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COMP27112

Computer Graphics and Image Processing

9: Surface detail

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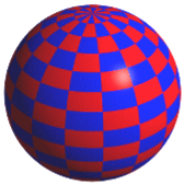
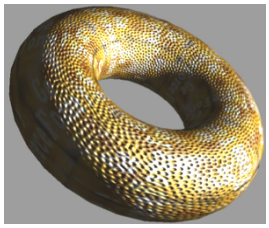
Surface detail

- We'll look at two methods for adding **surface detail** to rendered surfaces
  - Texture mapping



  - Bump mapping



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Defining a texture

- A texture is defined as a 2D array of "texels", often read from an image file

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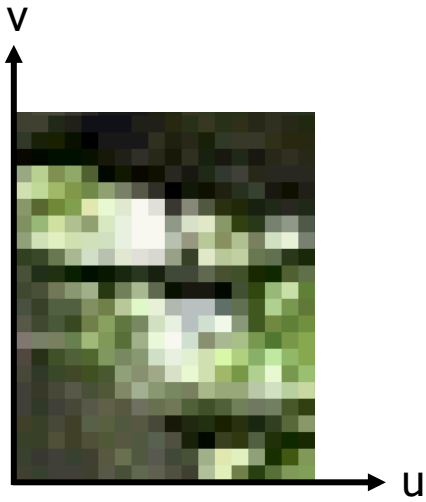
Texture coordinates

- A texture is defined in its own coordinate system, conventionally referred to as (u,v)



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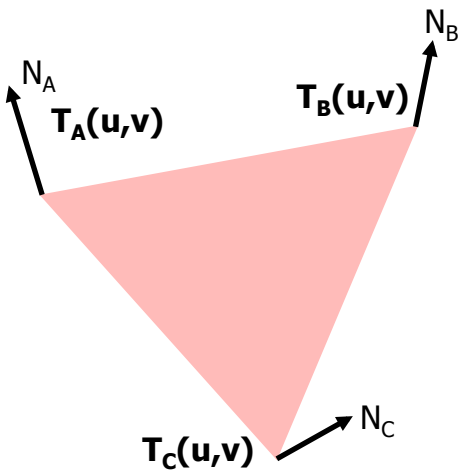
Mapping texture per-polygon

- We associate (u,v) texture coordinates with each (x,y,z) vertex of a polygon
- And interpolate the texture coordinates during scan-conversion
- Then we **blend** the pixel colour with the texture colour



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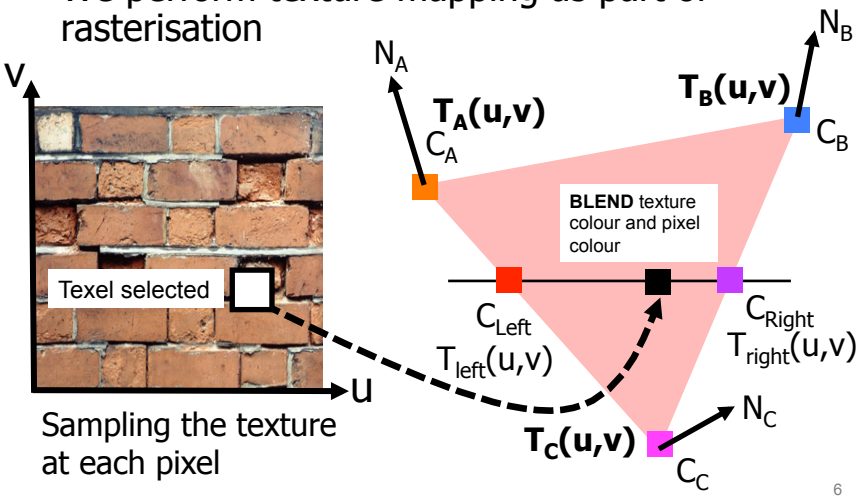
Performing texture mapping

- We perform texture mapping as part of rasterisation



Sampling the texture at each pixel

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Meshes and seams

- In order to realistically texture a mesh, we often have to use multiple textures in different places, which can give rise to ugly "seams"

- One solution is to use textures that are "seamless", so the edge of one exactly matches the edge of another

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Resolution mismatches

- We have to deal with two situations:
  - When pixel resolution **>** texture resolution (i.e. texels are bigger than pixels). So we need to **filter** the texture
  - When texture resolution **>** pixel resolution (i.e. pixels are bigger than texels). So we need to **filter** the texture
- Each situation requires a different approach

