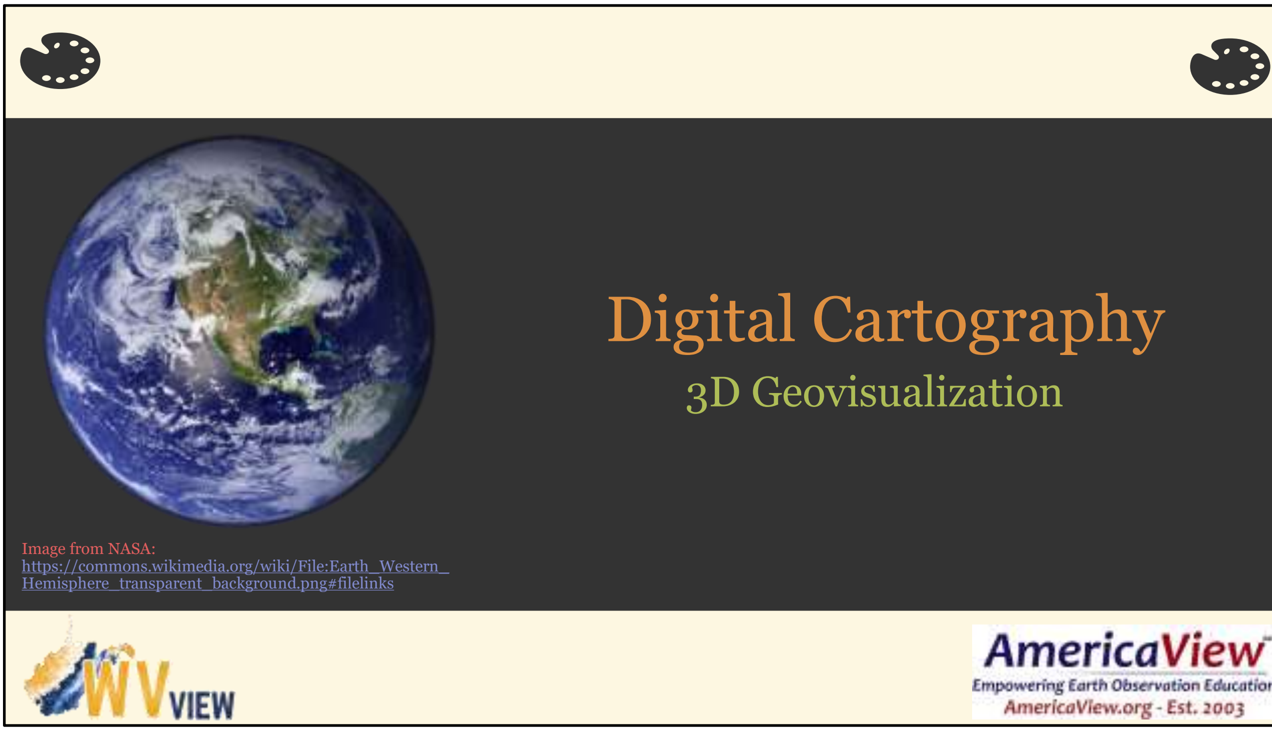


This last module provides an introduction to 3D cartography. This is a complex topic that is still evolving, so our goal here is just to offer an introduction. Note that we have an entire course on the WV View website focused on 3D GIS that this module draws from.

Module Topics

1. 3D data types and models
2. LODs
3. Extrusion
4. 3D symbols for points, lines, and polygons
5. UV mapping
6. Procedural symbol generation
7. Point cloud visualization
8. Voxel or multidimensional raster visualization
9. Labeling in 3D
10. 3D web apps
11. Images and fly-throughs
12. Interactive, virtual, and augmented reality

2

These are the topics covered in this module.

What are the applications of 3D GIS?

