TEXTURAL TRANSFORM

FINAL PROJECT

COMPUTER VISION, FALL 2016

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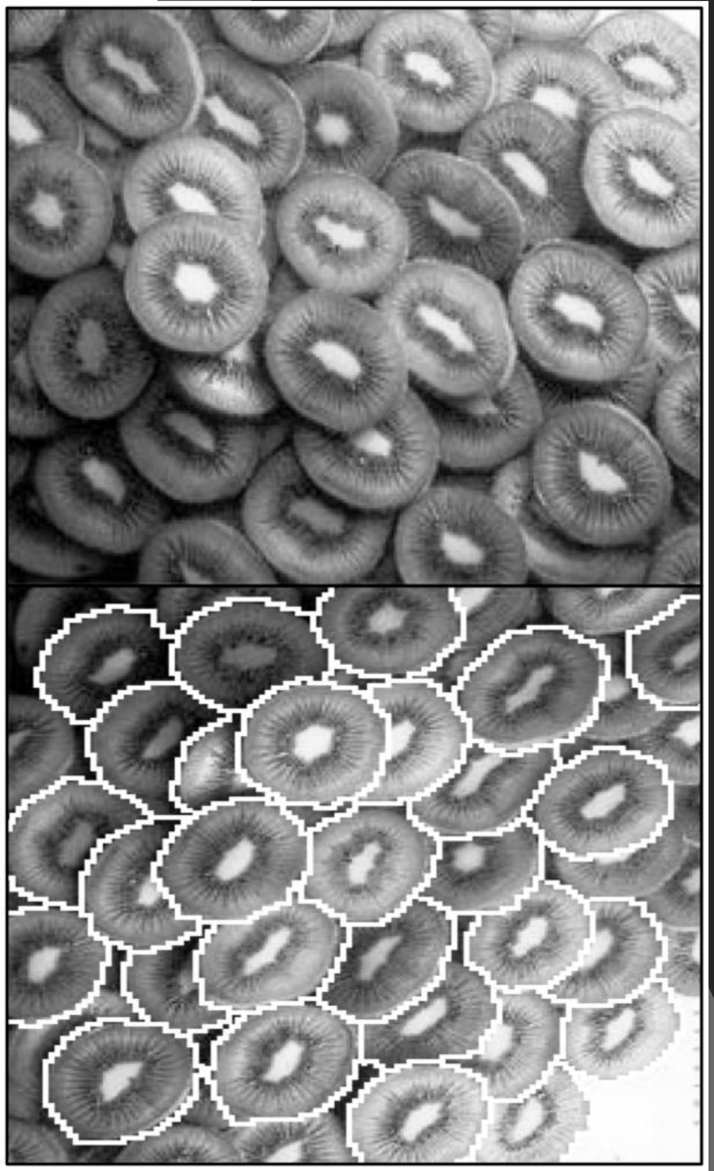
TEXTURE

- Important property of surfaces which characterizes their nature.
- Every object has a different texture.
- Image texture gives us information about the spatial arrangement of color or intensities in an image or a region. (Wiki)



TEXTURE ANALYSIS

- Structured approach : Textured image is composed of 'Texel's'.
  - A Texel is a pattern of pixels that repeat throughout the textured image.
- Statistical approach:
  - Edge based.
  - Energy based.
  - Autocorrelation and Power Spectrum.
  - Co-occurrence matrix based.

GCLM BASED TEXTURE ANALYSIS

- GCLM : Gray-level co-occurrence matrix.
- Any patch of an image that shows a texture is a region having a stochastic dependency among the pixel values of the patch.
- Functionals of the co-occurrence matrix can be used as features in distinguishing one texture from another.

I

1	1	5	6	8
2	3	5	7	1
4	5	7	1	2
8	5	1	2	5

GLCM

	1	2	3	4	5	6	7	8
1	1	2	0	0	1	0	0	0
2	0	0	1	0	1	0	0	0
3	0	0	0	0	1	0	0	0
4	0	0	0	0	1	0	0	0
5	1	0	0	0	0	1	2	0
6	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0
8	0	0	0	0	1	0	0	0

GCLM ANALYSIS

$$N_1 = \{((r,c),(u,v)) \in (R \times C)^2 \mid (u,v) = (r-1, c+1) \text{ or } (u,v) = (r+1, c-1)\}$$
$$P_1(i,j) = \frac{\#\{((r,c),(u,v)) \in N_1 \mid \mathcal{I}(r,c) = i \text{ and } \mathcal{I}(u,v) = j\}}{\# N_1}$$

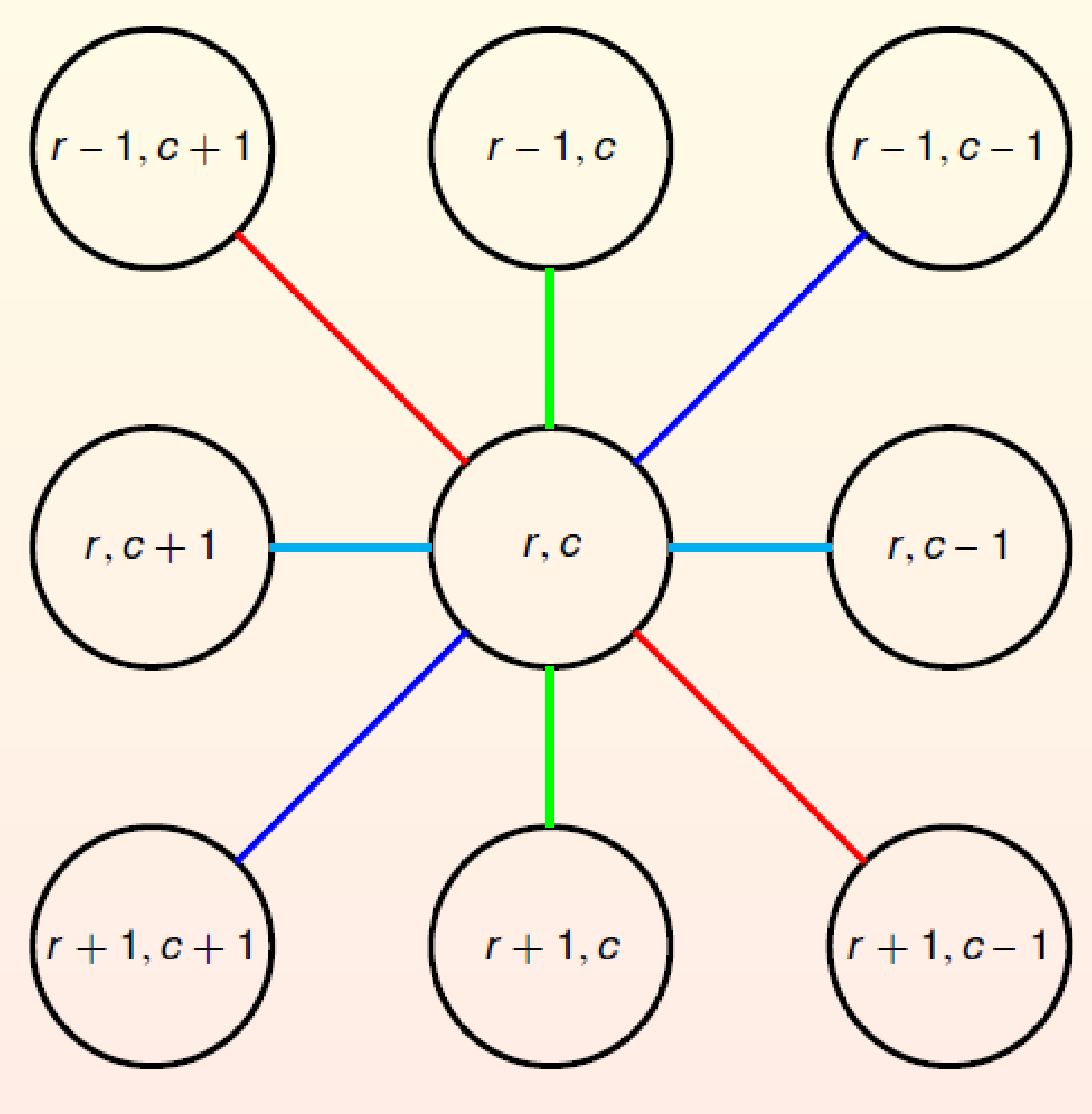
$$N_2 = \{((r,c),(u,v)) \in (R \times C)^2 \mid (u,v) = (r, c+1) \text{ or } (u,v) = (r, c-1)\}$$
$$P_2(i,j) = \frac{\#\{((r,c),(u,v)) \in N_2 \mid \mathcal{I}(r,c) = i \text{ and } \mathcal{I}(u,v) = j\}}{\# N_2}$$

$$N_3 = \{((r,c),(u,v)) \in (R \times C)^2 \mid (u,v) = (r-1, c-1) \text{ or } (u,v) = (r+1, c+1)\}$$
$$P_3(i,j) = \frac{\#\{((r,c),(u,v)) \in N_3 \mid \mathcal{I}(r,c) = i \text{ and } \mathcal{I}(u,v) = j\}}{\# N_3}$$

$$N_4 = \{((r,c),(u,v)) \in (R \times C)^2 \mid (u,v) = (r-1, c) \text{ or } (u,v) = (r+1, c)\}$$
$$P_4(i,j) = \frac{\#\{((r,c),(u,v)) \in N_4 \mid \mathcal{I}(r,c) = i \text{ and } \mathcal{I}(u,v) = j\}}{\# N_4}$$

$$N(r,c) = \{(r,c)\} \cup \bigcup_{k=1}^{4} N_k(r,c)$$

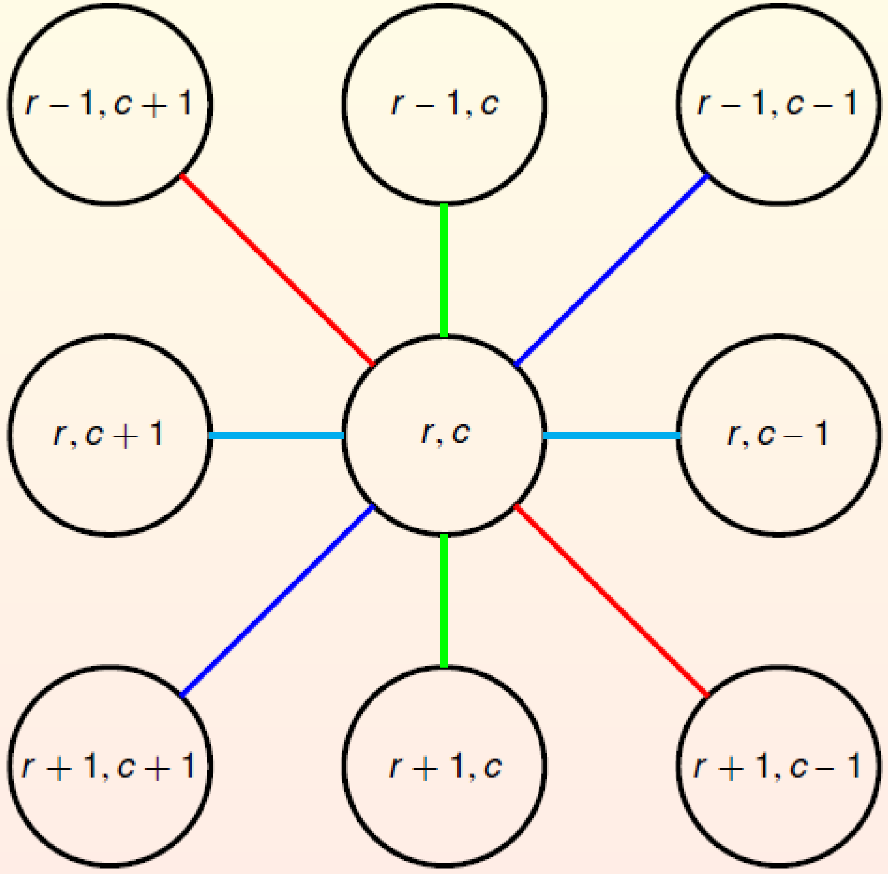
Neighborhood Joint Probability: $P(I(u,v) : (u,v) \in N(r,c))$



