



# CSE 101

## Slide Set 11

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## Computer Graphics



- 10.1 The Scope of Computer Graphics
- 10.2 Overview of 3D Graphics
- 10.3 Modeling
- 10.4 Rendering
- 10.5 Dealing with Global Lighting
- 10.6 Animation

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## 2D Versus 3D Graphics



- **2D Graphics:** Deals with manipulating two-dimensional images
- **3D Graphics:** Deals with producing and displaying images of three-dimensional virtual scenes.

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## What is Computer Graphics?



Geometric Modeling

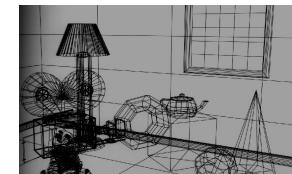
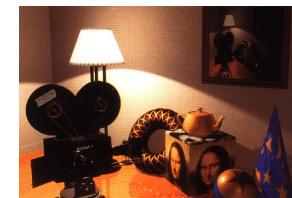


Image Synthesis



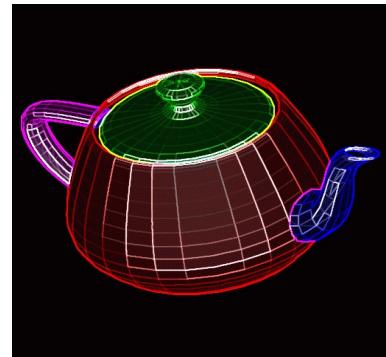
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## What is Computer Graphics?



Hidden Surface  
Elimination



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## What is Computer Graphics?



Shadows



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## What is Computer Graphics?



Texture Mapping



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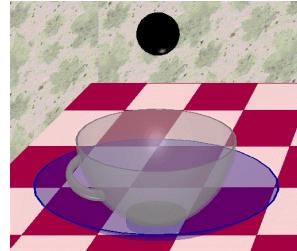
Complex Geometry



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Transparency



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Environment Mapping



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## What is Computer Graphics?



Games



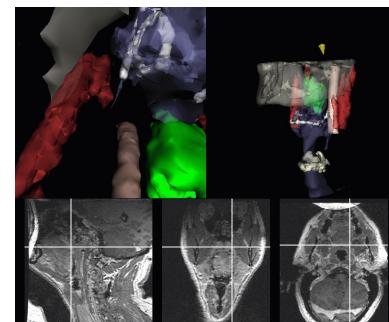
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Medical Applications



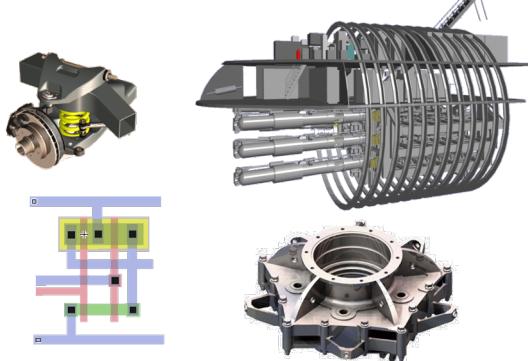
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## What is Computer Graphics?



Computer Aided Design (CAD)



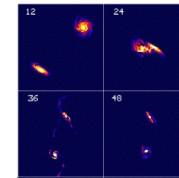
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## What is Computer Graphics?



Scientific Visualisation



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## What is Computer Graphics?



Films and Animation



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15 Square: Final Fantasy  
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## Image Processing & Computer Vision



- Image enhancement
- Feature extraction
- Pattern recognition
- 3D model extraction



IMAGE PROCESSING AND  
COMPUTER GRAPHICS ARE  
**REVERSE IN RESPECTIVE  
DIRECTIONS ???**

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## Image Processing & Computer Vision



Computer Graphics creates images from models while Image Processing creates models from images



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## Why Study Computer Graphics?



- Graphics is cool
  - I like to see what I'm doing
  - I like to show people what I'm doing
- Graphics is interesting
  - Involves *simulation, algorithms, architecture...*
- I'll never get an Oscar for my acting
  - But maybe I'll get one for my CG special effects
- Graphics is fun

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A "photograph" of a virtual world produced using 3D graphics (from Toy Story by Walt Disney Pictures/Pixar Animation Studios) © Corbis/Syagma



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## Photorealism



- Near photo quality
- Involves two elements
  - Accurate graphical representations of objects
  - Good physical descriptions of the lighting effects (reflections, transparency, texture and shadows)

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**Ivan Sutherland (1963) - SKETCHPAD**