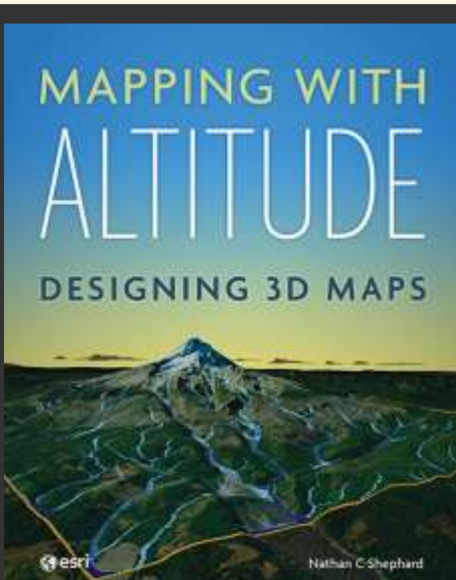
- Geovisualization
- Urban planning
- Digital twins
- Forestry
- Infrastructure
- Landscape architecture
- Hazard assessment
- Subsurface geology
- Augmented reality
- Animation
- Filmmaking

Screen capture from Google Earth

3

Visualizing geospatial data in 3D has many applications in many fields, as highlighted on this slide.

Book Recommendation



https://www.esri.com/en-us/esri-press/browse/mapping-with-altitude

4

There are a surprisingly limited number of books that focus on 3D geovisualization that are kept up-to-date. If you are interested in a textbook on this topic, I recommend *Mapping with Altitude: Designing 3D Maps* by Nathan Shepard.

Benefits of 3D

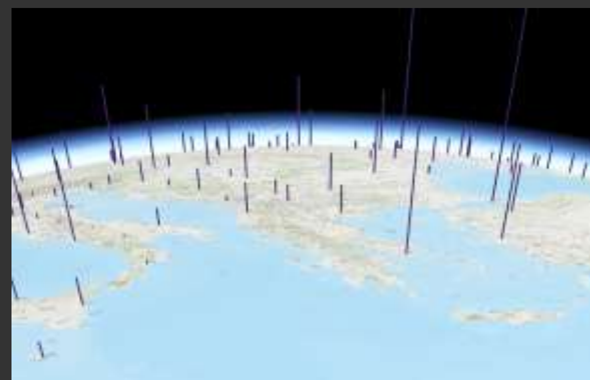
1. Engaging and interactive
2. Can be intuitive
3. Can be immersive
4. Provide information about vertical structure when it is important
5. Expands means to represent geographic data and phenomena
6. Provides new means to communicate

5

There are many benefits to presenting your data in 3D as noted on this slide.

Challenges with 3D

1. Can be difficult to judge relative sizes of features
2. Map content may be hidden behind other content
3. Can be hard to navigate
4. 3D data may be harder to create or obtain
5. Can be confusing and disorienting
6. Can be memory and graphics intensive



However, there are also some challenges associated with visualizing and presenting data in 3D. In other words, 3D is not always the best choice. There are many situations were a 2D representation is adequate or even preferable to a 3D alternative.

One key issue is that it, compared to a 2D map space, 3D spaces can be more difficult to navigate and can be disorienting. They can also stress bandwidth, memory, and/or computer graphics.

In short, as a mapping professional, you need to determine when a 3D representation is preferable or more effective. If you choose to use them, then you need to consider how best to generate a product that is useful, engaging, and practical. As with other cartographic products, you should always have an intended audience in mind as you create data and produce 3D geovisualizations.

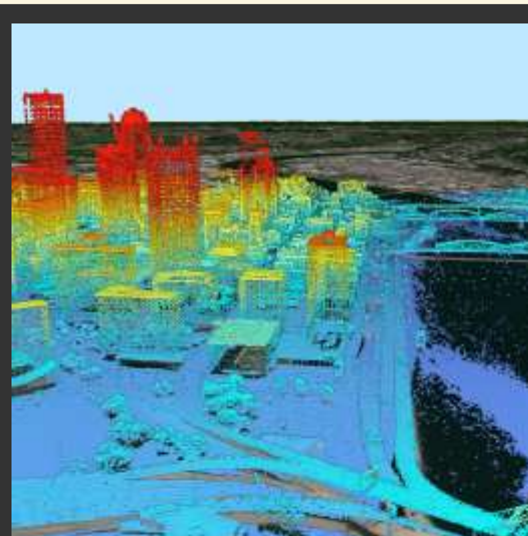
3D Data Models

7

3D data models are data structures specifically designed to represent full three-dimensional information, not just 2D data with elevation values.