TEXTURE TRANSFORM IMAGE

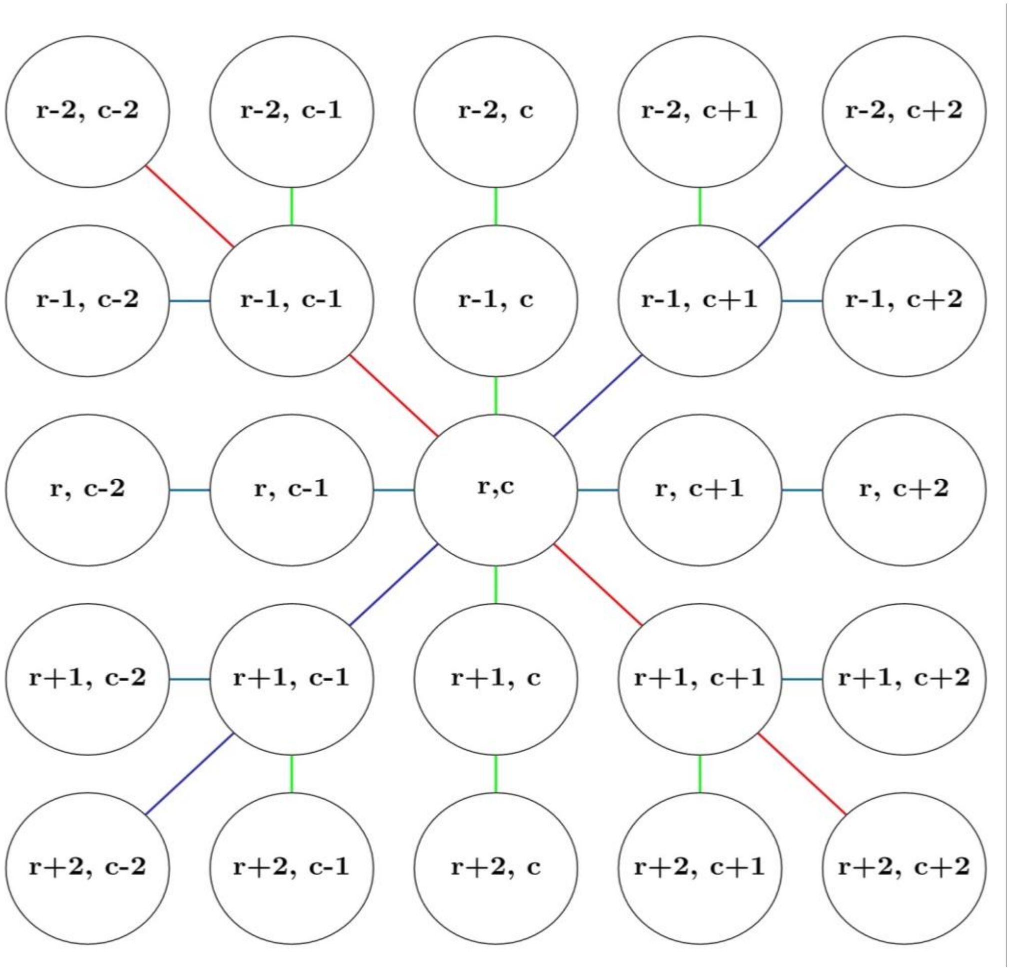
- $\mathcal{I}$ Input Image
- P_k, $k = 1, 2, 3, 4$ Cooccurrence Probabilities
- N_k, $k = 1, 2, 3, 4$ Local Neighborhoods
- $\mathcal{J}$ Output Image

$$\mathcal{J}(r,c) = \sum_{k=1}^{4} \sum_{(u,v)\in N_k(r,c)} P_k(\mathcal{I}(r,c), \mathcal{I}(u,v))\theta_k$$



5-Neighborhood GCLM

- The 5-N GCLM looks at a 5x5 neighborhood.
- Should detect coarser textures.



EXAMPLES

Input image

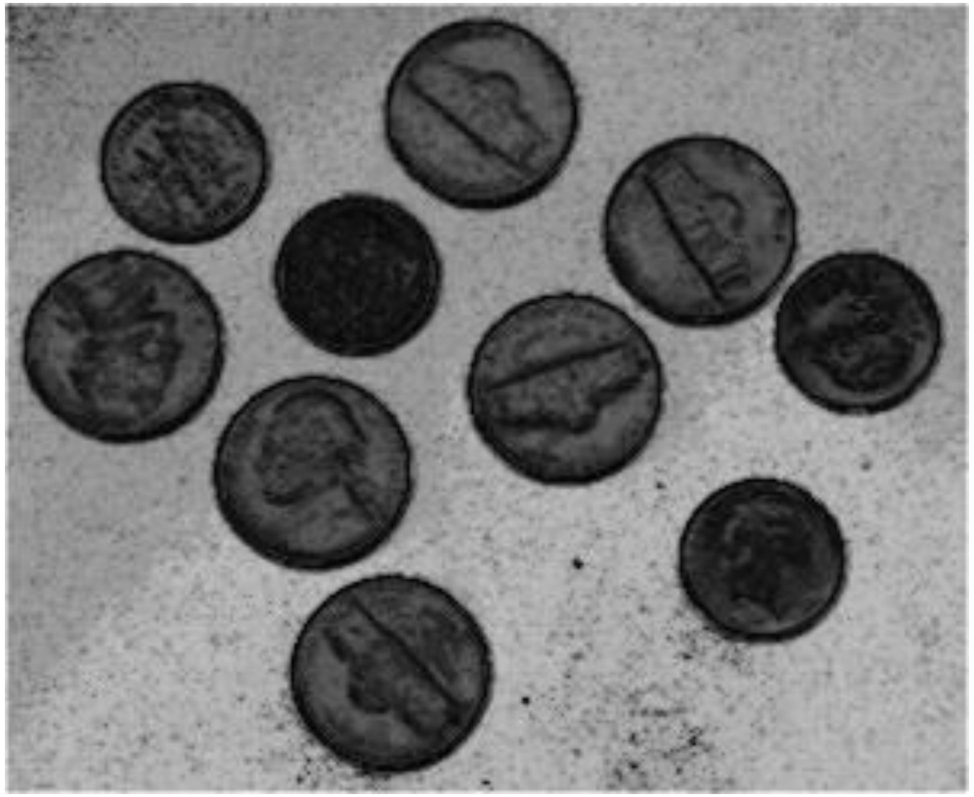
Texture transform image (3-N)

Input image

Texture transform image (5-N)

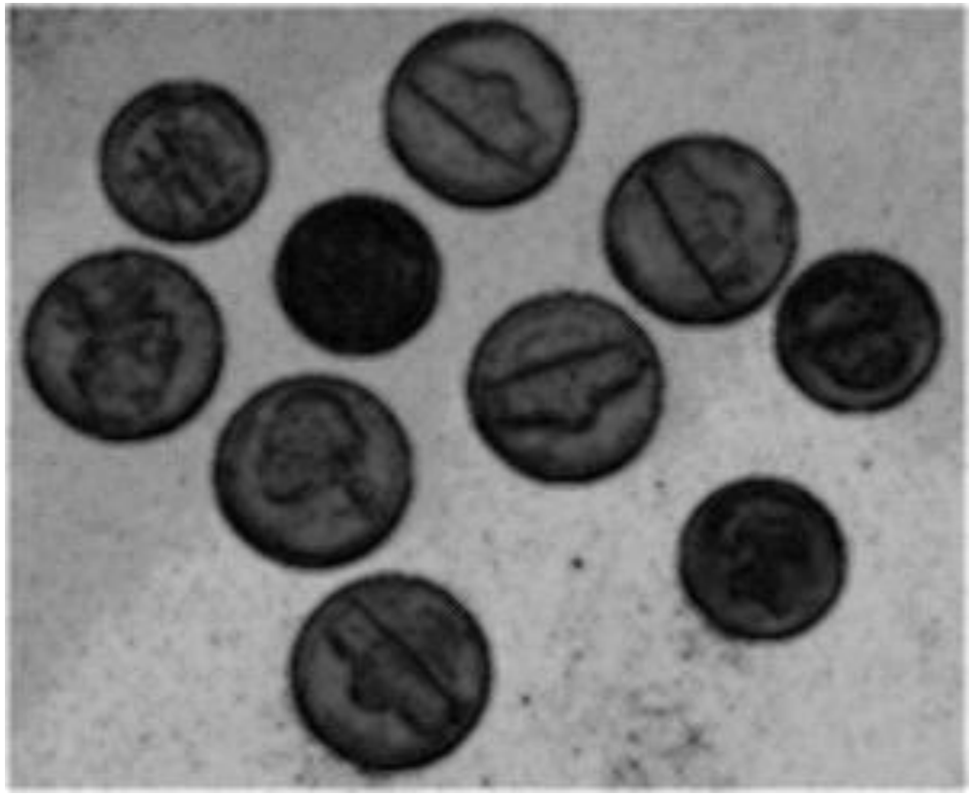
Input image

Texture transform image (3-N)

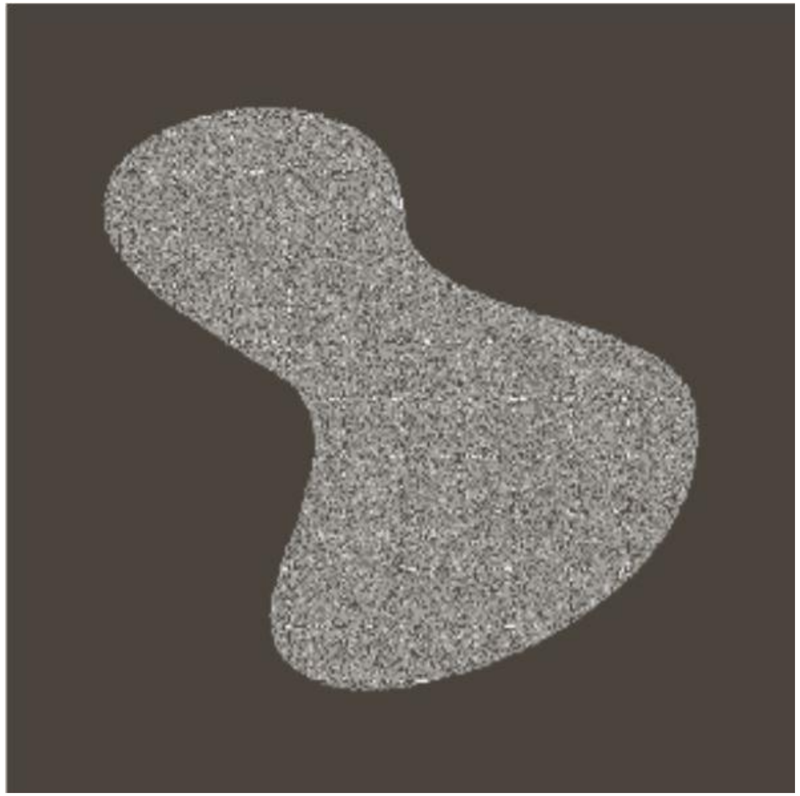


Input image

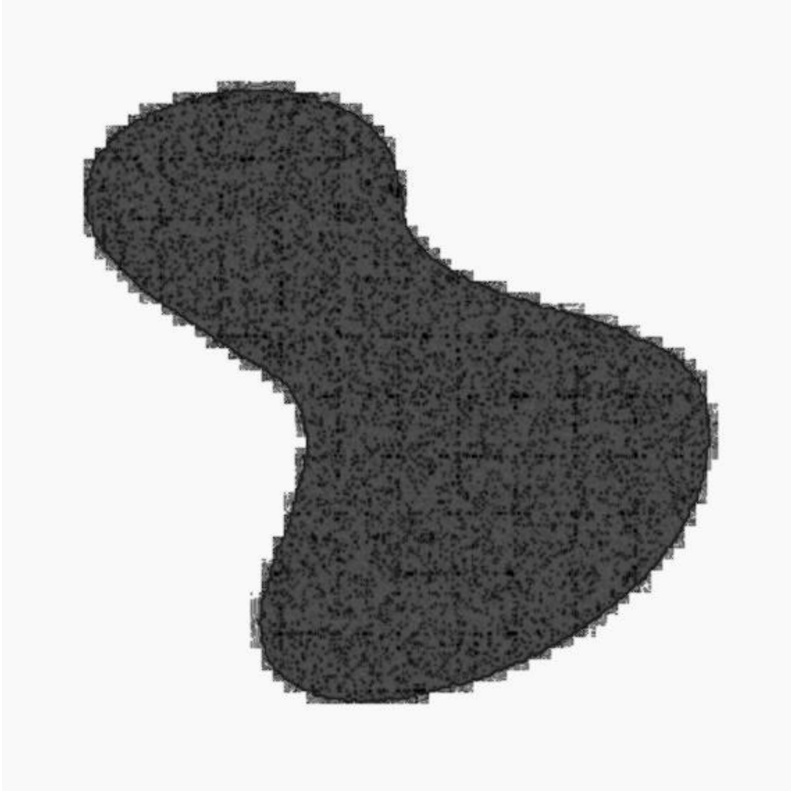
Texture transform image (5-N)



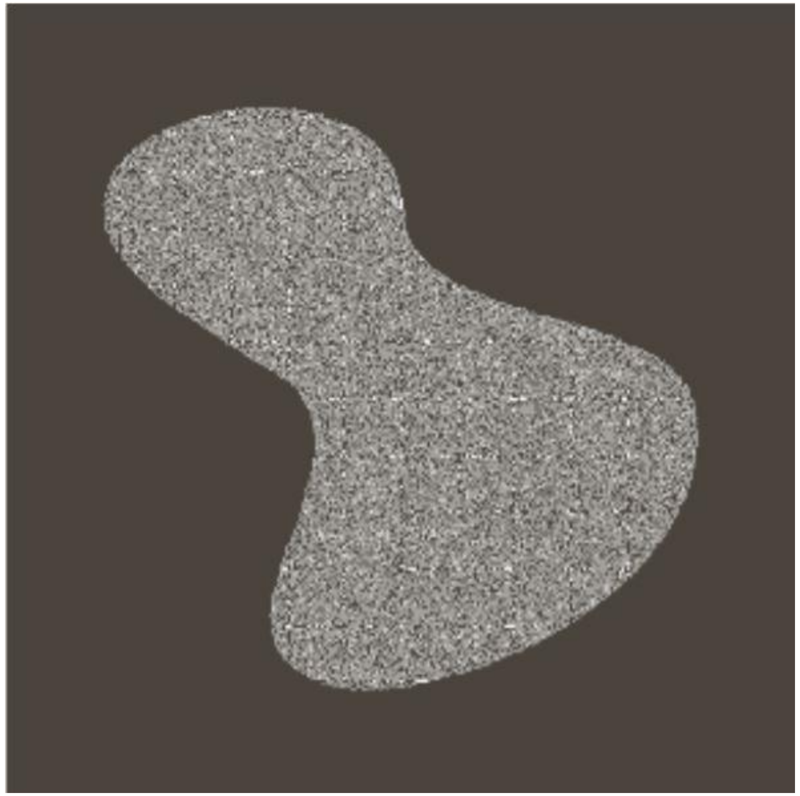
Input image



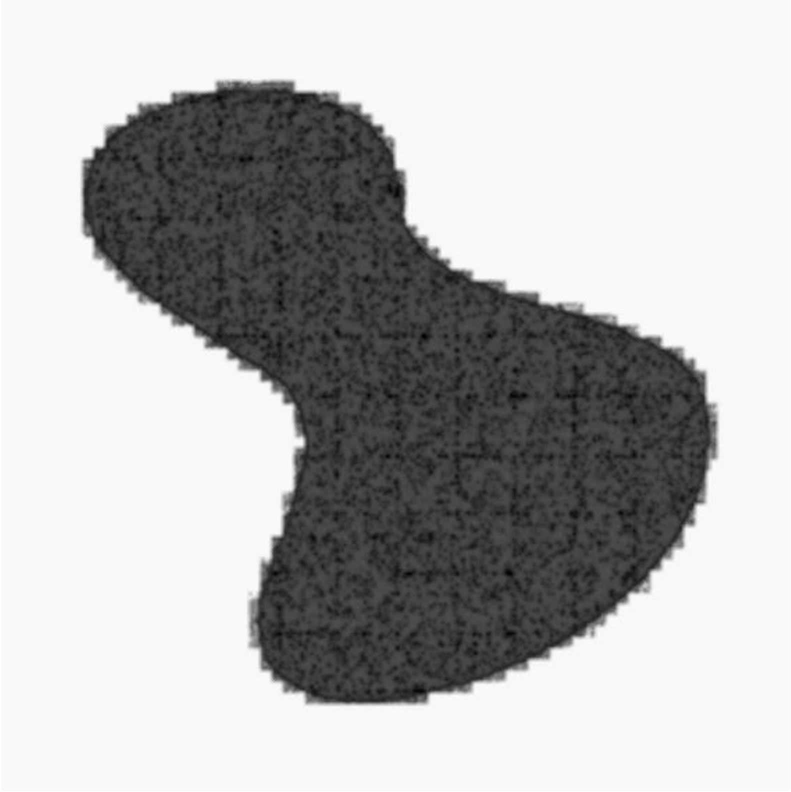
Texture transform image (3-N)



