Advanced Texturing

More uses for texture maps

Programming – Computer Graphics

Contents

- Light Maps
- Specular Maps
- Gloss Maps
- Glow Maps
- Environment Maps
  - Cube Maps
  - Sphere Maps
  - Reflection with Environment Maps
- Reflection Maps
- Bump Maps
- Normal Mapping
- Non-2-dimensional Textures
  - 1-deminsion Textures
  - 3-dimension Textures
- Texture Packing and Atlas

aie
SPECIALIST EDUCATORS IN
GAMES, ANIMATION & FILM VFX

Texture Recap

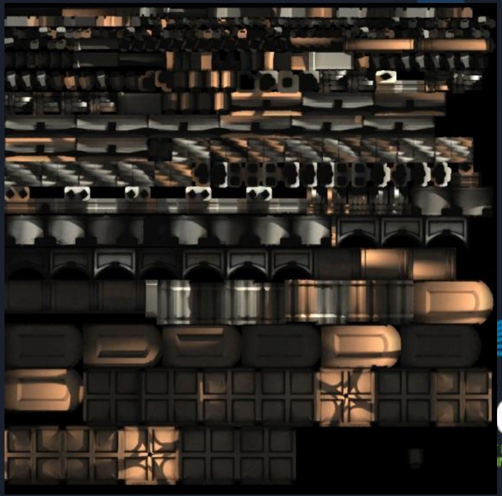
- Textures add colour to our meshes

- But textures don't have to represent diffuse colour!
  - Surface properties, such as shine or reflectivity
  - Directional information
  - Pre-computed information

Light Maps

- Light information is pre-calculated by artists and baked into textures
  - Lighting is reduced to a single texture sample
  - This colour is multiplied against the material colour in a Fragment Shader

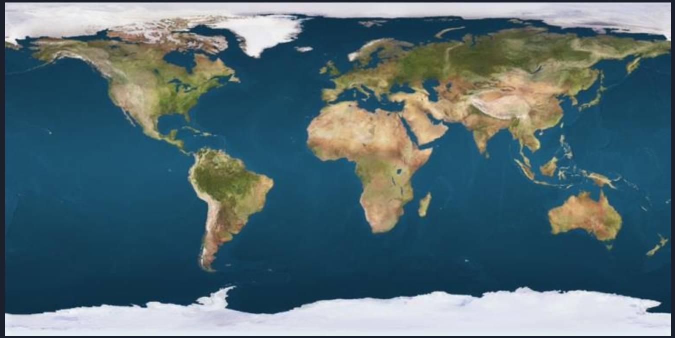
- Can drastically improve performance and look of games
  - Especially mobile platforms

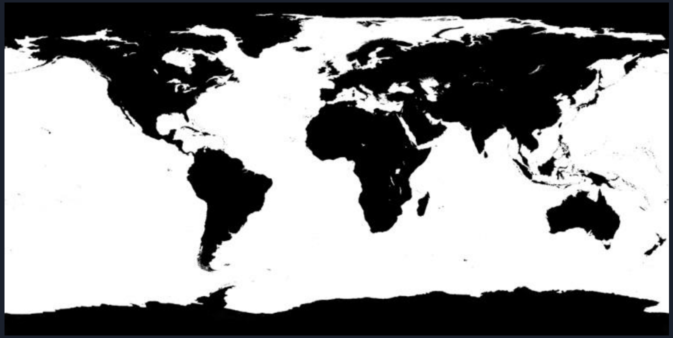


- Has some downfalls
  - Dynamic objects in the scene have no influence over lighting
  - Memory use is increased with added textures that can't be tiled

Specular Maps

- Like Diffuse Maps but instead effect the Specular portion of the lighting equation
- Generally there are two types of specular maps
  - Greyscale (most common)
  - Coloured
- Greyscale simply multiplies against the calculated specular colour to darken areas of a surface that aren't shiny
- Coloured work similar to Greyscale but also replace the material specular colour in the lighting equation



