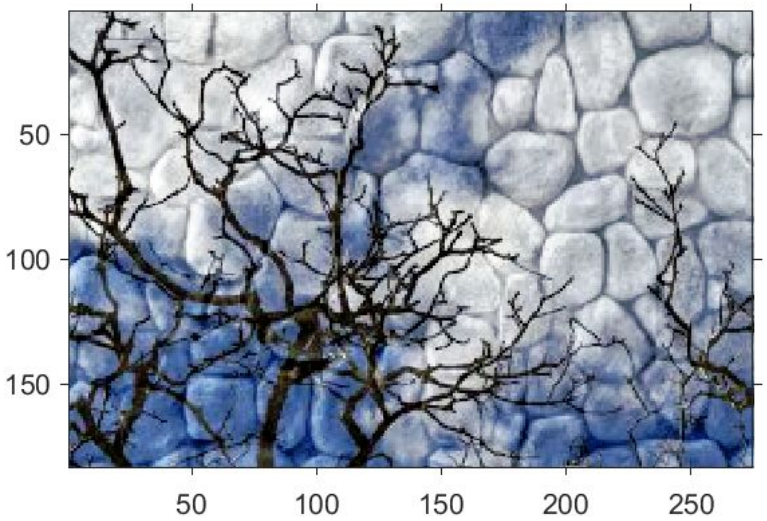

Texture Image
50
100
150
50
100
150
200
250
300


Fusion Image
50
100
150
50
100
150
200
250
300

- Depth = 4
- t = 0.15

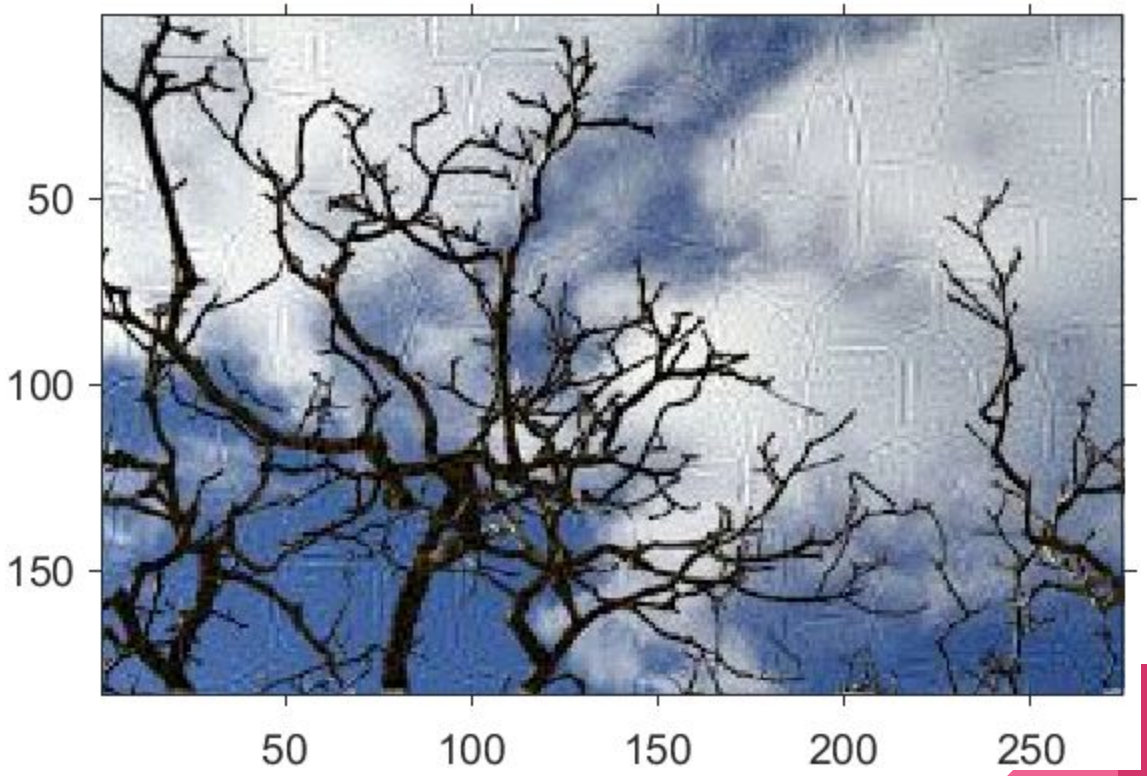


Fused Image

