Multiresolution Painting

- Recent Development

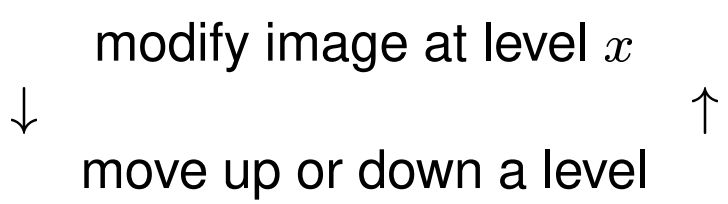
  View and Modify the Image
  at Multiple Resolution Levels

- Advantages
  - Quick Changes (large areas)
  - Unlimited Detail (small areas)

- Applications
  - Interactive Paint
  - Color Correction
  - Size Independent Compositing
  - Variable Resolution Exhibition

System Structure

- The Painting Process



  - Operations

    Paint: paint on the current view

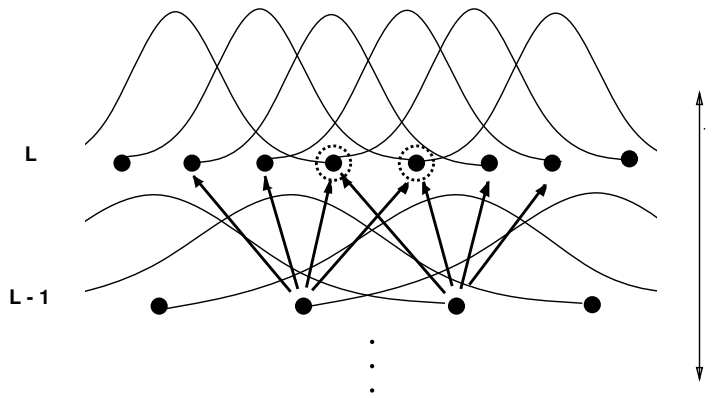
    Push: magnify by a factor of two

    Pop: demagnify the view

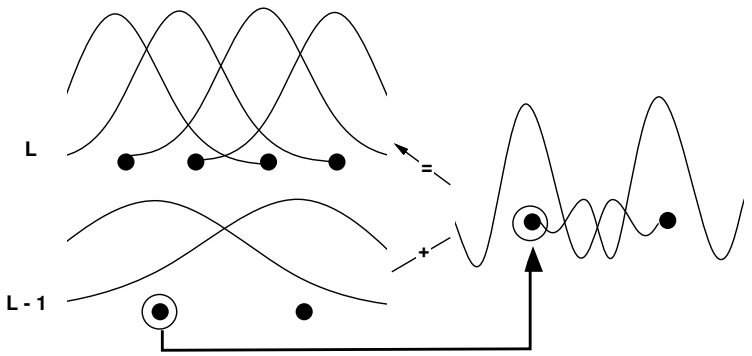
- Computational Support
  - Multiresolution Image Representation
  - Painting over Multiple Levels

Need for a Linear Decomposition

- Propagating changes in a MIP Pyramid



- Propagating changes in a Wavelet Pyramid



Multiresolution Representation

- Low Pass Pyramid
  - Redundant Representation
  - Used when painting at level j

- Band Pass Pyramid
  - Linear Description:

    $I = \sum_j d_j \psi_j + c_0 \phi_0$
  - Used as Internal Representation

Painting over Multiple Levels

- Painting
  - While painting at level j
    - Composite A OVER c_j
    - Accumulate α

- Propagation
  - When changing level
    - if moving UP
      Bandpass Decomposition
    - if moving DOWN
      Lazy Evaluation
      Propagate α

Painting Process

Main

```
Paint_init(canvas_size);
while not quit do
  switch on paint_op:
  case PAINT:
    Drop_paint(draw_path, brush);
  case BRUSH:
    Set_Brush(attributes);
  case ZOOM_IN:
    Paint_change_level(down, cursor_xy);
  case ZOOM_OUT:
    Paint_change_level(up, cursor_xy);
```

