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Colour Fractal Image Generation

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Overview

- Context
- Motivation
- Solution
- Results
- Conclusions

Context

- Fractal analysis
  - Fractal measures for quantifying the complexity of an object / image
- Applications
  - Color image/texture characterization and classification
  - Color image segmentation

Motivation

- No algorithms for real color fractal image generation!
- Color fractal image generation
  - With known properties
  - To calibrate new algorithms for fractal dimension estimation for color images
    - Natural images
    - Dermatologic images

Fractal Generation Techniques

- Only for black-and-white and grey-scale images!
  - Probabilistic approaches (fractional Brownian motion, midpoint displacement algorithm etc.)
  - Spectral approaches (FFT-based)
  - Other approaches (e.g. Takagi, random cuts)

Fractional Brownian Motion

- **fBm** (a.k.a. **1/f²** noise) is the most useful mathematical model for random fractals
- For a fBm $V_H(t)$

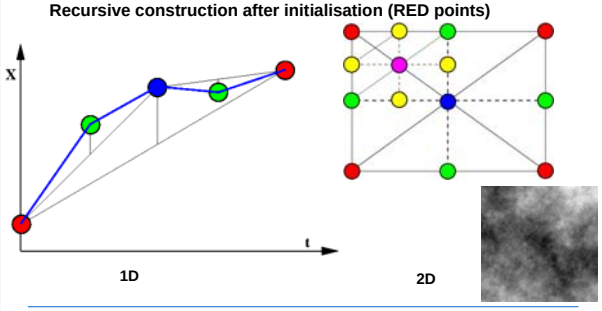
$$\Delta V = V(t_2) - V(t_1)$$
$$\Delta t = t_2 - t_1$$

$$E\{|\Delta V|\} \propto |\Delta t|^H$$

$$E\{|\Delta V|^2\} \propto |\Delta t|^{2H}$$

Original Midpoint Displacement

Recursive construction after initialisation (RED points)



1D **2D**

Extension to Color

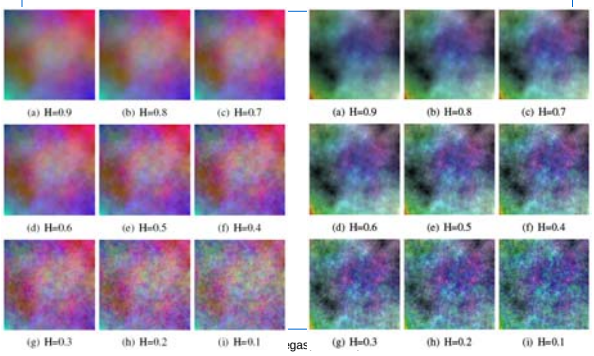
- Independent (uncorrelated) colour planes
- First approach: an RGB generator
  - Cubical shape space
- A more “natural” way: the HSV color fractal image generation

Our Approach

- Modified Midpoint Displacement Algorithm for **5D** spaces (objects)
- Two Color spaces used for generation
  - RGB & HSV (then converted to RGB)

```
FOR x := 0 TO N STEP D DO
   FOR y := 0 TO N STEP D DO
      X[x][y][r] := X[x][y][r] + delta * Gauss()
      X[x][y][g] := X[x][y][g] + delta * Gauss()
      X[x][y][b] := X[x][y][b] + delta * Gauss()
   END FOR
END FOR
```

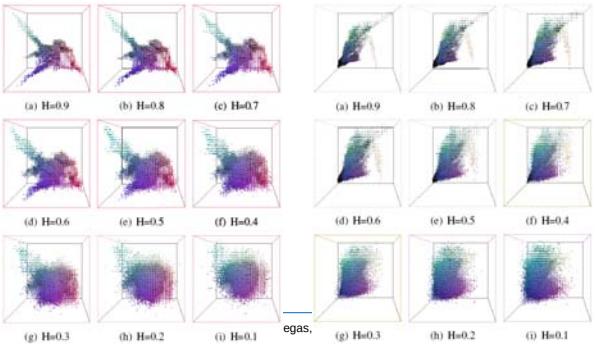

Results RGB / HSV



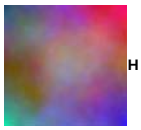
Fractal Generation Validation

- *How to validate the generator without a color fractal estimator?*
- Solution: complexity of the FBM α *H*
  - 3D histograms
  - Co-occurrence matrices (on each color plane)
  - 3D increments histograms

3D Histogram Analysis



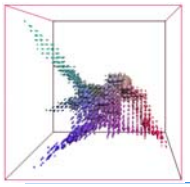
3D Histogram Analysis

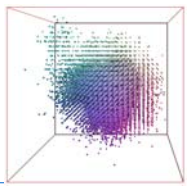


H = 0.9

H = 0.1

The fine details of more complex colour fractals lead to a bigger cloud in the 3D histogram

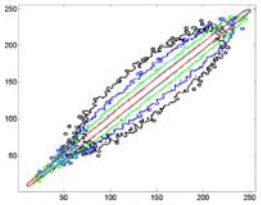




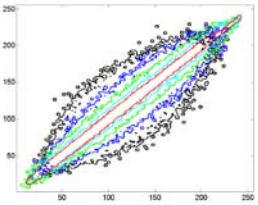
Co-occurrence Matrices

High complexity → large colour difference between neighbors → large cloud

H = 0.9 (RED CURVE) … H = 0.1 (BLACK CURVE)

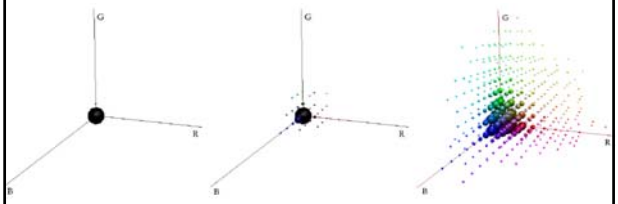


(a) RGB



(b) HSV

3D Increments between neighbors



(a) H = 0.9 (b) H = 0.5 (c) H = 0.1

Same observation, this time for vectorial (3D) differences

Conclusions

- New approach for generating real colour fractal objects / images
- Independent processing of the 3 color components
- The occupancy of the space (RGB / HSV)
  - proportional to the Hurst factor
- Higher complexity obtained with HSV