Point Clouds

- Collection of *x*, *y*, *z* coordinates
- Can have additional attributes
- Can be referenced to a local coordinate system
- Can be referenced to a true geographic or projected coordinate system
- Often generated using lidar or photogrammetry

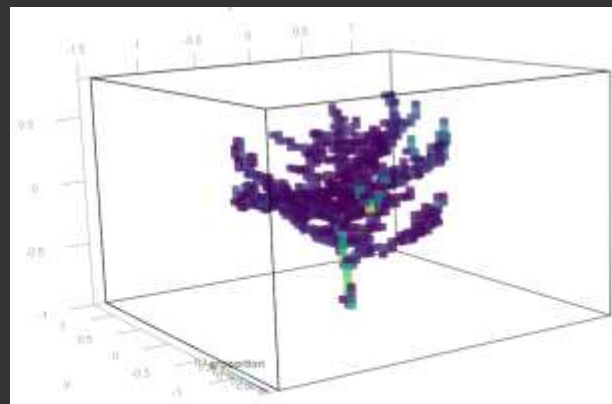


8

A point cloud is a collection of x, y, z coordinates, typically generated from lidar or photogrammetry sources. Each point represents a location in 3D space where a measurement was taken. Point clouds often contain millions or even billions of points. Each point can have associated attributes beyond just the coordinates (e.g., lidar points typically include intensity values and classification information). Point clouds can be referenced to local coordinate systems or to geographic or projected coordinate systems, depending on how they were collected. The beauty of point clouds is that they're completely general—they can represent any 3D phenomenon without requiring any assumptions about the data structure.

Voxels

- ❖Cells → Cubes
- ❖Each unit is a volume
- ❖Length in all three dimensions does not need to be the same
- ❖Can store a value or multiple values at each location



9

Voxels are a 3D extension of the pixel concept. If a pixel is a 2D cell in a raster, a voxel is a 3D cubic cell in a volumetric grid. Unlike raster cells, which often have the same height and width, voxels can have different dimensions in the x, y, and z directions. For example, you might have cells that are 5 meters in x and y but 1 meter in z. Each voxel can store a value or multiple values, representing whatever phenomenon you're modeling. Voxels are particularly useful when you have volumetric data like 3D atmospheric models or subsurface geological models.

Mesh

- True 3D geometry
- Still made up of vertices connected into faces
- Commonly triangles, but some software allow for other geometries

10

A mesh is a true 3D geometric model made up of vertices connected into faces. While it's mathematically similar to 2D polygon geometry, it extends the concept fully into 3D. Most meshes are made up of triangular faces, though some software allows other polygon types. Each vertex has x, y, and z coordinates, and the faces are defined by which vertices they connect. Meshes are the standard representation in 3D graphics software and game engines because they're efficient to render and manipulate.

Multipatch

- Vector data with 3D geometry
- Single feature made up of connected patches
- Each feature can have associated attributes
- Primarily used in ESRI software
- Stored as a feature class in a geodatabase

11

Multipatch is an ESRI-specific data structure for 3D geometry. Unlike meshes which are general 3D objects, a multipatch is specifically a feature class with 3D geometry where each feature is a single connected surface made up of patches. Each feature has associated attributes in a database table, making multipatches appropriate for structured GIS work where you're managing discrete 3D objects with properties. Multipatches are stored in geodatabases, which is ESRI's native data management system.

