Procedural Bump Mapping and Noise

Code and images from Ebert, David S., editor, *Texturing and Modeling: a Procedural Approach*. 1994

Bump Mapping - Computing N’

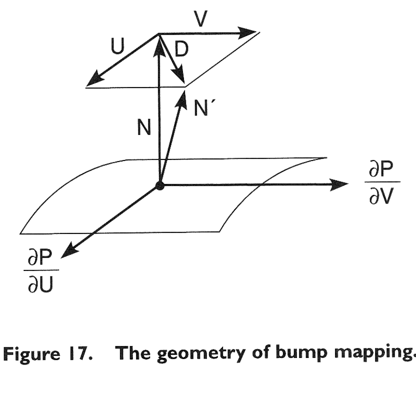

Figure 17. The geometry of bump mapping.

F(u,v) =
bump height function

P(u,v) =
surface position

U = ∂f/∂u (N x ∂P/∂v)

V = -∂f/∂v (N x ∂P/∂u)

D = U + V

N′ = (N + D) / | N + D |

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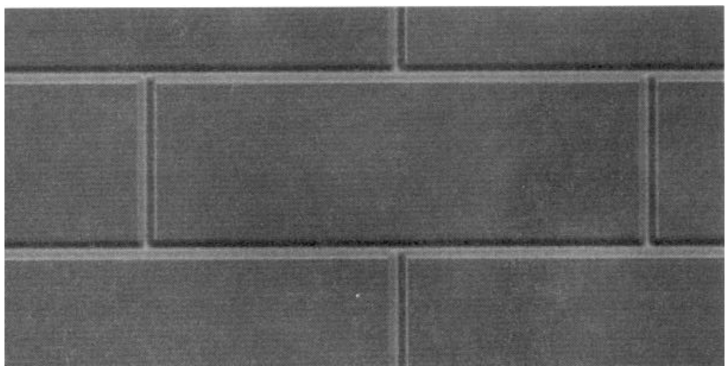
Bump-Mapped Brick



Example - Bumped Brick

Describe height function in terms of texture coordinates

Using built-in RenderMan functions:

- **displace point along normal according to height**
- **find partial derivatives of new surface with respect to texture coordinates**
- **cross the partials to get vector normal to new surface**

Without Special Assistance

Compute ∂P/∂u and ∂P/∂v analytically according to surface geometry (e.g. sphere)

OR

- Evaluate P at 4 nearby points by varying u and v slightly, then approximate partial using differences

Compute ∂f/∂u and ∂f/∂v analytically according to height function

Apply preceding formulas

Bevelling Effects

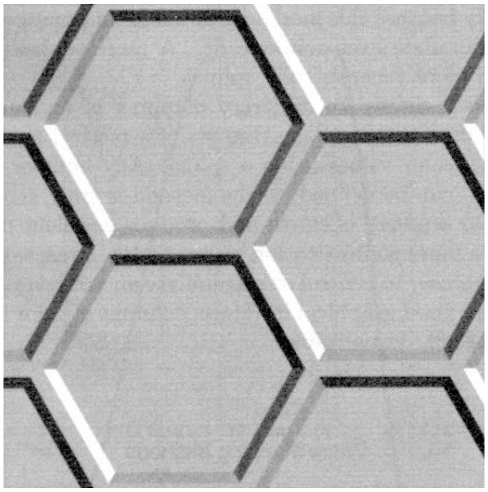
Nice ridges along edges of geometric figures

Parameters:

- Total ridge and plateau widths
- slope at top and bottom of ridge

Use perpendicular direction to closest edge as D (to add to normal), and scale according to ridge function

Bevelling



Noise Functions

Break up regularity

Enable modelling of irregular phenomena

White Noise

Sequence of random numbers

Uniformly distributed

Totally uncorrelated

- no correlation between successive values

Not desirable for texture generation

- Too sensitive to sampling problems
- Arbitrarily high frequency content

Ideal Noise for Texture Generation

Repeatable pseudorandom function of inputs

Known range [-1, 1]

Band-limited (maximum freq. about 1)