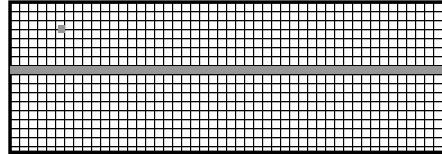
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- pop-up menus
- constraint-based drawing
- hierarchical modeling

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## Display Technologies: CRTs



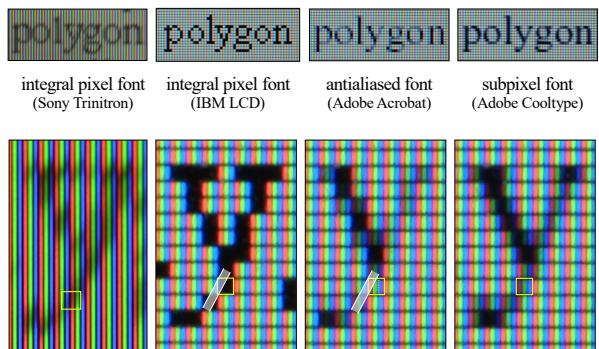
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- Raster Displays
  - Raster: A rectangular array of points or dots
  - Pixel: One dot or picture element of the raster
  - Scan line: A row of pixels

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**Triads versus pixels**



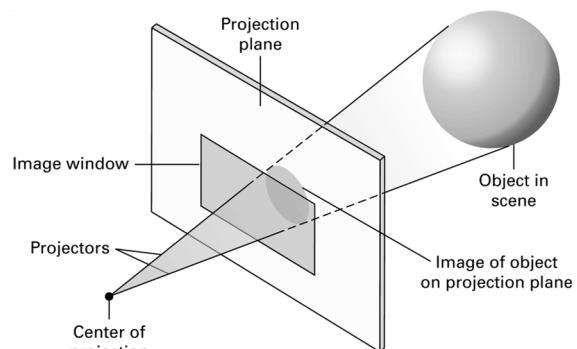
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integral pixel font (Sony Trinitron)    integral pixel font (IBM LCD)  
 antialiased font (Adobe Acrobat)    subpixel font (Adobe Cooltype)

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## The 3D graphics paradigm



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Projection plane  
 Image window  
 Projectors  
 Center of projection  
 Object in scene  
 Image of object on projection plane

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## Modeling Objects



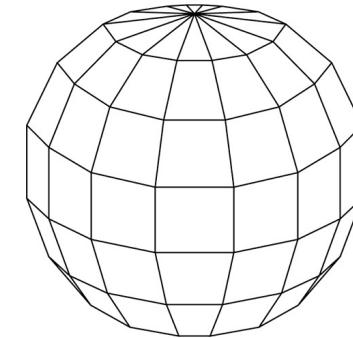
- Shape: Represented by a polygonal mesh obtained from
  - Traditional mathematical equations
  - Bezier curves and surfaces
  - Procedural models
  - Other methods being researched
- Surface: Can be represented by a texture map

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## A polygonal mesh for a sphere

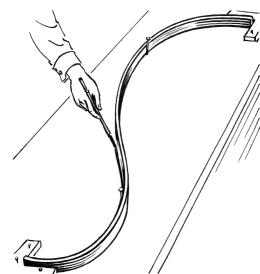


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## Splines

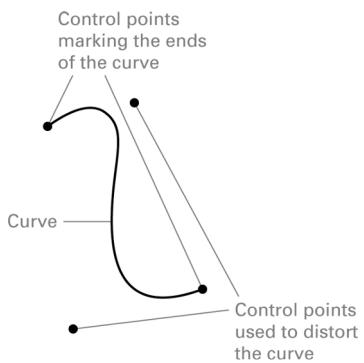


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## A Bezier curve



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**Growing a polygonal mesh for a mountain range**

a. Identify the midpoints  
Midpoint Midpoint Midpoint

b. Connect the midpoints  
Midpoint Midpoint Midpoint

c. Move the midpoints  
Midpoint Midpoint Midpoint

d. Repeat the process on the smaller triangles

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A scene from Shrek 2 by Dreamworks SKG (© Dreamworks/The Kobal Collection)

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**Reflection Versus Refraction**

- Reflection: Light rays bounce off surface.
  - Specular light
  - Diffuse light
  - Ambient light
- Refraction: Light rays penetrate surface.