Drop Paint

```
forall xy in region
  img[c+xy]=PAINT(img[c+xy],region[xy]);
```

Paint

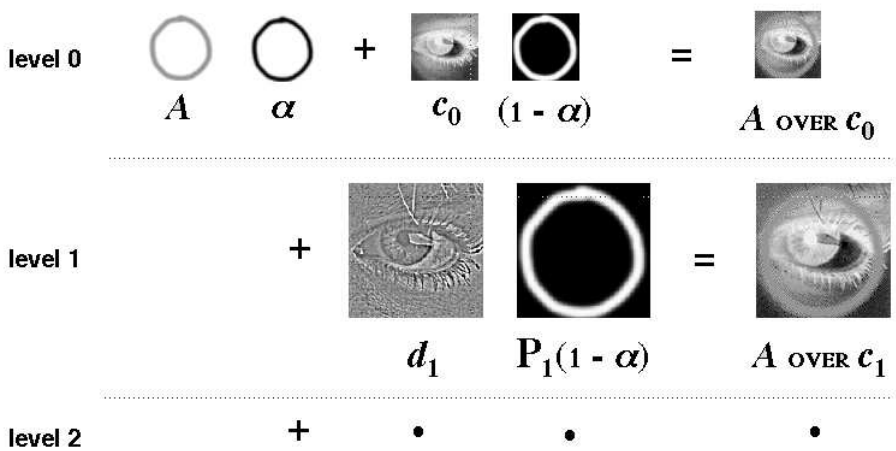
```
p2.c = p2.c+(1.0-p1.a)*p1.c;
p2.a = p2.a+(1.0-p1.a)*p1.a;
```

Multiresolution Compositing

$$A\alpha + c_o(1-\alpha) + \sum_j d_j P_j(1-\alpha)$$

- Canonical Case:
  - Image A at level 0
  - Mask α of A
  - Band Pass Pyramid
    $\sum_j d_j \psi_j + c_0 \phi_0$

    where P_j : projection onto level j

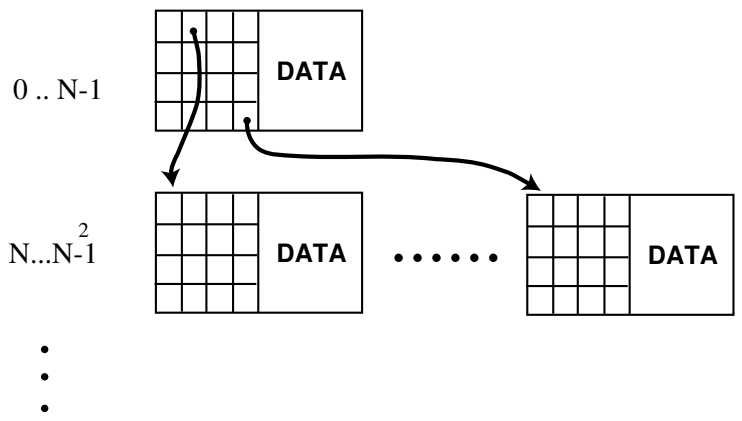


Changing Levels

```
Paint_change_level(delta, center)
{
Put_image(curr_level)

if (delta > 0) /* magnify */
   propagate mask to next level

   Wavelet_sca_reconstruct(app_cur, t1);
   Wavelet_det_reconstruct(det_cur, t2);
   Composite(t1, t2, m_next, app_next);
   Put_image(next_level);

   clear and store mask at curr_level
else  /* demagnify */
   Wavelet_decompose(app_cur, app_nxt, det_nxt);
   Put_image(next_level);

compute new window
Get_image(next_level);
}
```

Memory Management

- Virtual Array
  - Tree of Pages
- Page
  - Pointers to Descendent Pages
  - Actual Data



- Virtual 2D Canvas (N = $res \times res$)
  - Page 0 is in the first page.
  - Pages 1...N-1 in pages pointed to by first page.
  - Pages N...N*N-1 in pages pointed to by ...

