Computer Graphics: Intro

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Fundamentally: Light Transport

The Rendering Equation

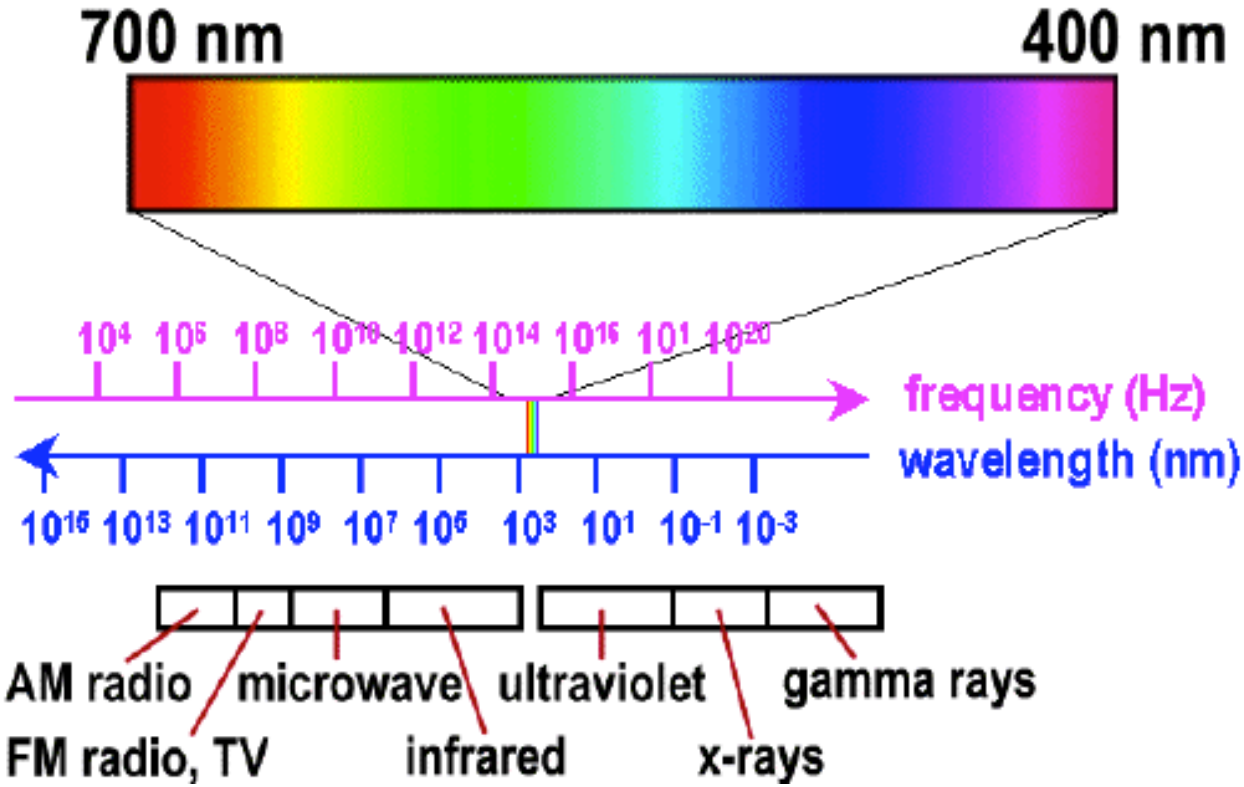
- *I(x,x')* = intensity passing from x' to x
- *g(x,x')* = geometry term (1, or $1/r^2$, if x visible from x', 0 otherwise)
- *ε(x,x')* = intensity emitted from x' in the direction of x
- *ρ(x,x',x'')* = scattering term for x' (fraction of intensity arriving at x' from the direction of x'' scattered in the direction of x)
- S = union of all surfaces

$$I(x,x') = g(x,x')\left[\epsilon(x,x') + \int_S \rho(x,x',x'')I(x',x'')dx''\right]$$

Modeling Color - Physics

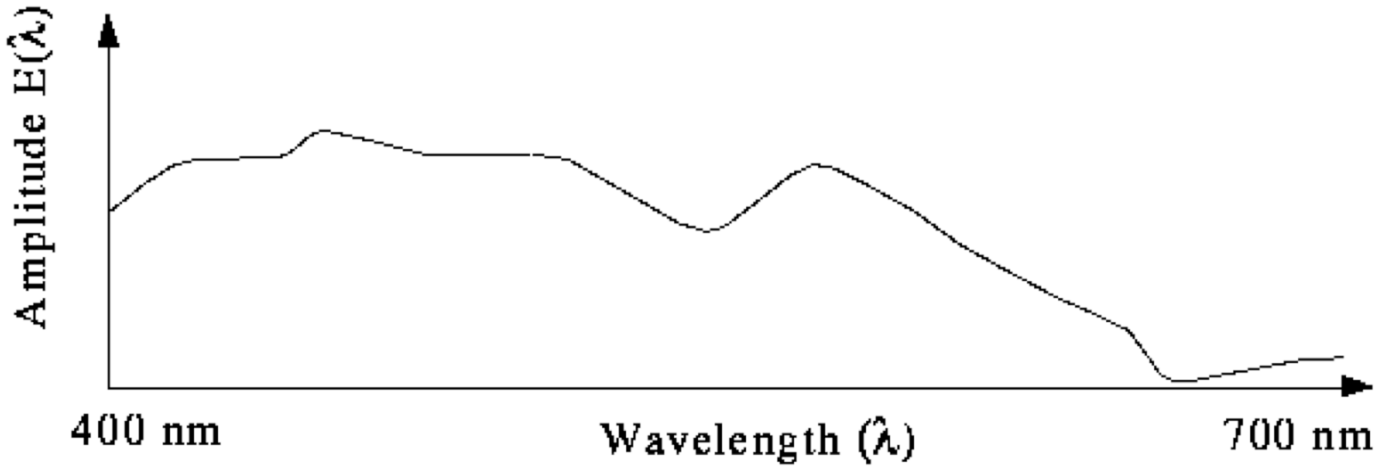
- It’s all electromagnetic (EM) radiation
  - Different colors correspond to radiation of different wavelengths
  - Intensity of each wavelength specified by amplitude
    - Frequency = 2 pi/wavelength
- We see EM radiation within the 400-700 nm range, the tiny piece of spectrum between infra-red and ultraviolet

