UNIVERSITY OF DERBY

5CM507 Graphics

Lecture 07 Texture Mapping

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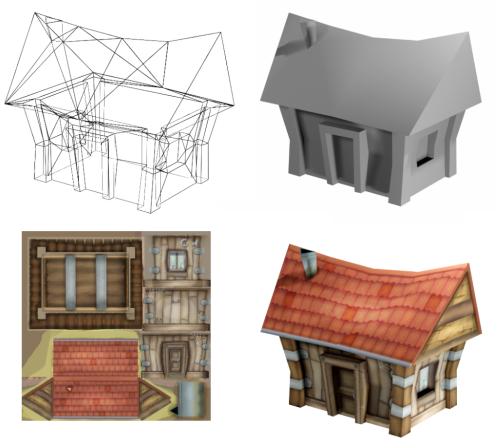
2025 年 11 月 9 日

Last Week

- Bidirectional Reflectance Distribution Function (BRDF)
- Microfacet-based relfection models, GGX

Contents

- Texture
- Texture Coordinates
- Mapping between the Object Space and Texture Space
- Appying the Texture : Texture Sampling
- Mip-mapping



Introduction of Texture Mapping

Combining Geometric Modeling and Images

Character Modelling

Use images to present surface details.

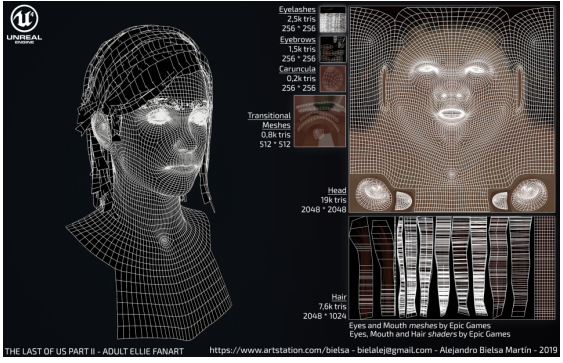
Most common: diffuse colour texture.