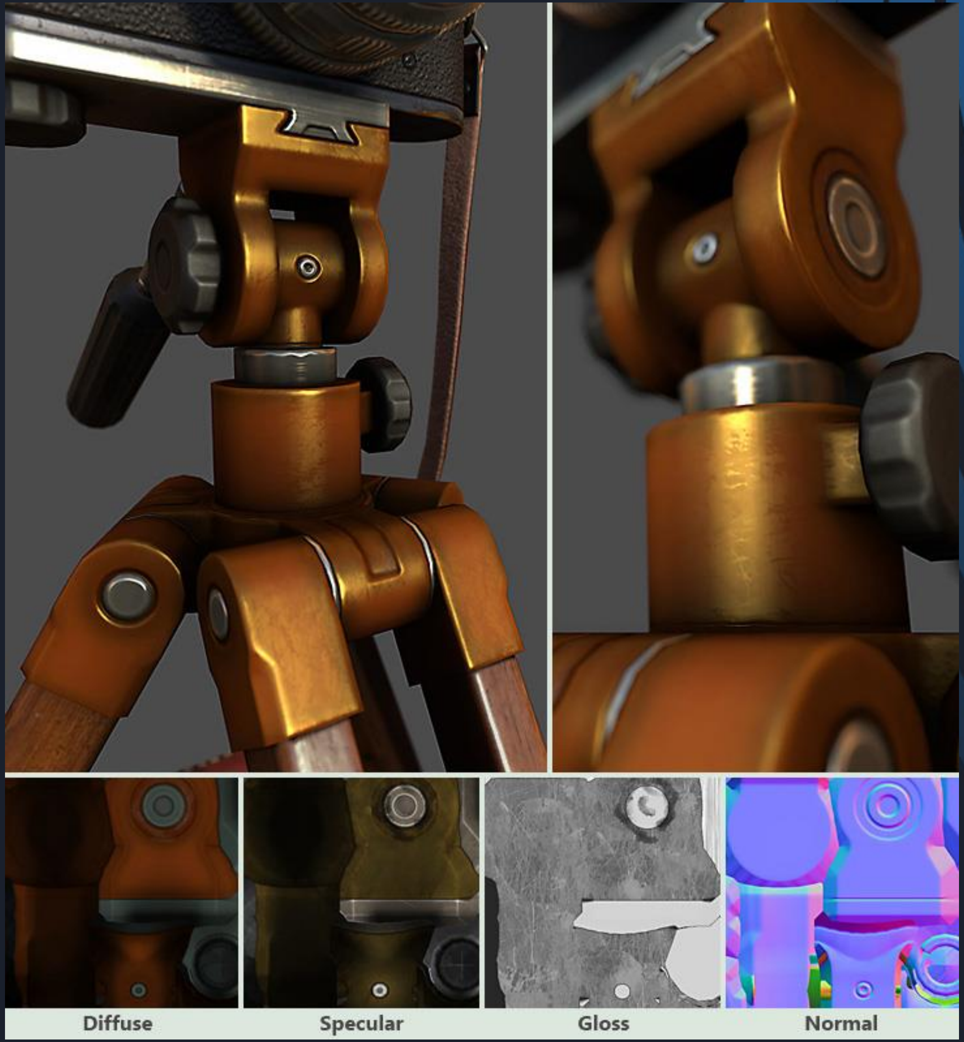


Gloss Maps

- Gloss Maps work in tandem with Specular Maps to modify the Specular Power portion of the Phong equation
  - Note not all lighting equations use a Specular Power

- Normally a greyscale value used to define the sharpness of the specular highlight

- In Physically-based Rendering (PBR) a gloss map typically represents surface roughness