Visible Light



Color and Wavelength

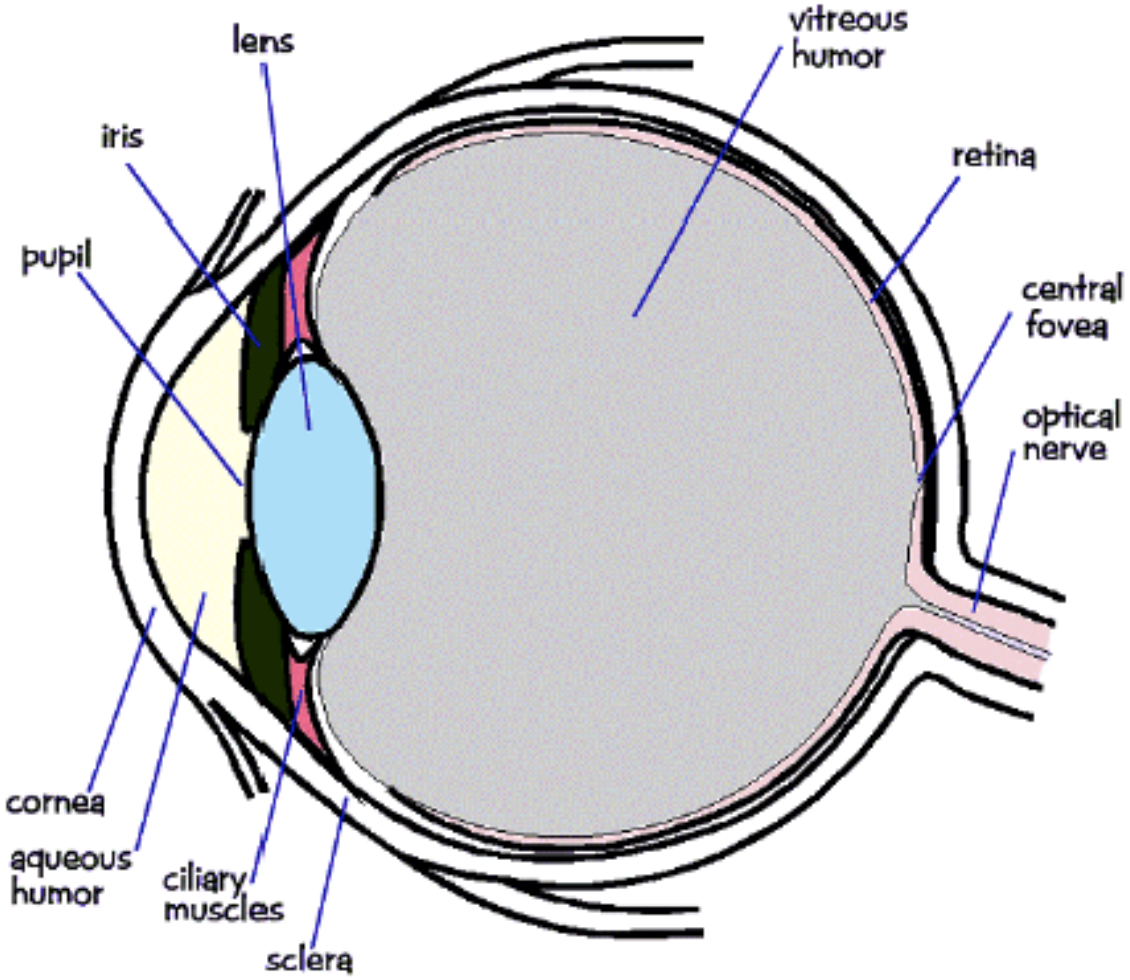
Most light we see is not just a single wavelength, but a combination of many wavelengths like below. This profile is often referred to as a spectrum, or spectral power distribution.



3-Component (Tristimulus) Color

- The de facto representation of color on screen display is RGB. (additive color)
- Some printers use CMY(K), (subtractive color)
- Why?
  - The color spectrum can be represented by 3 basis functions?

The Eye


lens
vitreous humor
iris
retina
pupil
central fovea
optical nerve
cornea
aqueous humor
ciliary muscles
sclera

Color is Human Sensation

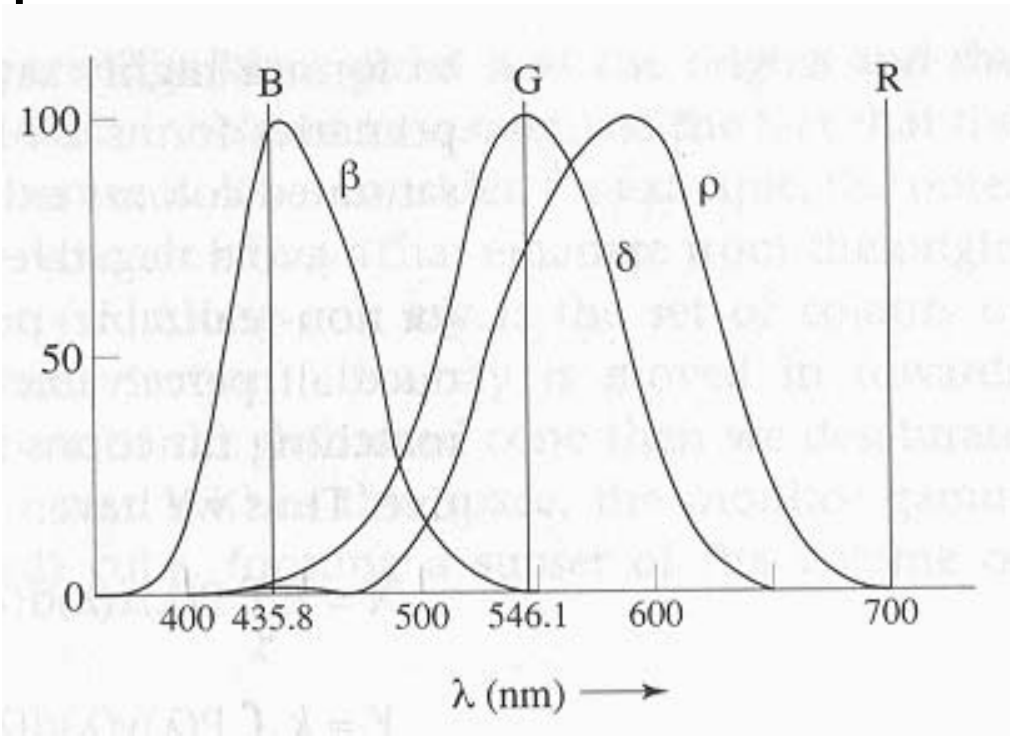
- Cone and rod receptors in the retina
- Rod receptor is mostly for luminance perception
- 3 different types of cone receptors in the fovea of retina, responsible for color representation. Each type is sensitive to different wavelengths

Cone Receptors

- There are three types of cones, referred to as S, M, and L. They are roughly equivalent to blue, green, and red sensors, respectively.
- Their peak sensitivities are located at approximately 430nm, 560nm, and 610nm for the "average" observer.

