3D GIS

3D Scenes

Creating realistic 3D visualizations requires understanding how cameras and lighting work in 3D space. This module covers camera concepts from photography, how to position and configure cameras in Blender, various lighting techniques and strategies, and how to apply these concepts in geospatial visualization tools like ArcGIS Pro. By the end of this lecture, you'll understand how to create compelling 3D visualizations using proper camera and lighting techniques.

Module Topics

1. Local vs. global scenes
2. Navigating in a 3D scene
3. Simulating cameras
4. Soft vs. hard light
5. Light types
6. Lighting configurations
7. HDRIs
8. Illumination in ArcGIS Pro
9. Other considerations in ArcGIS Pro

These are the topics covered in this module.

Local vs. Global Scene

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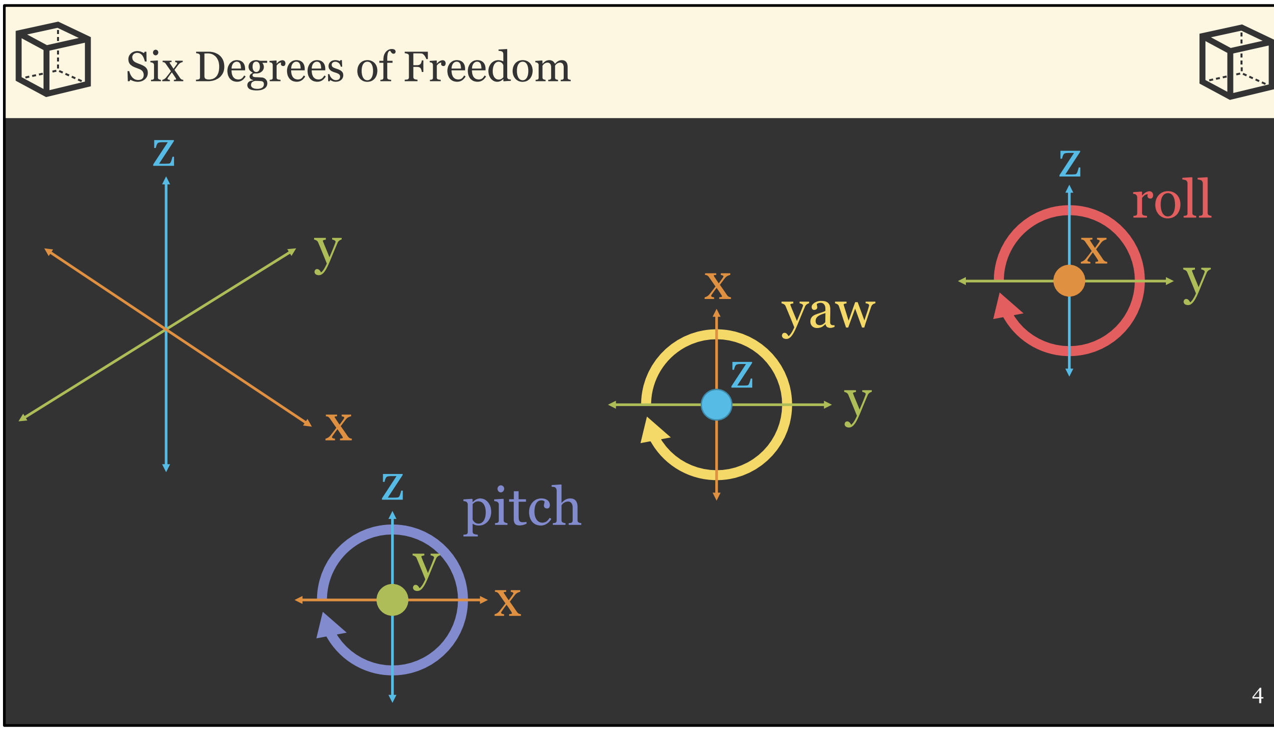
A local scene uses a projected surface or Cartesian space as opposed to a digital globe, as is used by a global scene. Local scenes are generally used for larger scale products, such as those covering individual cities, portions of cities, or sites whereas digital globes and global scenes are used for smaller scale products, such as those covering large regions, entire continents, or the entire globe.



Objects and cameras in 3D space have six degrees of freedom, also known as 6DOF. The three translational degrees are movement along the X, Y, and Z axes. The three rotational degrees are yaw, pitch, and roll. Yaw is rotation around the Z axis, pitch is rotation around the X axis, and roll is rotation around the Y axis. These six parameters fully define an object's position and orientation in 3D space.

Simulated Cameras

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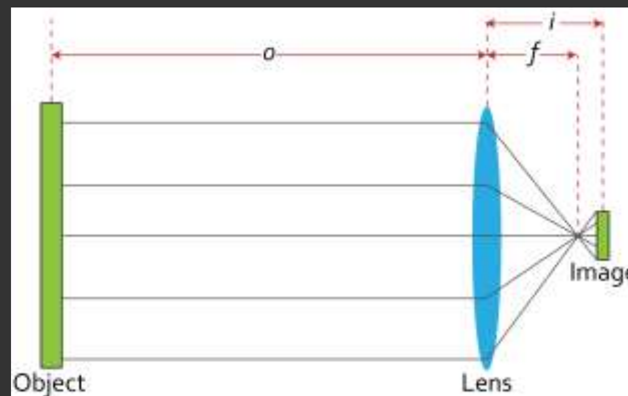
Simulated cameras in 3D software like Blender are designed to mimic real-world cameras. Understanding real camera behavior and parameters helps you create more realistic and intentional visualizations. Real cameras have specific properties like focal length, aperture, and shutter speed that affect how images are captured. We can simulate these properties in our 3D camera to achieve specific visual effects.