Live Paint

- *New Tool, designed for MPS*
  - Procedural Textures
  - Multiscale Structure
- Features
  - Complex Patterns
  - Automatic Generation of Detail

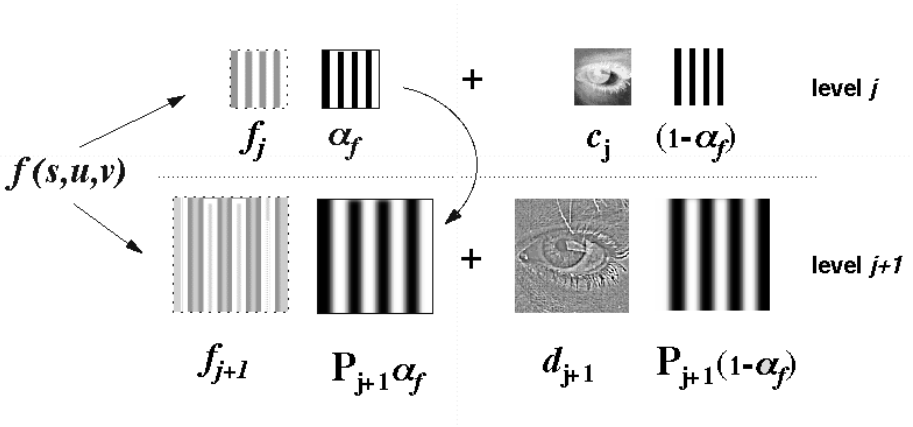
Multiresolution Procedural Textures

- Procedural Bandpass Pyramid: f (s,u,v)
  - Algorithmic Representation
  - Domain
    - Spatial
    - Scale

- Texture Alpha Channel: α_f
  - Texture Propagation: add details
  - Lazy Evaluation
    - Texture Channel Flows Down

Texture Refinement Mechanism

- Procedural Multiresolution Compositing



- *Changes to Basic Procedure*

Procedural Band Pass Pyramid

- Components
  - Base Procedure (s = 0)
    - initial appearance
    - called when the texture is first painted
  - Detail Procedure (s ¿ 0)
    - add detail
    - called during magnification

Example

Stripe Texture

```
Base(x)
{
  if (x mod 2 = 0)
    1
  else
    0
}

Detail(x,l)
{
  t = x mod 2l
  if (t = 0 or t = 2l-1-1)
    1
  else if (t = 2l-1 or t = 2l-1)
    -1
  else
    0
}
```

Texture Primitive

- Instance
  - Id
  - Type
  - Base Level

- Representation
  - Procedure: f.type (s, u, v)
  - Texture Alpha Channel: α_{id}

Examples

- White
  if *dlevel* = 0 then 1 else 0

- Rock
  pseudorandom(x,y,*dlevel*) / $2^{dlevel/2}$

- Stripes
  sqr_wave(x) / $(dlevel + 0.4)^{0.1}$

- Sawtooth
  saw_wave(x) / $(dlevel + 1)^{0.14}$

- Squares
  sqr_wave(x) * sqr_wave(y) / $(dlevel + 0.1)^{0.14}$

sqr_wave(x)
  if i = 0 or i = n/2-1 then 1 else
  if i = n/2 or i = n-1 then -1 else 0
saw_wave(x)
  if i = 0 then 1 else
  if i = n-1 then -1 else 0
n := $2^{dlevel+1}$
i := x mod *n*