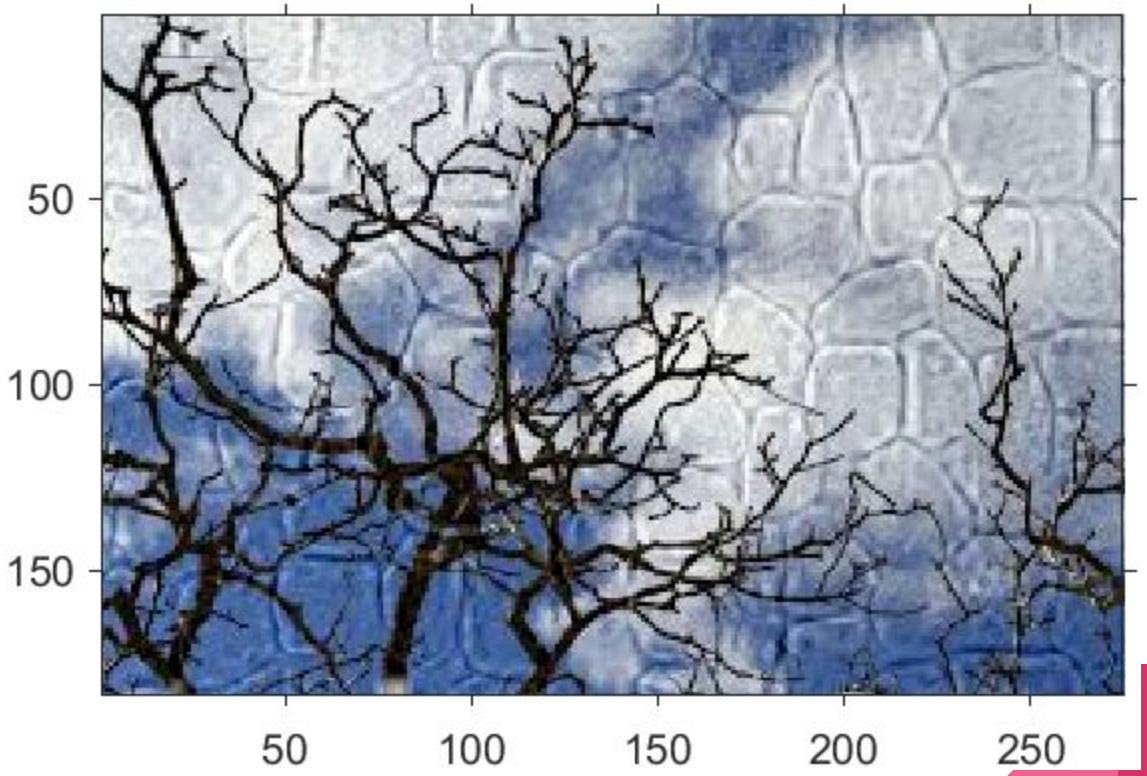


- Depth = 4
- t = 0.4

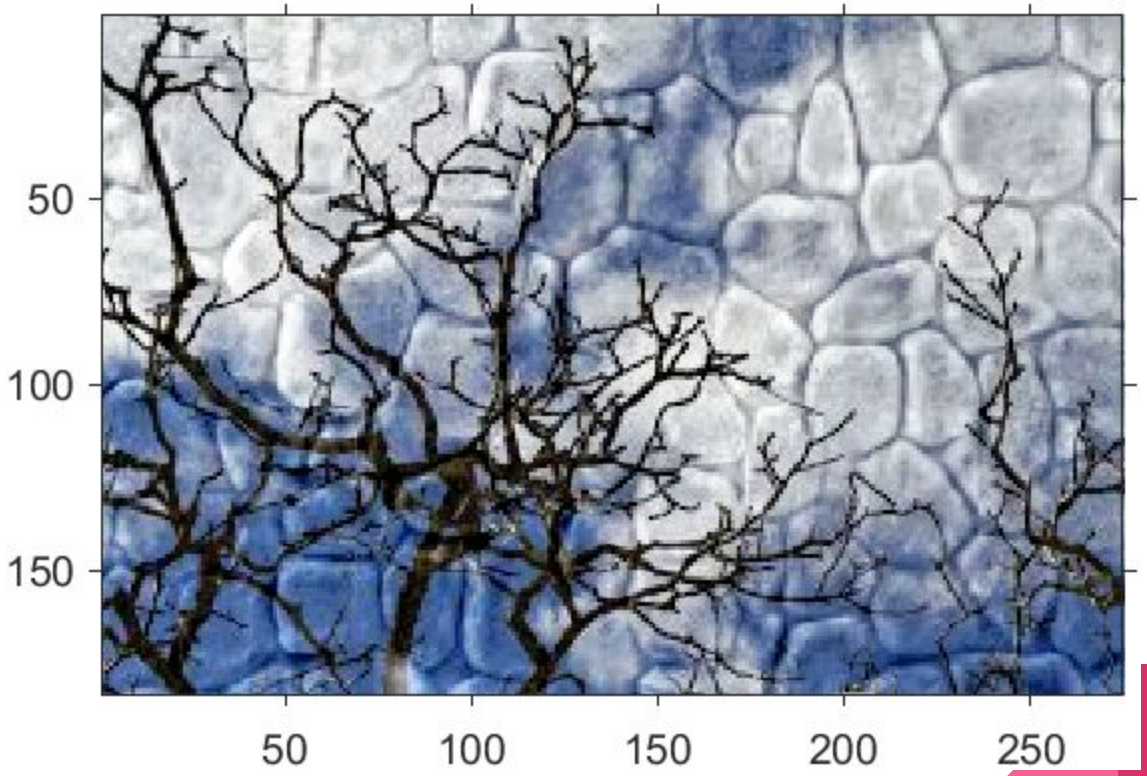
Depth 1



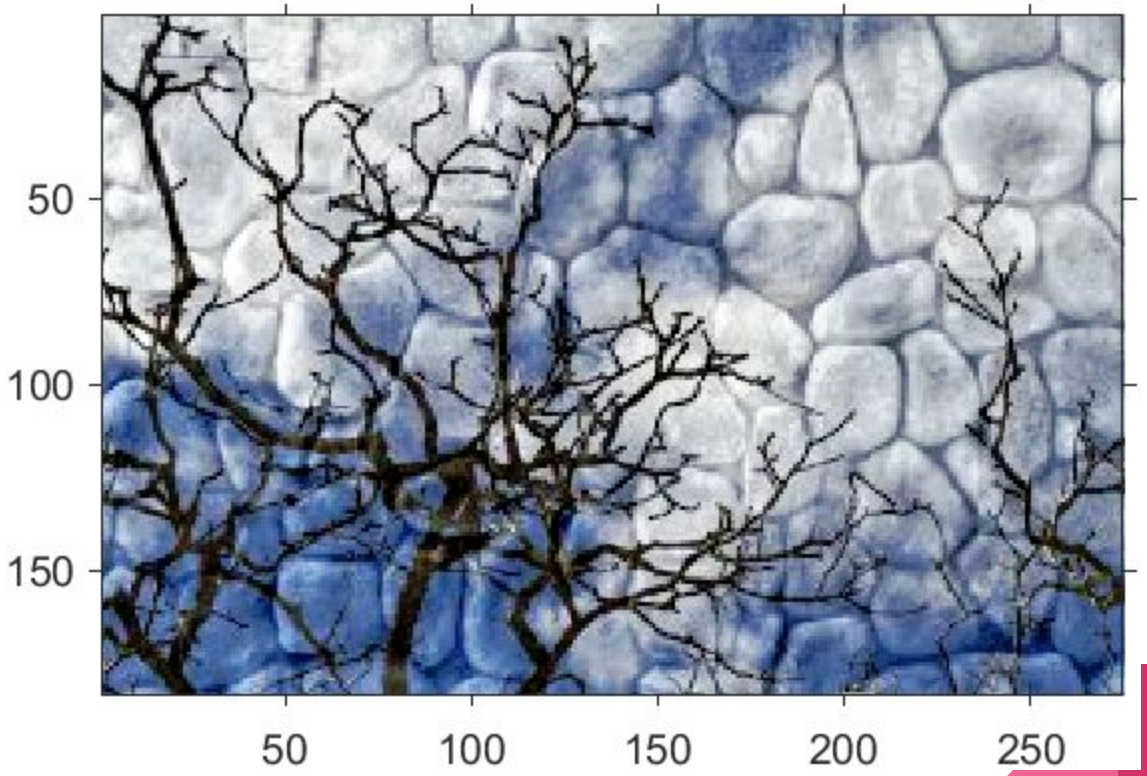
Depth 2



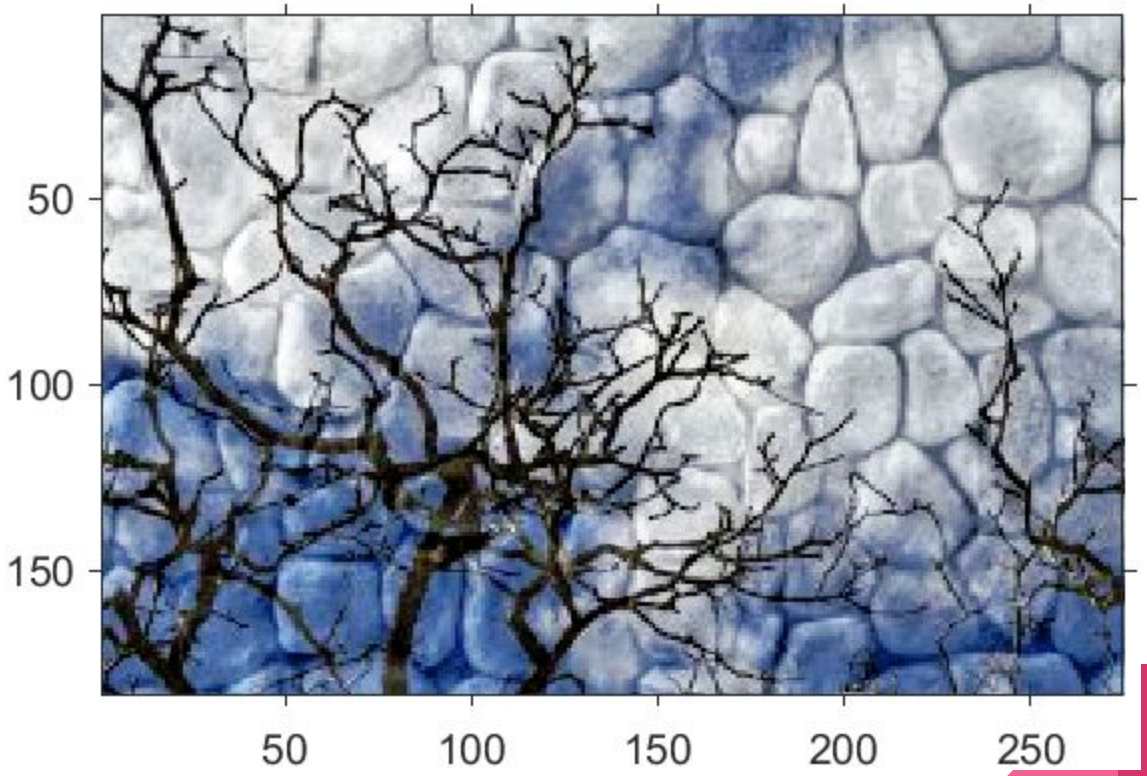