Limitation of Knowledge

- We don’t know the precise light sensitivity on each person’s retina.



So, what is the standard color?

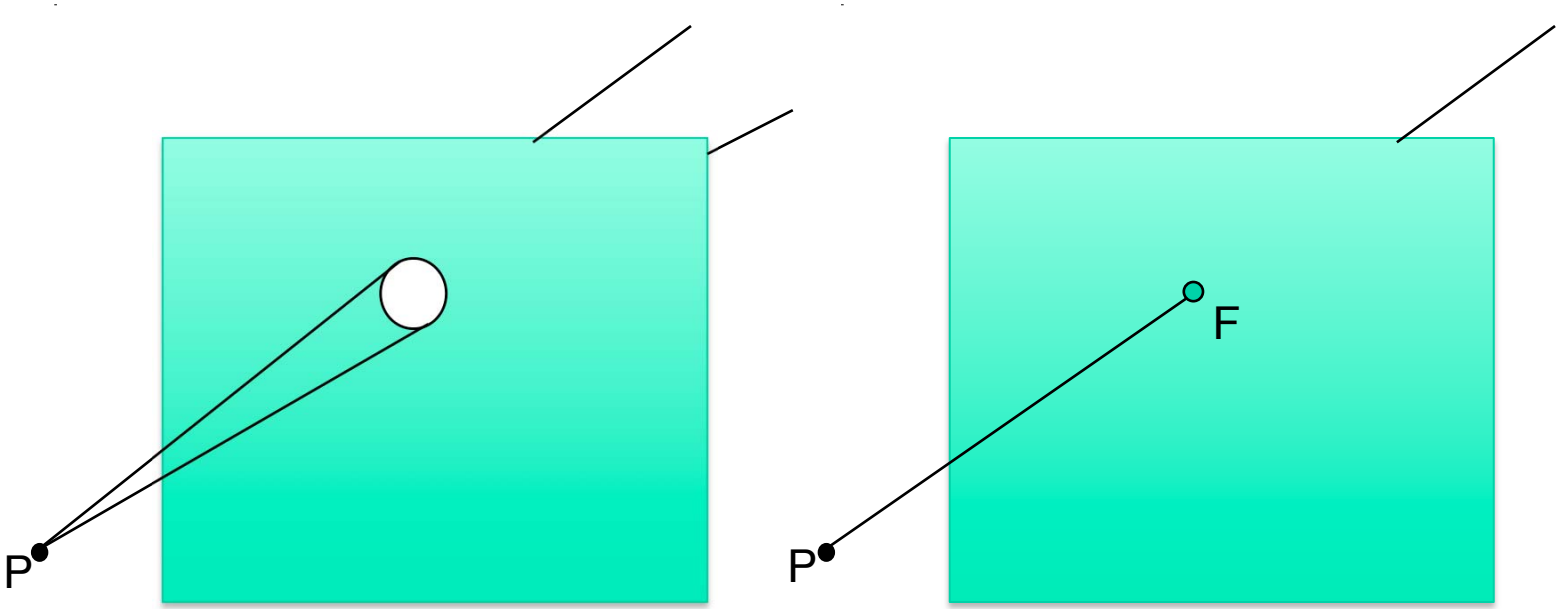
- The basis of comparison is not math!!
- The basis of comparison is human color matching experiments
- 100% mathematically correct light object interaction need to be evaluated at more than 3 points in the spectrum

Main Color Spaces

- CIE XYZ, xyY
- RGB, CMYK
- HSV (Munsell, HSL, IHS)
- Lab, UVW, YUV, YCrCb, Luv,

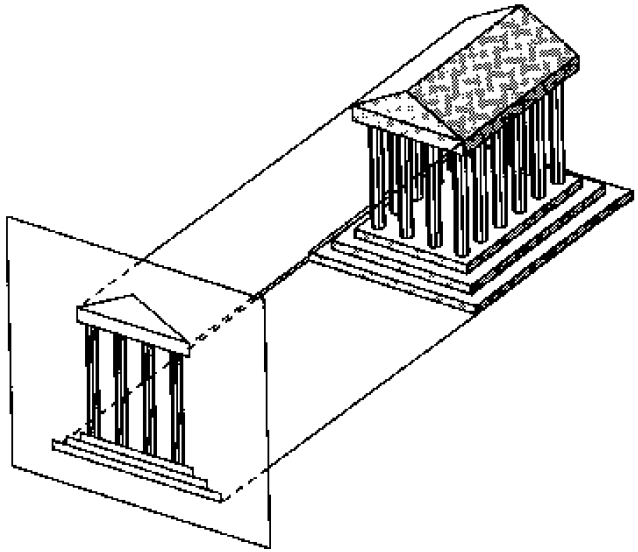
Modeling Eye– Pin Hole Camera

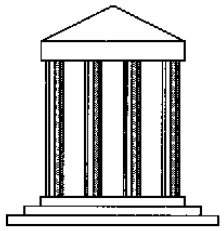
- Visibility cone with apex at observer
- Reduce hole to a point – the cone becomes a ray
- Pin hole – focal point, and center of projection