Focusing an Image

- The lens collects light rays that are being reflected at multiple angles and makes them converge on a focal point so that a sharp image is produced
- Focal length = distance from lens surface to focal point (mm)
- Telephoto = longer focal length/more “zoomed in”
- Wide angle = shorter focal length/more “zoomed out”



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In real photography, a camera lens collects light rays that are being reflected at multiple angles and makes them converge on a focal point so that a sharp image is produced. Focal length is the distance from the lens surface to the focal point, measured in millimeters. Telephoto lenses have longer focal length and produce a more zoomed-in appearance. Wide-angle lenses have shorter focal length and produce a more zoomed-out appearance.

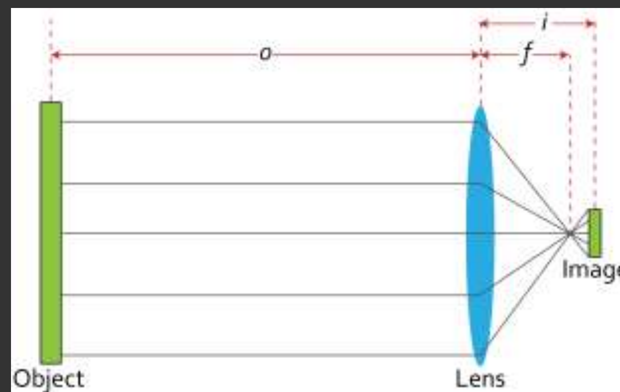
Telephoto lenses tend to compress distance while wide-angle lenses expand distance. In other words, the focal length has other impacts other than just the field of view.

Focusing an Image

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

- f = focal length
- o = distance between lens and object
- i = distance between lens and image plane
- Depth of Field = range of distances where focus is acceptable

*As o approaches infinity, $1/o$ approaches zero, and $i = f$



The lens equation relates focal length, object distance, and image distance. As the object approaches infinity, the reciprocal of object distance approaches zero, and image distance approaches focal length. Depth of field is the range of distances where focus is acceptable, meaning objects within this range appear sharp.

Exposure

- Aperture
  - Determines how much light can pass through
  - Focal ratio (*f*-numbers) = ratio of the diameter of the lens aperture to the length of the lens (f/1.4, f/2.0, f/2.8, f/4.0, f/5.6, f/8.0)
  - Lower *f*-number = aperture is more open/more light passes through
  - Higher *f*-number = aperture is more closed/less light passes through
  - Lower *f*-number = shallow depth of field
  - Higher *f*-number = greater depth of field

https://commons.wikimedia.org/wiki/File:Lenses_with_different_apertures.jpg

Aperture determines how much light can pass through the lens. Focal ratio, expressed as f-numbers like f/1.4, f/2.0, f/2.8, f/4.0, f/5.6, or f/8.0, is the ratio of the lens aperture diameter to the lens length. Lower f-numbers mean the aperture is more open and more light passes through. Higher f-numbers mean the aperture is more closed and less light passes through. Lower f-numbers create shallow depth of field, while higher f-numbers create greater depth of field.

Exposure

- Aperture
  - Determines how much light can pass through
  - Focal ratio (*f*-numbers) = ratio of the diameter of the lens aperture to the length of the lens (f/1.4, f/2.0, f/2.8, f/4.0, f/5.6, f/8.0)
  - Lower *f*-number = aperture is more open/more light passes through
  - Higher *f*-number = aperture is more closed/less light passes through
  - Lower *f*-number = shallow depth of field
  - Higher *f*-number = greater depth of field

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Aperture affects both exposure and depth of field. Lower f-numbers create shallow depth of field, meaning only a small range of distances is in sharp focus. This effect is often used in photography to isolate subjects from their background. Higher f-numbers create greater depth of field, meaning more of the scene is in sharp focus. Understanding aperture is essential for controlling both exposure and focus in your images.

Exposure

- **Shutter Speed**
  - Controls how long light is able to collect
  - How long shutter remains open
  - Measured as fraction of second
  - 1/30 = shutter is open for 1/30th of a second
  - Leaving shutter open can cause blurring of motion

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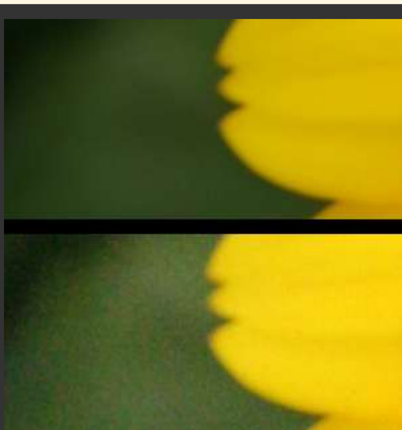
Shutter speed controls how long light is able to collect on the camera sensor. Shutter speed is measured as a fraction of a second. For example, 1/30 means the shutter is open for one-thirtieth of a second. Digital sensors do not have a physical shutter; instead, the shutter speed relates to how long light energy is collected or how long the sensor charges. Longer exposure times allow more light to reach the sensor but can cause blurring if the camera or subject moves. Shorter exposure times reduce motion blur but let in less light.