Depth 3



Depth 4

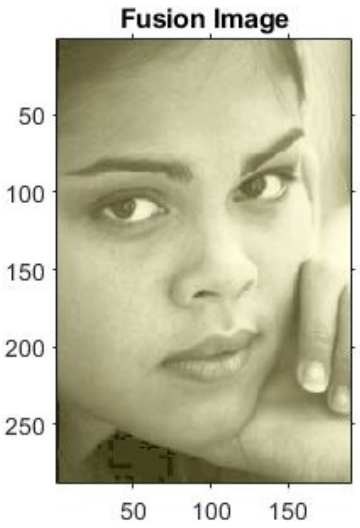


Depth 5

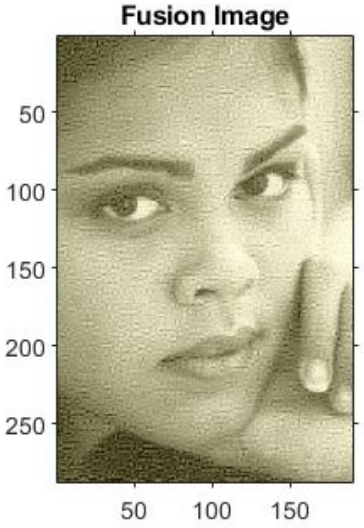


Animation

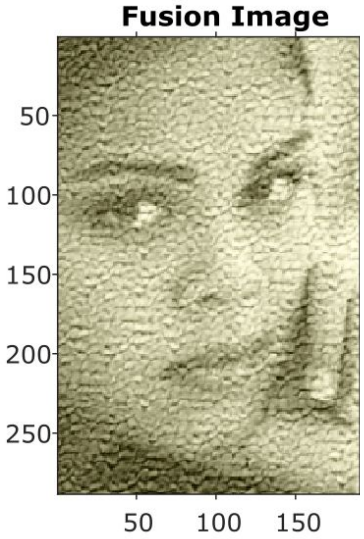
Video showing progressive depth variation



