Procedural Texturing

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Procedural Texturing

- Procedural texturing is the process of generating texture data algorithmically at render time, rather than getting texture data from a previously stored image
- This allows texture maps to be defined as procedural functions
- This is nice for things like organic, bumpy, irregular surfaces that can be defined by non-repeating functions
- This reduces visual tiling artifacts that can be visible when texture maps are repeated over and over
- Procedural texturing also allows for effectively unlimited resolution, as details are described by mathematical functions rather than pixels of a fixed size

Solid Textures

- It is also possible to use volumetric or *solid textures*
- Instead of a 2D image representing a colored surface, a solid texture represents the coloring of a 3D space
- Solid textures are often procedural, because they would require a lot of memory to explicitly store a 3D bitmap
- A common example of solid texture is marble or granite. These can be described by various mathematical functions that take a position in space and return a color
- Texturing a model with a marble solid texture can achieve a similar effect to having carved the model out of a solid piece of marble

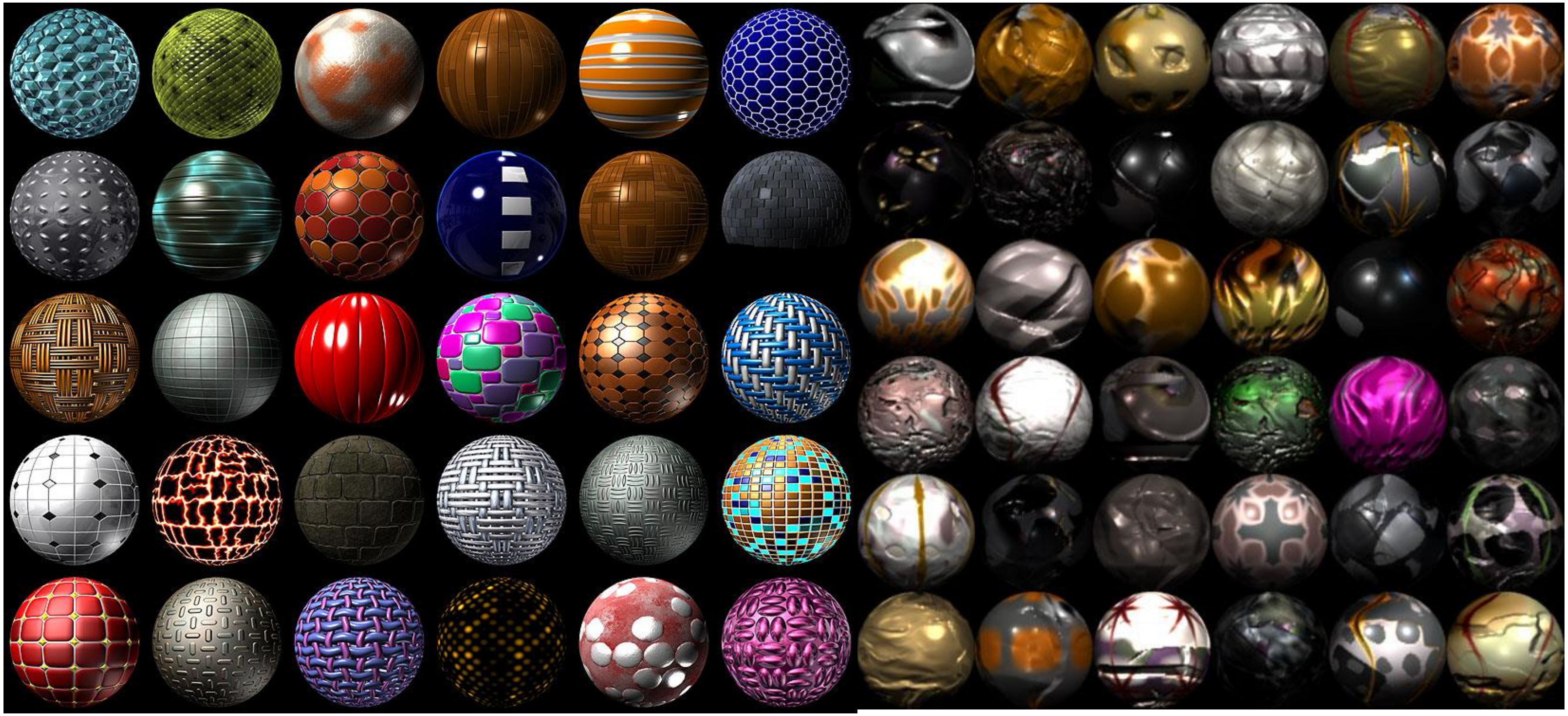
Procedural Texturing

- Procedural texturing is used throughout the movie industry and a lot of production time goes into writing procedural shaders for specific effects
- Procedural functions are used to generate colors, displacements, volumes, or can affect any other visual property or BRDF attribute
- There is no limit to the functions that could be used to generate the desired effects, but there are some standard functions and common approaches used across a variety of different tools and renderers