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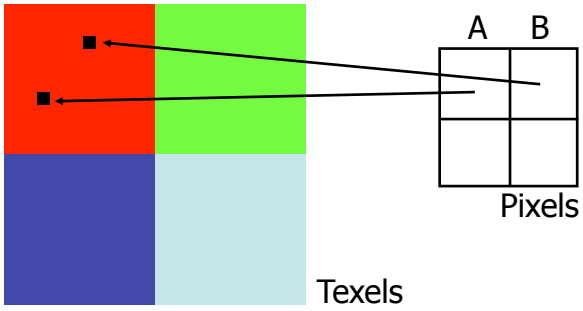
pixel res. > texel res.

- Pixels A and B happen to map to the same texel, because pixel resolution > texel resolution



- We'll look at two approaches (there are more):
  1. No filter
  2. Bilinear interpolation filter

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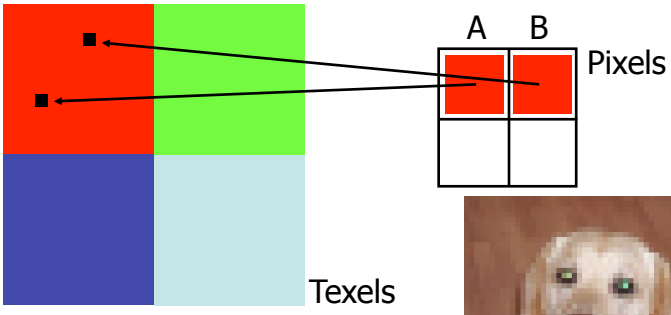
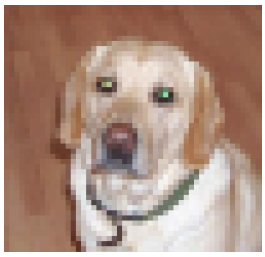
1. No filter

- We simply select the texel to which the pixel maps



- The resulting pixel image looks blocky



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Pixel resolution == Texel resolution

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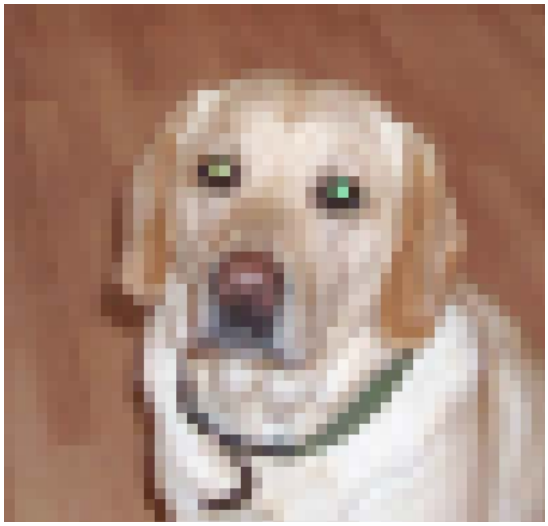
Pixel res. > Texel res. : no filter



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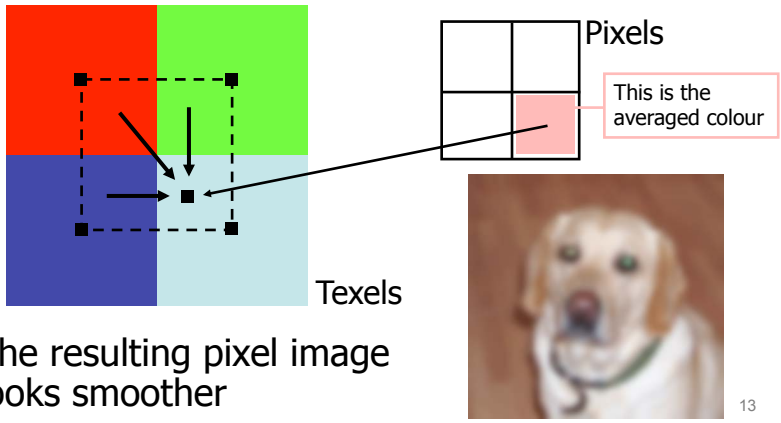
2. Bilinear interpolation filter

