Architecture of a Graphics Pipeline

5 February 2009
CMPT370
Dr. Sean Ho
Trinity Western University

Review last time

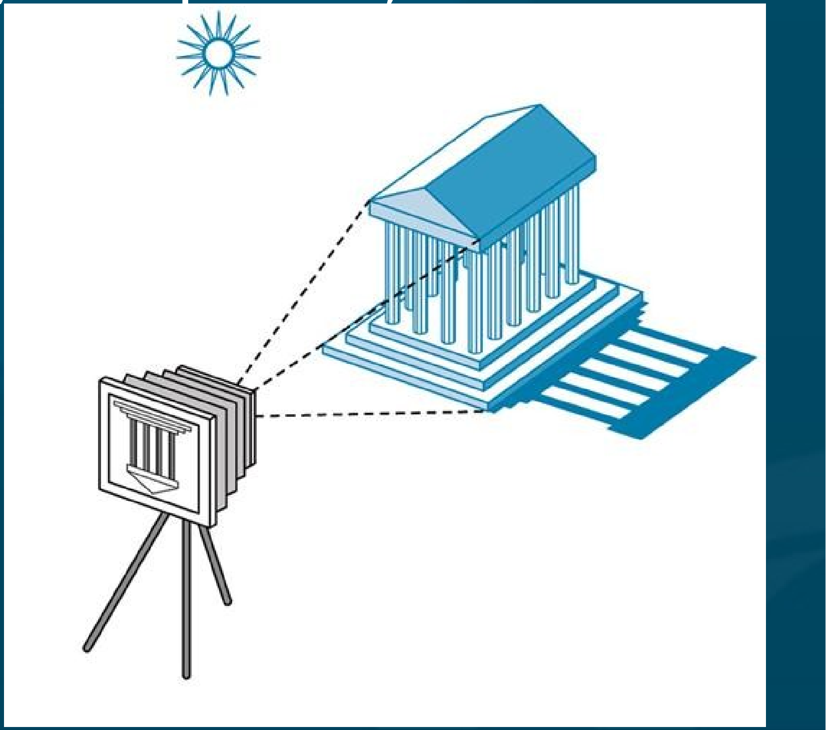
- Visual computing:
  - Computer graphics and image analysis
- Objectives of visual computing
  - Capture and understand reality
  - Emulate and enhance reality
  - Parthenon video
- Image formation
  - Camera model

What's on for today

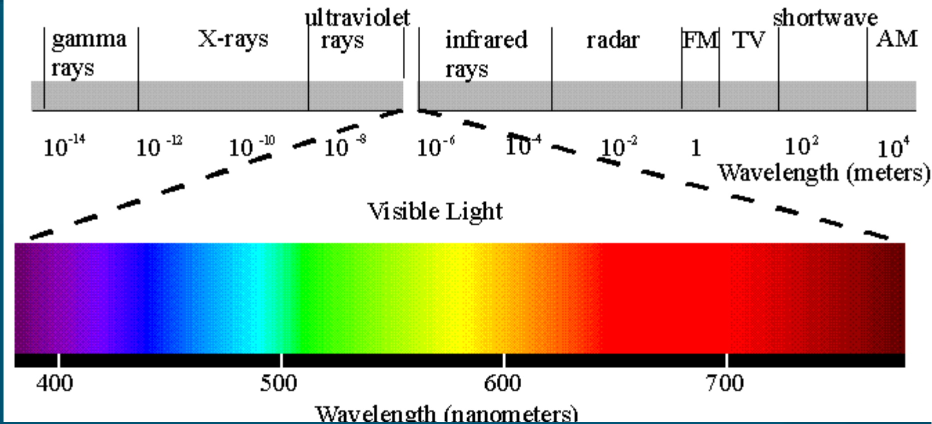
- Light and colour models
- Geometric representation: trimesh
- Off-line rendering: raytracing, radiosity
- Real-time interactive graphics pipeline:
  - Vertex processing
  - Clipping and culling
  - Rasterizing
  - Fragment processing