Input image



Texture transform image (5-N)



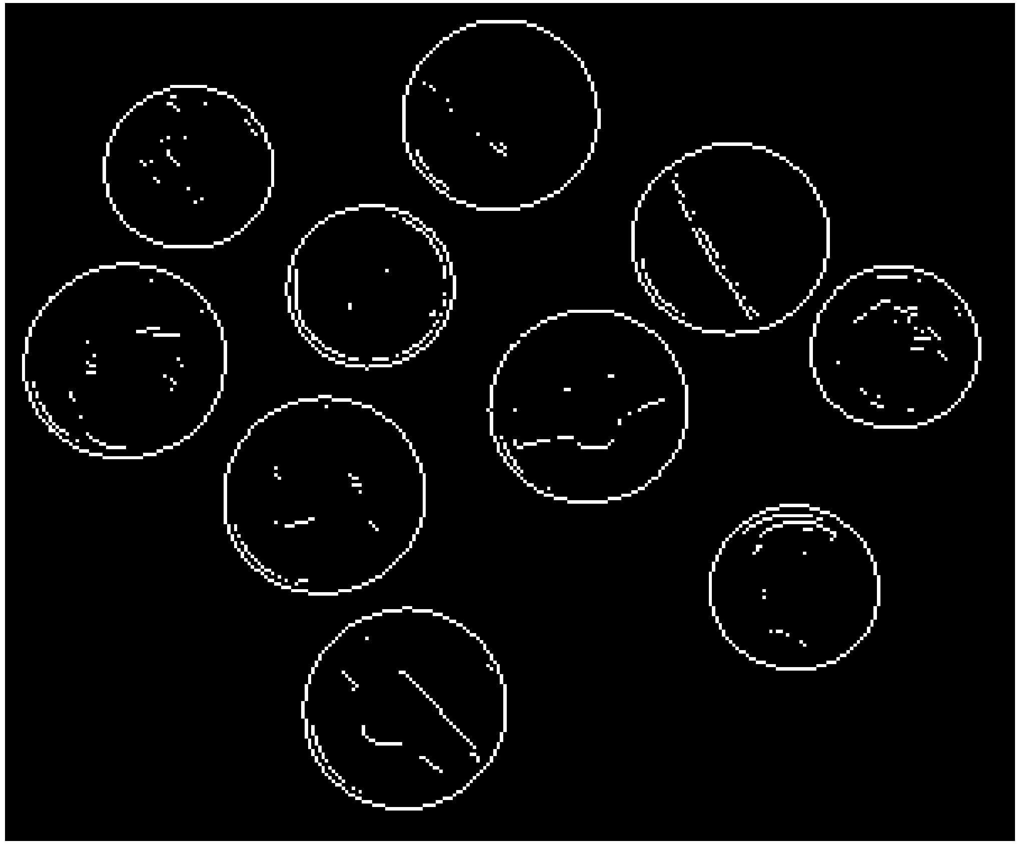
APPLICATIONS

- Edge Detection/ Object segmentation.
- Texture segmentation

Edge Detection

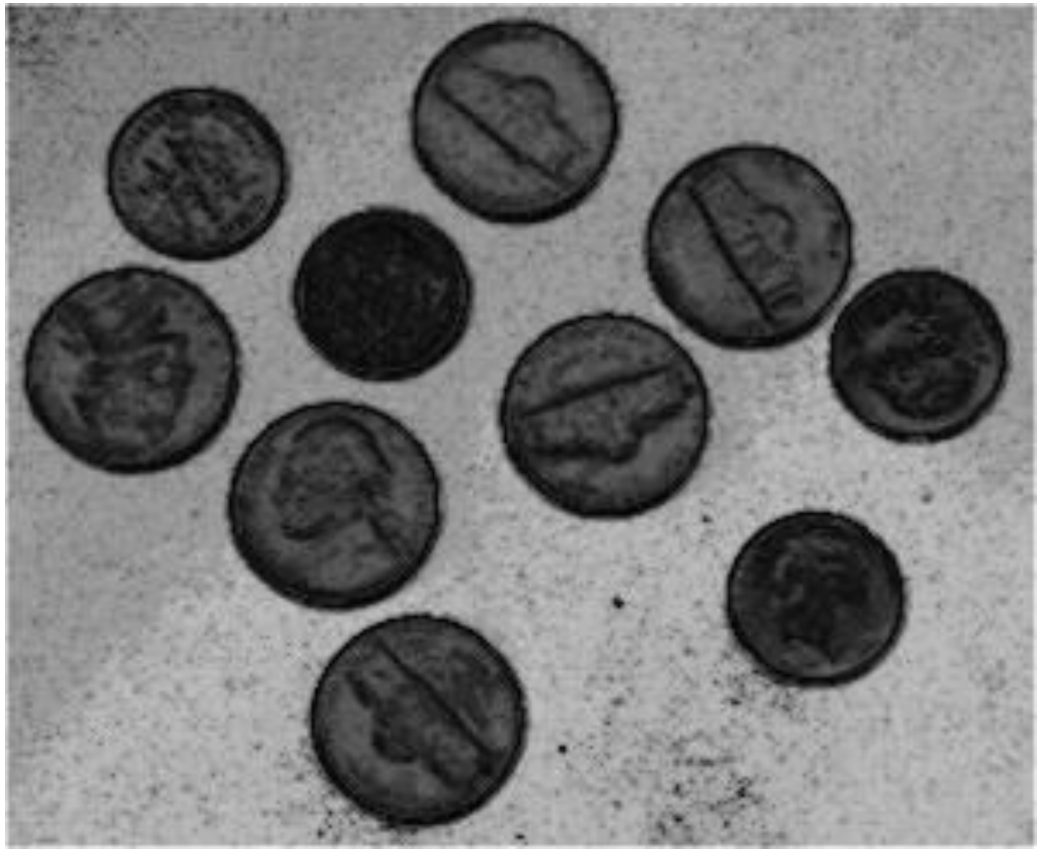
Input image

Output (Sobel filter)

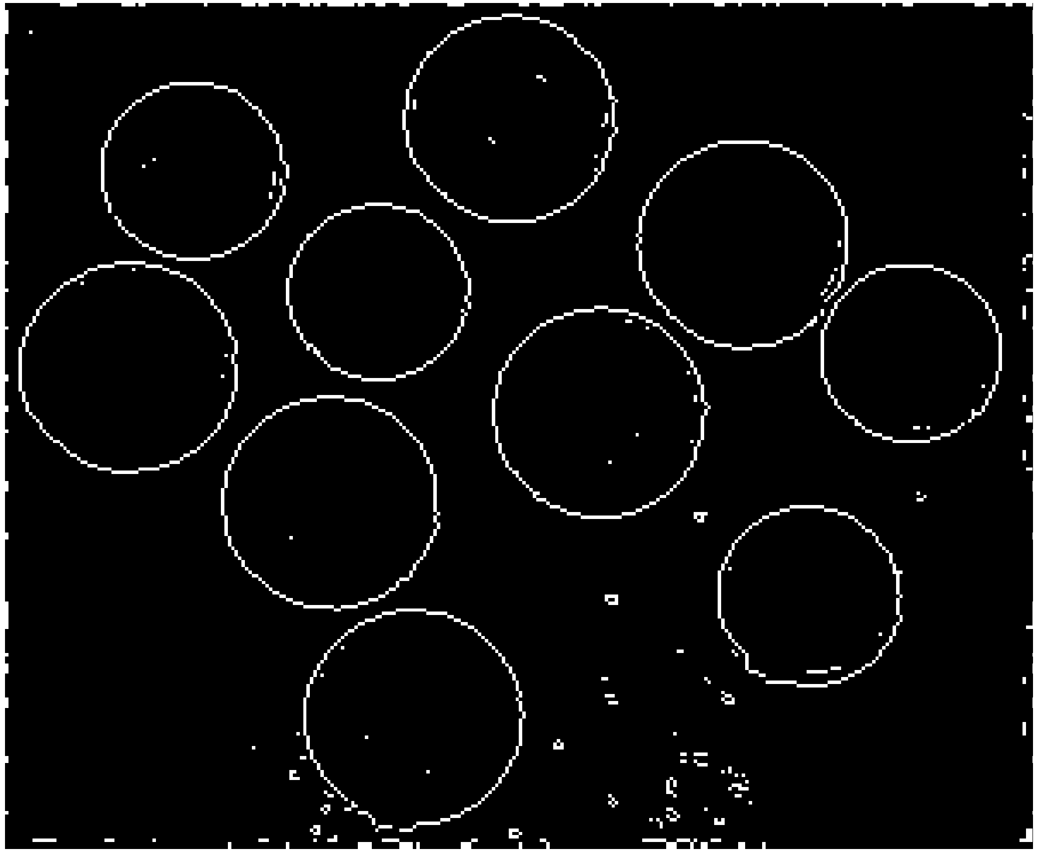


Edge Detection

Input image

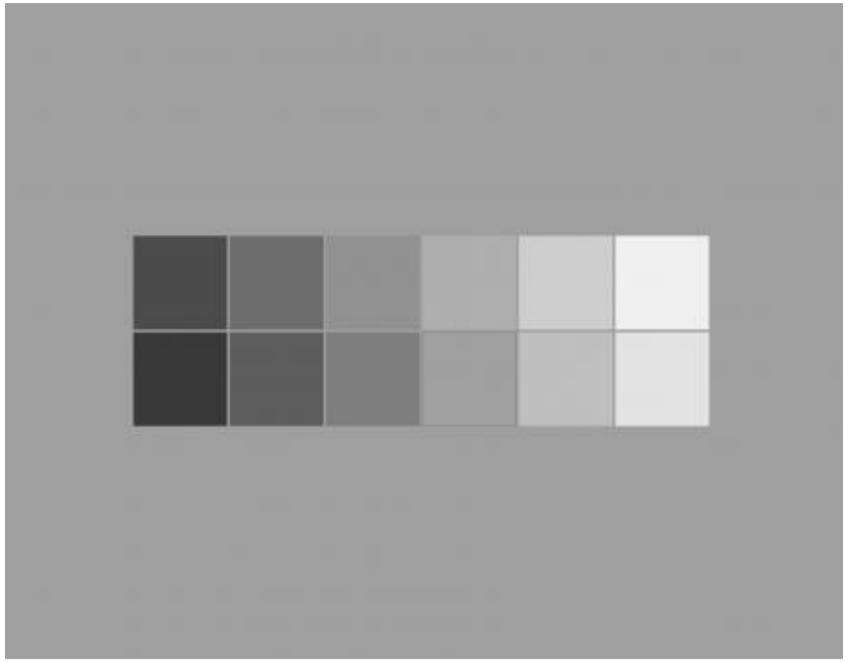


Output (Sobel filter)