Skin Rendering Detials

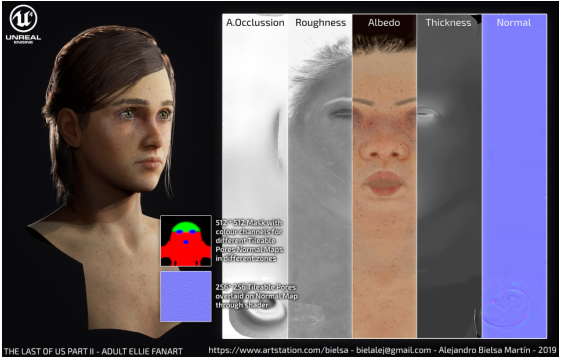
The Geometric Model

Character Modelling

Texture Mapping

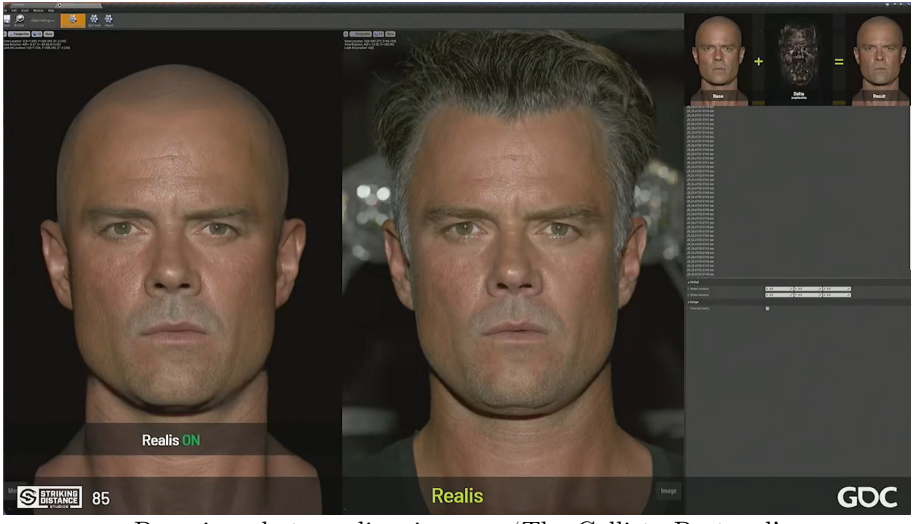


Texture Mapping



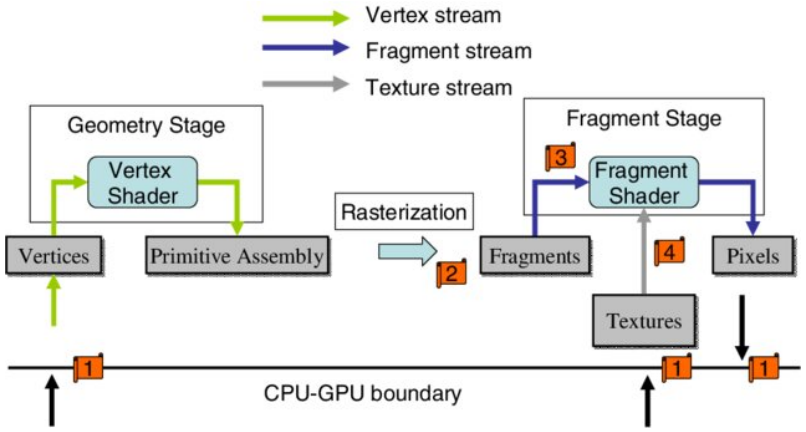
Head Texture Breakdown

Combining Texturing and Advanced Lighting



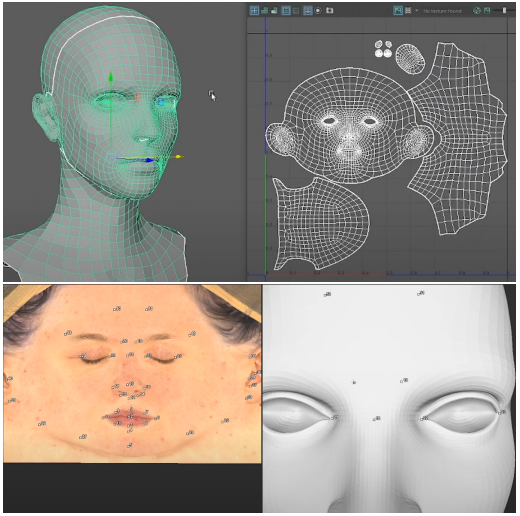
Pursuing photo-realism in game ‘The Callisto Protocol’

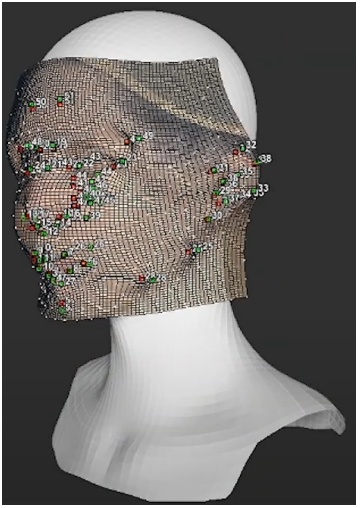
Texture Mapping in the Graphics Pipeline



Mapping 2D Textures to Surfaces in 3D

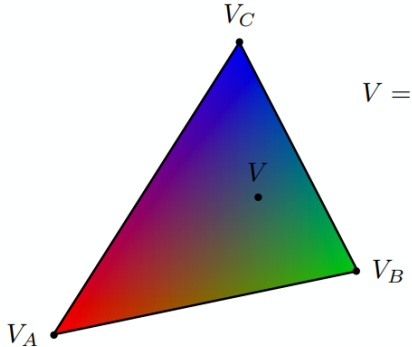
How to apply a 2D material onto a 3D object





Object-Texture Mapping: Vertex Texture Coordinates

- Texture : 2D images
- Vertex: 3D Position (x, y, z), normal vector $\vec{n} = (n_x, n_y, n_z)$
- Vertex: 2D Texture Coordinate (u, v) $(u, v \in [0, 1])$for each vertex



$$V = \alpha V_A + \beta V_B + \gamma V_C$$

V_A, V_B, V_C can be positions, texture coordinates, color, normal, depth, material attributes...