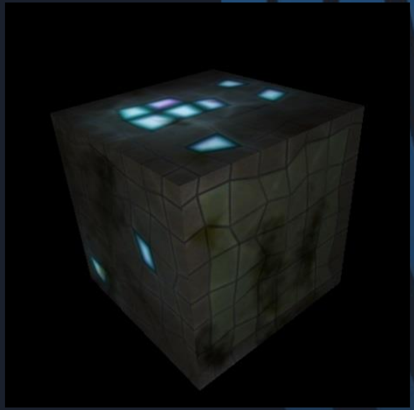


Glow Maps

- Glow Maps are meant to simulate glowing objects, as their name implies

- This is achieved in multiple ways:
  - The Glow Map contains colour and is sampled, sometimes multiplied against a brightness value, then added to the diffuse colour
  - Alternatively the Glow Map is a greyscale mask that specifies the area of a surface that can glow, with the colour coming from the diffuse map multiplied by the glow map, multiplied against a brightness value, then added to the diffuse again

- For the Glow to come "off" the model's surface, Post-Processing techniques involving Multiple Render Targets and Blurs are needed
  - More on this in a separate session



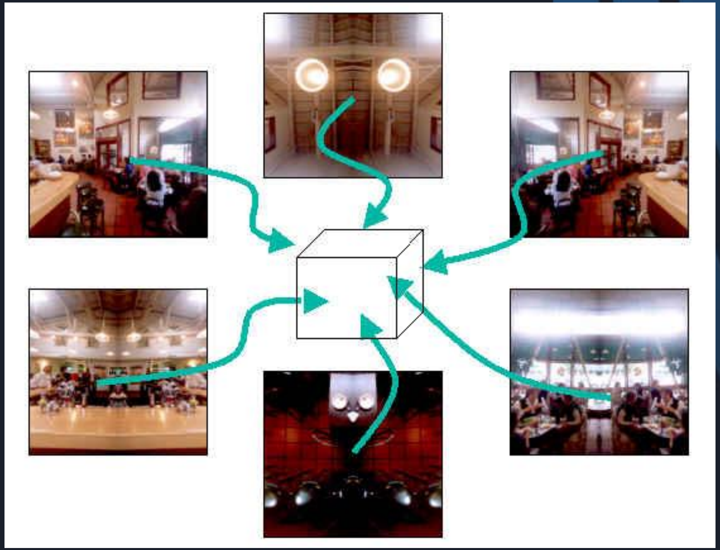
aie
SPECIALIST EDUCATORS IN GAMES, ANIMATION & FILM VFX

Environment Maps

- Environment mapping is a different form of texturing, where the texture coordinate used to sample the texture is instead a Normal
  - The Normal is used to sample a Cube Map or a Sphere Map

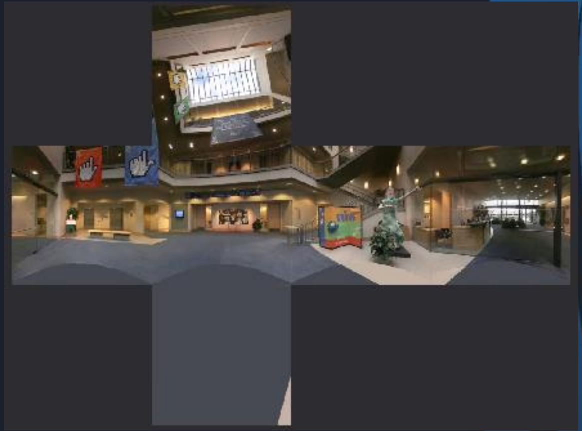
- The aim of Environment Mapping is to map surrounding environment information onto the surface of the model

- Environment Maps are tied closely to Reflection, but aren't necessarily limited to just reflections



Cube Maps

- For a Cube Map, think of a 6-sided box with textures on each side surrounding your mesh
  - *Starting from the centre of the box, travel in the direction of the surface normal until it intersects a side of the box*
  - The texel at the location intersected is the colour value used
- Cube Maps come in two varieties
  - 6 2-dimensional textures are loaded and assigned to the faces of a cube to create a Cube Map
  - A single 2-dimensional texture with a Cross pattern, with all the faces of the cube on the cross