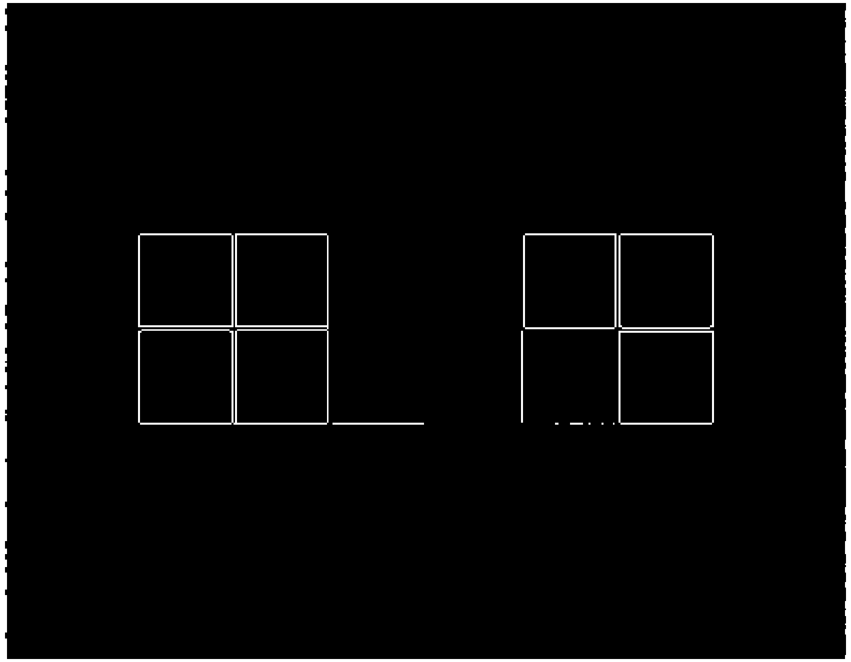


Edge Detection

Input image

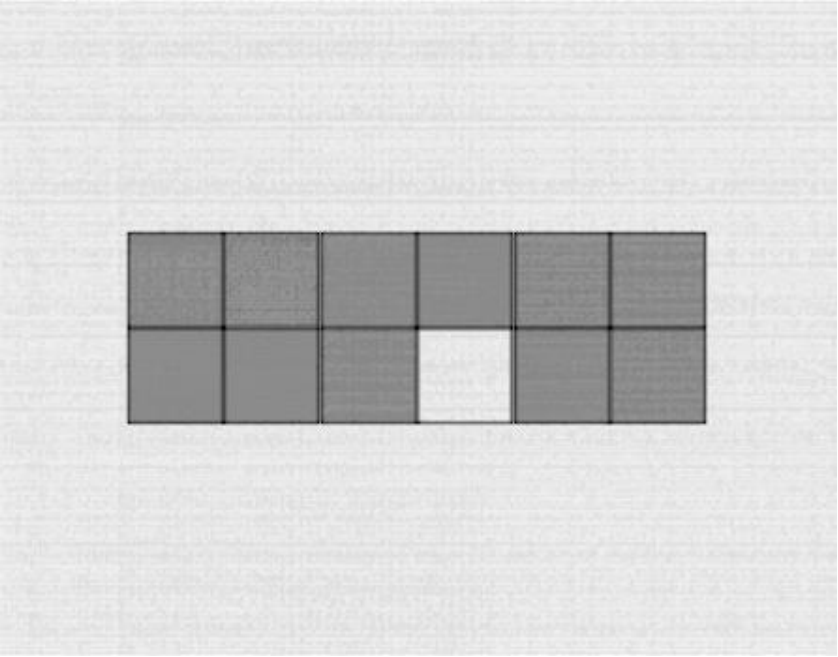


Output (Sobel filter)

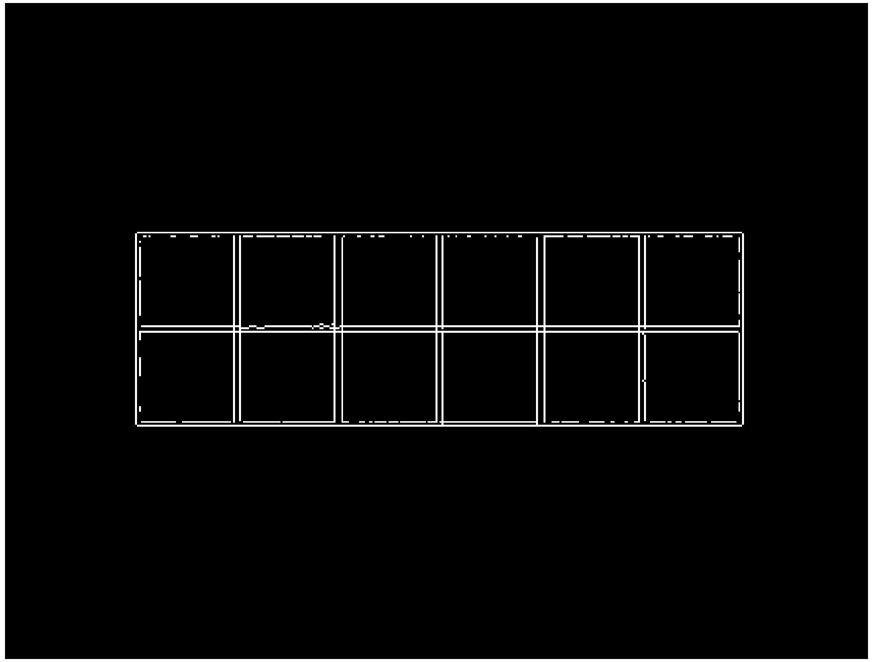


Edge Detection

Input image

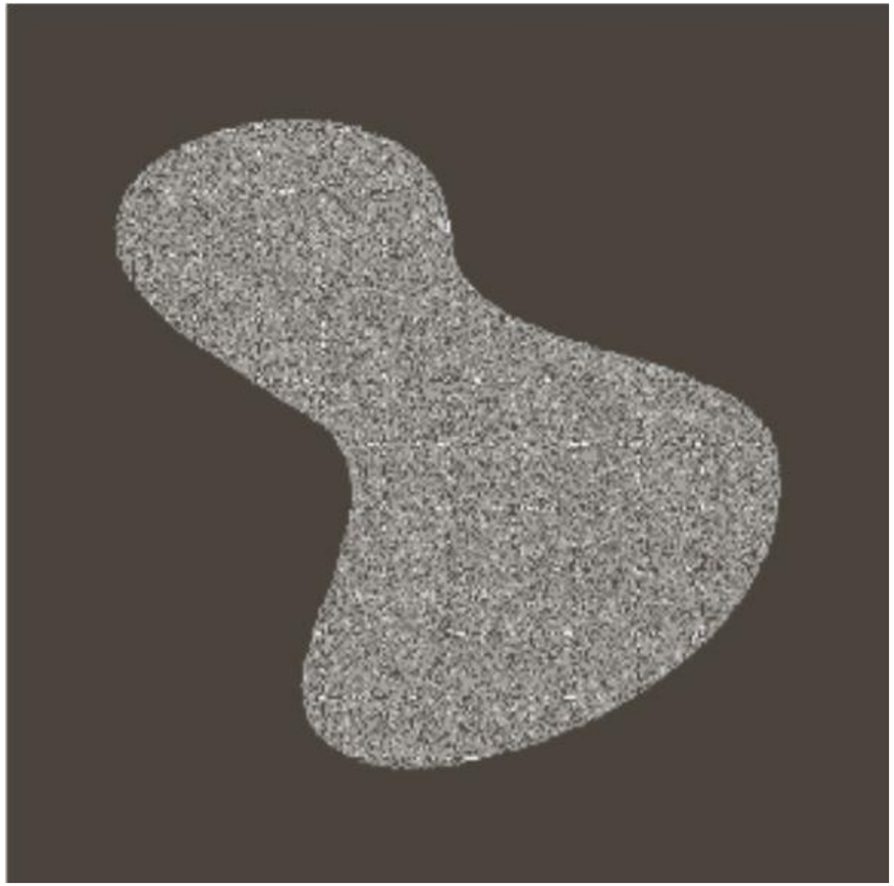


Output (Sobel filter)

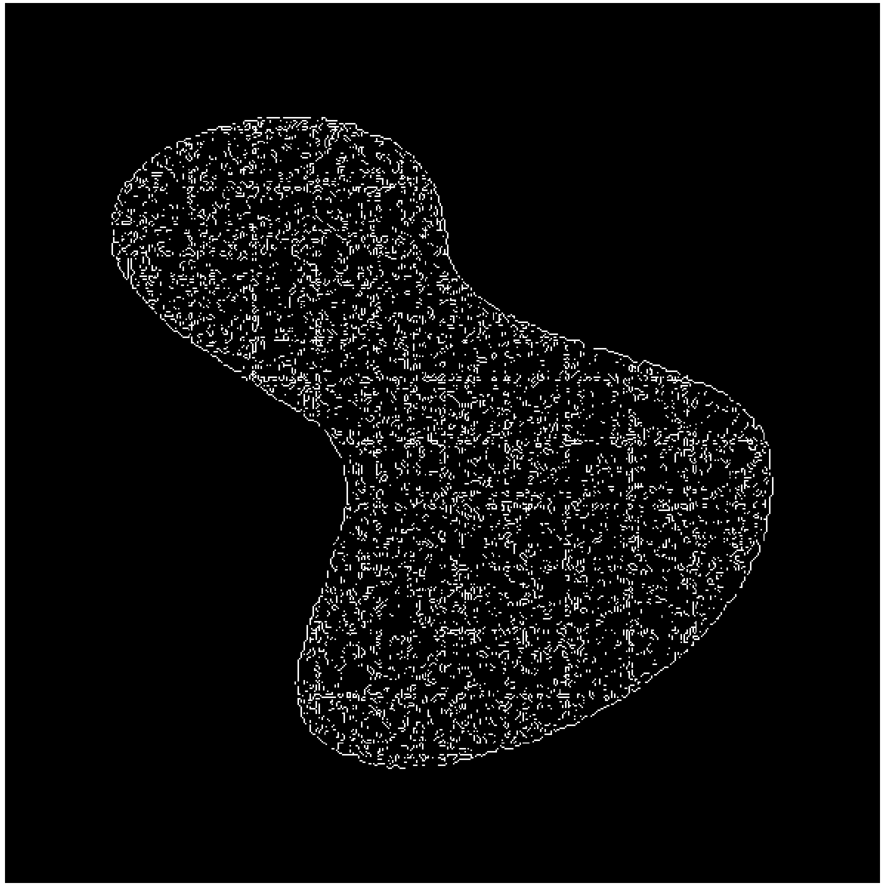


Edge Detection (Texture image)

Input image

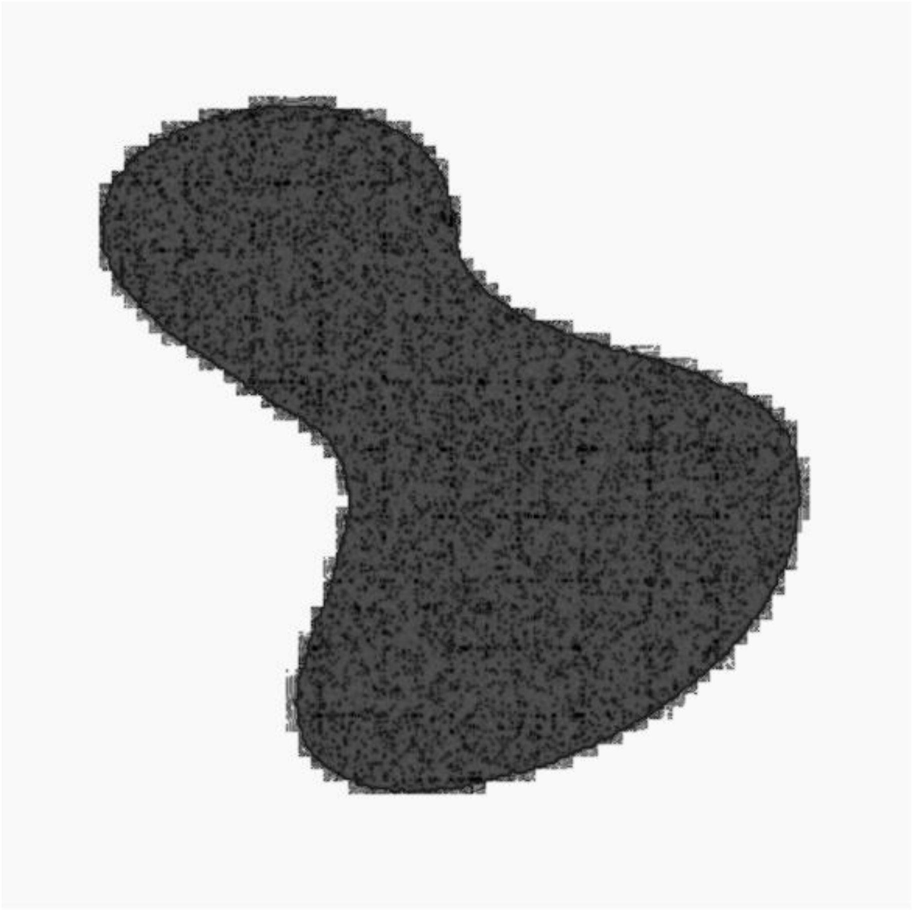


Output (Sobel filter)

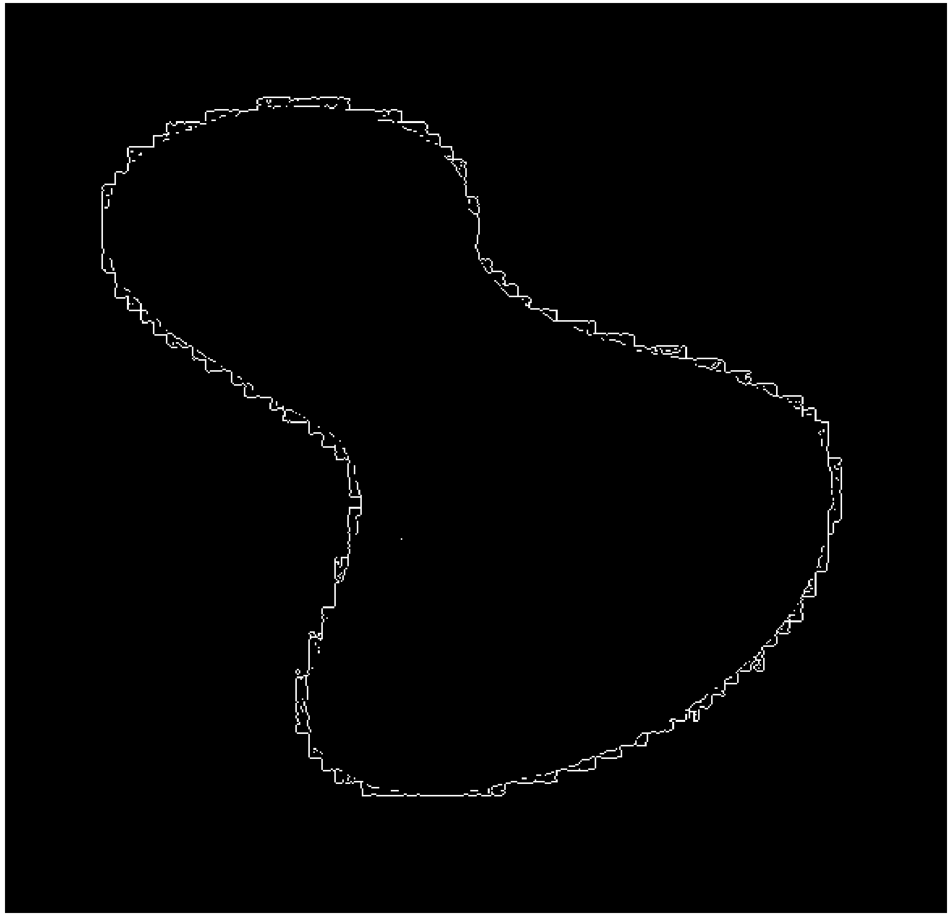


Edge Detection (Texture image)