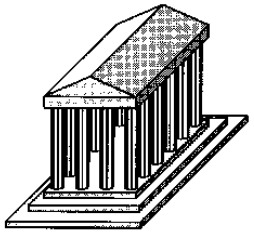
Modeling Eye - The Viewer

- Viewing: camera position and direction
- Projection: reduce 3D to 2D

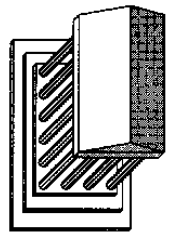




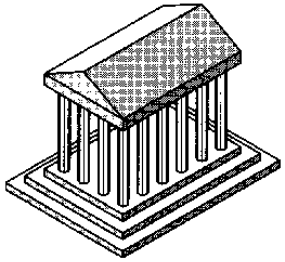
Front elevation



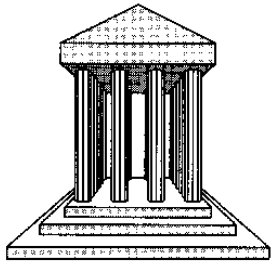
Elevation oblique



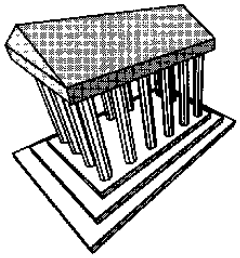
Plan oblique



Isometric



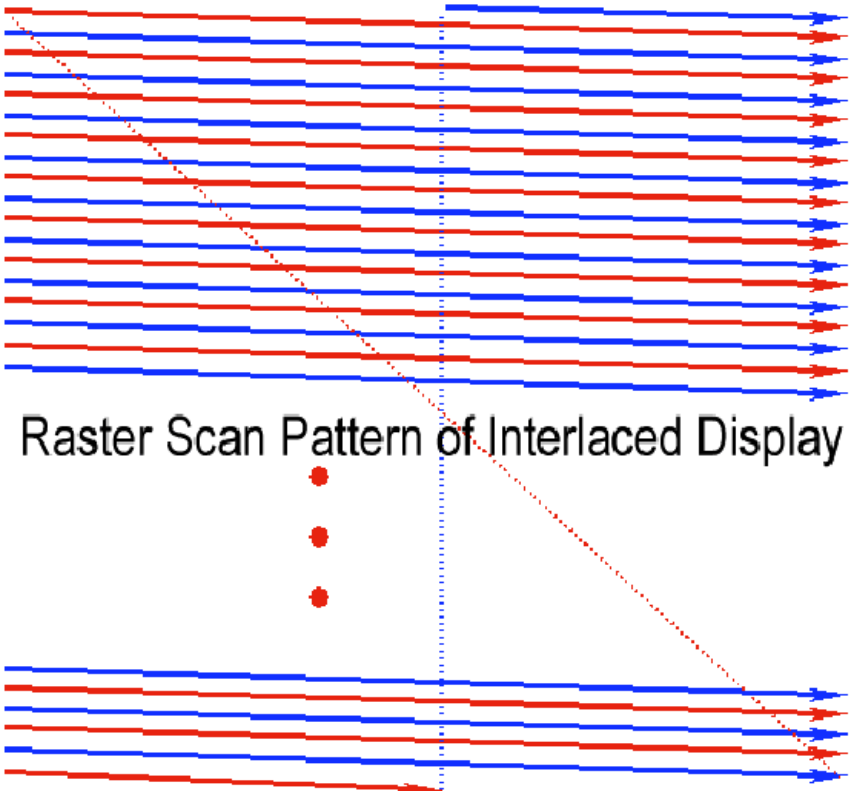
One-point perspective



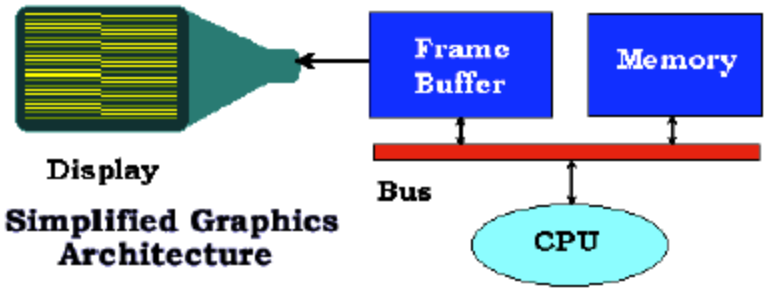
Three-point perspective

Modeling Eye – Frame Buffer, Image, Raster Display

- TV boom made it cheap
- Entire screen painted 30 times/ sec
- Screen is traversed 60 times/ sec
- Even/ Odd lines on alternate scans, ‘interlace’.

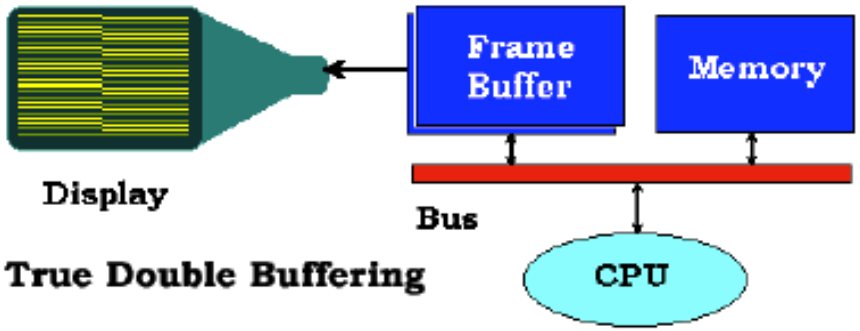


Raster Displays



- Display synchronized with CRT sweep
- Special memory for screen update
- Pixels are the discrete elements displayed
- Generally, updates are visible

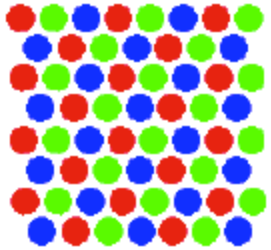
Double Buffer

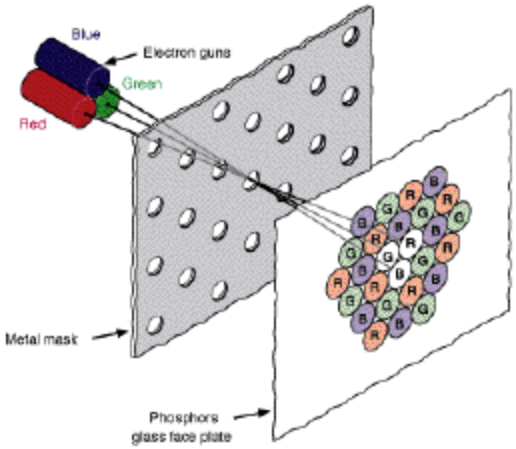


- Adds a second frame buffer
- Swaps during vertical blanking
- Updates are invisible
- Costly