Exposure



https://commons.wikimedia.org/wiki/File:ISO_comparison.jpg

- ISO
  - Level of sensitivity of sensor or film to light
  - Low numbers = low sensitivity to light
  - High numbers = high sensitivity to light
  - High ISO = increased grain/noise

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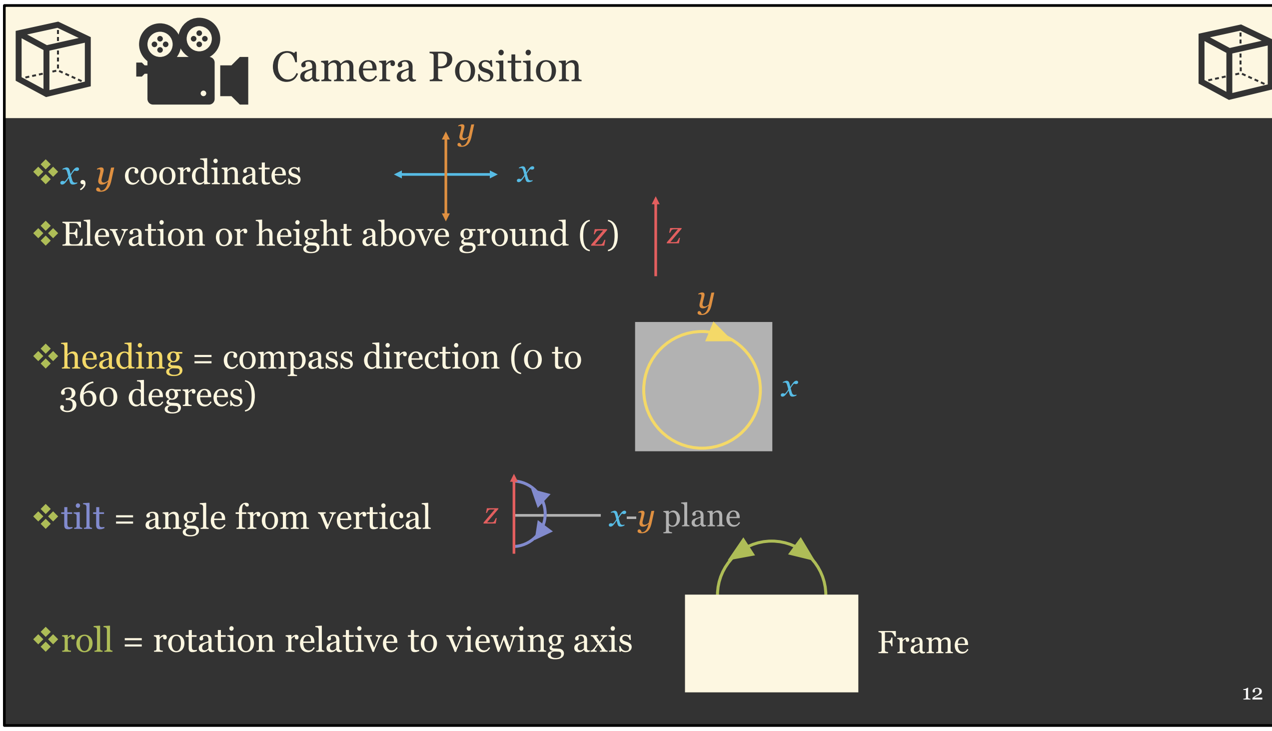
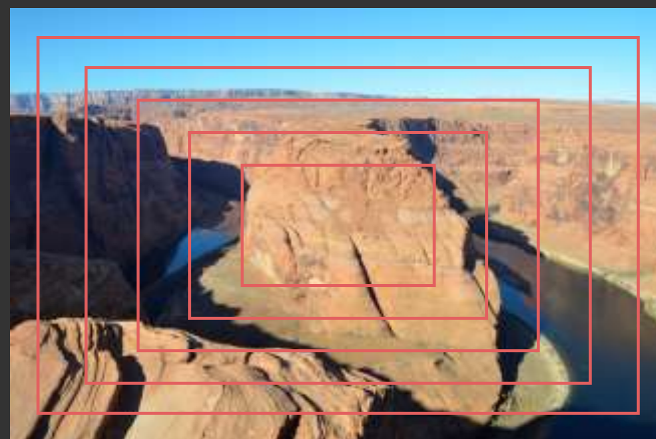
ISO is the level of sensitivity of the camera sensor or film to light. Low ISO numbers mean low sensitivity to light, requiring more light to properly expose the image. High ISO numbers mean high sensitivity to light, allowing proper exposure with less light. The disadvantage of high ISO is increased grain or noise in the image. Understanding ISO helps you balance exposure and image quality.



Camera position in 3D space is defined by three translational coordinates and three rotational parameters. The X and Y coordinates define horizontal position in the scene plane. The Z coordinate defines elevation or height above ground. Heading is the compass direction, measured from 0 to 360 degrees. Tilt is the angle from vertical, controlling whether the camera looks down or up. Roll is rotation relative to the viewing axis, controlling whether the camera image is level or tilted.