Basic Operations

- There are several basic features of a procedural texture function
- In general, they take a 2D or 3D texture coordinate as input and produce a vector of values as output (typically a color, displacement, etc.)
- Some common tools include:
  - Grids, bricks, etc.
  - Color ramps
  - Lerp, spline, & smooth step functions
  - BRDF selection & blending

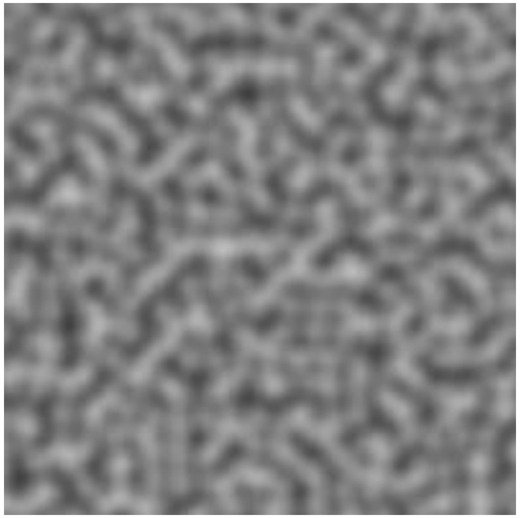
Procedural Shaders



Noise

Noise

- Many procedural textures are built up from *noise* functions
- A *noise* function is an n-dimensional function that generates a random pattern with some adjustable properties
- There are many popular noise functions that generate different patterns, but generally, noise functions are designed to generate variation at a specific spatial frequency



Noise Functions

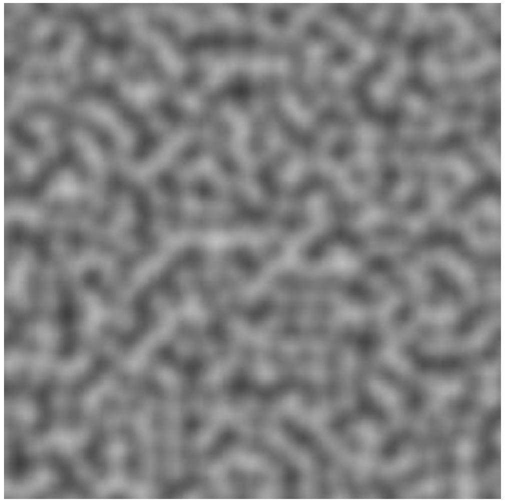
- There are many popular methods for implementing noise functions
- Many of them are based on starting with some lattice of random numbers
- *Value noise* uses a lattice of random values that represent the value of the noise field at the lattice points, and then uses cubic interpolation to determine the value in between the lattice points
- *Gradient noise* uses values of zero at the lattice points combined with random gradient vectors, and is sometimes combined with value noise
- *Fourier synthesis* adds up several sine waves of varying amplitudes, frequencies, and phase shifts
- *Sparse convolution* is not a lattice method, and instead uses a Poisson distribution of filter functions. It is a more expensive technique that avoids the XY gridding artifacts of many other noise techniques