Integrated Mesh

- 3D mesh
- One surface (not individual features)
- Can be colorized or texturized
- Commonly created from photogrammetry or lidar
- Texturized with imagery
- Treated as 3D image

https://www.arcgis.com/home/item.html?id=3816389e961d4fac8b787068d0e3e2d1

12

An integrated mesh is a specialized 3D layer type, typically created from photogrammetry or lidar data. Unlike other data types that represent individual features, an integrated mesh is a single continuous 3D surface. Integrated meshes are often created from drone or aerial photogrammetry and may be textured with imagery to provide photorealistic 3D visualization. They're treated as complete 3D images rather than as structured geometric features, making them ideal for visualization but less suitable for feature-based analysis.

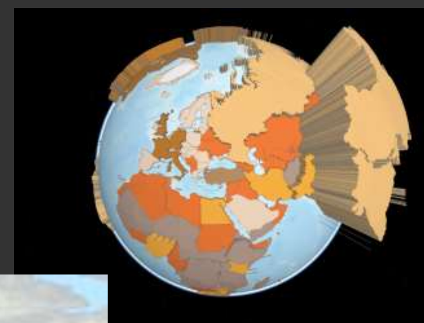
3D Symbology for 2D Data

13

We will now discuss means to represent 2D data using 3D symbology with a focus on thematic mapping.

Realistic -- Mixed Reality -- Thematic

- Symbology can very from:
  - Fully photorealistic
  - A mix of photorealistic and thematic
  - Fully thematic
- Best option depends on use case



14

Symbology approaches range along a spectrum from fully photorealistic to fully thematic.

Fully photorealistic visualization aims to depict the real world as accurately as possible, using realistic textures, lighting, and colors. This approach is excellent for communication and public engagement but can be computationally expensive and may obscure thematic data patterns.

Fully thematic visualization uses abstract colors and symbols to represent data values, following cartographic conventions. This approach is excellent for scientific analysis and pattern recognition but may appear less intuitive to general audiences.

Effective visualizations often use a mix of photorealistic and thematic elements, balancing visual appeal with data clarity. The best option depends on your specific use case, audience, and intended message.

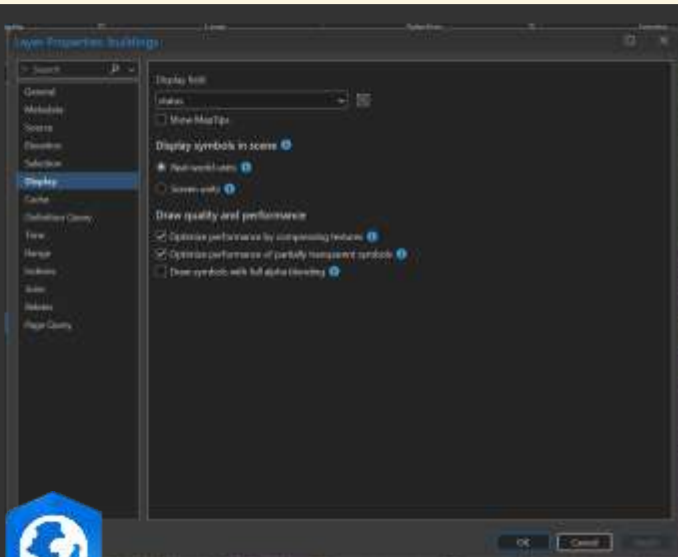
LODs

- Levels of Detail
- Different version of the same data used at different scales
- Zoom Out = Lower polygon count/Less detailed mesh
- Zoom In = Higher polygon count/More detailed mesh

15

Levels of detail, or LODs, are different versions of the same geographic data used at different scales. As you zoom out, lower polygon count and less detailed mesh versions are displayed for performance. As you zoom in, higher polygon count and more detailed mesh versions are displayed for visual quality. This approach balances performance and visual quality, allowing fast interaction at all scales. LODs are particularly important in 3D visualization where rendering complex geometry can be computationally expensive.