Field of View

- Depends on focal length
- Can simulate depth of field based on aperture



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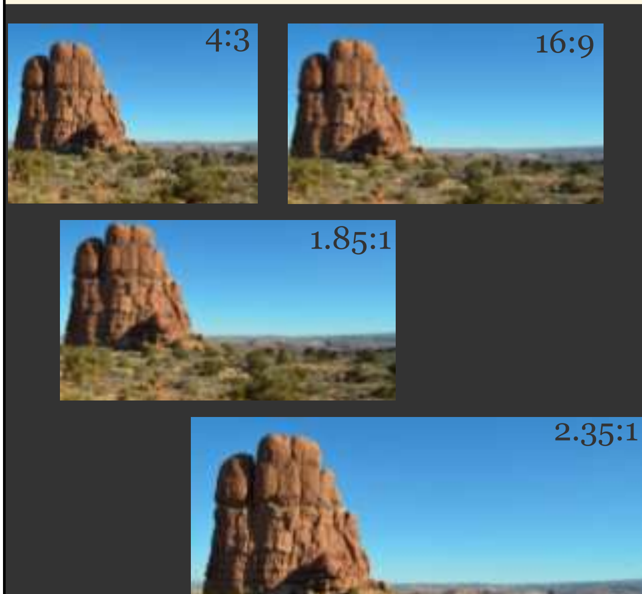
Field of view depends on the focal length of the camera. Longer focal lengths create narrower fields of view. You can also simulate depth of field based on aperture settings. This allows you to create photorealistic images where only a specific range of distances is in sharp focus.

Aspect Ratio



- width-to-height ratio
- Can be custom
- Common:
  - 3:2 = 35 mm film, DLSR camera
  - 4:3 = SDTV
  - 16:9 = HDTV
  - 1.85:1 = Cinema
  - 2.35:1 = Cinemascope
  - 9:16 = smart phone (vertical)

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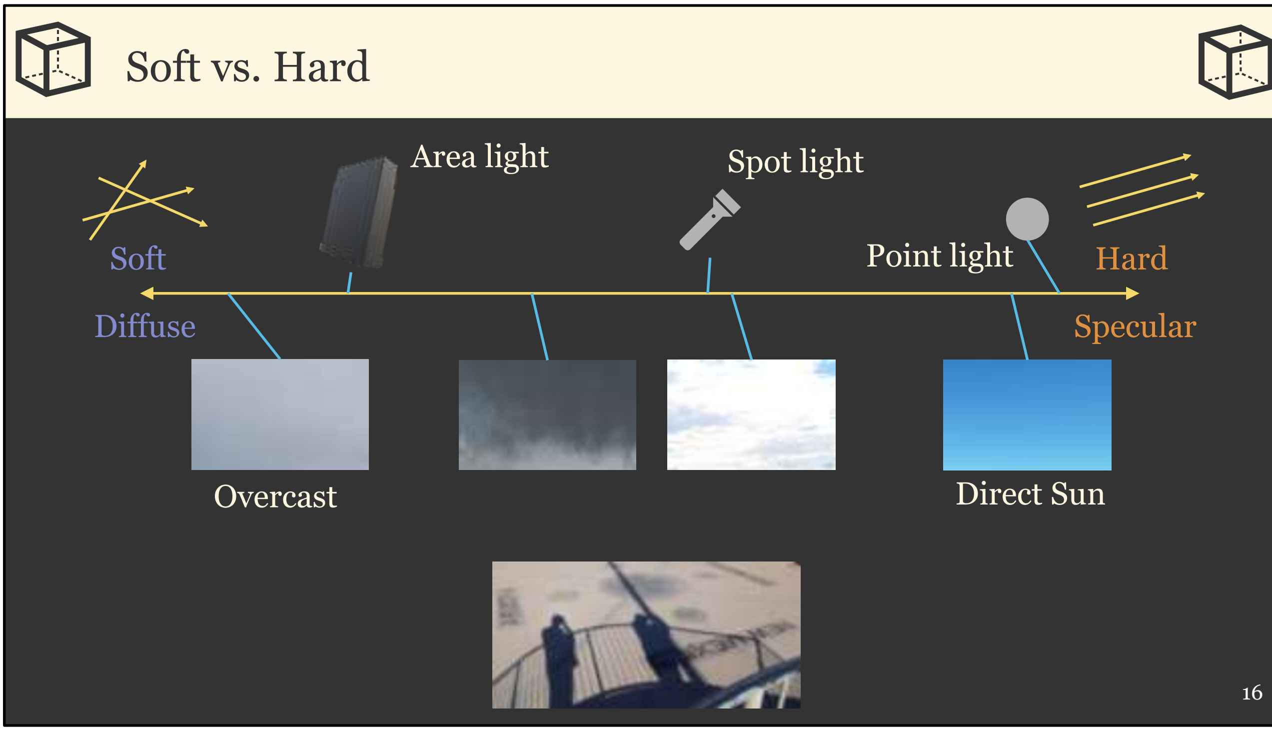
Aspect ratio is the width-to-height ratio of the image. Aspect ratios can be custom, but common ratios include 3:2 for 35mm film and DSLR cameras, 4:3 for SDTV, 16:9 for HDTV, 1.85:1 for cinema, and 2.35:1 for cinemascope. Mobile phones typically use 9:16 for vertical orientation. Choosing the right aspect ratio affects how your visualization is perceived.