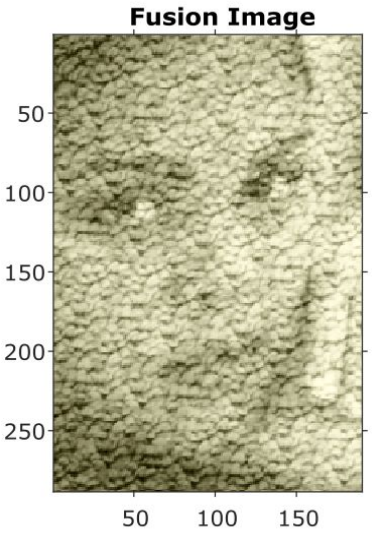
depth=0



depth=1



depth=2



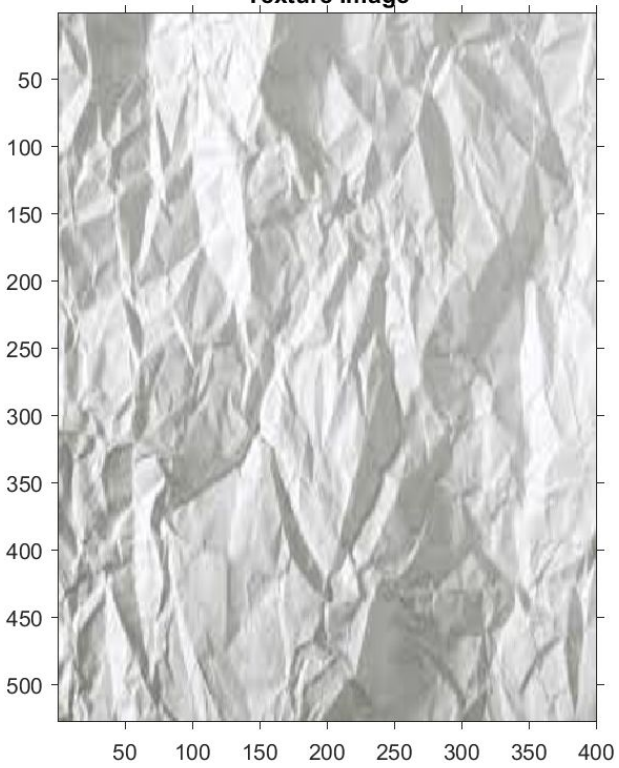
depth=5

Depth analysis with hue transfer

Achieved by performing Histogram matching of fusion histogram with texture histogram

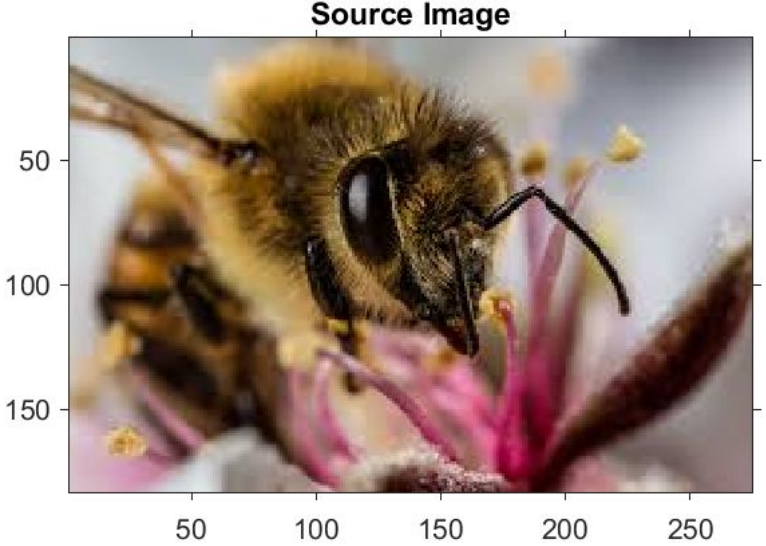
Source Image

Texture Image



Fusion Image

- Depth = 4
- t = 0.4


Source Image
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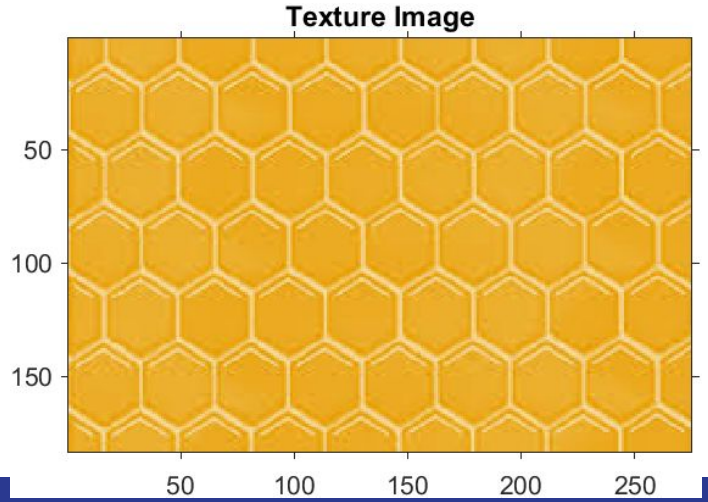
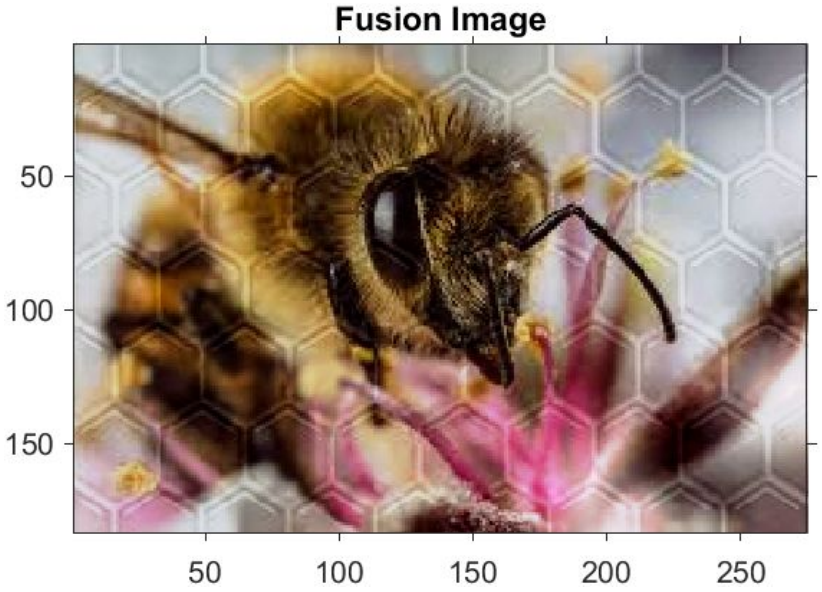

