Bump Mapping

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What is Bump-Mapping?

Bump-mapping is the process of creating the illusion of 3D depth by using a manipulated surface normal in the lighting, rather than actually creating the extra surface detail.
Definition of Height Fields -- Think of the Pin Box!
terrain.vert

```cpp
#version 330 compatibility
out vec3 vMCposition;
out vec3 vECposition;
out vec2 vST;

void main( )
{
  vST = gl_MultiTexCoord0.st;
  vMCposition = gl_Vertex .xyz;
  vECposition = ( gl_ModelViewMatrix * gl_Vertex ).xyz;
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```
terrain.frag, l

```cpp
#version 330 compatibility

uniform float uLightX, uLightY, uLightZ;
uniform float uExag;
uniform vec4 uColor;
uniform sampler2D uHgtUnit;
uniform bool uUseColor;
uniform float uLevel1;
uniform float uLevel2;
uniform float uTol;
uniform float uDelta;

in vec3 vMCposition;
in vec3 vECposition;
in vec2 vST;

const float DELTA = 0.001;

const vec3 BLUE = vec3(0.1, 0.1, 0.5);
const vec3 GREEN = vec3(0.0, 0.8, 0.0);
const vec3 BROWN = vec3(0.6, 0.3, 0.1);
const vec3 WHITE = vec3(1.0, 1.0, 1.0);

const float LNGMIN = -579240./2.; // in meters, same as heights
const float LNGMAX = 579240./2.;
const float LATMIN = -419949./2.;
const float LATMAX = 419949./2.;
```

Floating-point texture whose .r components contain the heights (in meters)
void main()
{
    vec2 stp0 = vec2( DELTA, 0.);
    vec2 st0p = vec2( 0., DELTA );
    float west   =  texture2D( uHgtUnit, vST-stp0 ).r;
    float east   =  texture2D( uHgtUnit, vST+stp0 ).r;
    float south  =  texture2D( uHgtUnit, vST-st0p ).r;
    float north  =  texture2D( uHgtUnit, vST+st0p ).r;

    vec3 stangent = vec3( 2.*DELTA*(LNGMAX-LNGMIN), 0., uExag * ( east - west ) );
    vec3 ttangent = vec3( 0., 2.*DELTA*(LATMAX-LATMIN), uExag * ( north - south ) );
    vec3 normal = normalize( cross( stangent, ttangent ) );

    float LightIntensity = dot( normalize( vec3(uLightX,uLightY,uLightZ) – vMCposition ), normal );
    if( LightIntensity < 0.1 )
        LightIntensity = 0.1;
    if( uUseColor )
    {
        float here = texture2D( uHgtUnit, vST ).r;
        vec3 color = BLUE;
        if( here > 0. )
        {
            float t = smoothstep( uLevel1-uTol, uLevel1+uTol, here );
            color = mix( GREEN, BROWN, t );
        }
        if( here > uLevel1+uTol )
        {
            float t = smoothstep( uLevel2-uTol, uLevel2+uTol, here );
            color = mix( BROWN, WHITE, t );
        }
        gl_FragColor = vec4( LightIntensity*color, 1. );
    }
    else
    {
        gl_FragColor = vec4( LightIntensity*uColor.rgb, 1. );
    }
}
Terrain Height Bump-mapping: Exaggerating the Height

No Exaggeration

Exaggerated

Oregon State University
Computer Graphics
Terrain Height Bump-mapping: Coloring by Height
Terrain Height Bump-mapping: Coloring by Height

No Exaggeration

Exaggerated
Terrain Height Bump-mapping: Even Zooming-in Looks Good

![Map showing locations of Portland, Salem, Corvallis, Eugene, and Crater Lake.](image)
Several textures are being mixed onto the surface of the globe.
The Second Most Straightforward Type of Bump-Mapping is

*Height Field Equations*

This is the coordinate system we will be using. The plane is X-Y with Z pointing up.
The Second Most Straightforward Type of Bump-Mapping is 

*Height Field Equations*

\[
z = Acos(2\pi Br + C)e^{-Dr}
\]

Radial-ripple equation with height decay

\[
x_{\text{tangent}} = \text{vec3}(1., 0., \frac{\partial z}{\partial x})
\]

\[
y_{\text{tangent}} = \text{vec3}(0., 1., \frac{\partial z}{\partial y})
\]

\[
\frac{\partial z}{\partial x} = \frac{\partial z}{\partial r} \frac{\partial r}{\partial x}
\]

\[
\frac{\partial z}{\partial y} = \frac{\partial z}{\partial r} \frac{\partial r}{\partial y}
\]

\[
\frac{\partial z}{\partial r} = -Asin(2\pi Br + C)(2\pi B)e^{-Dr} + Acos(2\pi Br + C)(-D)e^{-Dr}
\]

\[
r^2 = x^2 + y^2
\]

\[
2r \frac{\partial r}{\partial x} = 2x
\]

\[
\frac{\partial r}{\partial x} = \frac{x}{r}
\]

\[
2r \frac{\partial r}{\partial y} = 2y
\]

\[
\frac{\partial r}{\partial y} = \frac{y}{r}
\]
The Second Most Straightforward Type of Bump-Mapping is
*Height Field Equations*

You can sum the individual height field equations and get a result similar to that of summing the height field displacements.
Combining Bump and Cube Mapping