Texture coordination interpolation by the GPU

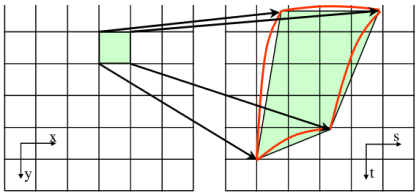
Applying the Texture : Texture Sampling

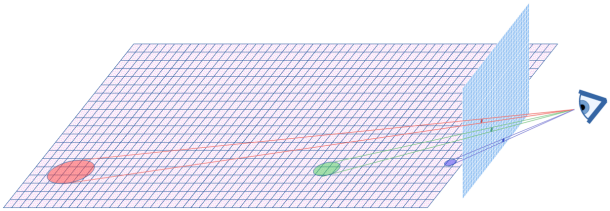
Pixel Footprint

Pixel footprint : an area in the texture space that a pixel corresponds to

It may cover multiple texels or less than one texel.

In the right example, areas close to the camera need higher resolutions, far away from the camera need lower resolutions

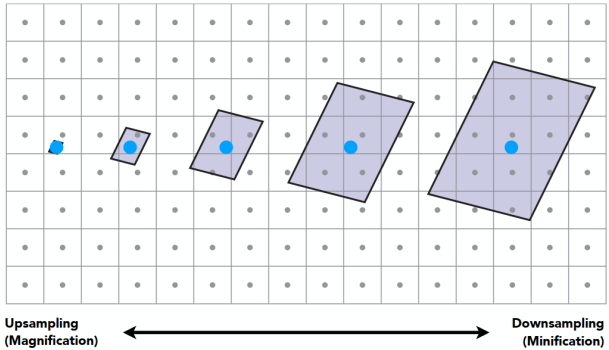




An analogy of pixel footprint

Texture Sampling

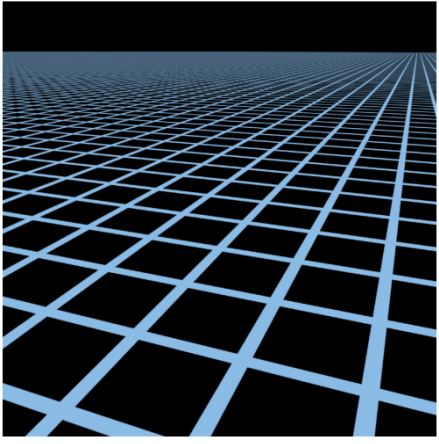
- Pixel footprint changes from pixel to pixel
- An analogy: polygons close to the camera require high-resolution textures, while those farther away use low-resolution textures.
- Resampling:
  - Less than one texel: Magnification to a higher resolution - Interpolation
  - More than one texel: Minification to a lower resolution - Filtering (Averaging)



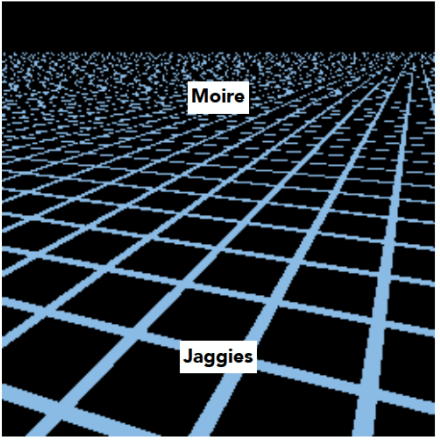
An illustration of pixel footprints. Left footprints can be thought as being closer to the camera, while right ones can be considered farther away.