Color CRT

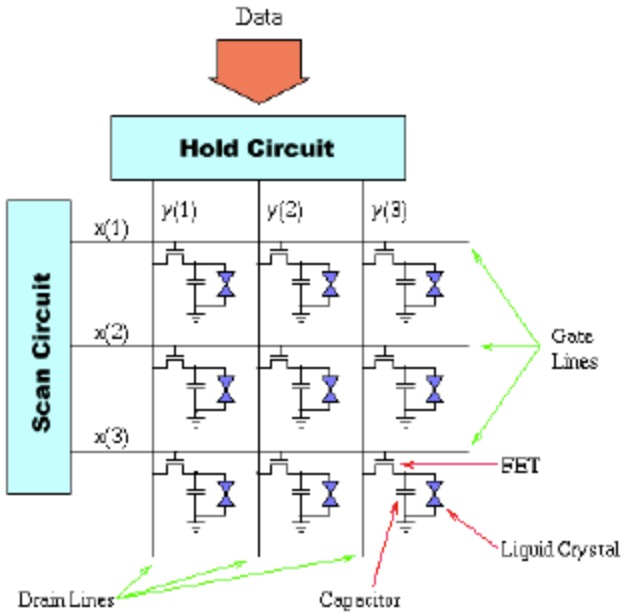
- Requires precision geometry
- Patterned phosphors on CRT face
- Aligned metal *shadow mask*
- Three electron guns
- Less bright than monochrome CRTs





Active Matrix LCD

- E field is retained by a capacitor so that the crystal remains in a constant state.
- Transistor switches are used to transfer charge into the capacitors during scanning.
- The capacitors can hold the charge for significantly longer than the refresh period
- Crisp display with no shadows.
- More expensive to produce.



Plasma Display

- Basically fluorescent tubes
- High- voltage discharge excites gas mixture (He, Xe), upon relaxation UV light is emitted, UV light excites phosphors

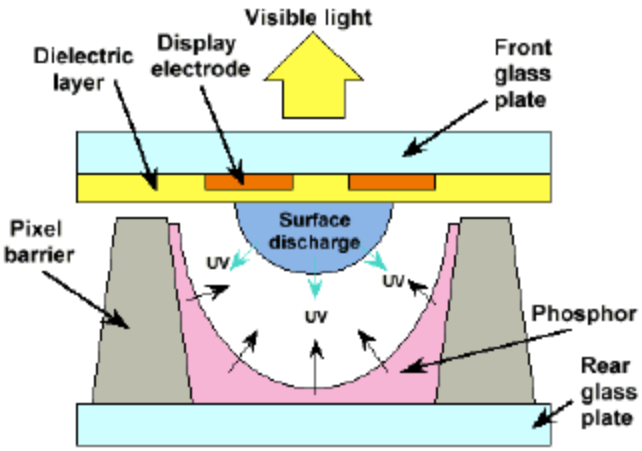
•Large view angle

•Large format display

•Less efficient than CRT, more power

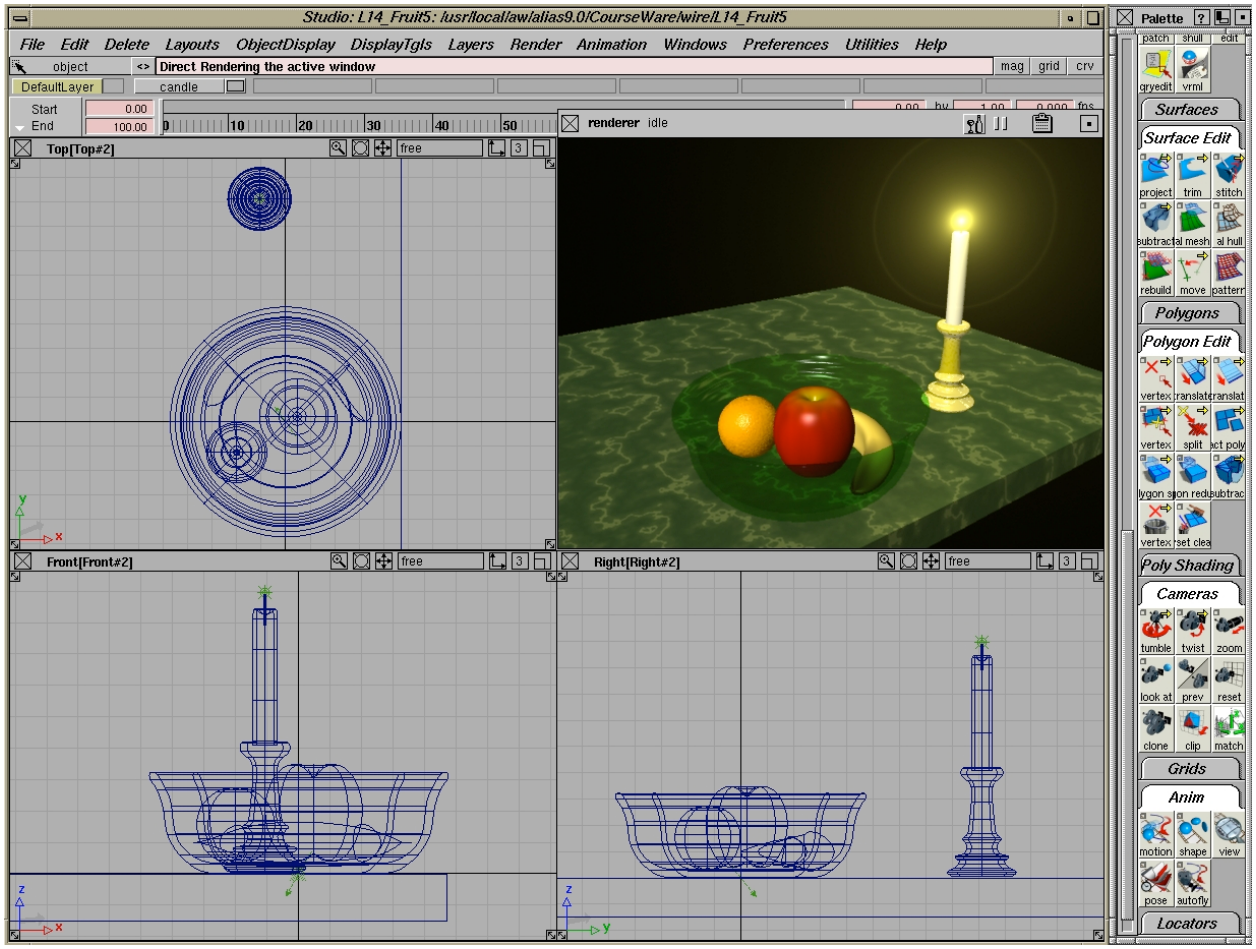
•Large pixels: 1mm (0.2 mm for CRT)