Input image



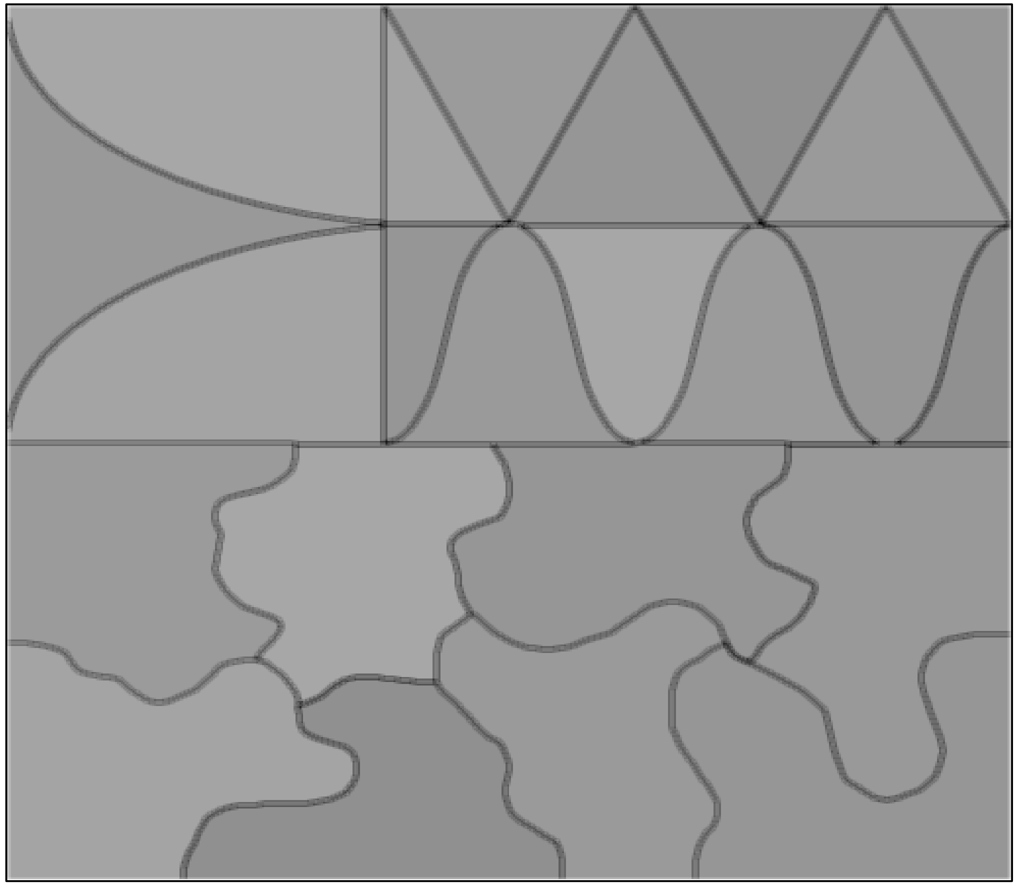
Output (Sobel filter)



Edge Detection

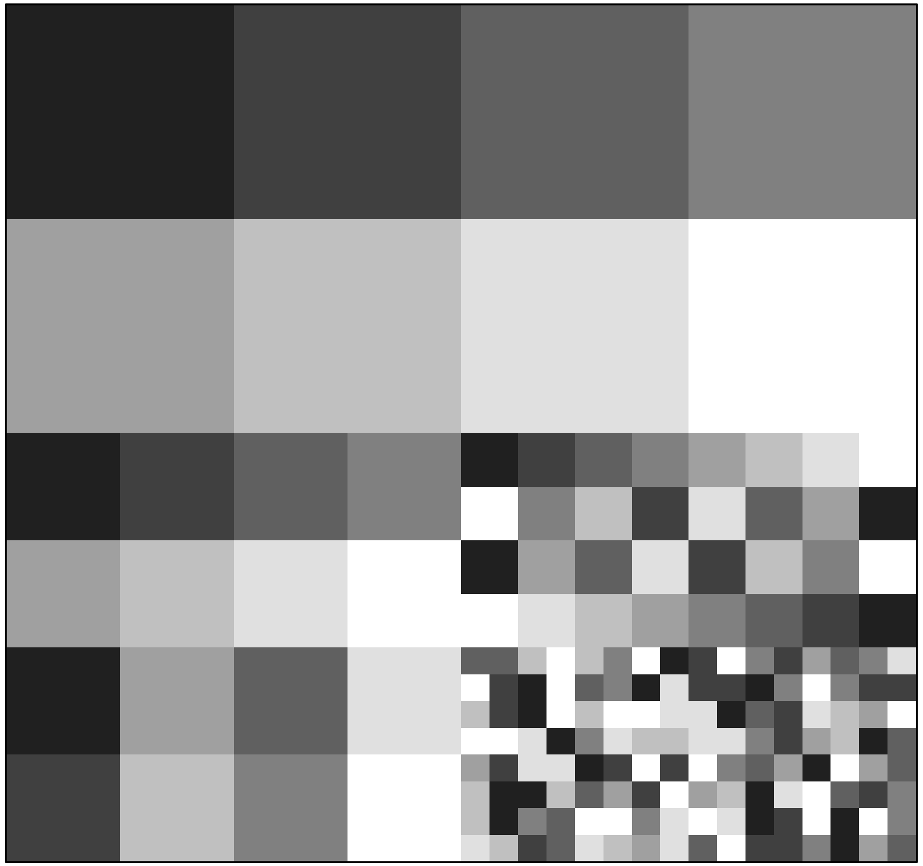
Input image

Output (Texture transform)

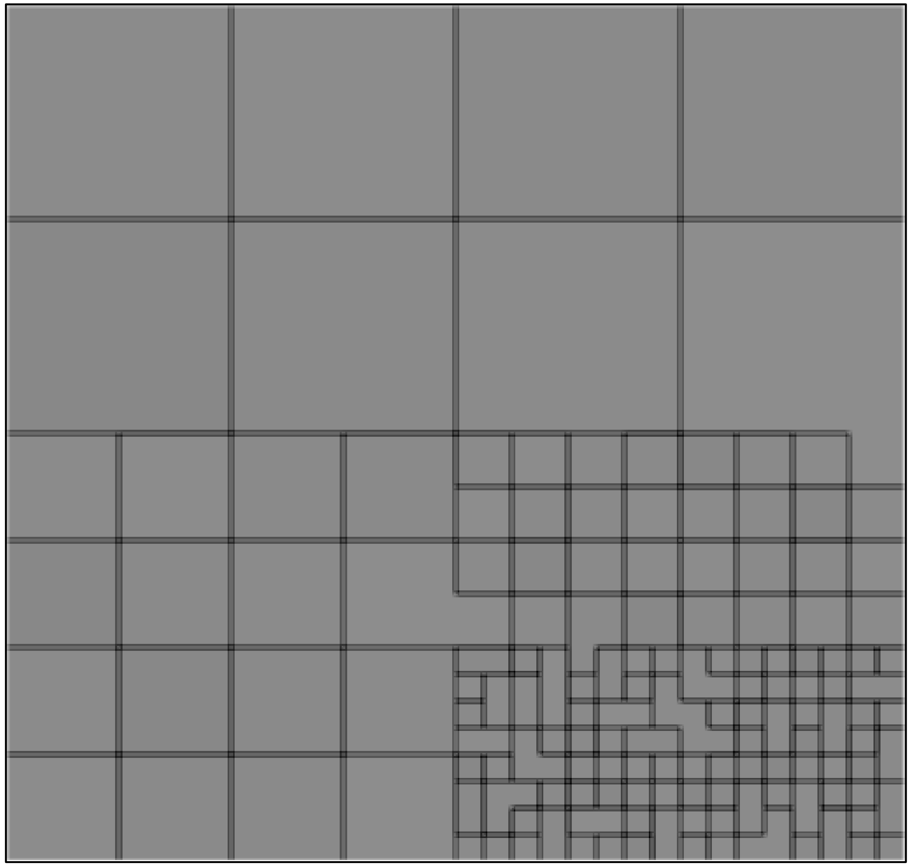


Edge Detection

Input image



Output (Texture transform)



TEXTURE SEGMENTATION SYSTEM

- It has three phases:
  - Image decomposition using a filter bank
  - Feature extraction, and
  - Clustering

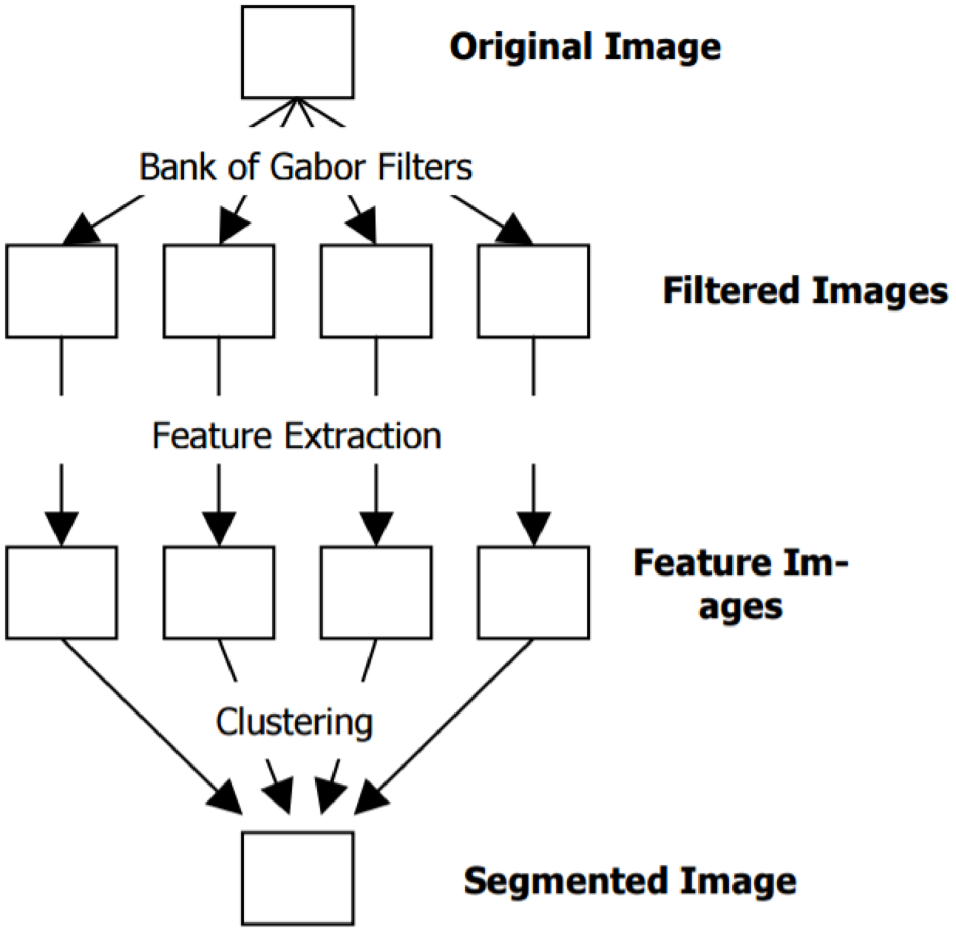
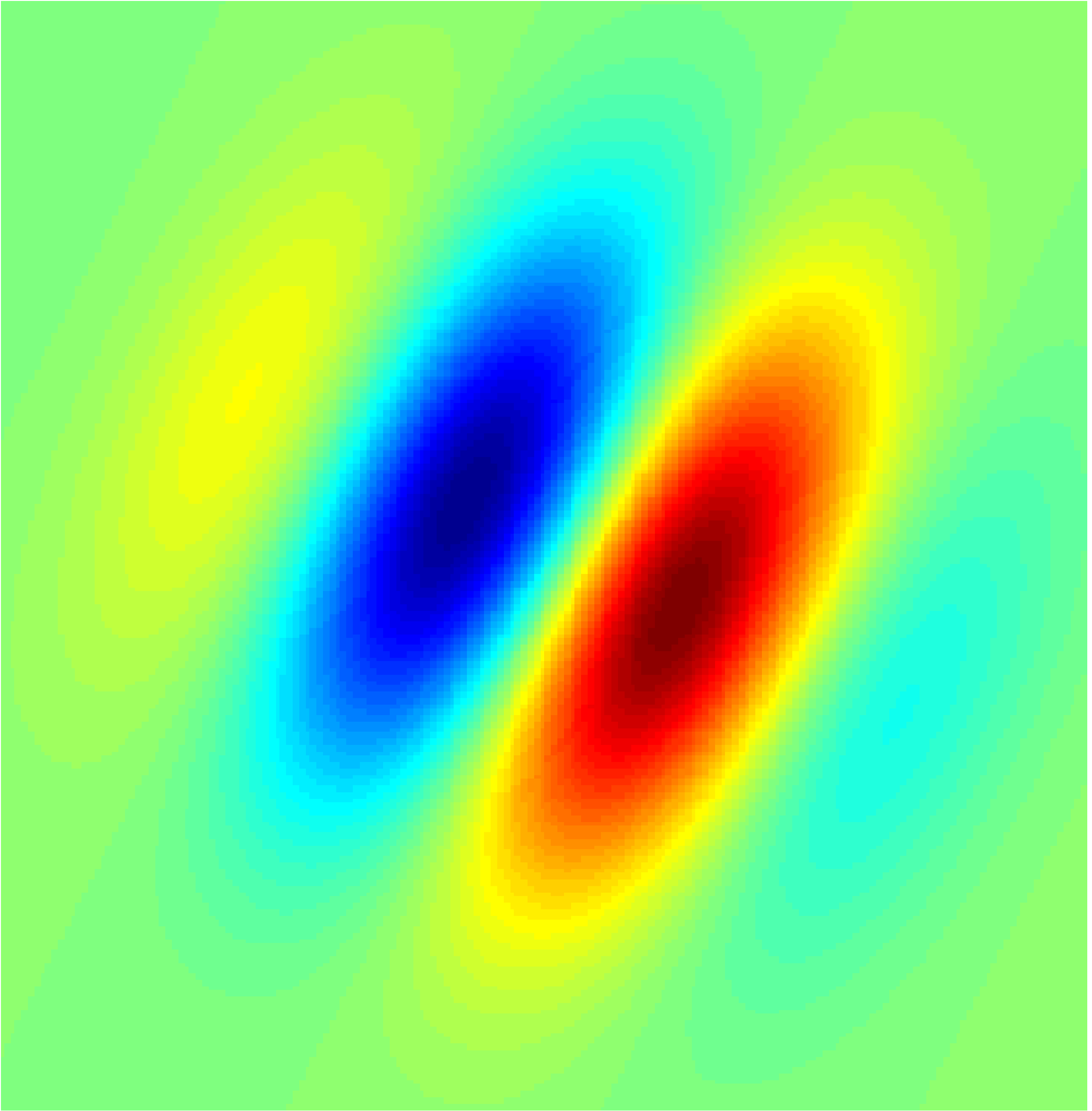