Problems with Naive Nearest Neighbour Sampling

Point-based Nearest-Neigbour sampling



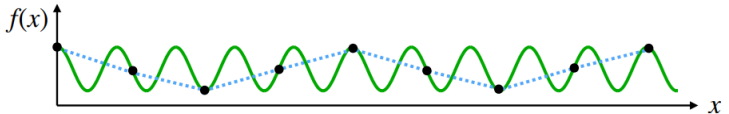
Reference



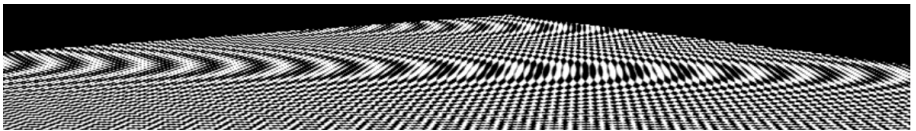
Point sampled

Aliasing - Moiré Patterns

Undersampling a high-frequency signal can result in aliasing



Undersampling



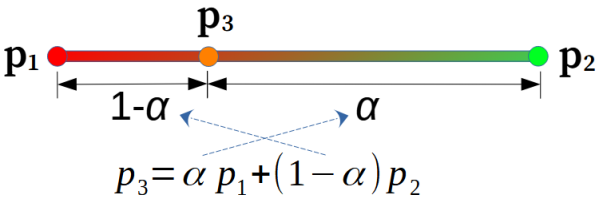
Moiré patterns

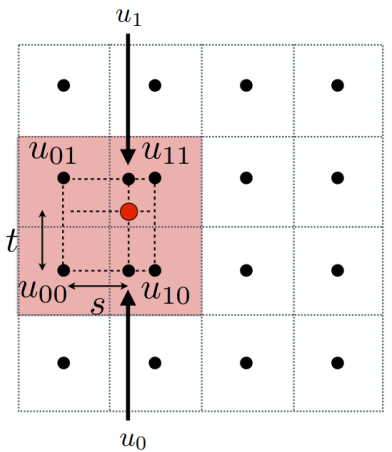
Magnification - Interpolation

The most common is bilinear interpolation.

Take 4 nearest sample locations, with texture values as labelled.

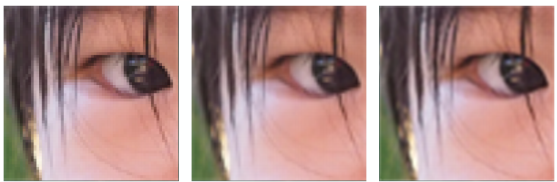
- $u_0 = u_{10}s + u_{00}(1-s)$
- $u_1 = u_{11}s + u_{01}(1-s)$
- $f(x,y) = u_0(1-t) + u_1 t$





Magnification - Interpolation

Bilinear interpolation usually gives pretty good results at reasonable cost



Surfaces close to the camera in Halflife 3 show signs of texture magnification

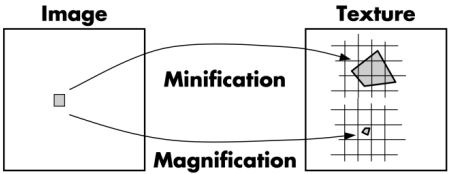
Minification - Filtering (Averaging)

Challenges:

- Many texels can contribute to pixel footprint
- Shape of pixel footprint can be complex

Idea:

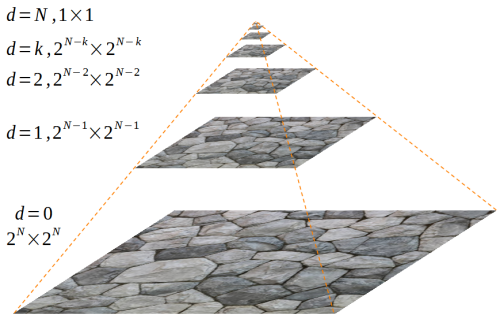
- Reduce the resolution of texture
- Provide multiple low resolutions
- For each pixel, choose an appropriate resolution