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**Reflected light**

Light source  
Normal  
Incident ray  
Angle of incidence  
Reflected ray  
Angle of reflection

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## The Physics of Reflection



- Ideal diffuse reflection
  - An *ideal diffuse reflector*, at the microscopic level, is a very rough surface (real-world example: chalk)
  - Because of these microscopic variations, an incoming ray of light is equally likely to be reflected in any direction over the hemisphere:



*What does the reflected intensity depend on?*

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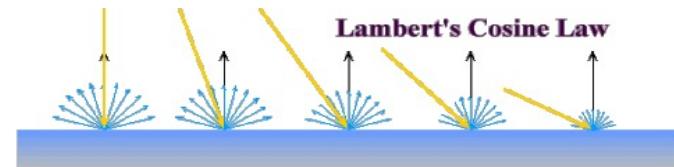
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## Lambert's Law



### Lambert's Cosine Law



- Illumination on surface is proportional to the cosine of the angle of incidence

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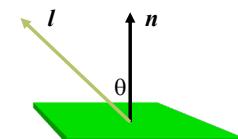
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## Computing Diffuse Reflection



- The angle between the surface normal and the incoming light is the *angle of incidence*:



$$I_{\text{diffuse}} = k_d I_{\text{light}} \cos \theta$$

- In practice we use vector arithmetic:

$$I_{\text{diffuse}} = k_d I_{\text{light}} (\mathbf{n} \cdot \mathbf{l})$$

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## Illumination models

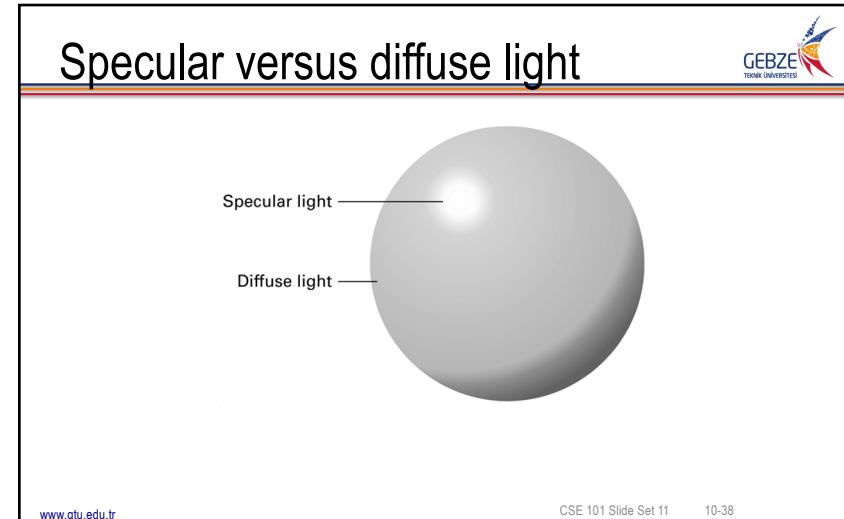


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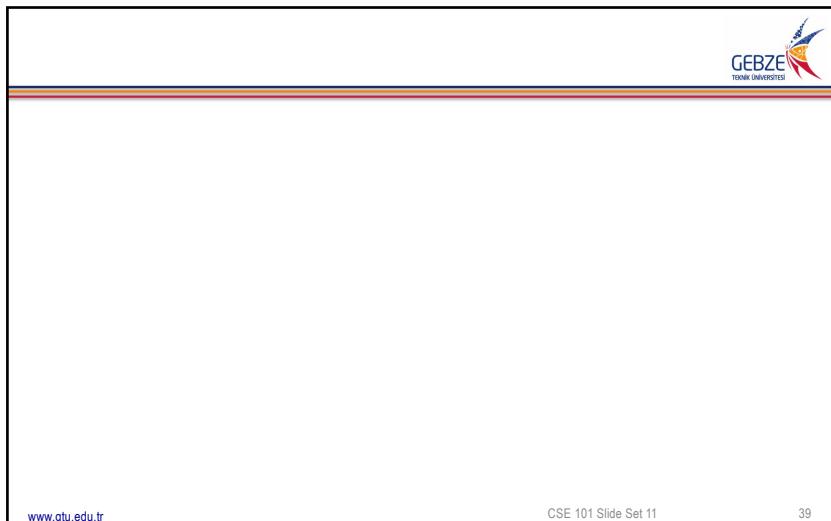
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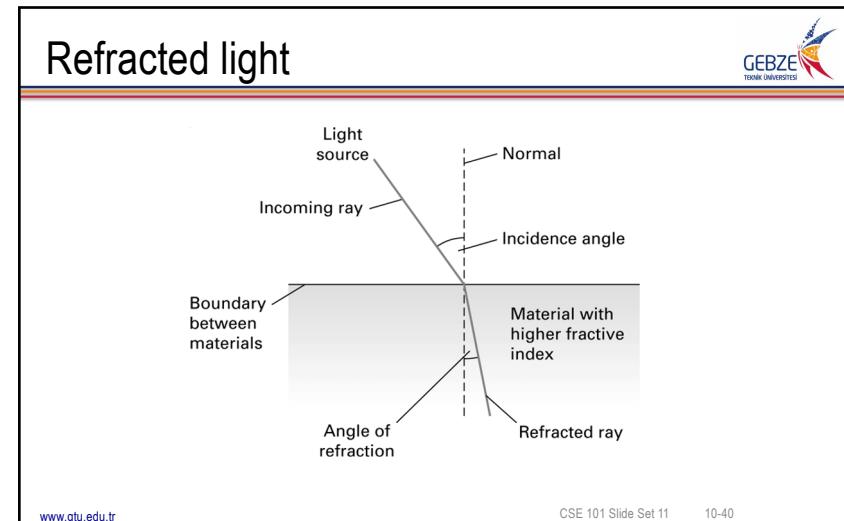
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## Rendering