- We compute a texel colour from adjacent texels, **averaging** horizontally and vertically



- The resulting pixel image looks smoother

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Pixel resolution == Texel resolution

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Pixel res. > Texel res. : bilinear filter

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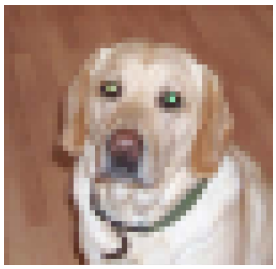
Texture filtering: comparison

Unfiltered texture (1 to 1 pixel correspondence)



No filter

Bilinear interpolation filter

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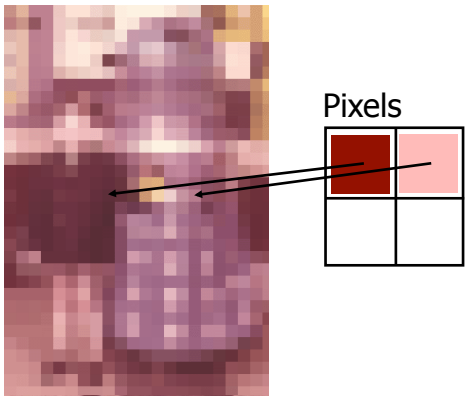
texel resolution > pixel resolution

- If texel resolution **>** pixel resolution, **adjacent** pixels may map to texels **far apart** in the texture, leading to "missing detail" (aliasing)

- In animated sequences especially, we see unpleasant aliasing effects, as pixels "pop" on and off, or change colour unexpectedly in each frame



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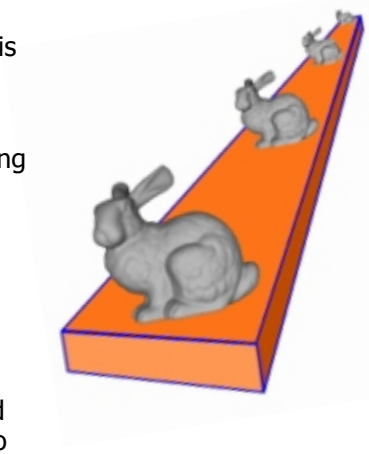
Mipmap filtering

- One technique to minimise this effect is "mipmapping"

- mip = *multum in parvo* (Latin), meaning "many things in a small place"

- The idea is simple: the further away from the viewpoint, the less detail we need

- So, we use a **set** of texture maps, and **select** which map to use, according to the **distance** of a pixel from the viewer



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Creating a mipmap

t0 t1 t2 t3 t4 (etc)

t0 is the original full-resolution texture

Starting from the original texture (t0), we repeatedly create smaller versions of it (t1, t2 etc), downsampling by ½ each time, until we reach a 1x1 texture. This is a **pre-processing** procedure, and we store each texture in memory.

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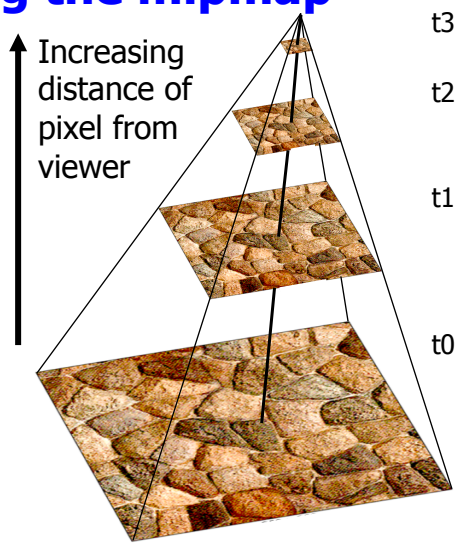
Rendering using the mipmap

- When rendering, we select one of the textures according to the **distance** of the pixel from the viewpoint
- Alternatively, we can also choose the **two closest** textures, and do bilinear interpolation – for extra smoothness