Lighting is one of the most important aspects of creating compelling 3D visualizations. Proper lighting can make the difference between a mediocre render and a photorealistic one. In this section, we'll explore different types of lights, how they behave, and how to use them effectively in your scenes.



Lights can be classified as either soft or hard. Soft lights diffuse light broadly, creating subtle shadows. Hard lights produce sharp, well-defined shadows. Area lights and the sky in overcast conditions produce soft light. Spot lights and direct sun produce hard light. Understanding the difference between soft and hard light is crucial for achieving specific moods and effects.

Window Light

- Often softer than direct sunlight
- May be harder than overcast light
- Similar to an area light
- Impacted by
  - Outside lighting conditions
  - Window size
  - Distance from window
  - Window material

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Window light is a common light source in photography and 3D visualization. Window light is often softer than direct sunlight but may be harder than completely overcast light. Window light is similar to an area light in Blender. The character of window light is impacted by outside lighting conditions, window size, distance from the window, and window material. Learning to simulate window light effectively adds realism to interior scenes.

Soft vs. Hard

- Point Light
  - Mimics light bulb, candle, small lamp
  - Emits spherically (not directional)
  - Intensity falls off with distance
  - Hard light (can soften)
  - Define radius to soften
- Spot Light
  - Mimics flashlight, stage spotlight, desk lamp
  - Emits as cone (directional)
  - Intermediate hardness
  - Distance-based fall off

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Point lights mimic light bulbs, candles, and small lamps. They emit light spherically in all directions, making them non-directional. Intensity falls off with distance from the light. Point lights are naturally hard lights but can be softened by defining a radius. Spot lights mimic flashlights, stage spotlights, and desk lamps. They emit light as a cone, making them directional. Spot lights have intermediate hardness and distance-based falloff.

Soft vs. Hard

- Area Light
  - Window light, softbox, LED panel
  - Light from a defined shape
  - Soft
  - Directional but spread out
- Sun
  - Mimics the sun
  - No position, just direction
  - No distance fall off
  - No size defined
  - Can be flat

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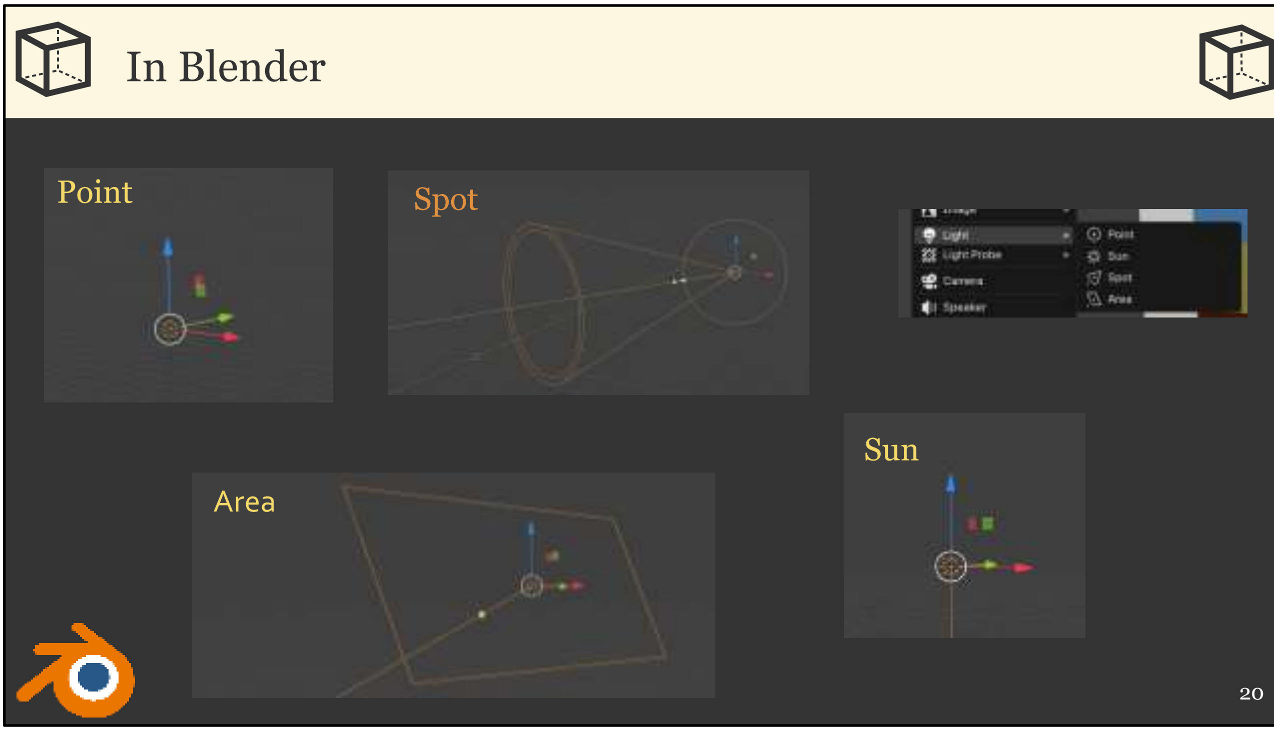
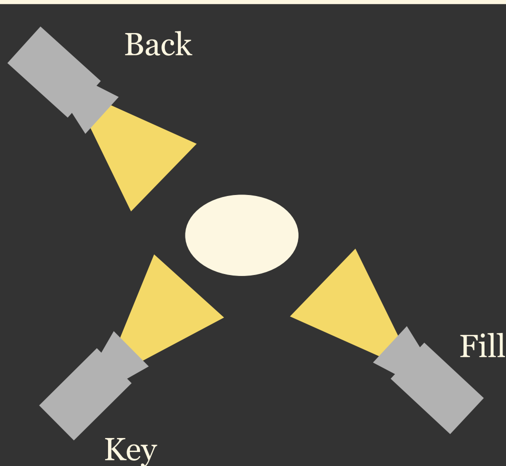
Area lights mimic window light, softboxes, and LED panels. They emit light from a defined shape and produce soft light that is directional but spread out. Sun lights mimic the sun. They have no position, only direction, and no distance falloff. Sun lights are often used as flat, directional light sources in outdoor scenes.