•Phosphors depletion



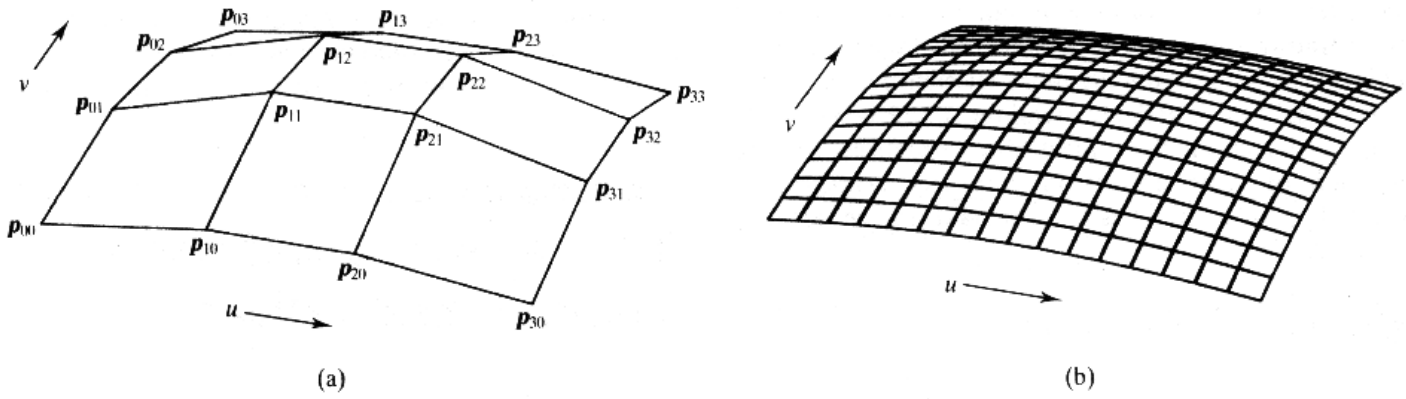
Modeling Geometry

- Example modeling package: Alias Studio



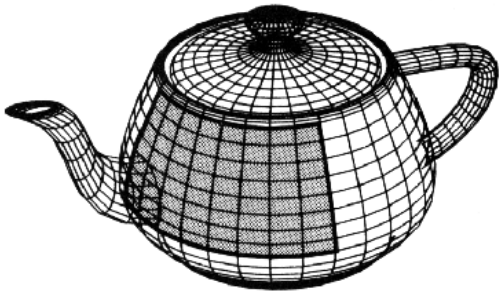
Patch – Parametric Surface

- Use patches model as implicit or parametric surfaces
- Beziér Patches : control polyhedron with 16

