COMP220: Graphics & Simulation

5: Textures and models

Learning outcomes

- **Explain** how a complex 3D model is represented in memory
- **Explain** how a 2D texture image can be wrapped onto a 3D model
- **Write** programs which draw textured meshes to the screen

Basic texture mapping

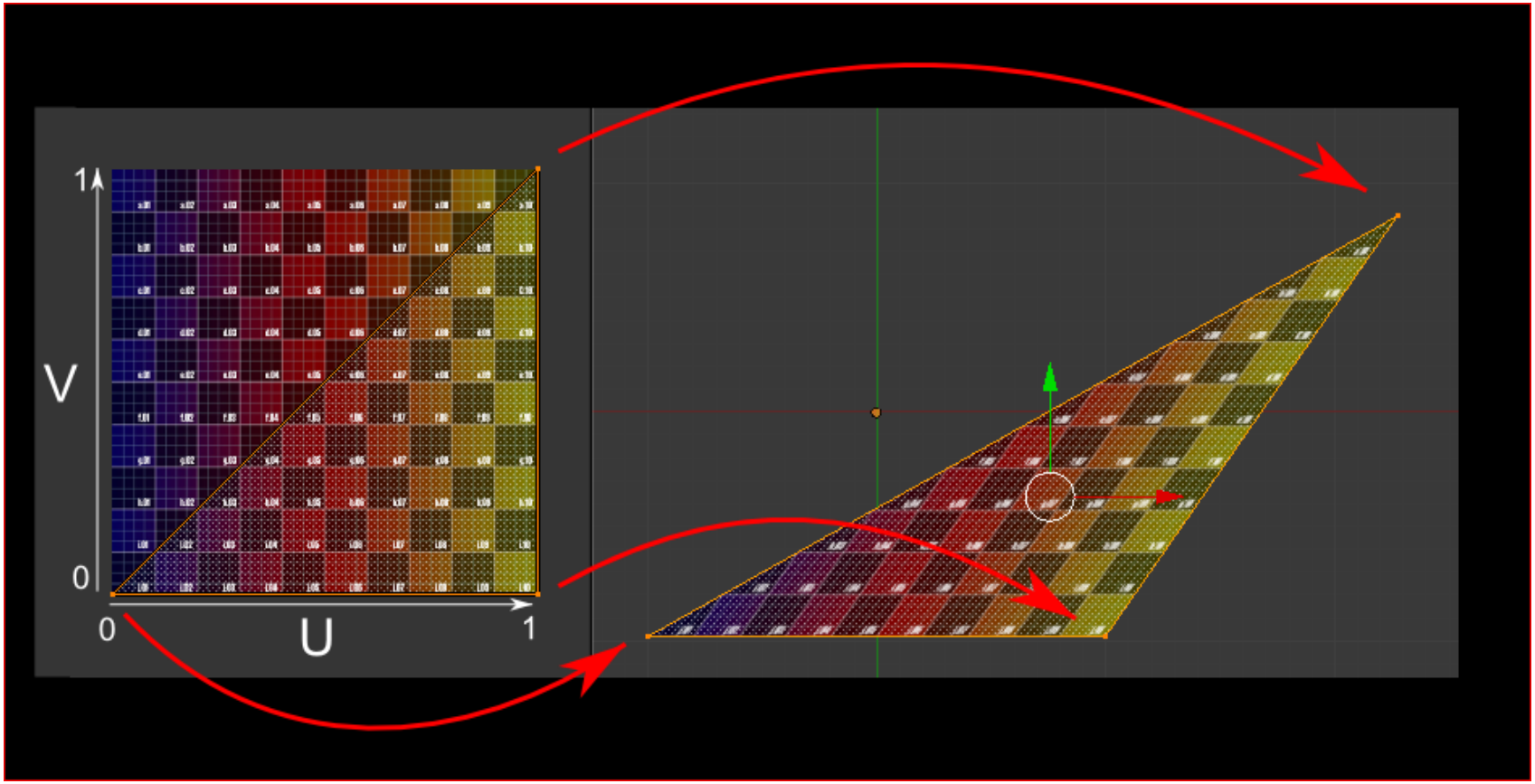
Loading textures from a file

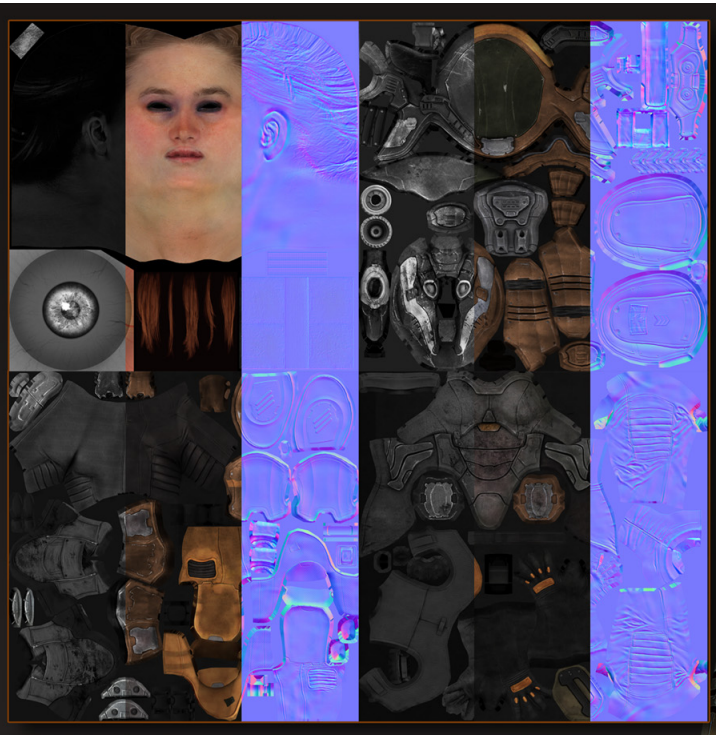
- The **SDL_Image library** lets us load images from JPG, PNG, BMP etc.
- Steps:
  - Load the image with `IMG_Load`
  - Create a texture with `glGenTextures`
  - Bind the texture with `glBindTexture`
  - Load the pixel data into the new texture with `glTexImage2D`
  - Set the texture filtering modes with `glTexParameteri` (more on this later)

Texture coordinates

- We use **UV coordinates** to refer to points in a texture
- *u* axis is horizontal and ranges from 0 (left) to 1 (right)
- *v* axis is vertical and ranges from 0 (bottom) to 1 (top)
- (So really just another name for *xy* coordinates in texture space)
- Basic idea of texture mapping: give each vertex a *uv* coordinate, and interpolate across the triangle

UV coordinates





Specular/Diffuse/Normal

UV layout/Masking maps

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Textures in GLSL

Fragment shader:

```
in vec2 textureCoords;
uniform sampler2D textureSampler;

void main()
{
    fragmentColour = texture(textureSampler,
        textureCoords);
}
```

Texture filtering

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

- **Linear interpolation** (`GL_LINEAR`) smooths between pixels
- **Nearest neighbour** (`GL_NEAREST`) is pixelated but may be slightly faster
- **Anisotropic filtering** improves the quality of linear interpolation but is slower
- **Mip-mapping** pre-calculates scaled down versions of the texture — improves quality but costs memory