Figure 1. Texture segmentation process

FILTER BANK

- Convolution of image with a bank of 2-d Gabor filters.
- In spatial domain, 2-d Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave.



Example of 2d Gabor filter

FEATURE EXTRACTION

- They used only the real part of the Gabor filter.
- Used a non-linear sigmoidal function :

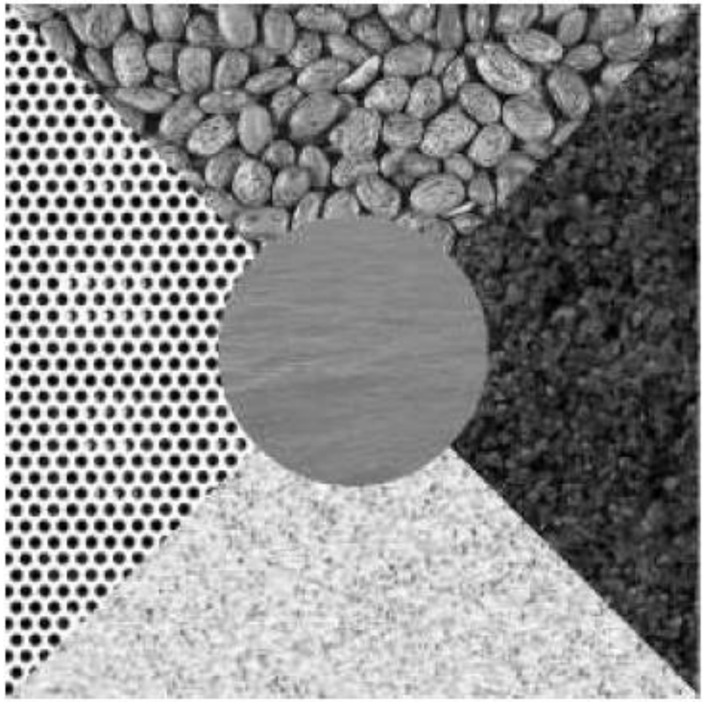
$$\tanh(\alpha t) = \frac{1 - e^{-2\alpha t}}{1 + e^{-2\alpha t}}$$

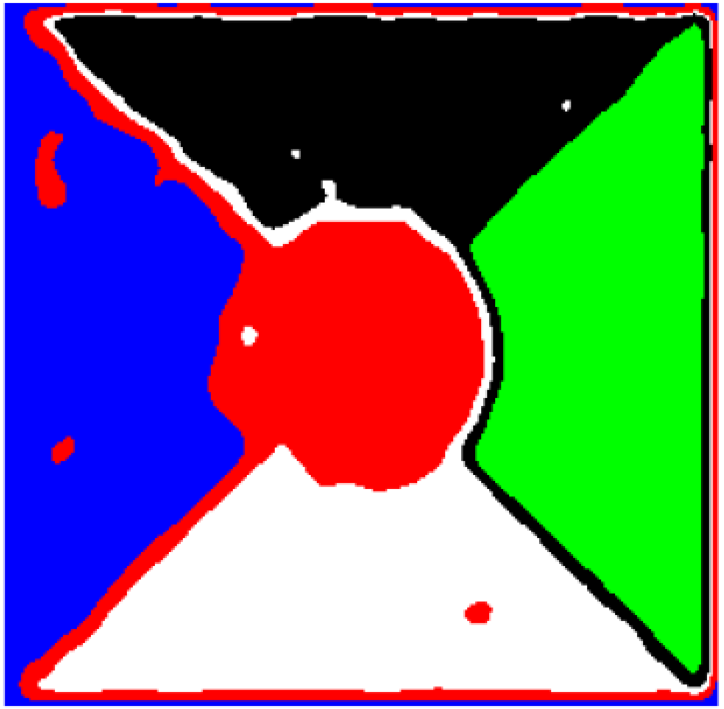
- Applied Gaussian smoothing to filtered image.
- Also took into account spatial adjacency of pixels.
- The resulting feature image has enhanced features.

CLUSTERING

- Clustering is used to group the pixels having similar textures together.
- The pixel coordinates (spatial adjacency) are two additional features.
- They used K-means clustering.
    1. Initialize centroids of K-clusters randomly.
    2. Assign each sample to the nearest centroid.
    3. Calculate centroids (means) of K-clusters.
    4. If centroids are unchanged, done. Otherwise, go to step 2.