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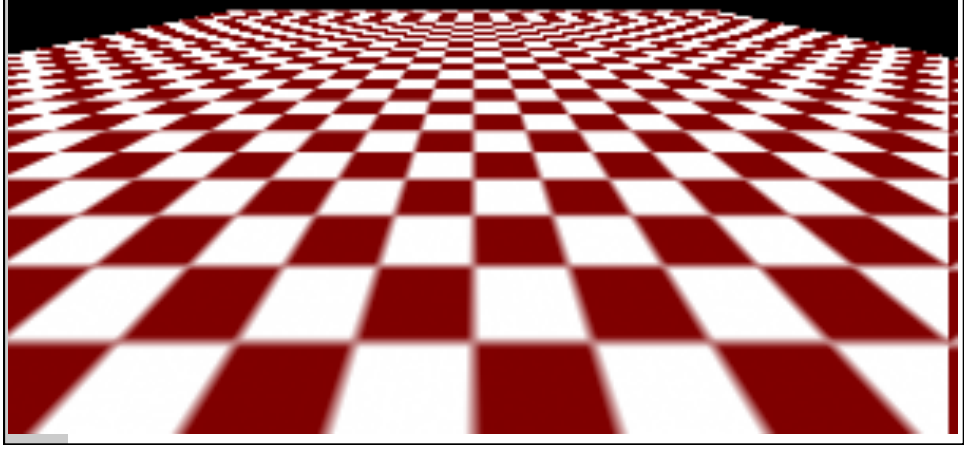
Mipmaps

With no mipmapping, we see aliasing on distant polygons



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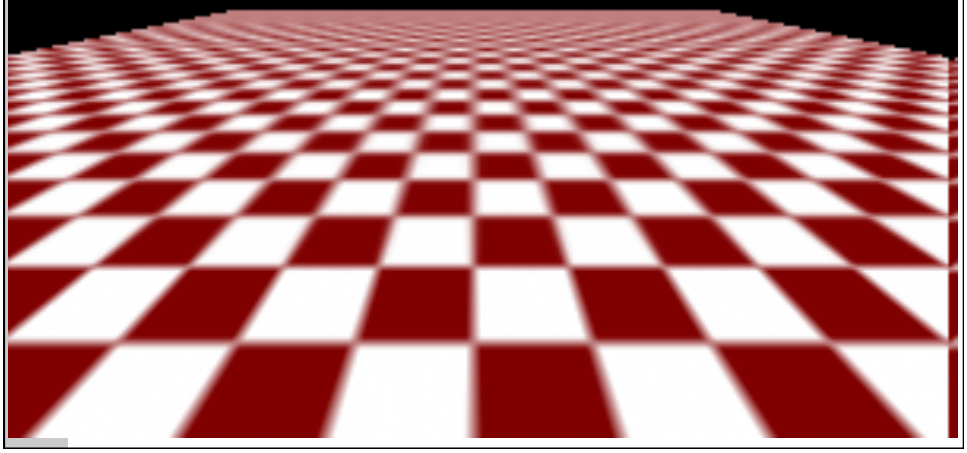
Mipmaps

With mipmapping, the aliasing is replaced by blurring



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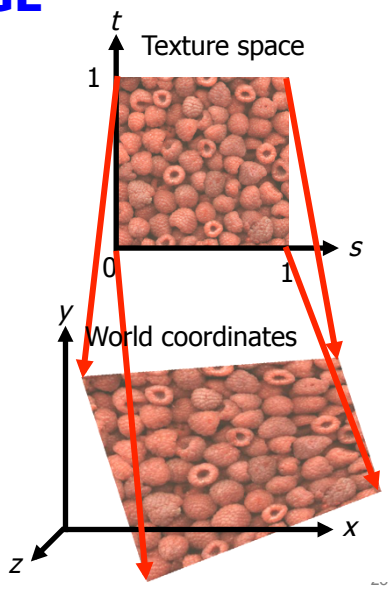
Textures in OpenGL

```
/* First call functions to
   read texture from
   image file, and to set
   its properties - how
   it affects pixels */

/* Now use it */

glBegin(GL_QUADS);
 glTexCoord(0.0, 0.0);
   glVertex3f(x0, y0, z0);
 glTexCoord(1.0, 0.0);
   glVertex3f(x1, y1, z1);
 glTexCoord(1.0, 1.0);
   glVertex3f(x2, y2, z2);
 glTexCoord(0.0, 1.0);
   glVertex3f(x3, y3, z3);
glEnd();
```