Mip-Map

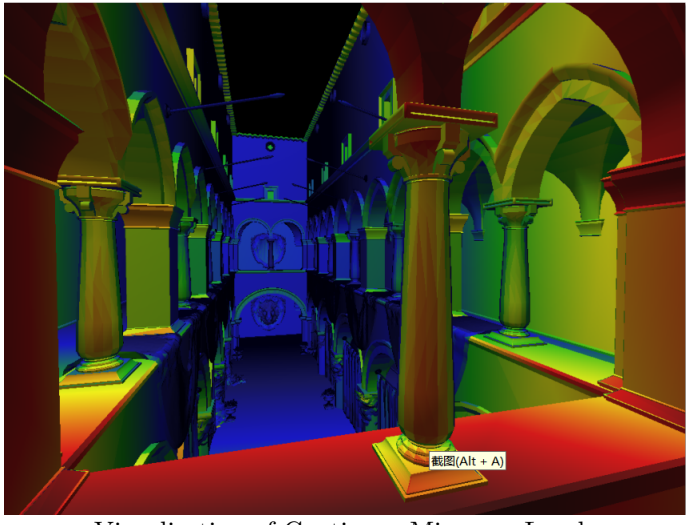
Multi-level Area Averaging : Mip-map

- Multiple level of texture resolutions
- Closeup faces : higher res
- Distant faces : lower res
- Interpolates between the two closest levels
- Latin multum in parvo (”much in a small space”).



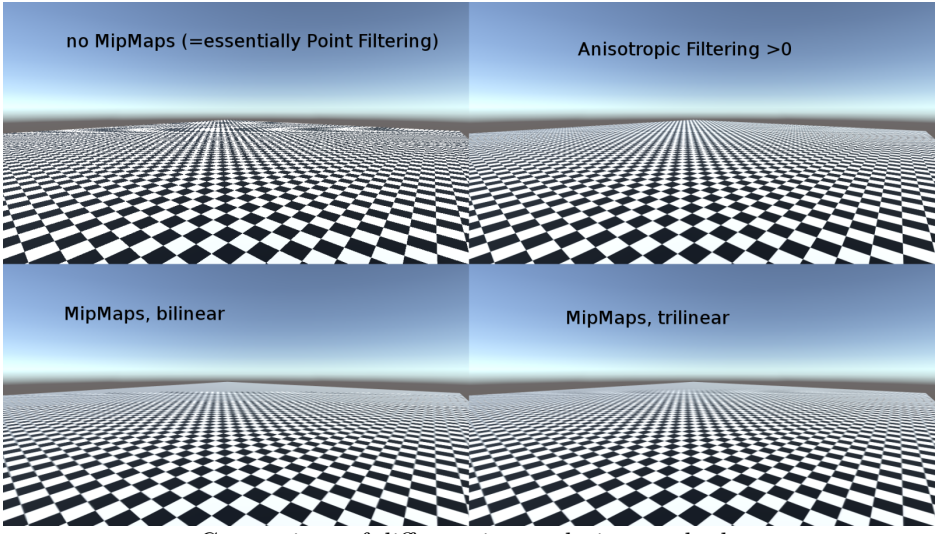

```
glGenerateMipmap(GL_TEXTURE_2D);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR_MIPMAP_LINEAR);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, GL_LINEAR);
```

Visualisation of Mip-map levels



Visualisation of Continous Mip-map Levels

Comparison



Comparison of different interpolation methods

Anisotropic Filtering

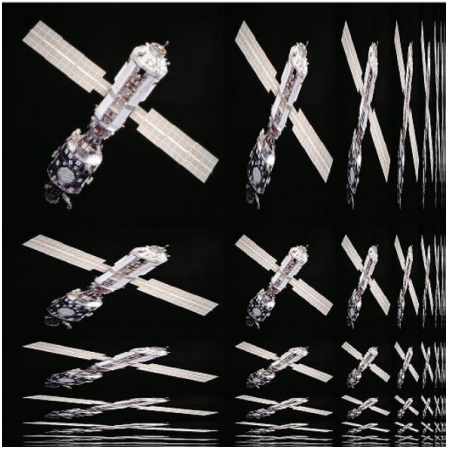
- Better than Mip-maps

Anisotropic Filtering Off

Anisotropic Filtering On

Anisotropic Filtering: Rip-maps (not required)

- Separate downsample of u from that of v
- 4x memory
- a Mip-map is a diagnal of a Rip-map



Summary

- Texture Coordinates
- Object-Texture Mapping
- Texture Sampling
  - Magnification
  - Minification
  - Mip-mapping
  - Anisotropic mapping

Questions?