Image formation

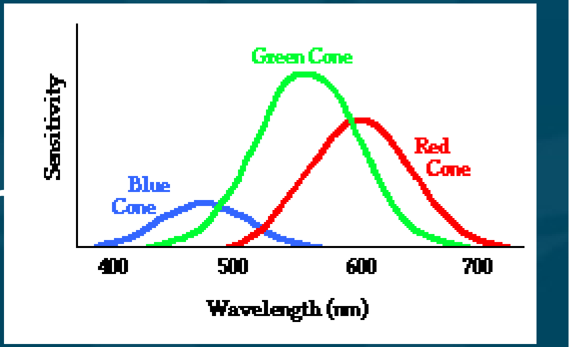
- Components to produce a static image:
  - Objects
    - Geometry (vertices, faces, etc.), material properties: colour, shininess, bumpiness, etc.
  - Light sources
    - Colour spectrum, direction, area, etc.
  - Viewer
    - Camera model: lens, depth of field, etc.



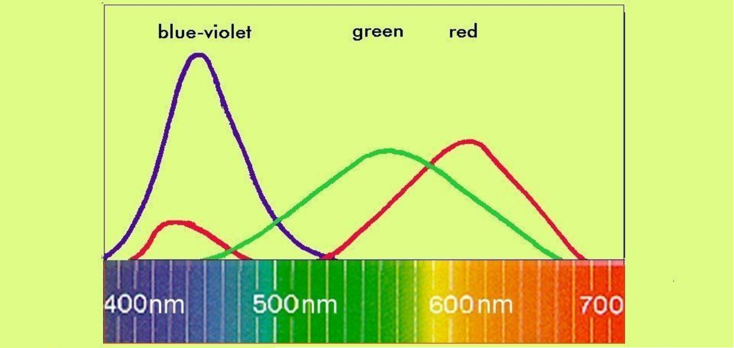
Light



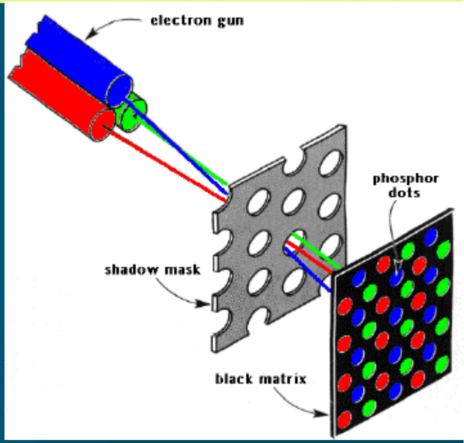
- Visible light is electromagnetic radiation about 350-750nm in wavelength (~400 to 850 THz in frequency)
- Light colour is a frequency distribution of energy
  - Lasers: monochromatic
- But our eyes only have four kinds of sensors:
  - Rods: luminance (shades of grey)
  - R,G,B cones: chrominance (colour
  - Each sensor has its own frequency response curve



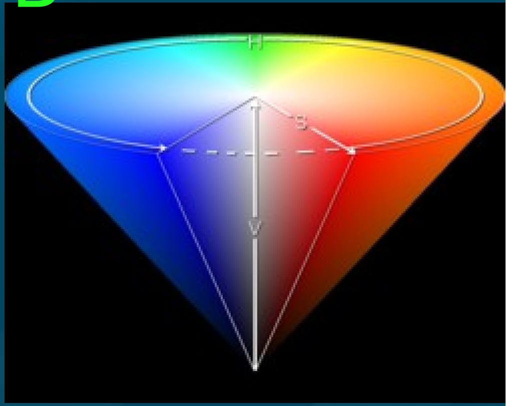
Colour models



- Frequency distribution at each pixel
- RGB: matches our cones
  - Additive colour: CRTs use 3 electron guns
  - Must still define chromaticities of R,G,B