Texture Combination

- Composite Texture
  - Vector of Texture Alpha Channels

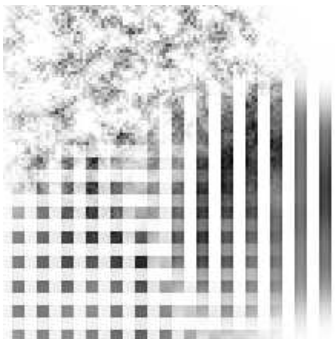
    $a = (a_1, a_2, \ldots, a_n)$

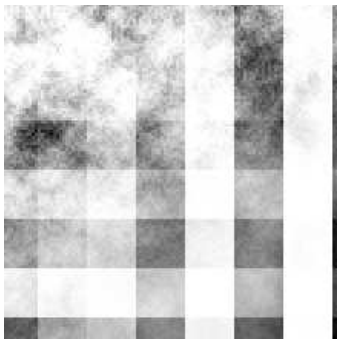
- Mixture Scheme
  - Linear Blend

    $\sum_i P_j \alpha_i f_i(j - b_i, x, y)$

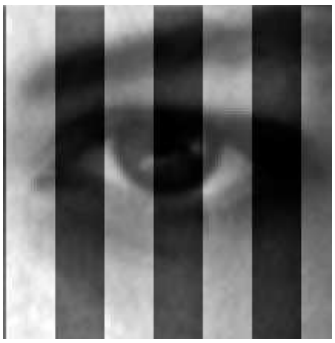
Examples

- Rock, Squares and Stripes

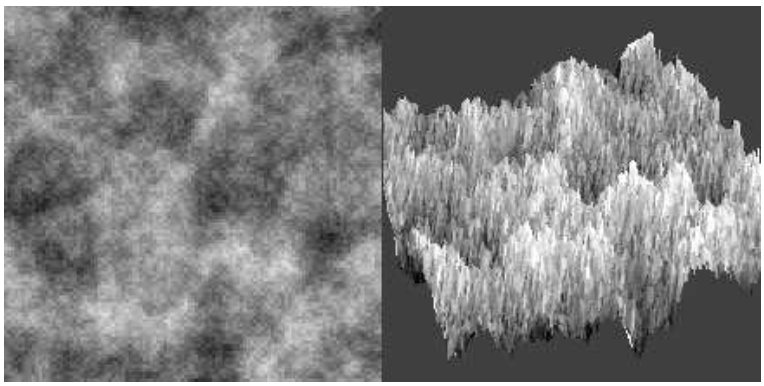


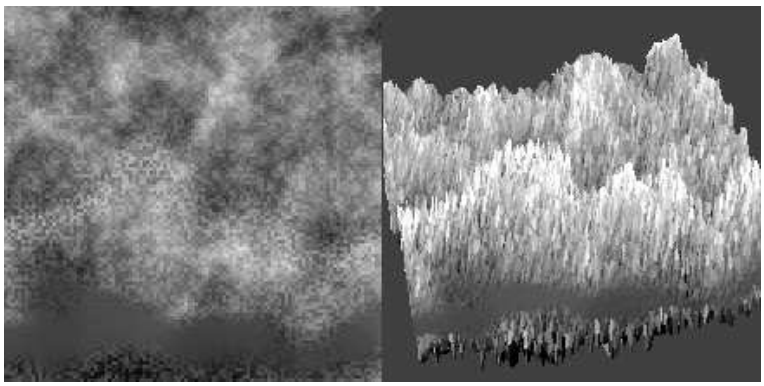


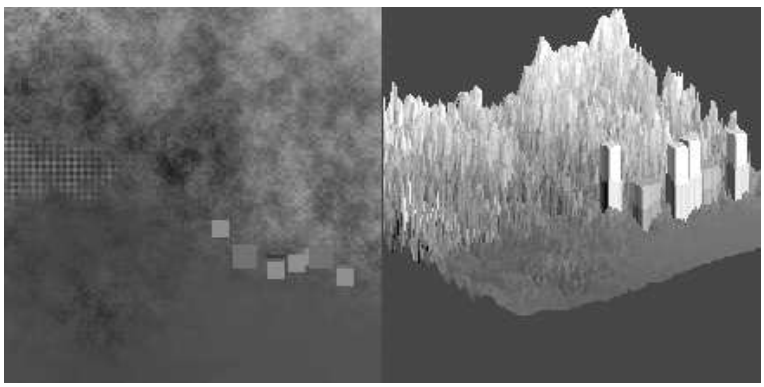
- Compositing over an Image



Application: Terrain Model







Conclusions

- Review
  - Active Texture
    - Procedural
    - Multiscale
  - Implementation Framework
    - Primitive Textures
    - Texture Combination

- Future Work
  - Improve the Framework
    - Layers
    - Interpreted Code
  - User Interface
    - Texture Generators
    - Environment for Texture Design
  - Images
    - Texture from Samples
    - Extrapolation