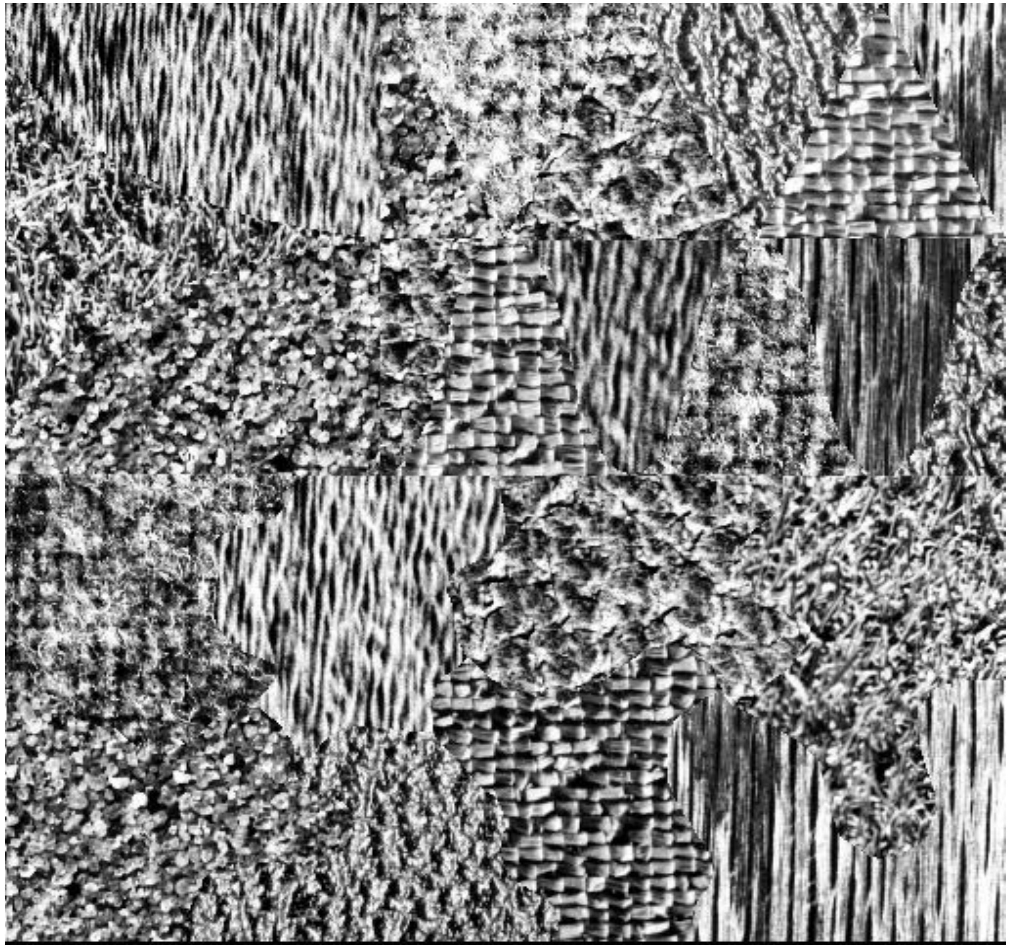
A SAMPLE RUN

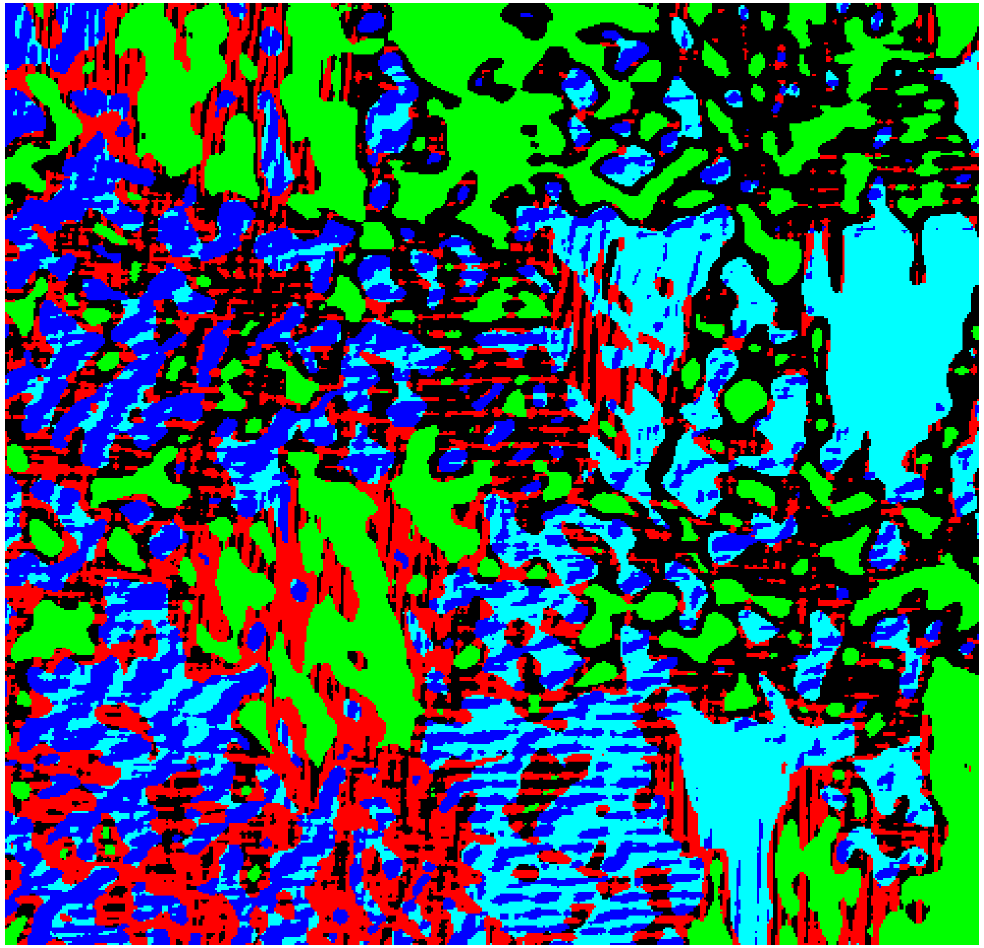




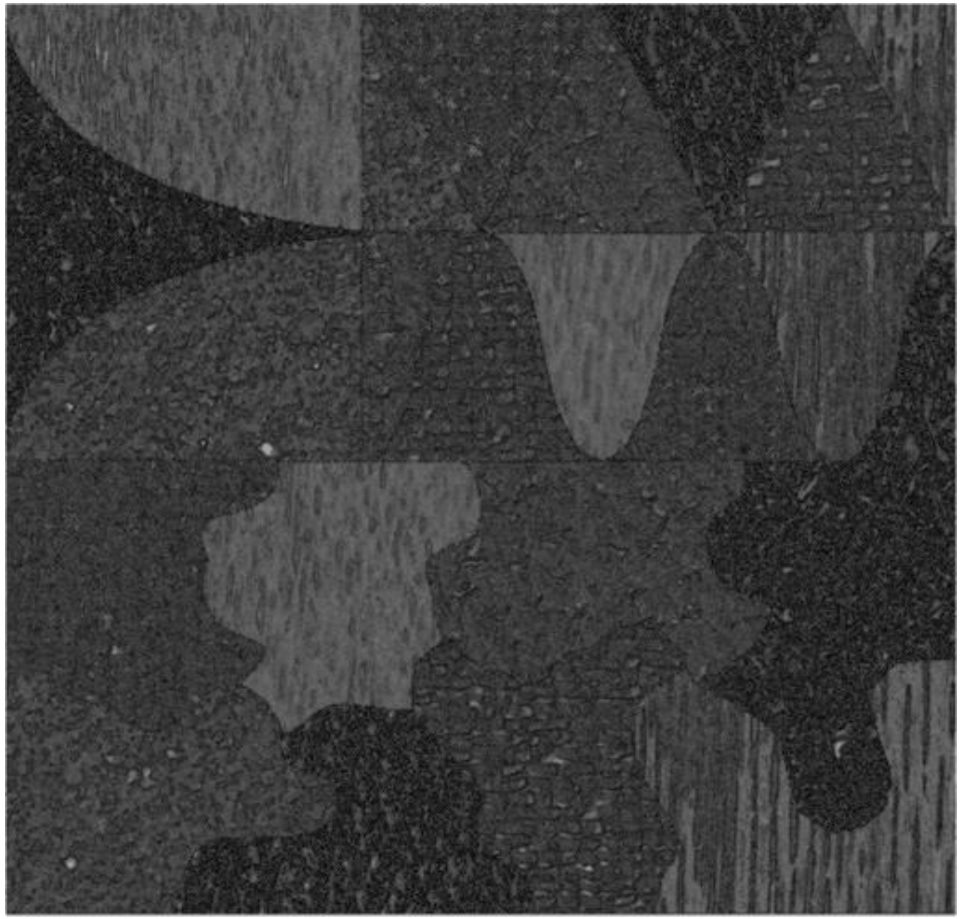
INPUT → FEATURE IMAGE → SEGMENTED IMAGE

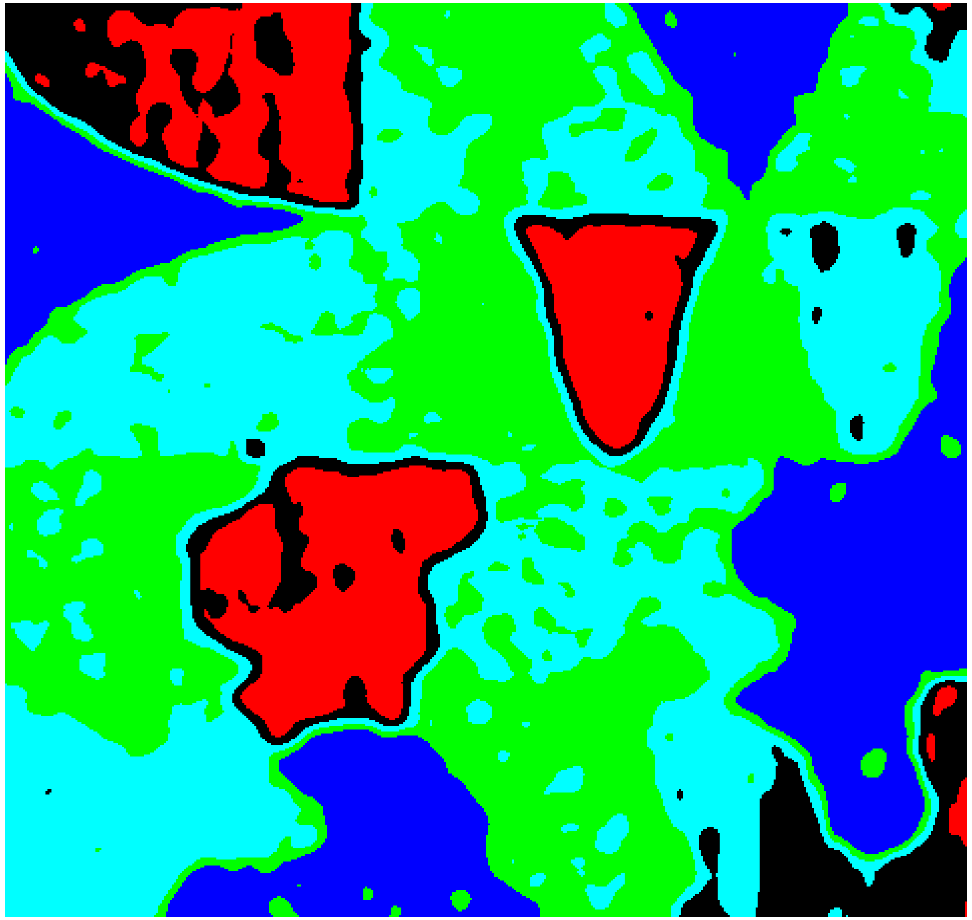
Segmenting Complex Texture Images



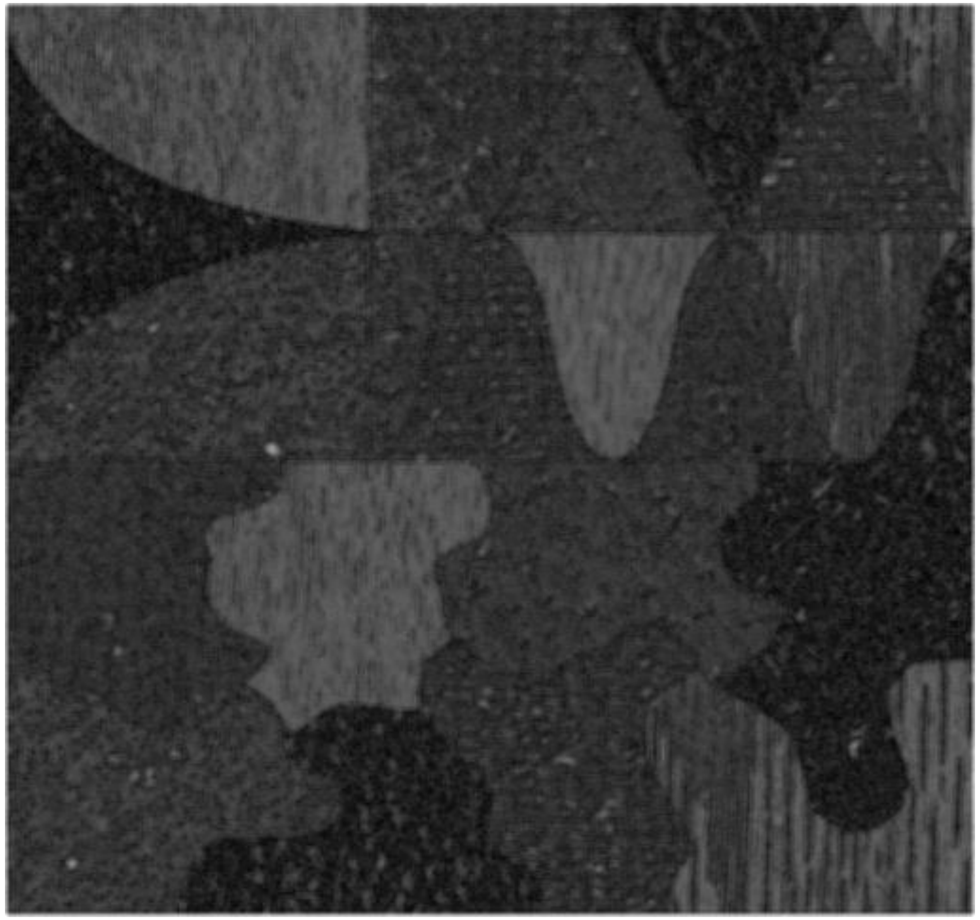


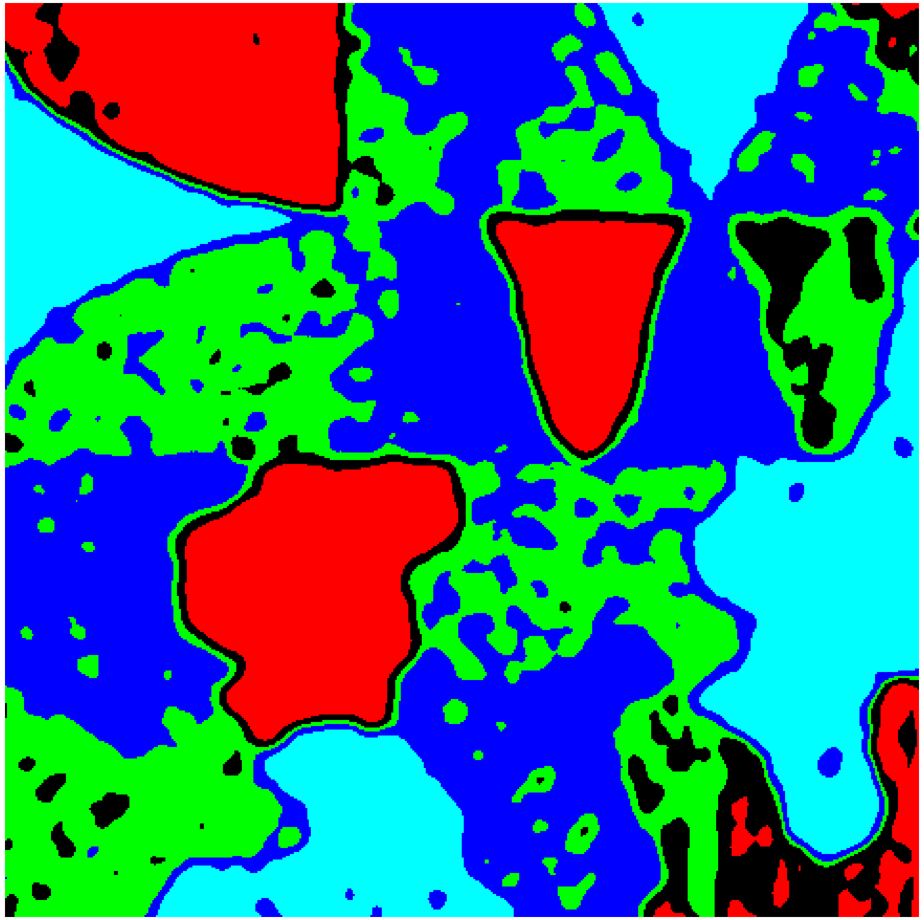
Using texture transform image (3-N)



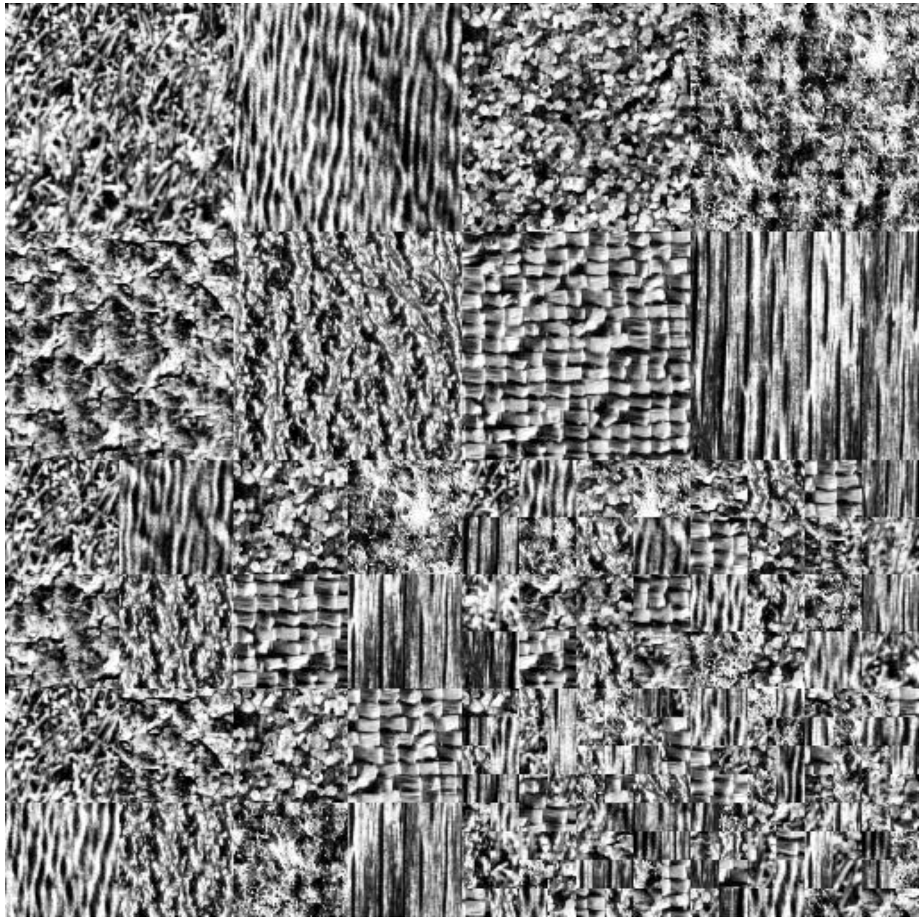


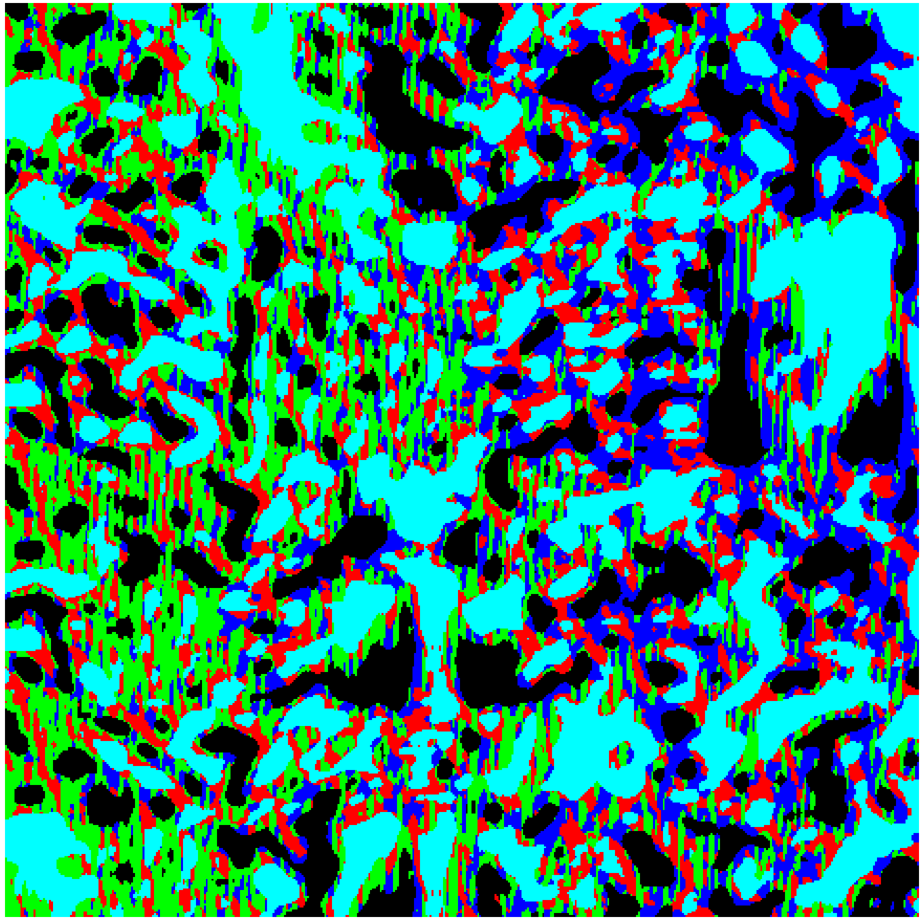
Using texture transform image (5-N)