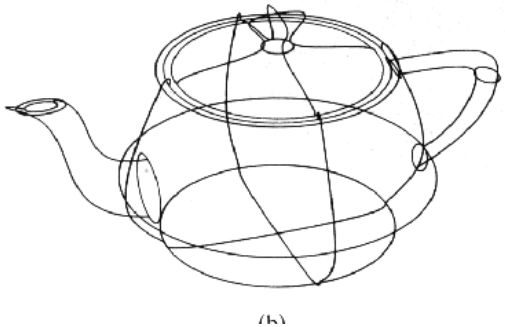


Patches

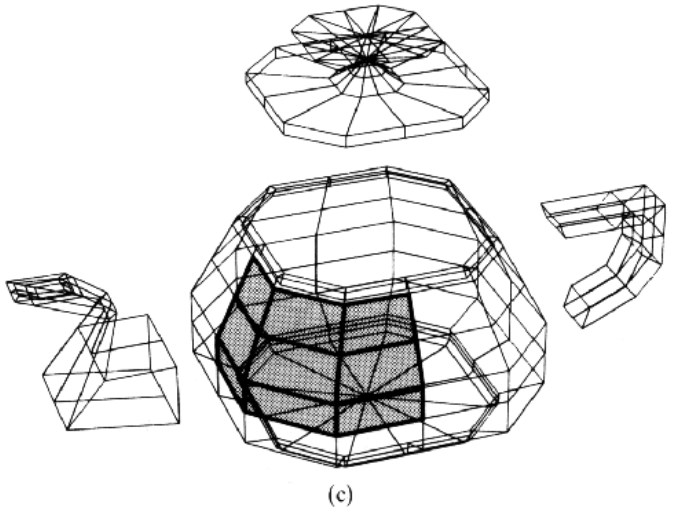
- The Utah Teapot: 32 patches



single shaded patch

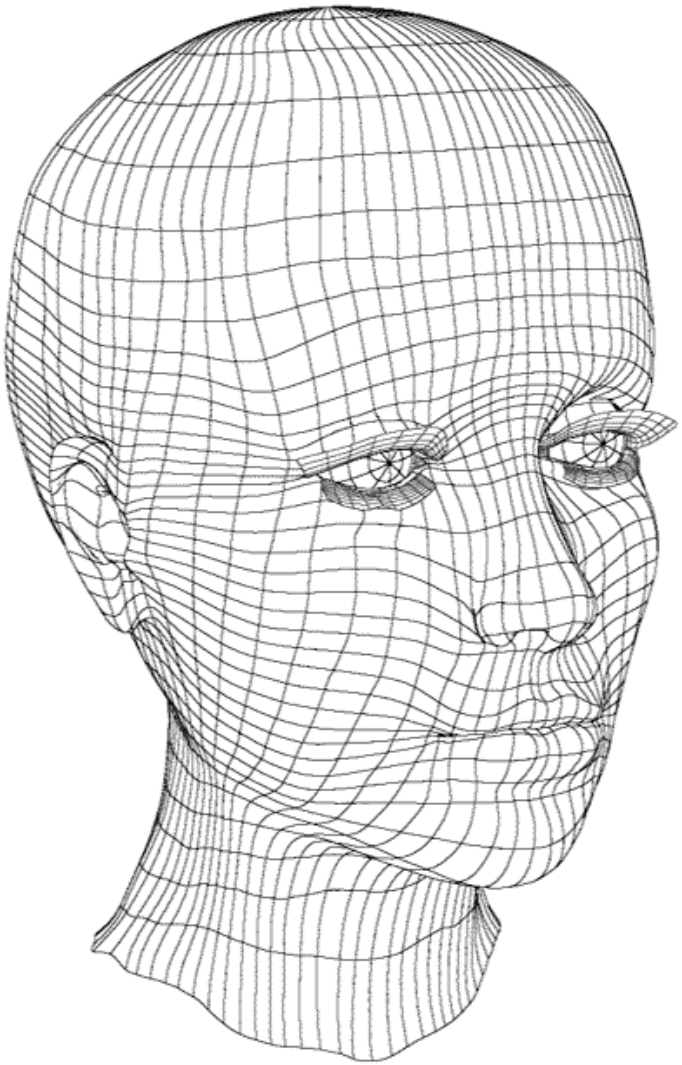


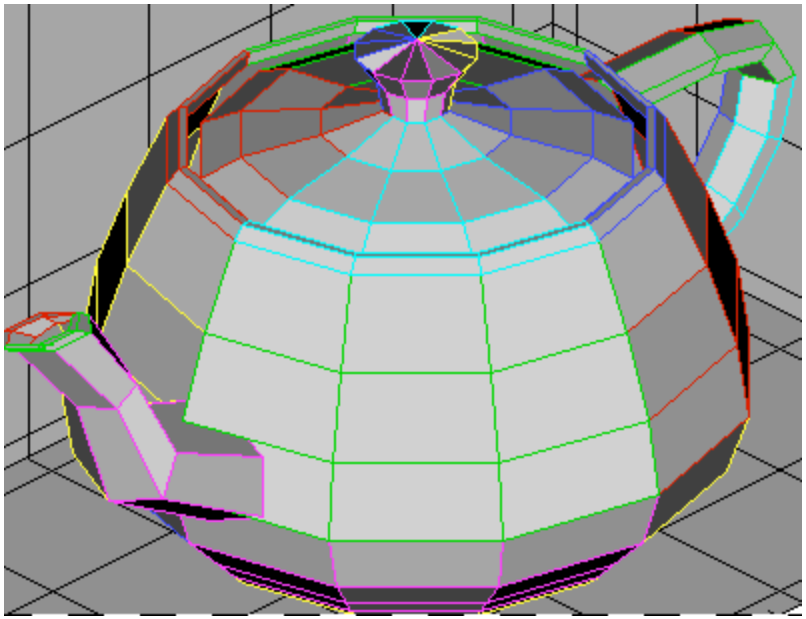
Patch edges



wireframe of the control points

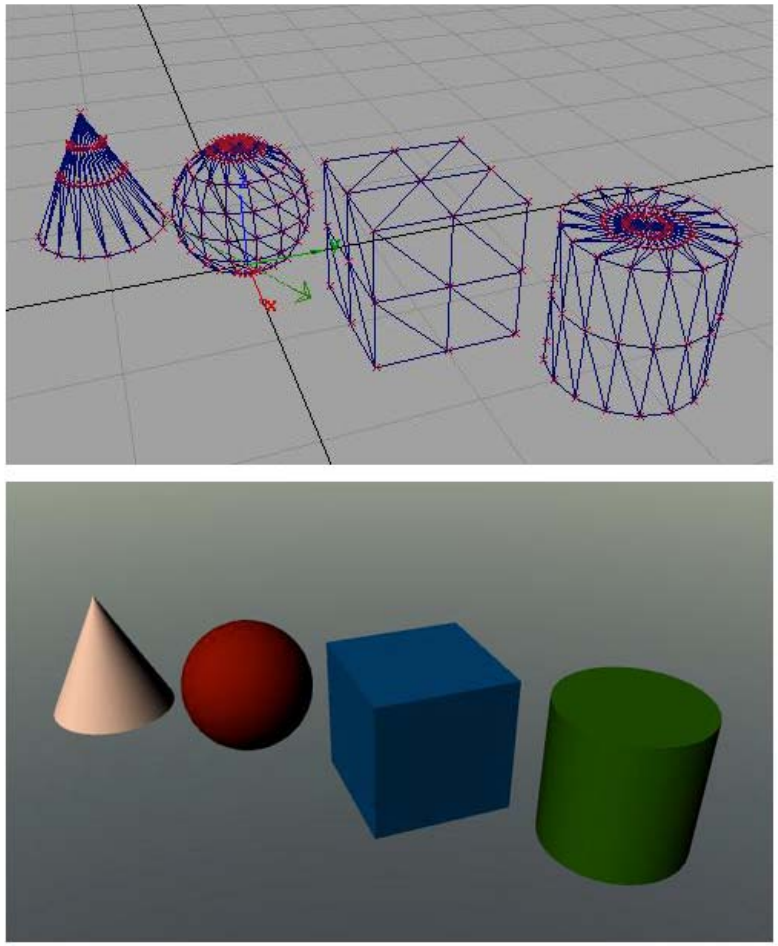
Patches to Polygon Meshes



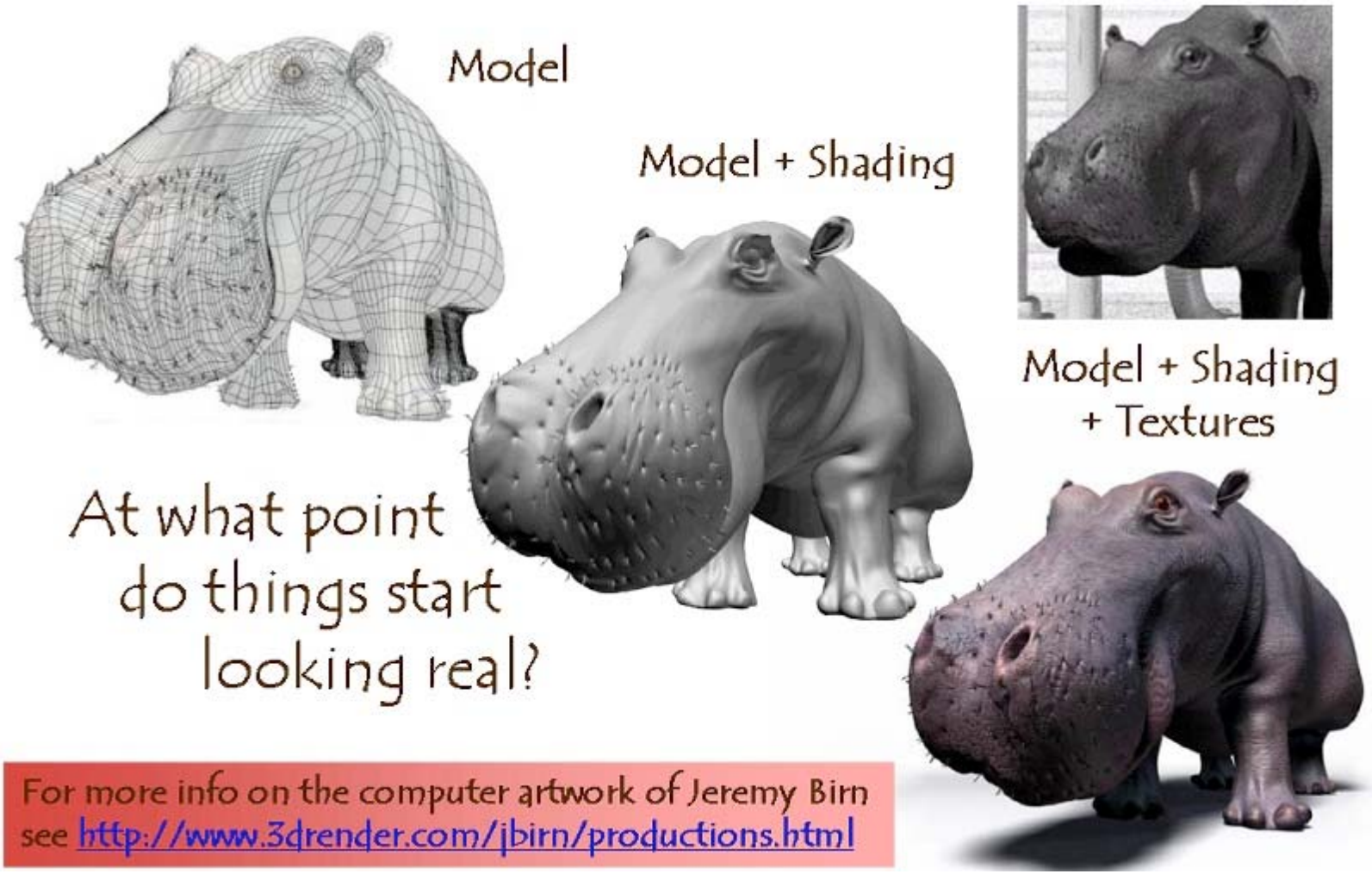


Triangle Meshes

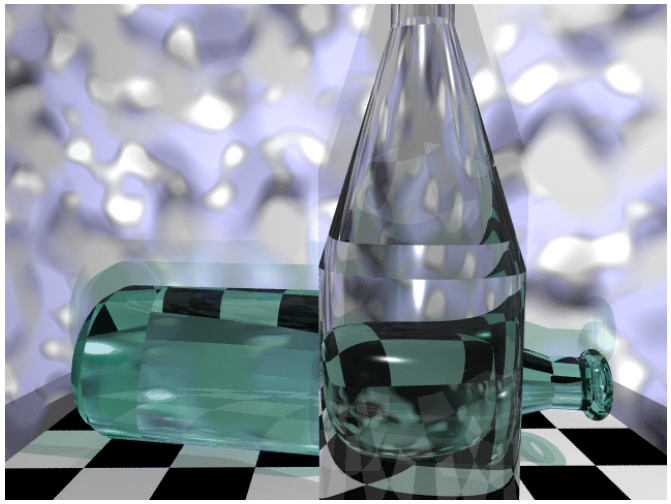
- Set of surface polygons that enclose an object interior, polygon mesh
- De facto: triangles, triangle mesh.