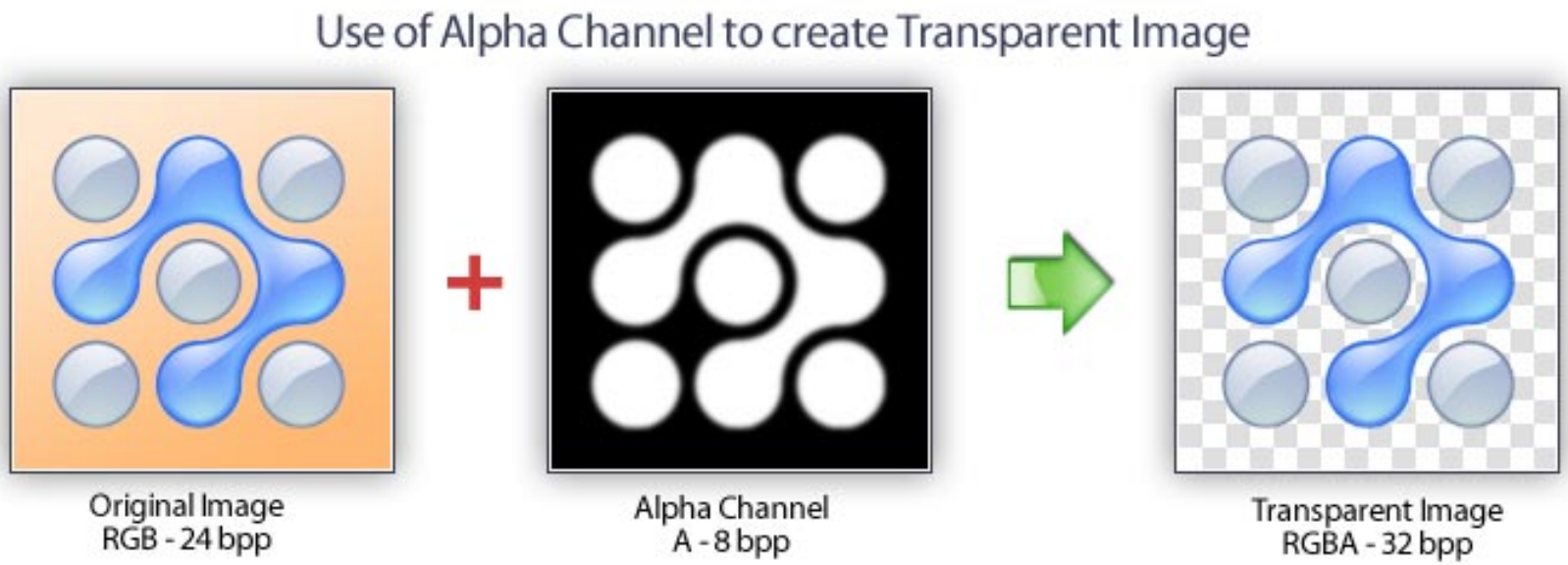
Texture dimensions

- In the old days, OpenGL required textures to have **power of two** dimensions
  - $2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, \ldots$
- Nowadays **non-power of two (NPOT)** textures are widely supported
- Still better to stick to powers of two as some things work better (e.g. mipmapping)
- NB: **rectangular** textures are fine, but **square** textures make UV coordinates saner

Transparency

Alpha

- We are used to working with colours in **RGB** space
- We can also work in **RGBA** space, where A = alpha = transparency
- $A = 0 \implies$ fully transparent
- $A = 1$ (or $A = 255$) $\implies$ fully opaque



Alpha in OpenGL

- Use **`vec4`** instead of **`vec3`** for colours
- Textures can have an **alpha channel**
  - PNG supports alpha channels, JPG and BMP do not
- Need to enable **alpha blending**

```
glEnable(GL_BLEND);
glBlendFunc(GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA);
```