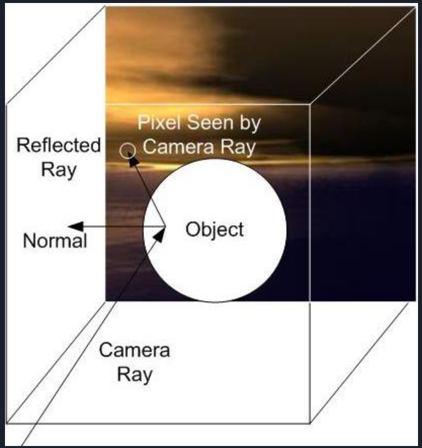


Sphere Maps

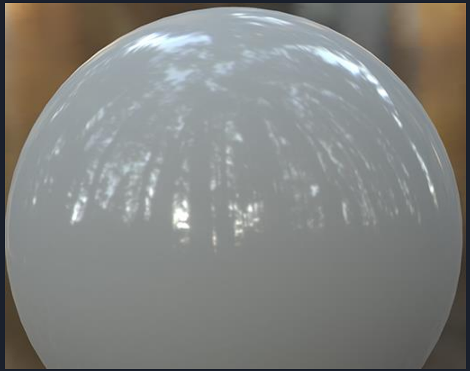
- For a Sphere Map, think of a sphere surrounding your mesh
  - *Starting from the centre of the sphere, travel in the direction of the surface normal until it intersects the side of the sphere*
  - The texel at the location intersected is the colour value used
- Sphere maps are just a single 2-dimensional texture
  - The surface normal is converted from 3-axis (x,y,z) into a 2-dimensional texture coordinate using a method to map the surface of a sphere to a 2-D image
- Sphere Maps aren't used as often as Cube Maps any more
  - They were mostly used before multiple textures could be used at once on the GPU
  - Suffer from artefacts at the edge of the sphere

Reflection with Environment Maps

- Using Environment Maps we can easily represent reflection of a static scene
  - Dynamic reflection is possible if we dynamically recreate the Cube / Sphere Map each frame



- A normalised vector from the camera to the surface is reflected by the surface normal, then used to sample the environment map



Reflection Maps

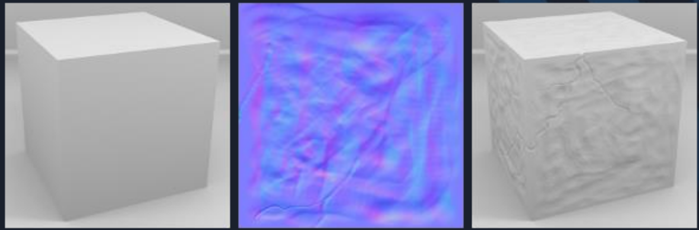
- Reflection Maps can be thought of as similar to a greyscale Specular Map
  - A 2-dimensional surface texture used to specify shiny and non-shiny surfaces on the model

- The Environment Map is sampled as usual, then multiplied by the sampled greyscale Reflection Map
  - This allows us to have a model that may have non-shiny leather straps, with shiny gold buckles, or shiny paint chips on a wooden cart that reflect a blue sky

Bump Mapping and Normal Mapping

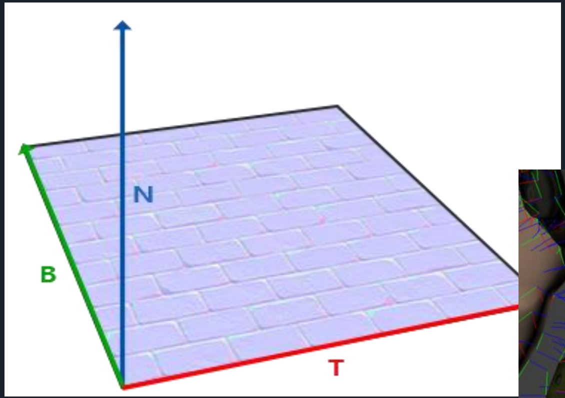
- At the beginning of the per-pixel lighting revolution there was Bump Mapping
  - Greyscale "bump" textures were used to calculate a per-pixel normal by evaluating the gradient in the texture
  - Didn't properly take triangle orientation into account
    - Only good for walls or floors with known static orientations