Modeling Material



Modeling A Scene

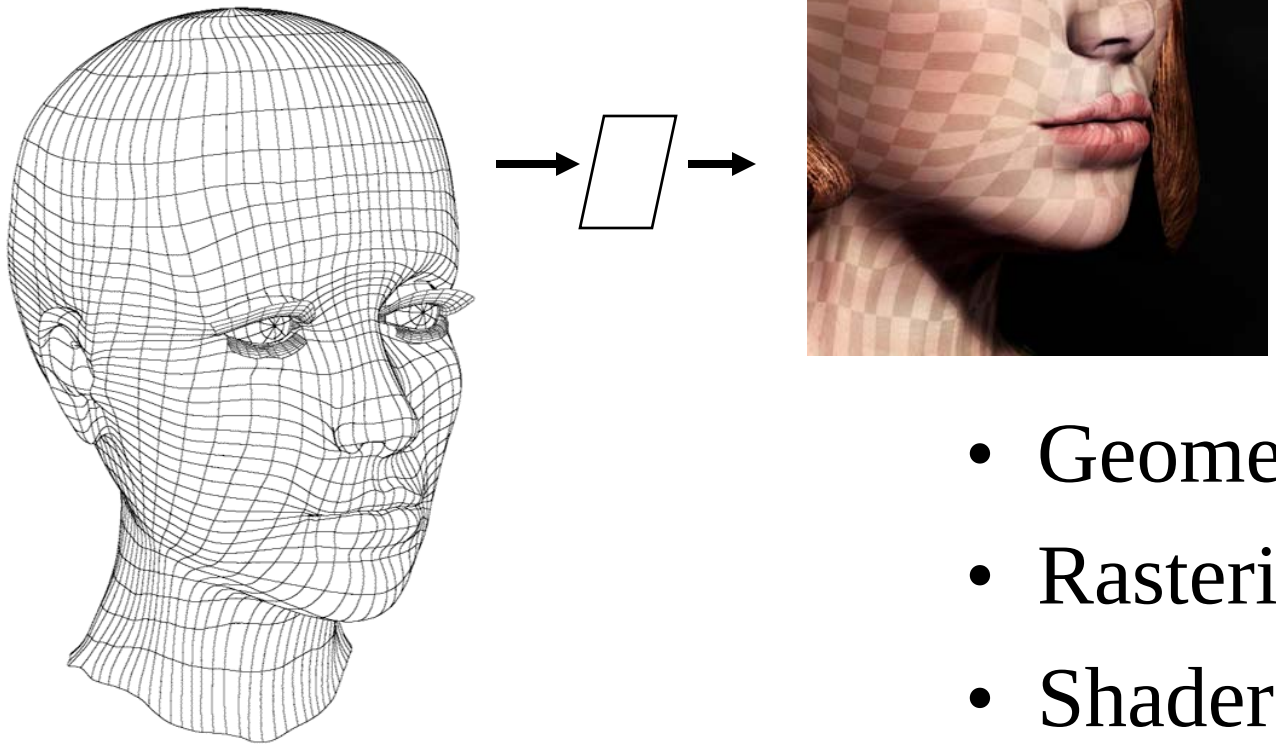


Required Background

- Basic linear algebra – matrices and vectors
- Data structure
- Computer Architecture
- Proficient programming
- Technical communication

Computer Graphics Subjects

- Rendering



- Geometry Processing
- Rasterization
- Shaders
- Graphics Architecture

Key Words so far

- (Surface) Geometry
- Viewing and projection
- Matrix Transformation
- Mesh and patch
- Rasterization
- Color model
- Texture, lighting and shading
- Pixels
- Framebuffer