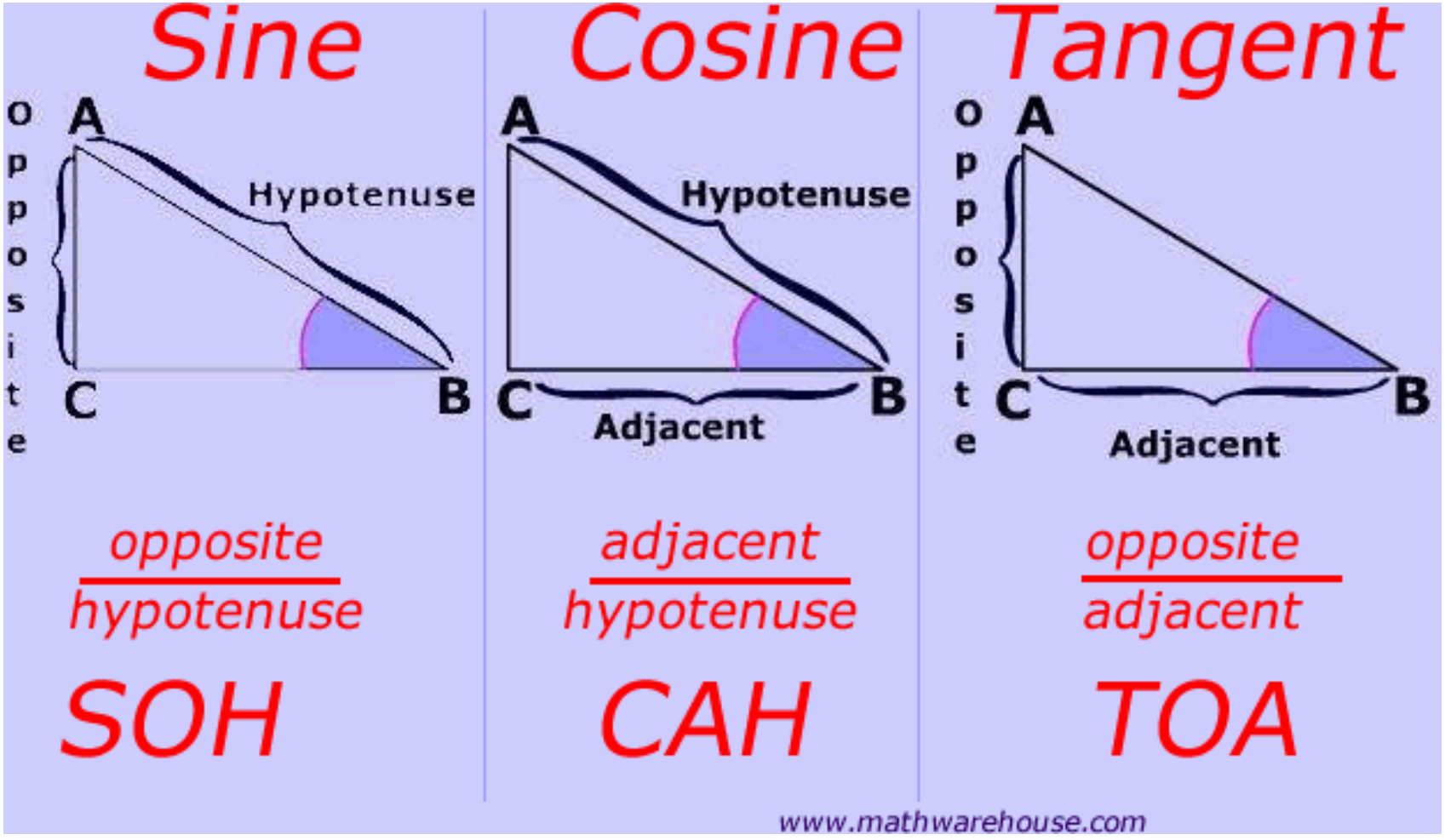
- Other values can be passed to `glBlendFunc` for special effects (e.g. **additive blending** is often used for particle effects simulating light, fire, explosions etc.)

Transparency and depth testing

- Recall we are using **depth testing**
  - Each fragment on screen remembers its **depth** (distance from the camera)
  - A new fragment is drawn **only if** its depth value is **less** than the current depth value
  - I.e. don't draw objects that should be behind something that was already drawn
- But if the object in front is (semi-)transparent, we want to see the object behind it!
- Solution: draw semi-transparent objects **after** opaque objects, and in **back to front** order
- Further discussion: `http://www.opengl-tutorial.org/intermediate-tutorials/tutorial-10-transparency/`