In Blender, you can create four types of lights. Point lights emit in all directions. Spot lights emit as a cone. Area lights emit from a defined shape. Sun lights emit as parallel rays in a specific direction. Each light type has different characteristics and uses for different scenarios.

Three-Point Lighting



Light	Purpose	Controls
Key	Main source on subject	Shape and contrast
Fill	Secondary light	Shadow softness
Back	Behind subject	Separation from background

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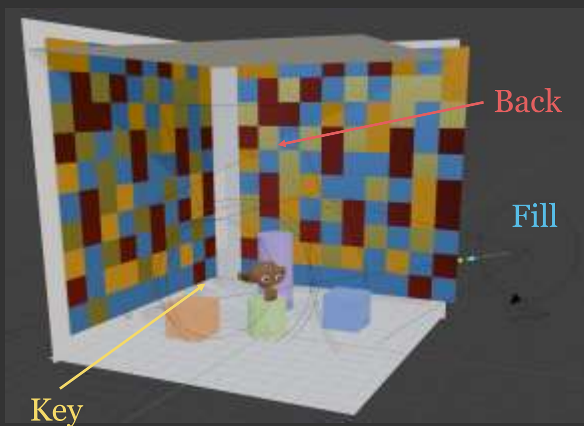
Three-point lighting is a fundamental lighting technique in photography and 3D visualization. The key light is the main source of light on the subject, controlling shape and contrast. The fill light is a secondary light that softens shadows. The back light is positioned behind the subject to separate it from the background. Together, these three lights create depth and visual interest.

Three-Point Lighting



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Three-point lighting creates depth and visual interest in your scenes. The key light provides the main illumination and casts shadows. The fill light softens the shadows created by the key light. The back light separates the subject from the background, adding depth. Mastering three-point lighting is essential for professional-quality visualizations.

HDRI

- High Dynamic Range Image
- Captures a wide range of brightness values
- Used for environmental lighting in 3D modeling
- Can be indoor or outdoor
- Many freely available online

Check out Poly Haven: https://polyhaven.com/hdris

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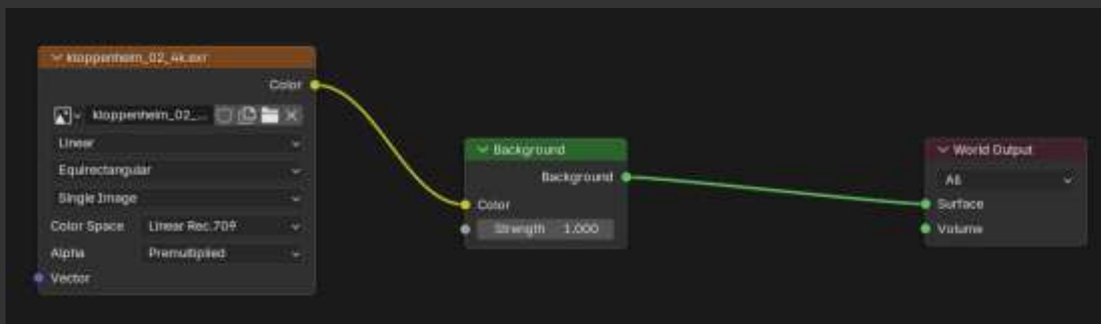
HDRI stands for High Dynamic Range Image. An HDRI captures a wide range of brightness values, from dark shadows to bright highlights. HDRIs are used for environmental lighting in 3D modeling, providing realistic lighting from all directions. HDRIs can represent indoor or outdoor environments. Many free HDRIs are available online from resources like Poly Haven.