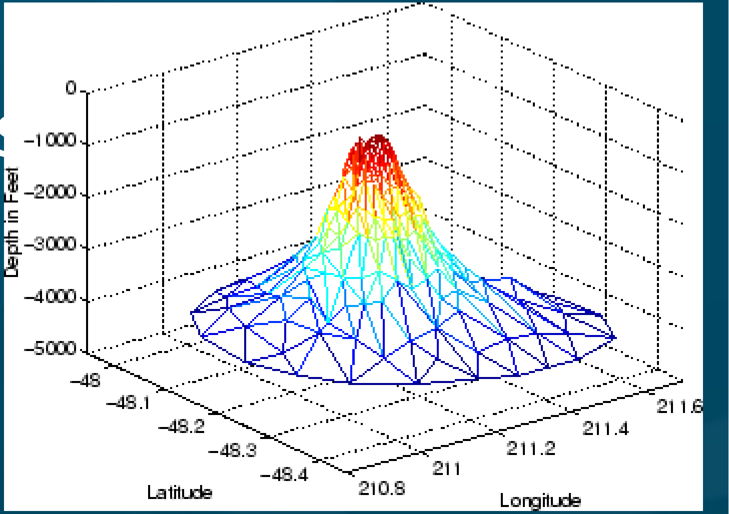
- CMYK: subtractive colour: C/R, M/G, Y/B
  - Inks/pigments: newspaper, paint
- HSV: hue, saturation, value

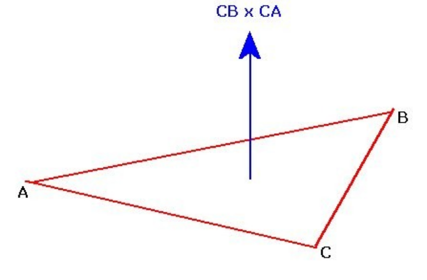


- CIELAB: lightness, a/b chrominance:
  - Absolute colour space: only depends on whitepoint
  - Convert to absolute via profile: AdobeRGB, sRGB

Geometric representation: trimesh

- The most common representation for the geometry of 3D surfaces is a triangle mesh:
  - Vertex list (point cloud): (x,y,z) coordinates
    - {0.2, 0., 2.7}, {0.2, -0.112, 2.7}, {0.112, -0.2, 2.7},
  - Face list: indexes into vertices
    - {12, 13, 14}, {13, 14, 15}, …
- Can also use other polygons
  - But triangle is a 2D simplex: Always flat
- Faces have normal vectors

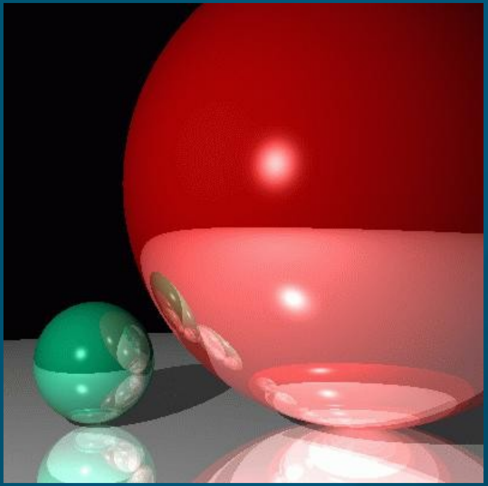




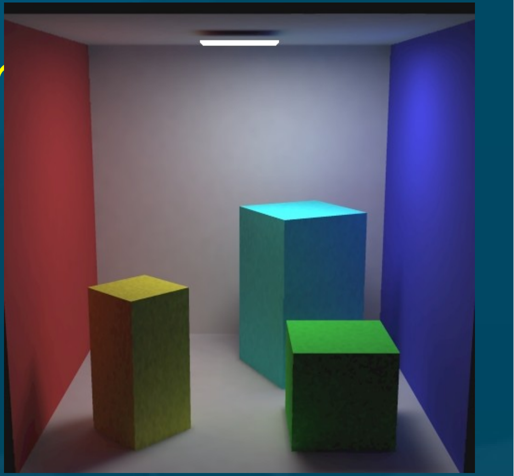
Off-line vs. real-time graphics

- Off-line rendering
  - Render time is not very important
    - Use big parallel render farms
  - Photo-realism is the priority
  - Raytracing, radiosity, other rendering methods
- Real-time (interactive) graphics
  - Perfect photo-realism is not so important
  - Frame rate is the priority: at least 60Hz
  - 3D modelling, CAD, scientific visualization
  - Graphics pipeline in video card or software