Perlin Noise

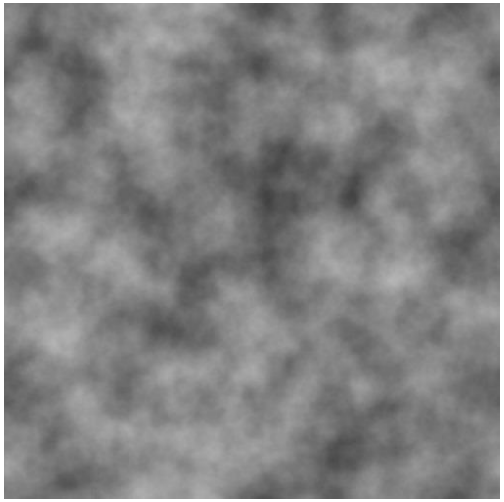
- Ken Perlin introduced the concept of procedural noise to the computer graphics community in 1985, and showed a wide variety of applications
- Modern variations of the classic Perlin noise are still popular today and are included in most 3D rendering tools

Turbulence

- *Turbulence* is a general concept that refers to combining multiple noise patterns at different frequencies
- This gives variation over a range of scales
- Typically, turbulence is a sum of N noise functions, where each function is roughly half the amplitude and twice the frequency of the previous function