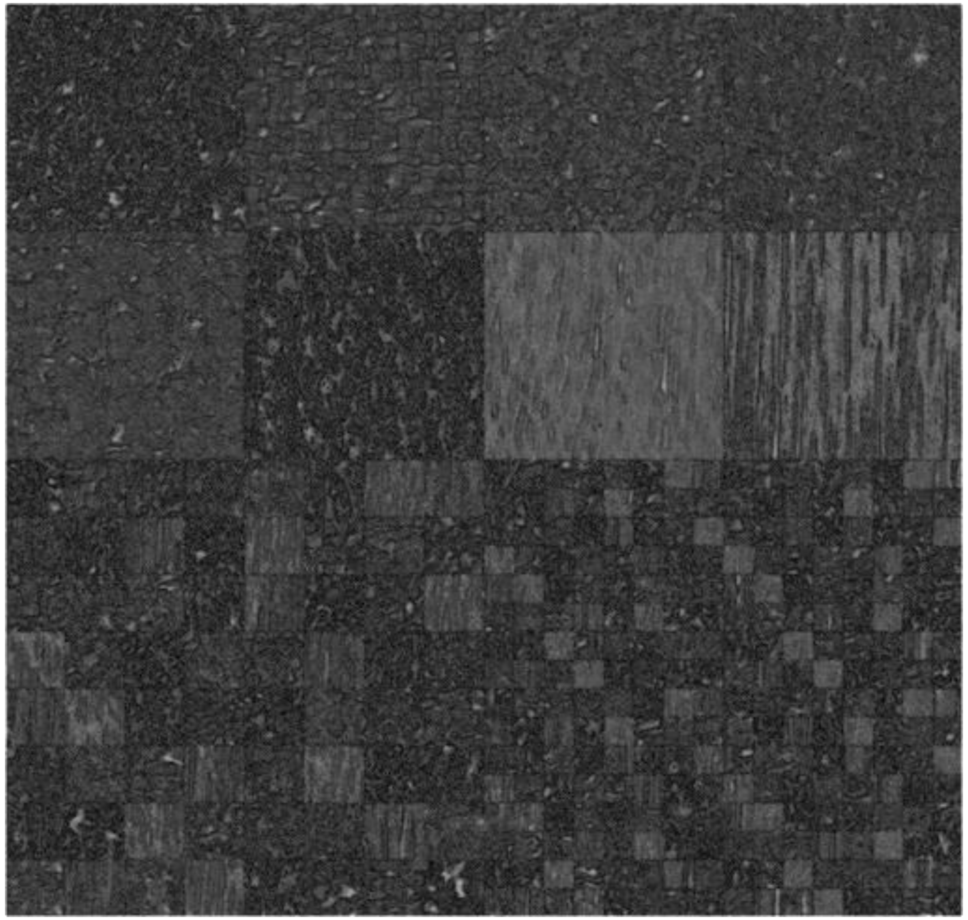


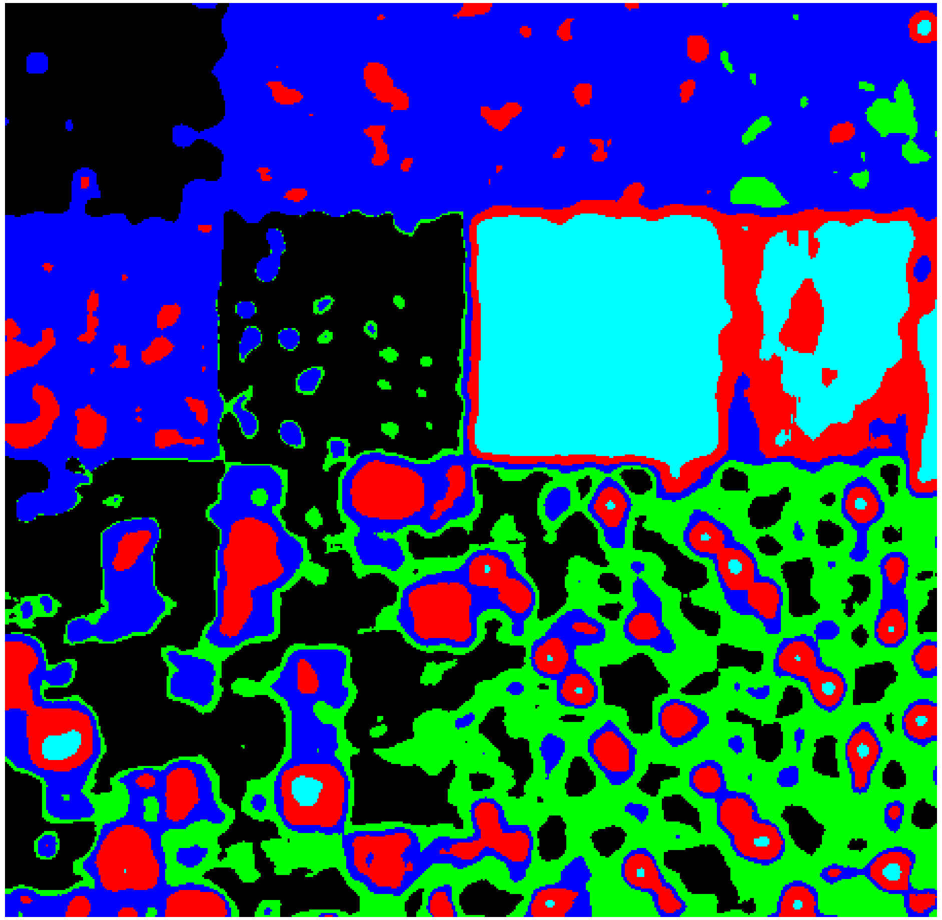
More examples



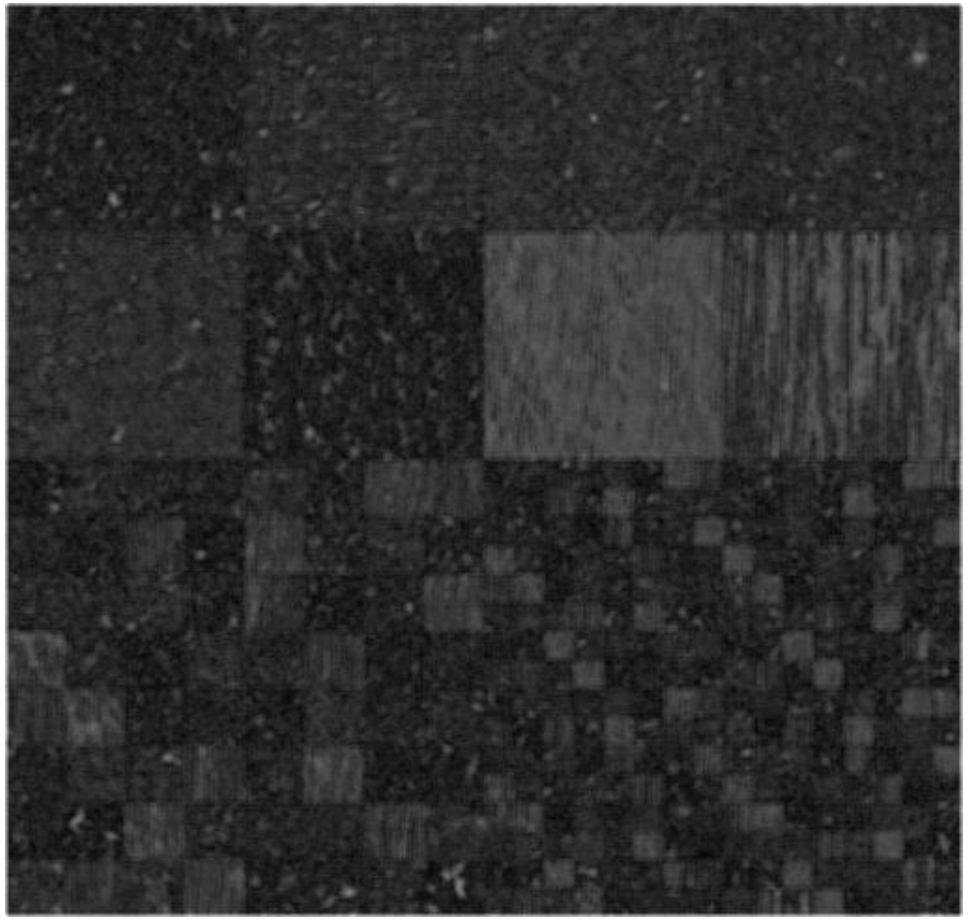


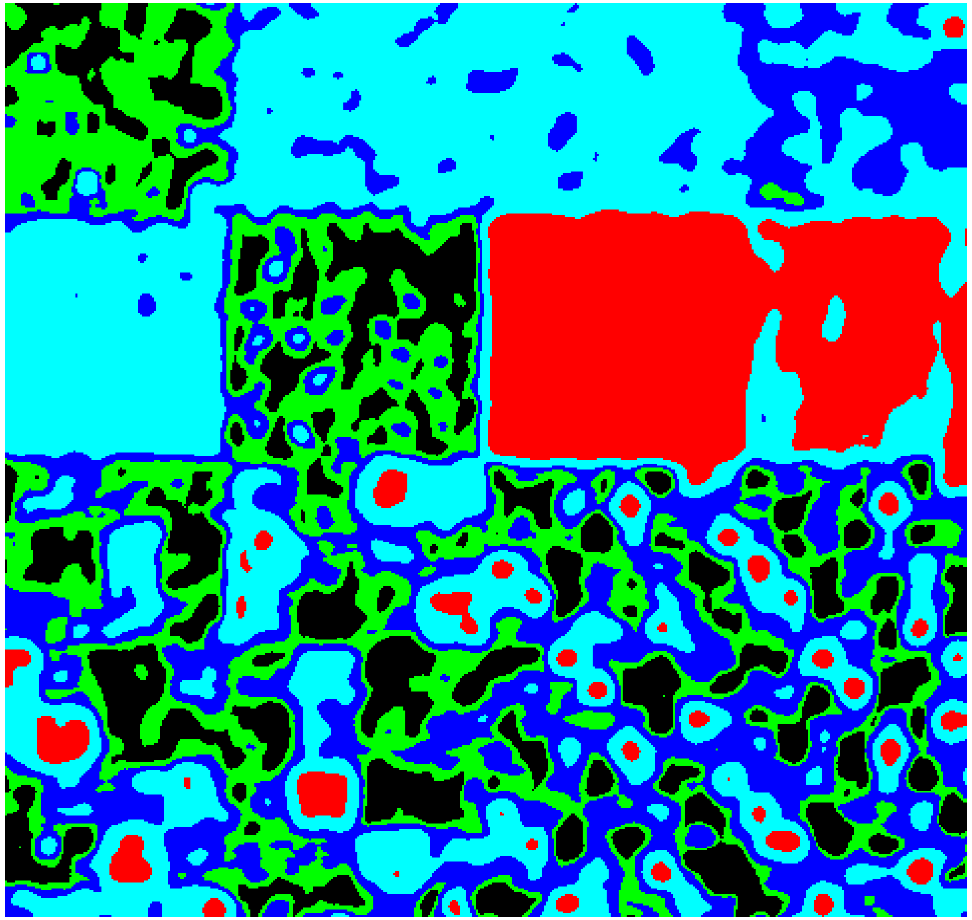
More examples (3N)





More examples (5N)





Summary

- Textural transformed image was in general more suitable for image analysis.
- The transformed image had better results in object segmentation and edge detection.
- For complex textural images, the transformed images showed better results.
- The performance difference for the 3-N and 5-N transformations were not significant.

Future Work

- The image segmentation implementation in the toolbox could segment a maximum of 5 different textures and hence was not good enough to reflect the true performance.
- It would also be interesting to see the performance of some other robust segmentation techniques, and compare the performance.
- To normalize the grayscale values in the range 0-255 min-max normalization was used, which is not the best approach. It would interesting to analyze the performance using other robust thresholding techniques.
- 5-N transformations didn't show any significant improvement in textural analysis using the structure suggested. It would be interesting to see if any structural changes can improve results.