Texture Image
50
100
150
50
100
150
200
250


Fusion Image
50
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150
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100
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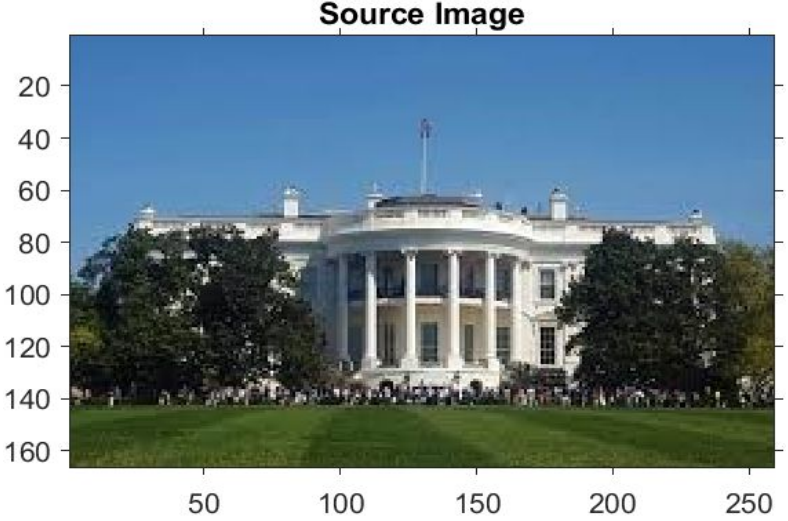
200
250

- Depth = 4
- t = 0.4


Source Image
20
40
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160
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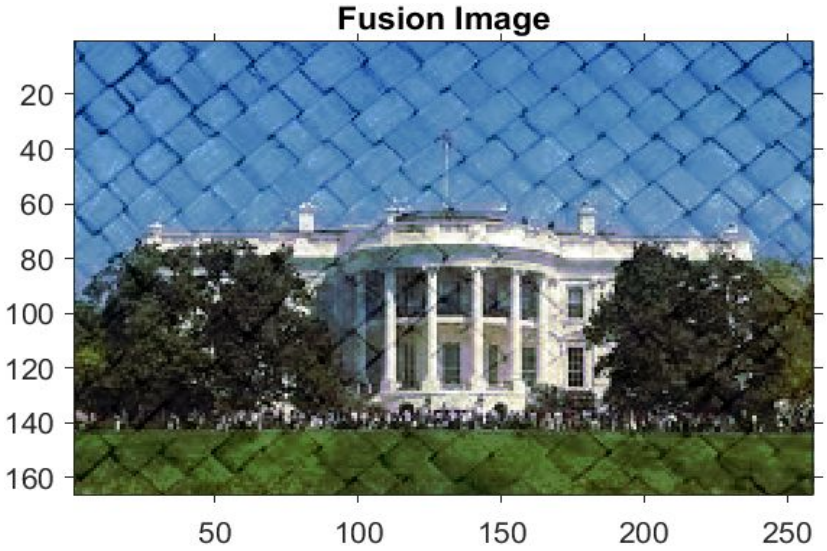
100
150
200
250