Apply an HDRI in Blender



Check out Poly Haven: https://polyhaven.com/hdris

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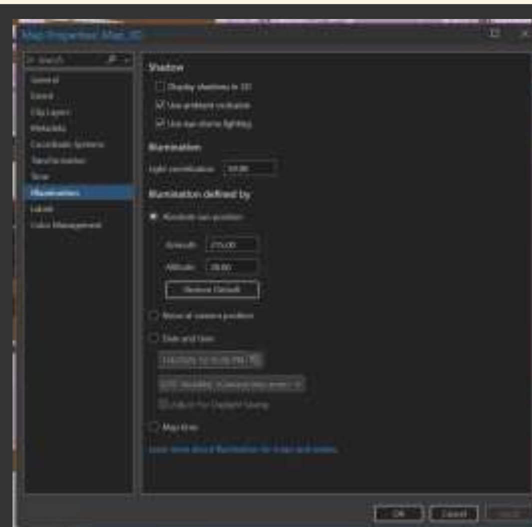
Applying an HDRI in Blender involves loading the image into the world environment settings. The HDRI then provides lighting and reflections for your entire scene from all directions. This technique creates very realistic lighting with minimal effort. Poly Haven is an excellent resource for free, high-quality HDRIs suitable for 3D visualization.

Illumination In ArcGIS Pro

- Can define sun position with azimuth and altitude
- Can use a specific time/day
- Noon at camera position = equal ambient light regardless of where on the globe the camera is positioned
- Ambient Occlusion = simulated how ambient light is blocked by 3D objects
- Eye-Dome Lighting = enhances edges/darkens pixels near edges or where there is sudden height changes
- Light Contribution = define brightness of the scene



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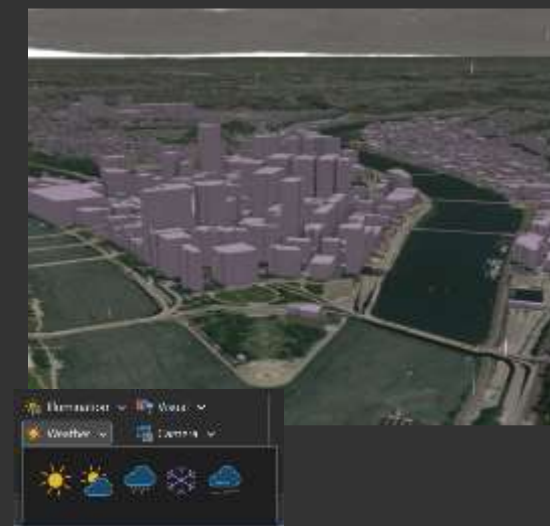
When working in ArcGIS Pro's 3D visualization environment, you have control over several illumination parameters. You can define sun position using azimuth and altitude angles. You can use a specific time and date, and the software calculates sun position accordingly. Noon at camera position means the sun is directly overhead, creating equal ambient light regardless of location. Ambient occlusion simulates how ambient light is blocked by 3D objects. Eye-dome lighting enhances edges and darkens pixels near sudden height changes. Light contribution controls the overall brightness.

Illumination In ArcGIS Pro

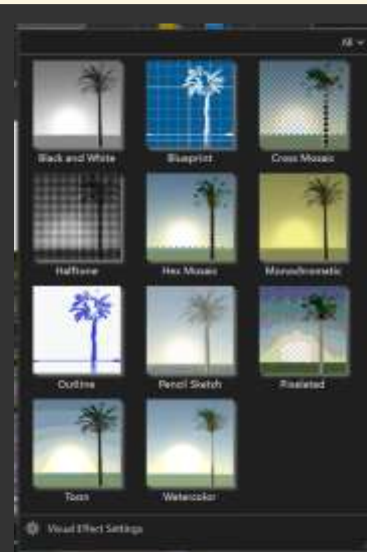
- Can simulate different weather conditions: sunny, partly cloudy, raining, snowing, foggy
- Different simulations have different settings



ArcGIS Pro allows you to simulate different weather conditions including sunny, partly cloudy, rainy, snowy, and foggy conditions. Different weather simulations have different settings and affect both lighting and visual appearance. This capability allows you to explore how different conditions affect your 3D scene.

Illumination In ArcGIS Pro

- Can also add visual effects



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Beyond basic lighting, ArcGIS Pro allows you to add visual effects to enhance your 3D visualizations. These effects can add atmosphere, drama, or specific mood to your scenes.

Illumination In ArcGIS Pro

- Post-processing effects
  - Bloom
  - Vignette
  - Grain
  - Color grading

Post-processing effects in ArcGIS Pro include bloom, which creates a glowing effect around bright areas, vignette, which darkens the edges of the image, grain, which adds texture, and color grading, which adjusts overall color tone. These effects can be applied after rendering to enhance the final image.