No obvious periodicities

Stationary and isotropic

- statistical properties invarient under translation and rotation

Lattice Noise

Low pass filtered version of white noise

- **Random values associated with integer positions in noise space**
- **Intermediate values generated by some form of interpolation**
- **Frequency content limited by spacing of lattice**

Generating a Lattice

Generate a fixed-size table of random numbers

Hashing function indexes into the table to get value at any lattice point

Example Lattice Indexing

```
#define TABSIZE        256
#define TABMASK        ( TABSIZE - 1 )
#define PERM(x)        perm[ (x) & TABMASK ]
#define INDEX(ix,iy,iz)                    \
        PERM((ix)+PERM((iy)+PERM(iz)))
```

perm contains random permutation of integers in

[0, TABSIZE - 1]

Value Noise

Create additional table of random values (in range [-1,1])

Index table according to permuation-based INDEX function just presented

(see sample code handout)

Interpolation Schemes

Linear interpolation -

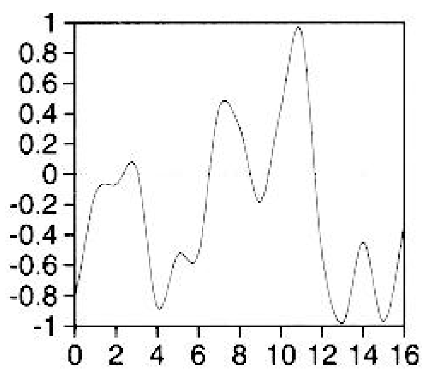
- **not really smooth enough**

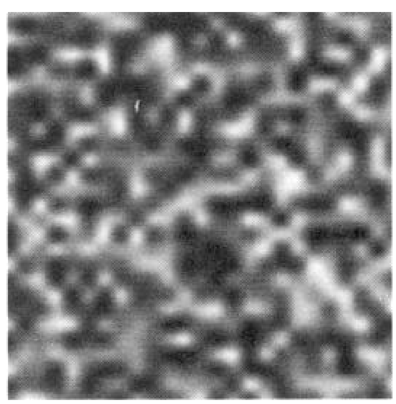
Quadratic or cubic spline interpolation

- **may still have some artifacts resulting from grid layout**

Convolution with radially symmetric filter kernel

1D and 2D Value Noise





Gradient Noise

Store direction vector at each lattice point

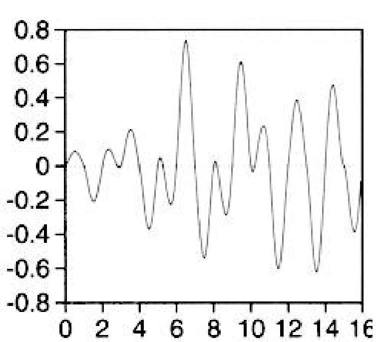
Noise values at lattice point is zero

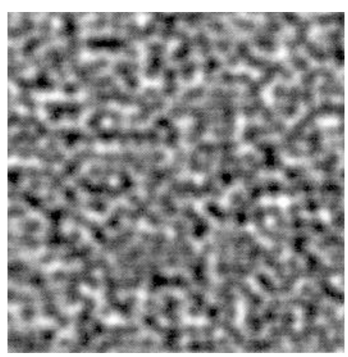
Computing intermediate values:

- **For each neighboring lattice point**
  - **compute displacement along direction**
- **Linearly interpolate between resulting 8 values to get final value**

(see sample code handout)

1D and 2D Gradient Noise





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Value vs. Gradient Noise

Both noises have limited frequencies

Value noise slightly simpler to compute

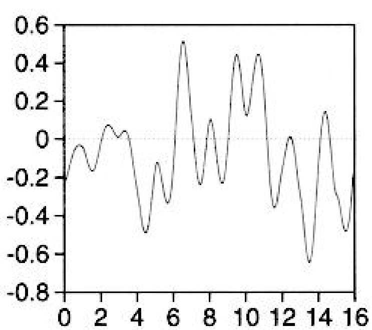
Gradient noise has most of the energy in the higher frequencies