Off-line rendering



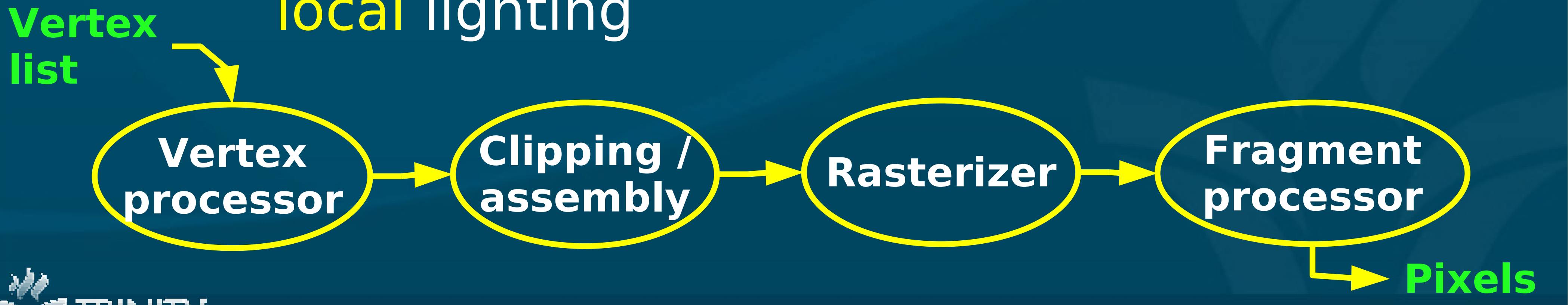
- Raytracing:
  - Cast rays from camera into scene until either absorbed or go to infinity
    - Sky sphere handles infinity
  - Reflections, translucency, refraction
  - Only trace rays that are needed



- Radiosity:
  - Light sources emit energy
  - Follow light energy as it bounces in scene
  - Global illumination: not view-dependent

Real-time graphics pipeline

- This is what your graphics card hardware does
- Input: scene objects, lighting, camera
  - Most of the data is the vertex list
- Output: pixels stored in the framebuffer
  - Raster graphics
- Usually processes objects one at a time: local lighting

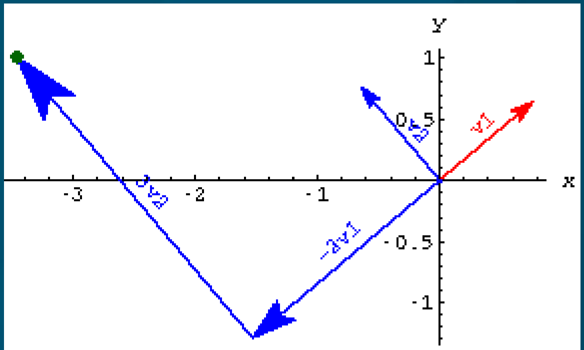


Vertex processor: T&L

- The vertex processor operates on each vertex independently: parallel processor
  - NVIDIA FX 5800 has 240 cores
- Its basic tasks are:
  - Transform: changing position/geometry of the vertex
  - Lighting: determining a RGB colour for the vertex: vertex shading

Vertex processor: transform

- Much of the work is in transforming vertices from one coordinate system to another:
  - Object-based coords
  - Camera-based coords
  - Screen-based coords



- Each transform is a matrix multiplication
- GPUs are highly optimized to do matrix multiply very fast in parallel
  - Vertex shaders can be programmed to do fancy effects (GLSL, HLSL, Cg)

Kinds of coordinate transforms

- The transformations done on vertices include:
  - Translation: shift in (x,y,z)
  - Rotation: e.g., 3 Euler angles
  - Scaling: uniform or along 3 axes
  - (Perspective, affine)
- 3D points are projected onto 2D image plane:
  - Perspective projection:
    - Projection lines meet at center of projection
  - Parallel projection:
    - Projection lines are all parallel