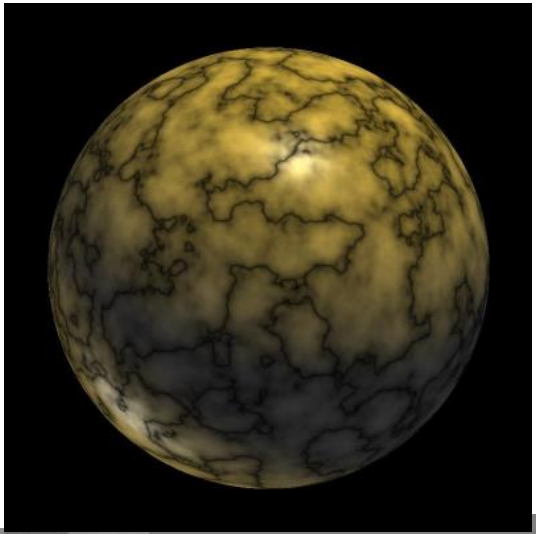


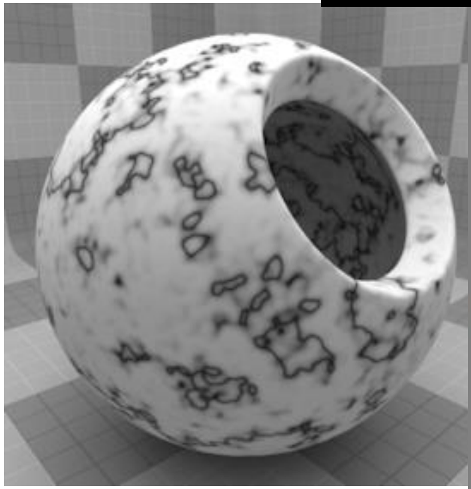
Noise



Turbulence

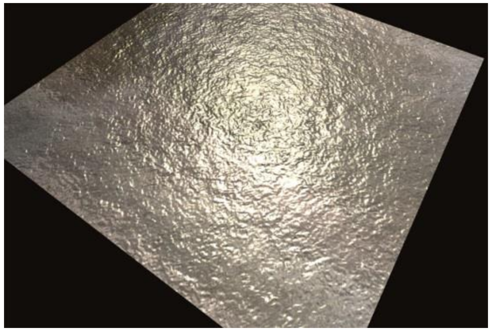
Using Noise





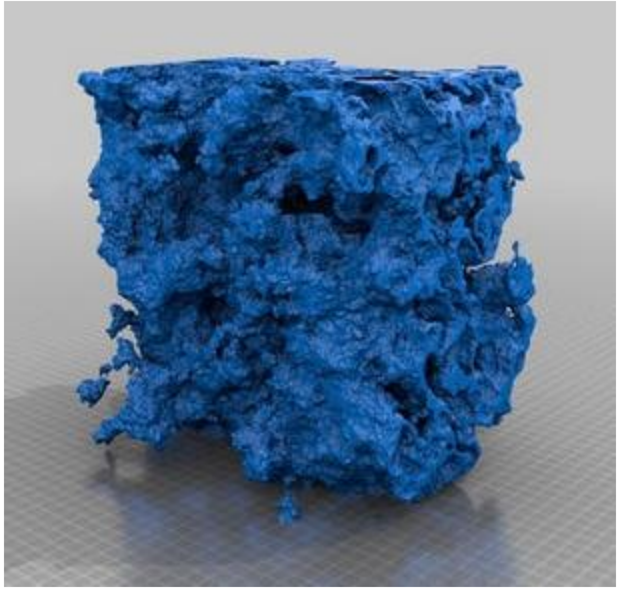
Displacement Noise

- Noise (and other procedural techniques) are also very useful for displacement maps and terrain generation as well



3D Noise

- 3D noise functions can be used to model solid or gaseous volumes



Noise Animation

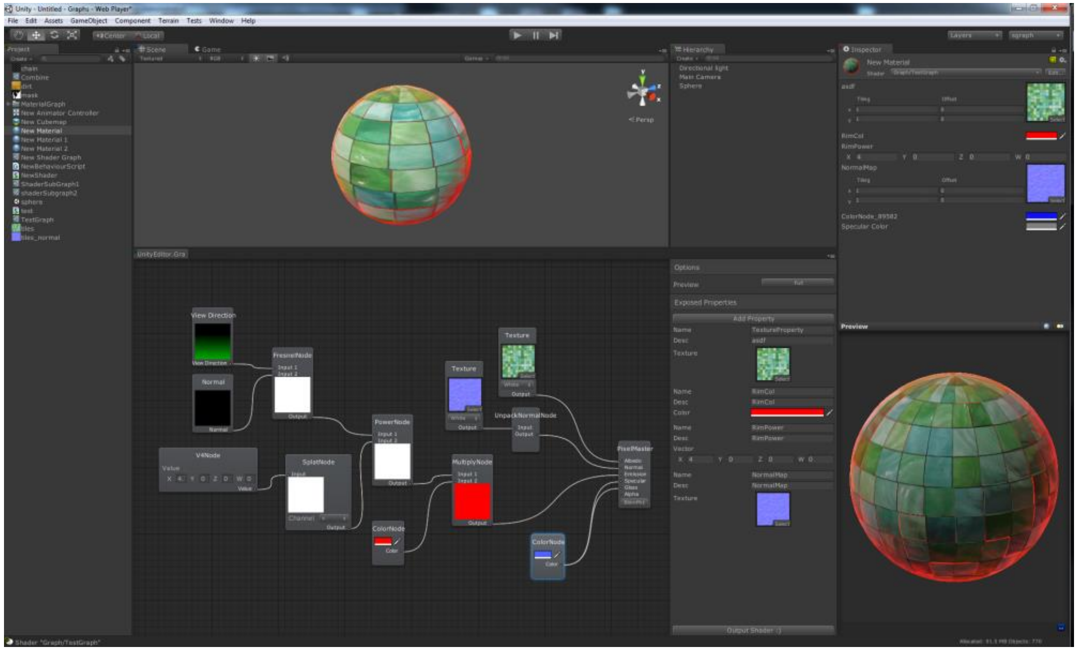
- If we use a 2D plane moving through a 3D noise function, we can generate animated effects such as fire
- It is also possible to use a 3D sub-volume of a 4D noise field to animate 3D fire

Worley Noise

- Another popular choice is the *Worley noise* function
- This one generates a cellular pattern that can be applied to a variety of applications

Shader Editors

- Many rendering systems (Maya, 3D Studio, etc.) have interactive editors that allow artists to create procedural shaders by connecting up components from a set of data flow tools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Inspector
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Input 1
Input 2
Output
V4Node
Value
X 4 Y 0 Z 0 W 0
SplatNode
Input
Channel
PowerNode
ColorNode
Color
Texture
UnpackNormalNode
Input
Output
MultiplyNode
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Output Shader :)
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