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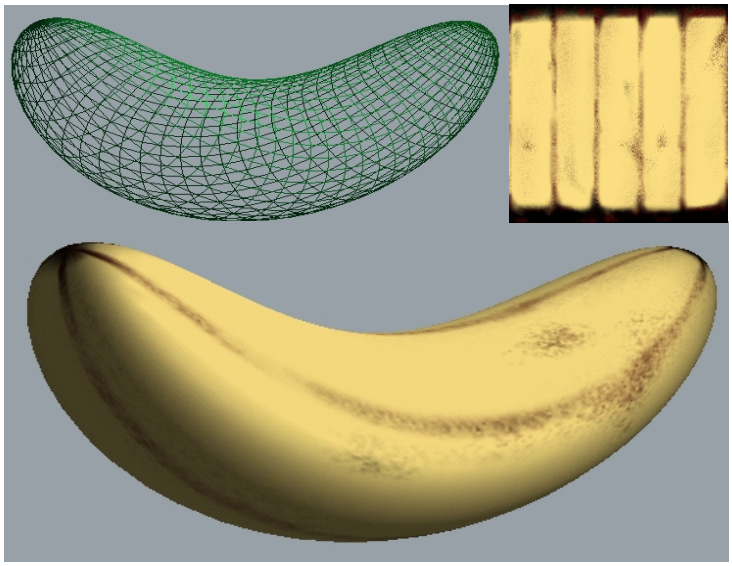
Texture example



James Sinnott

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Textures as "illumination"

- Textures can be used to add accurate illumination to a real-time scene:
  - Off-line, compute accurate diffuse illumination of the scene, using a global model (radiosity)
  - Save rendered surfaces as textures – called **lightmaps**
- In real-time, apply lightmap textures, and also actual surface textures.

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Lightmaps only

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Lightmaps blended with other textures

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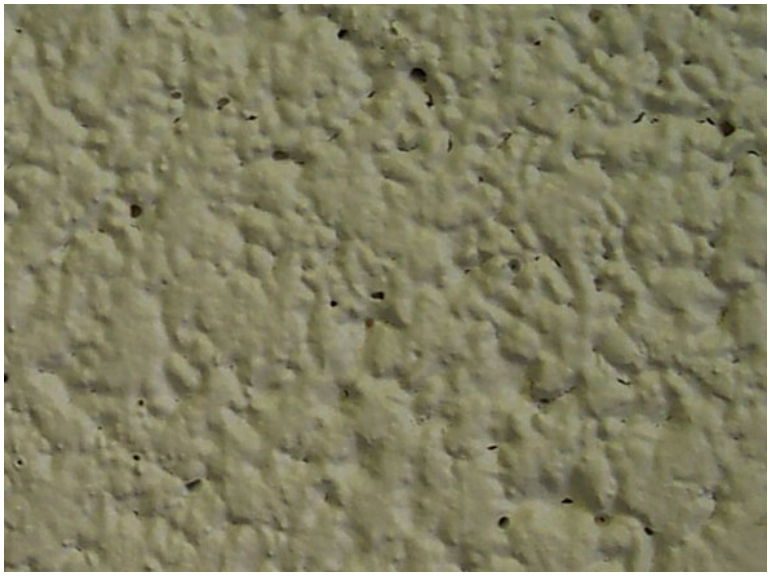
Modelling bumpy surfaces



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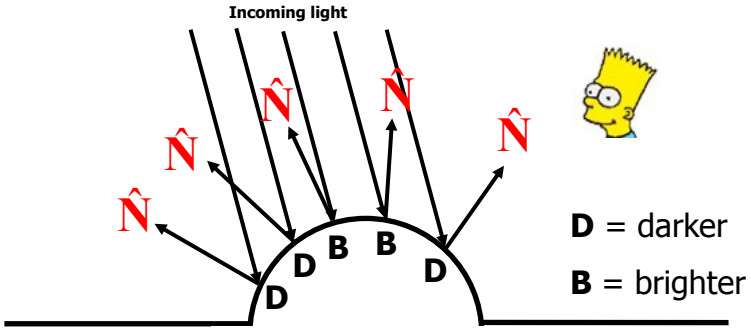
Bump mapping



- Why bumpy surfaces look bumpy
  - The **surface normals** change across the bumps, so the top of the bumps appear brighter than the sides

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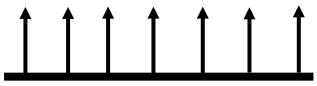
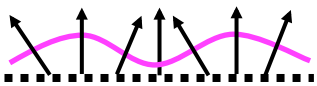
Bump mapping