More meshes

SOH CAH TOA


Sine
Cosine
Tangent
opposite
A
C
B
Hypotenuse
Adjacent
opposite / hypotenuse
adjacent / hypotenuse
opposite / adjacent
SOH
CAH
TOA
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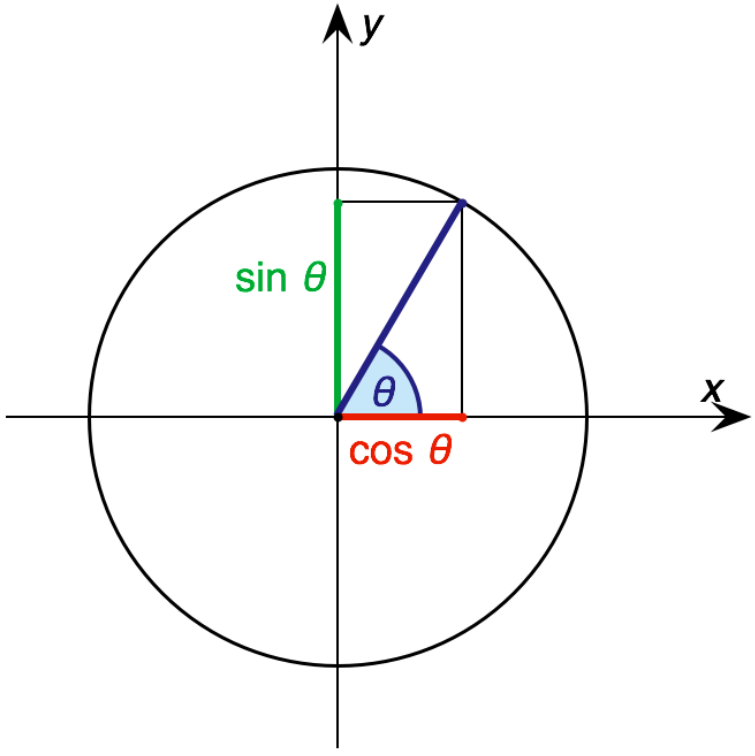
Drawing a circle



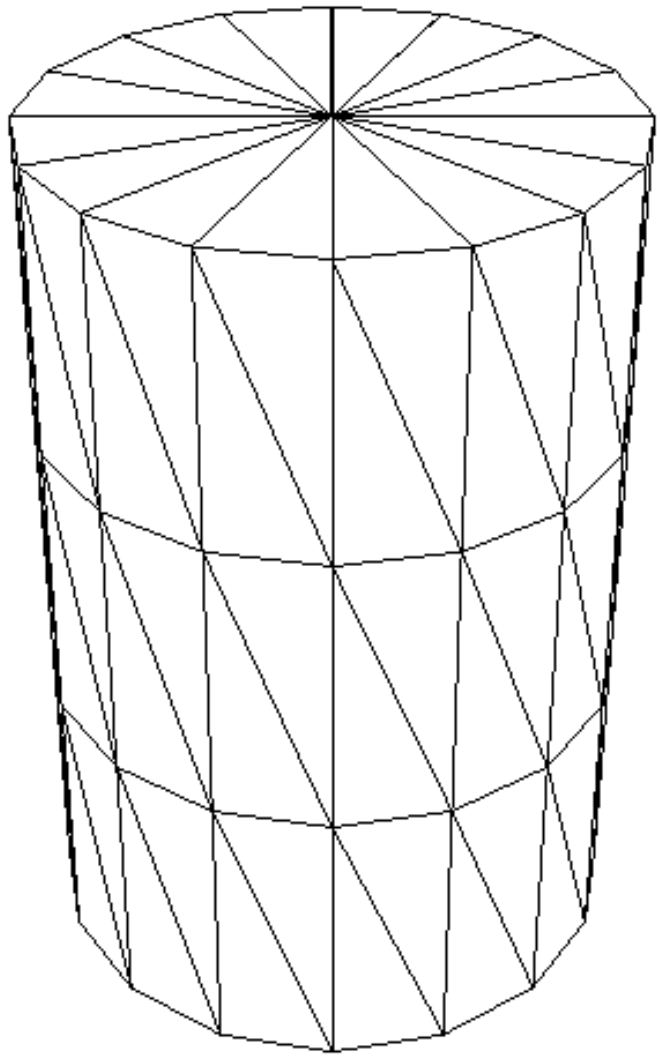
Circle of **radius** r
$\therefore$ hypotenuse = r

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{x}{r}$$
$$\therefore x = r\cos\theta$$

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{y}{r}$$
$$\therefore y = r\sin\theta$$

NB: this works even if $\cos\theta$ and/or $\sin\theta$ are negative (i.e. if θ is not between 0° and 90°)

Drawing a cylinder



Drawing a sphere