Fusion Image
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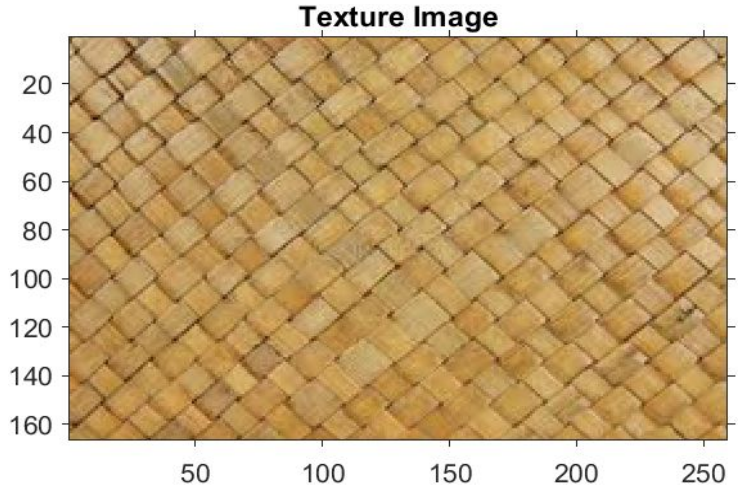
Texture Image
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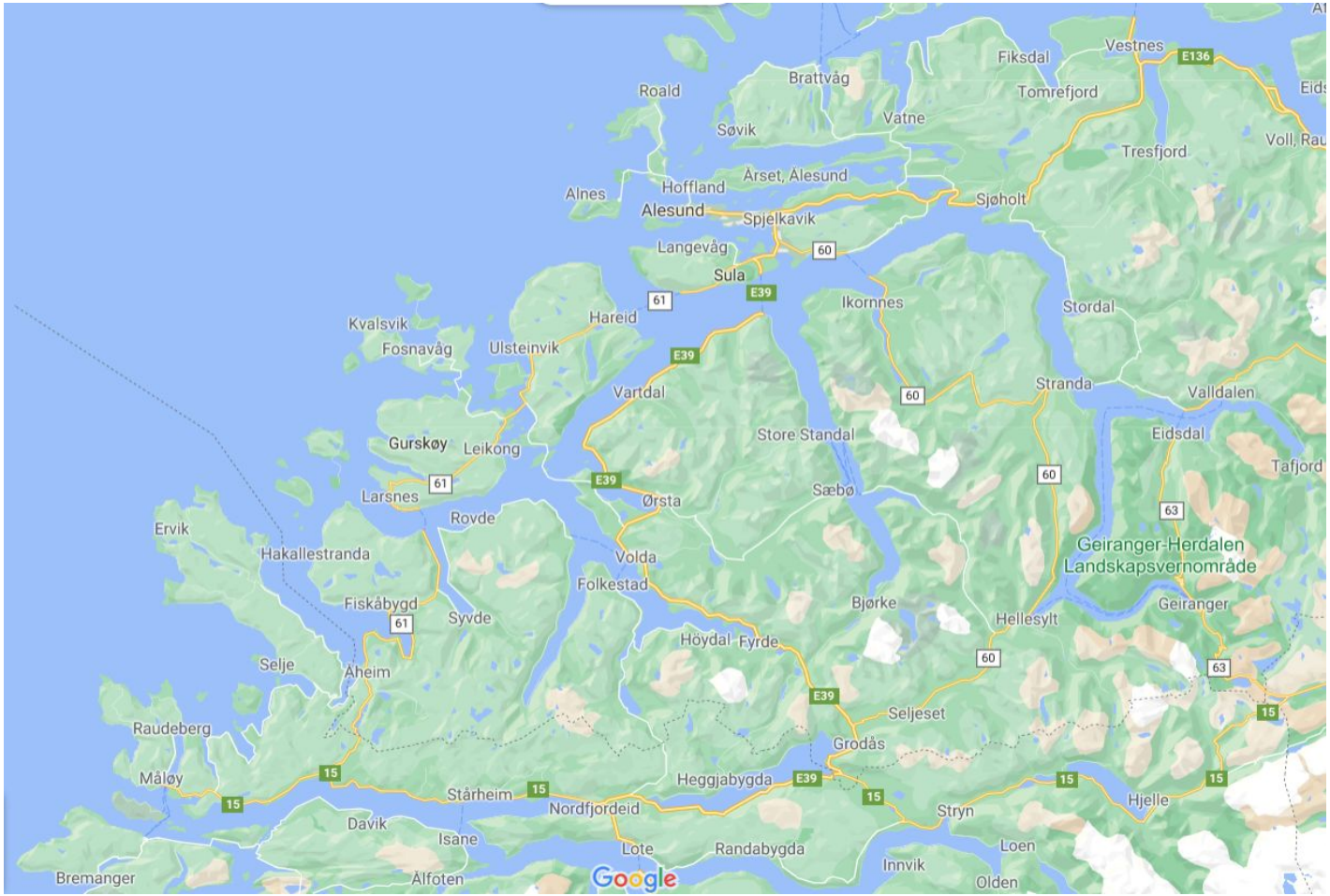
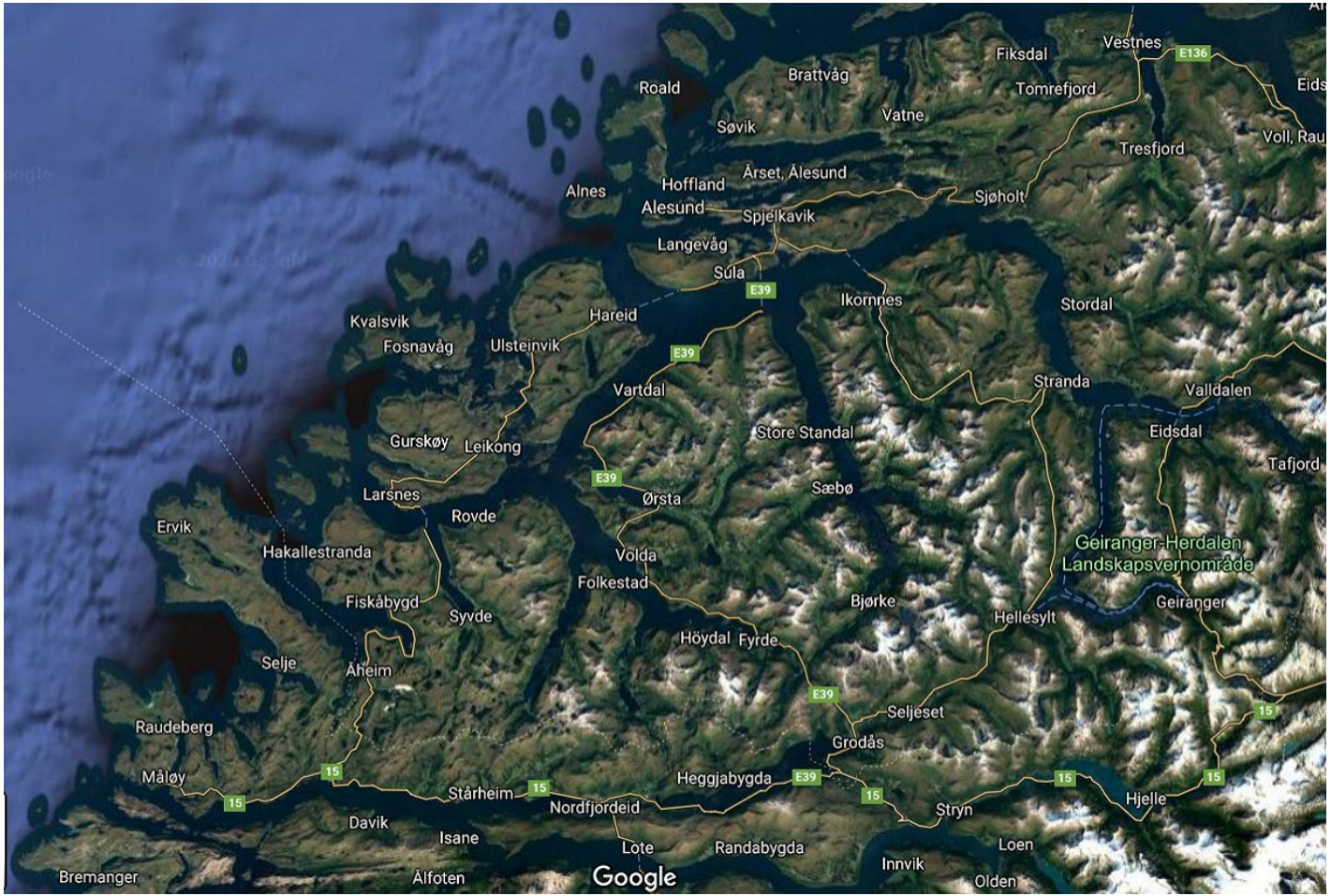
- Depth = 4
- t = 0.4