- Rather than alter the surface **colour**, as in texturing, we can **alter** the **surface normal**…
- …which has the same effect on the illumination model as if the surface were really geometrically different



Original normals



Altered normals

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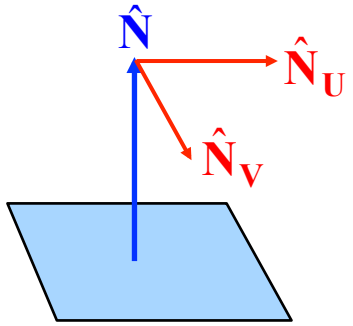
Altering a surface normal



- Step 1: Introduce two **unit** vectors $\hat{N}_U$ and $\hat{N}_V$ each orthogonal to the surface normal

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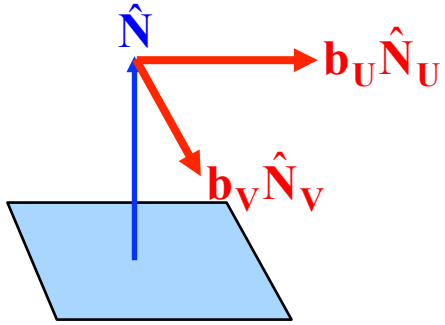
Altering a surface normal



- Step 2: Scale $\hat{N}_U$ and $\hat{N}_V$ by b_U and b_V
- To give the "bump vectors"

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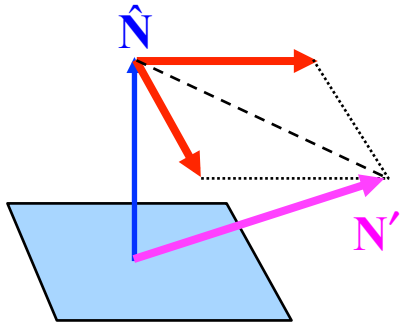
Altering a surface normal



- Step 3: Add the bump vectors to the original surface normal to get an altered surface normal
- $N' = \hat{N} + (b_U \hat{N}_U + b_V \hat{N}_V)$

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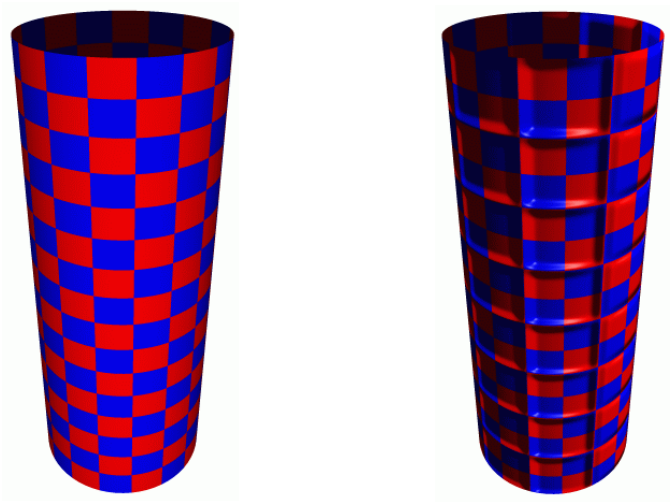
Bump mapping example



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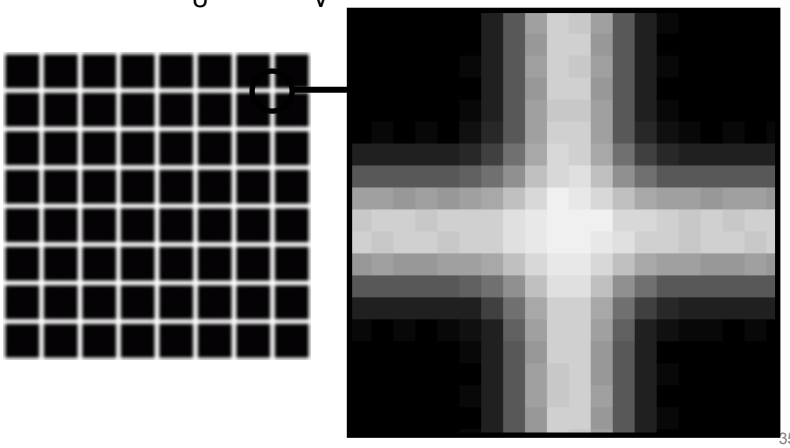
Deriving b_U and b_V