Other Considerations in ArcGIS Pro

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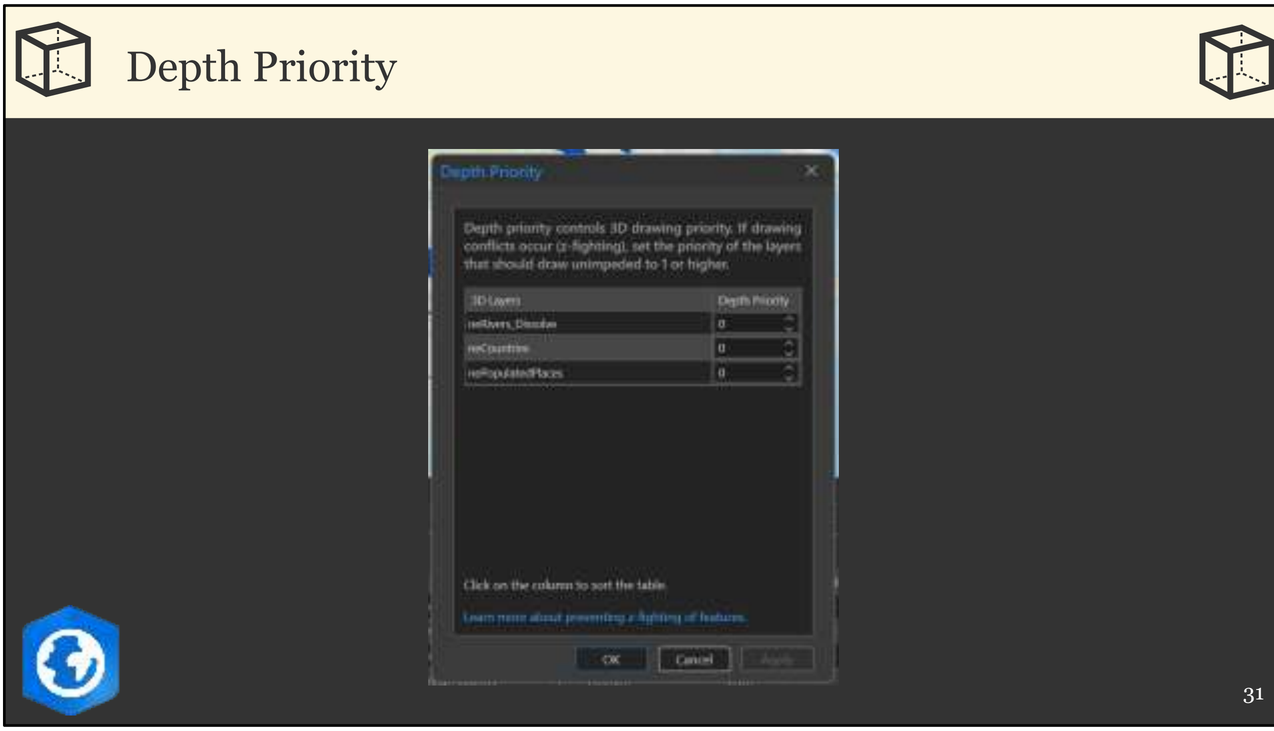
Beyond camera and lighting, there are other important considerations when creating 3D visualizations in ArcGIS Pro. These considerations affect how your scene is rendered and how users perceive the data.

View clipping controls how far out to render your scene. Setting appropriate clipping distances prevents rendering unnecessary distant geometry and can improve performance. Too short a clipping distance will cut off distant features. Too long a clipping distance can hurt performance.



Depth priority is an important consideration in 3D visualization. It affects the order in which objects are rendered and can impact both visual quality and performance.

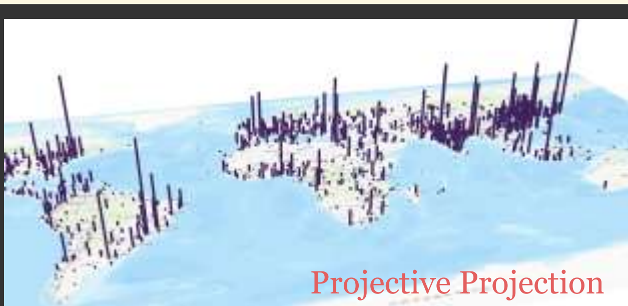
Face Culling

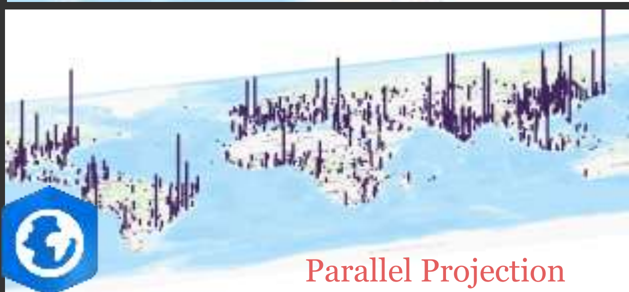
Method	Description
None	Turns off culling so you view both sides. This is the default.
Back	Turns on back face culling, eliminating those objects that face away from you. Use this to see through the back of objects.
Front	Turns on front-face culling, eliminating those objects from view that face you. Use this option to see through the front of an object.
Built-In	Turns on the feature's built-in face culling. This option is typically used with glTF models. If no built-in culling is present, the feature is drawn with back culling.

https://pro.arcgis.com/en/pro-app/latest/help/mapping/layer-properties/3d-effects.htm

Face culling determines which sides of polygons are visible. None turns off culling so you view both sides of polygons. Back face culling eliminates objects that face away from you, letting you see through the back. Front face culling eliminates objects facing you, letting you see through the front. Built-in face culling uses the feature's built-in settings. Understanding face culling helps optimize your scene rendering.

Drawing Mode


Projective Projection


Parallel Projection

- Projective projection = objects of same physical size/height not rendered the same
- Parallel projection = objects of same physical size/height are rendered the same

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Drawing mode affects how spatial relationships are represented. Projective projection represents realistic camera perspective, where objects of the same physical size may appear different depending on distance from camera. Parallel projection represents objects of the same physical size at the same rendered size, regardless of distance. This is often used in technical and architectural visualizations.

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.

Thanks! Hope you found this useful.