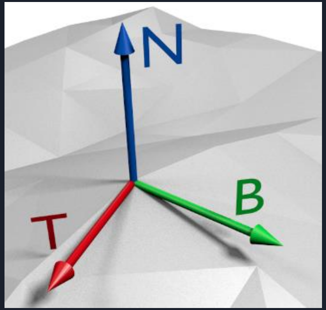
- As GPUs got more powerful we were able to finally take triangle orientation into account
  - Each vertex now has an additional normal, a Tangent, that was used along with the Normal to create a Tangent Basis Matrix
  - A Normal Map contains surface normal in texture / tangent space
  - The Tangent Basis Matrix is then used to transform between texture / tangent space and object / world space
    - Remembering that all lighting is calculated within the same space



Normal Mapping

- A Tangent Basis Matrix is a transform aligned to a surface, orientated to match the direction of a texture mapped across the surface
  - The surface Normal represents the Z axis in the transform
  - The direction that the U or S axis of the texture represents is the Tangent in the transform, which is the X axis
  - A Cross Product between the Normal and the Tangent, called the Bi-Tangent, represents the matrix's Y axis and the texture's V or T axis
    - Often incorrectly called a Bi-Normal





$$TBN = \begin{bmatrix} Tx & Bx & Nx \\ Ty & By & Ny \\ Tz & Bz & Nz \end{bmatrix}$$

Normal Mapping

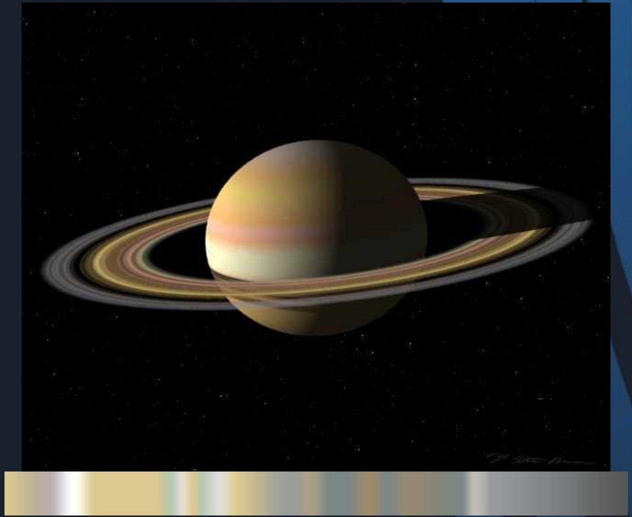
- Within a fragment shader a normal map would be sampled, using its RGB colour to represent a texture's tangent space Normal
- We then either transform the tangent space normal into the same space as a light or transform the light into tangent space, using the Tangent Basis Matrix
- It would then be used in lighting equations, rather than the vertex normal
  - The Normal and Tangent would be transformed by the model's matrices, then the Bi-Tangent formed with the Cross Product, and finally the Tangent Basis Matrix would be created that could transform texture space normals to world space, or used to transform light vectors to tangent space