- We can draw a texture to use as a **bump map** to derive b_U and b_V



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Format of a bump map

- We treat the value of each texel as a "height" which controls the bumpiness of the surface
- Here, the brighter texels are "higher" than the darker texels

4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	6	6	6
4	6	8	10	8	8	8	8	8
4	6	8	10	10	10	10	10	10
4	4	6	8	8	8	8	8	8
4	4	4	6	6	6	6	6	6
4	4	4	4	4	4	4	4	4

Hugo Elias

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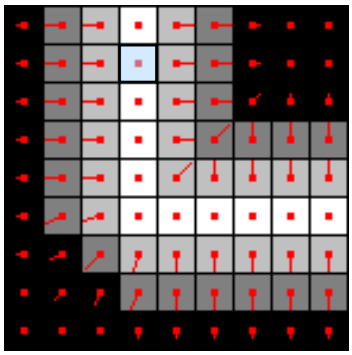
Deriving b_U and b_V

- For each texel T, we can compute its x and y **gradients** and use them as b_U and b_V:
  - $b_U = T(x-1, y) - T(x+1, y)$
  - $b_V = T(x, y-1) - T(x, y+1)$

(0,0)

4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	6	6	6
4	6	8	10	8	8	8	8	8
4	6	8	10	10	10	10	10	10
4	4	6	8	8	8	8	8	8
4	4	4	6	6	6	6	6	6
4	4	4	4	4	4	4	4	4



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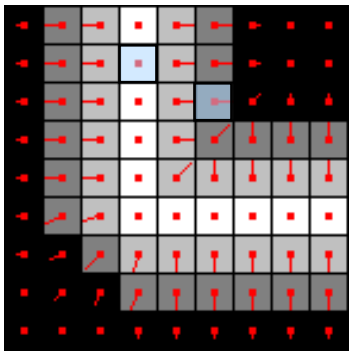
  - $b_U = T(x-1, y) - T(x+1, y)$
  - $b_V = T(x, y-1) - T(x, y+1)$

(0,0)

(4,0)

4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	6	6	6
4	6	8	10	8	8	8	8	8
4	6	8	10	10	10	10	10	10
4	4	6	8	8	8	8	8	8
4	4	4	6	6	6	6	6	6
4	4	4	4	4	4	4	4	4



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Deriving b_U and b_V

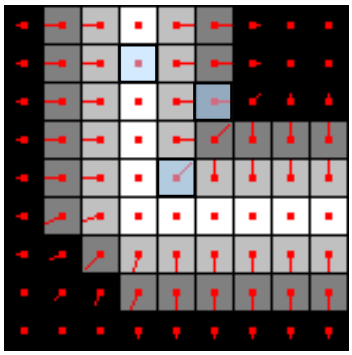
- For each texel T, we can compute its x and y **gradients** and use them as b_U and b_V:
  - $b_U = T(x-1, y) - T(x+1, y)$
  - $b_V = T(x, y-1) - T(x, y+1)$

(0,0)

(4,0)

(2,2)

4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	6	6	6
4	6	8	10	8	8	8	8	8
4	6	8	10	10	10	10	10	10
4	4	6	8	8	8	8	8	8
4	4	4	6	6	6	6	6	6
4	4	4	4	4	4	4	4	4



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Deriving b_U and b_V

- For each texel T, we can compute its x and y **gradients** and use them as b_U and b_V:
  - $b_U = T(x-1, y) - T(x+1, y)$
  - $b_V = T(x, y-1) - T(x, y+1)$

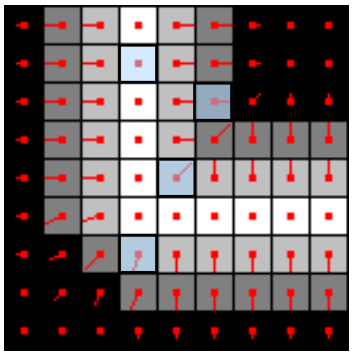
(0,0)

(4,0)

(2,2)

(-2,-4)

4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	4	4	4
4	6	8	10	8	6	6	6	6
4	6	8	10	8	8	8	8	8
4	6	8	10	10	10	10	10	10
4	4	6	8	8	8	8	8	8
4	4	4	6	6	6	6	6	6
4	4	4	4	4	4	4	4	4



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Bump mapping example

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