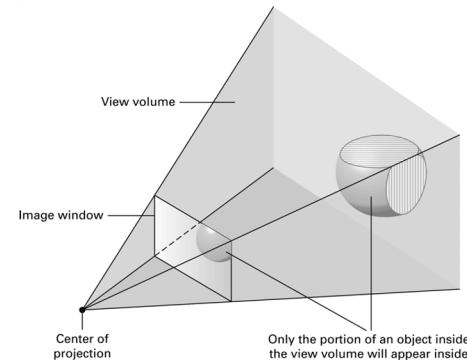
- **Clipping:** Restricts attention to objects within view volume
- **Scan Conversion:** Associates pixel positions with points in scene
- **Shading:** Determines appearance of points associated with pixels

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Identifying the region of the scene that lies inside the view volume

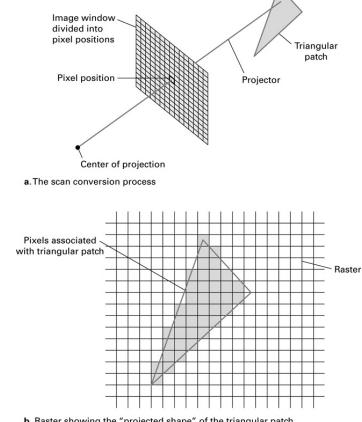


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## The scan conversion of a triangular patch



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## Shading Techniques



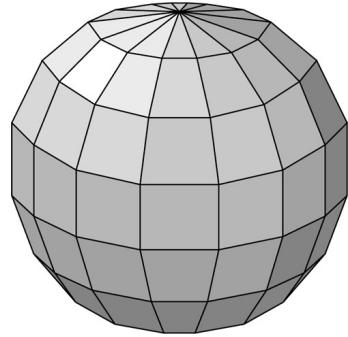
- **Flat Shading:** Creates faceted appearance
- **Gouraud and Phong Shading:** Creates smooth, rounded appearance
- **Bump Mapping:** Creates bumpy, rounded appearance

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A sphere as it might appear when rendered by flat shading



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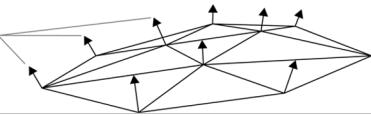
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A conceptual view of a polygonal mesh with normal vectors at its vertices



Vectors indicate the orientation of the original surface.



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A sphere as it might appear when rendered using bump mapping



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## Rendering Pipeline



- Consists of traditional algorithms for clipping, scan conversion, and shading
- Often implemented in firmware
- Used as an abstract tool in graphics applications

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## Local Versus Global Lighting



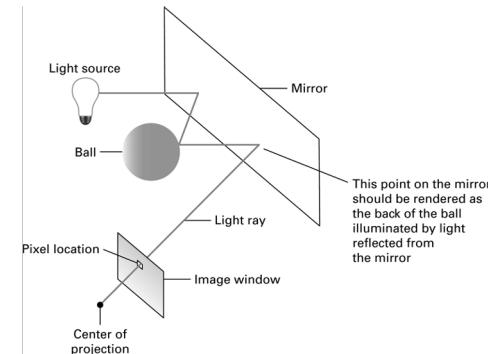
- Local Lighting Model: Does not account for light interactions among objects
- Global Lighting Model: Accounts for light interactions among objects
  - Ray Tracing
  - Radiosity

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## Ray tracing



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## Animation



- **Storyboard:** A sequence of sketches summarizing the entire animation
- **Frame:** One of many images used to create animation
- **Key Frames:** Frames capturing the scene at specified points in time
- **In-betweening:** Producing frames to fill the gaps between key frames

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## Simulating Motion



- **Dynamics:** Applies laws of physics to determine position of objects
- **Kinematics:** Applies characteristics of joints and appendages to determine position of objects
  - Avars
  - Motion Capture

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## Questions



- CSE461 covers computer graphics topics