$$n = texture(\, normalMap, texCoord) \times 2 \; - 1$$

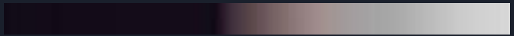
$$N = TBN \times n$$

Transforms Tangent-Space to Object-Space

1-Dimensional Textures

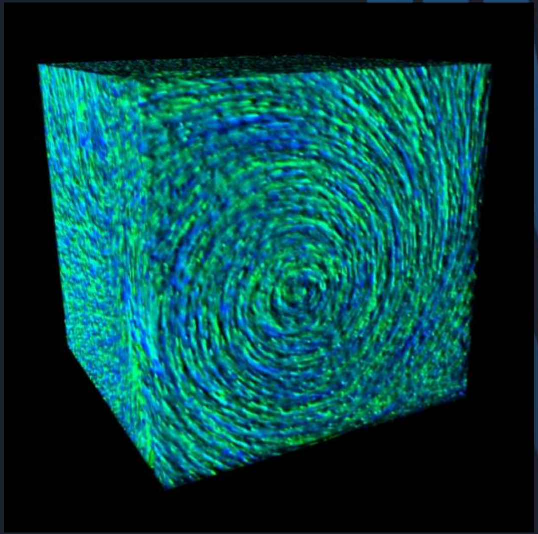


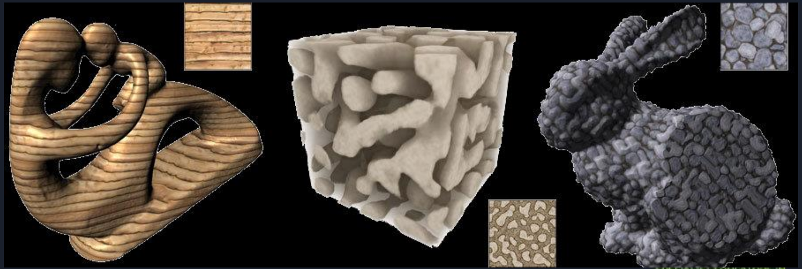
- As we've discussed not all textures are 2-dimensional
  - Cube Maps for example
- Textures can also be 1-dimensional
  - A single strip of pixels
- This type of texture is sampled with a 1-dimensional texture coordinate and has some interesting uses
  - Colour shades for a planet's dust ring
  - Ambient colour depending on time of day
  - Diffuse colour to use based on the Lambert Term in a Phong equation
    - This technique has been used in various games, such as Team Fortress 2



3-Dimensional Textures

- We can also make use of 3-dimensional textures
- Although uncommon, these types of textures are being used more and more, but generally not for traditional surface colours
  - Texels can represent Flow Fields of directions, used in Physics, A.I. and Particle FX
  - 3-dimensional light information for an area
  - Store smoke, heat, desnsity or fluid information for a volume
    - This type of texture is called a Voxel, a Volumetric Texel
- Can be procedurally generated using various noise functions and applied to a surface for procedural texture effects



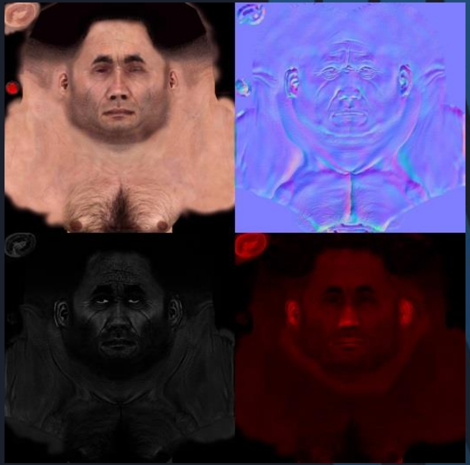


Texture Packing and Texture Atlas

- Commonly artists pack texture information to reduce texture counts
  - For example, greyscale specular data could be stored within the alpha channel of a diffuse texture
  - Gloss could be stored within the alpha channel of a coloured specular texture

- Another way of reducing texture counts is to use a Texture Atlas
  - Individual textures are arranged within a single larger texture to reduce texture state changes while rendering
  - Slight memory savings

Texture Packing and Texture Atlas



- When sampling texels the texture coordinates are offset to the location of the relevant texture data
  - Care must be made when sampling texels along the edge of a texture within an atlas as filtering can cause textures to bleed into each other

- Texture atlases are great when used with GUI and Particle FX rendering as all geometry can be batched together into a single mesh since they all use the same texture data

Summary

- There are many different forms of texturing and many different uses for textures
- Textures are just gridded buffers of data that can be sampled using filtering
  - The data does not have to be colour information
  - Many texel formats are available (1-4 channel, 1-32 bits per channel traditionally)

Further Reading

- Akenine-Möller, T, Haines, E, 2008, *Real-Time Rendering*, 3rd Edition, A.K. Peters

- Wolff, D, 2013, *OpenGL 4 Shading Language Cookbook*, 2nd Edition, PACKT Publishing