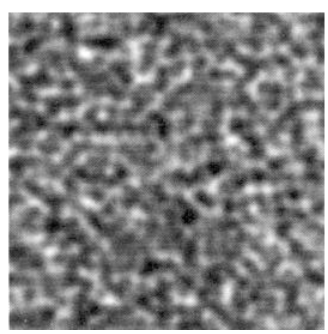
- **forced zero crossings**

Gradient noise has regularity because of zero crossings

Value Gradient Noise

Weighted sum of value and gradient noises





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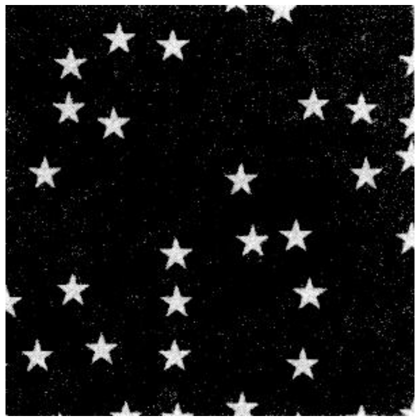
Example - Star Wallpaper



Example - Star Wallpaper

Divide 2D texture space into uniform grid

Decide whether or not to place a star in each cell

Perturb position of star within each cell

To render a point on surface, check nearby cells for stars which may cover point

(see code handout)

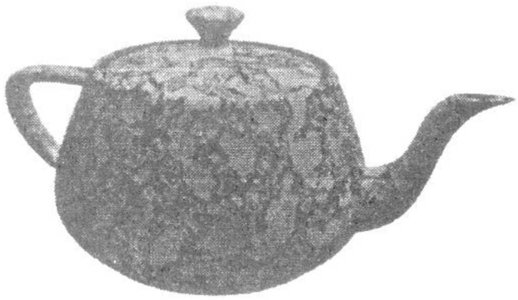
Example - Perturbed Texture

Example - Perturbed Texture

- Use noise function to apply perturbation to texture coordinates
- Look up image texture (or generate procedural texture) using modified coordinates

(see code handout)

Example - Blue Marble



Marble vase (right) from Foley, van Dam, Feiner, and Hughes. *Computer Graphics: Principles and Practice*.

Example - Blue Marble

Use 3D position to compute 3D texture coordinates

Accumulate noise functions at several frequencies

- **one type of spectral synthesis**

Use sum of noise to determine marble color

- **using spline interpolation between colors**

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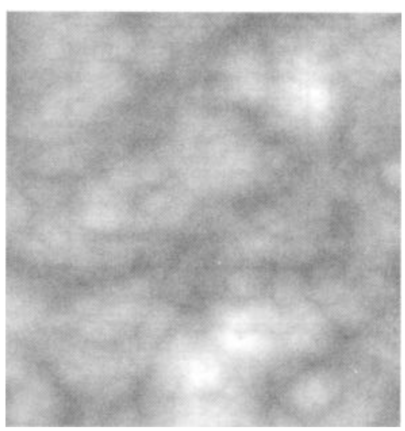
Modelling Gases

Represent 3D gas as density volume

Use turbulence function as basic gas description

Adjust turbulence by raising it to a power, taking the sine, etc.

Turbulence



Turbulence

```
float turbulence(point Q)
{
   float value = 0;
   for (f= MINFREQ; f < MAXFREQ; f *= 2)
        value += abs(noise(Q*f))/f;
   return value;
}
```

(in practice, don’t use a round number like 2)

Basic gas

```
float gas(point P, float max_density,
             float exponent)
{
   float turb, density;
   turb = turbulence(pt);
   /* or turb = (1 + sin(turbulence(pt)*PI))/2 */
   density =
        pow(turb*max_density, exponent);
   return density;
}
```

Placing and Shaping Gas

Place some primitive shape to contain density volume

Attenuate density to account for dissipation

Steaming teacup example

- attenuate according to distance from center of tea surface
- attenuate according to height above tea surface

Steaming Tea Cup

More Turbulence Uses

Add variation to color of surface textures

Use as bump mapping function to add variety to normals