Relief feature enhancement



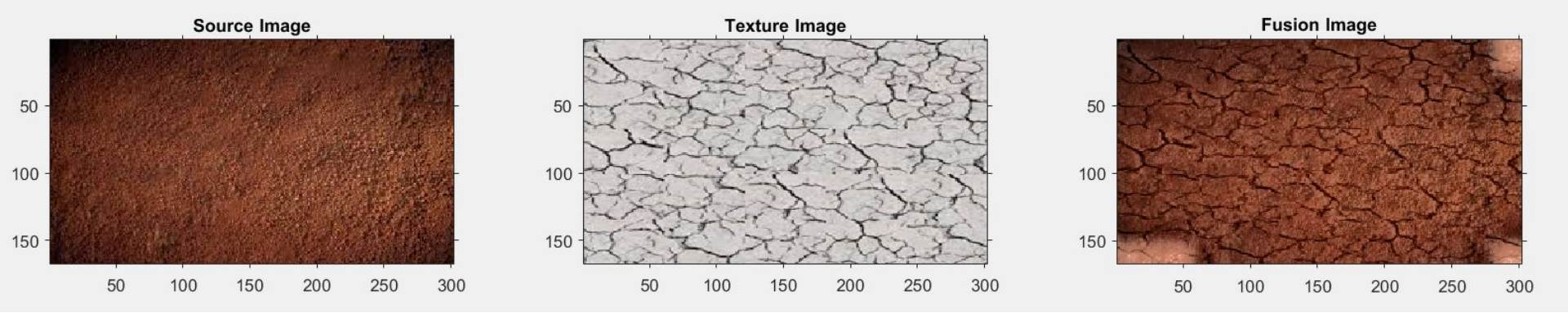
Relief feature enhancement



Relief feature enhancement

Limitation

- Sometimes if the parameters are not set correctly then white spots come in the picture hence parameters have to be tuned correctly for every image



- Depth = 4
- t = 0.3

Future work possible

- By using different fusion rules like window-based or region-based rules we can get different artistic results which can be explored further
- Extend the algorithm for very unequal sizes of source and texture images

GitHub Link for code

https://github.com/Ipsit1234/texture_transfer_using_wavelets

References

[1] Fast texture transfer through the use of wavelet-based image fusion https://ieeexplore.ieee.org/document/4420677

Thank you!