Screen vs. Actual Size



- ❖Real-world = use for known heights (m)
- ❖Screen = relative to screen display (px)

16

When extruding vector features to 3D, size can be specified either in real-world coordinates or in screen-relative coordinates. Real-world size uses actual measurements in the same units as the map, making features part of the 3D scene. Screen size uses relative pixel measurements, making features appear consistent regardless of camera distance, but breaking the illusion of 3D space.

Extrusion in ArcGIS Pro

Method	Description
None	Features are not extruded. This is the default.
Min Height (line and polygon extrusion only)	Add extrusion to each feature's minimum height. A z-value is calculated by adding the extrusion height to the minimum z-value of each feature. They are extruded to a flat top at that value.
Max Height (line and polygon extrusion only)	Add extrusion to each feature's maximum height. A z-value is calculated by adding the extrusion height to the maximum z-value of each feature. They are extruded to a flat top at that value.
Base Height	Add extrusion to each vertex of each feature's base height. A z-value is calculated for each vertex of the feature's base and each feature is extruded to those z-values. In the case of polygon features, top and base faces are created to connect to the extruded walls to construct a closed shape.
Absolute Height	Each feature is extruded to the specified z-value from a field or expression as a flat top, regardless of the z-values of each feature.

https://pro.arcgis.com/en/pro-app/latest/help/mapping/layer-properties/extrude-features-to-3d-symbology.htm

17

ArcGIS Pro provides multiple extrusion methods for converting 2D vector data to 3D. None indicates not extruding features, which is the default. Min Height adds extrusion to each feature's minimum height. Max Height adds extrusion to each feature's maximum height. Base Height adds extrusion to each vertex's base height. Absolute Height extrudes to a specified z-value from a field or expression as a flat top. Each method is appropriate for different data types and visualization goals.

Points: Thematic

- Extrude to a height based on an attribute
- Change extruded symbol
- Color extruded symbol

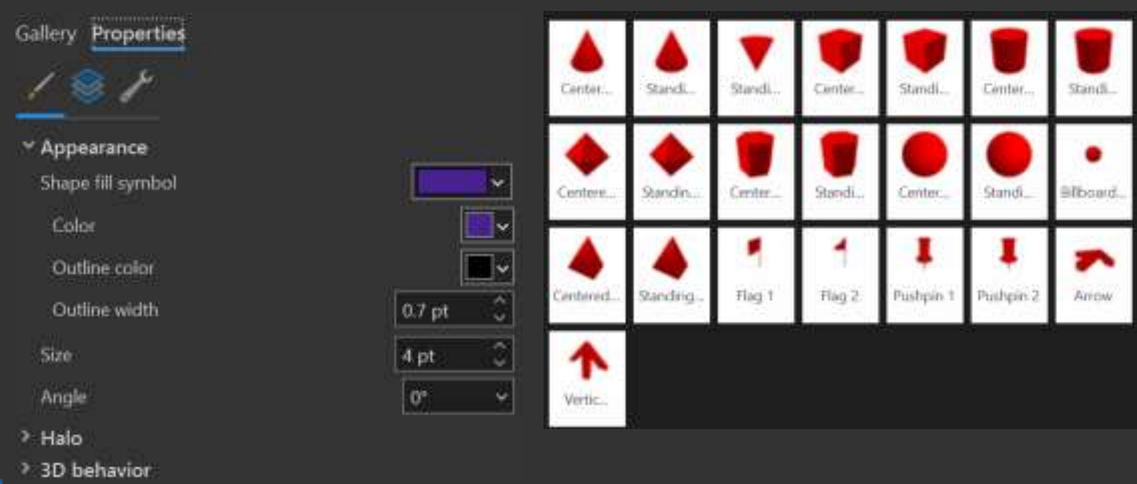
If using an attribute, may need to rescale.

18

For point features, thematic extrusion uses a height attribute to represent data values. You can extrude to a height based on an attribute value, change the extruded symbol appearance, and color the extruded symbol based on another attribute. This technique allows representing multiple data dimensions simultaneously in 3D space.

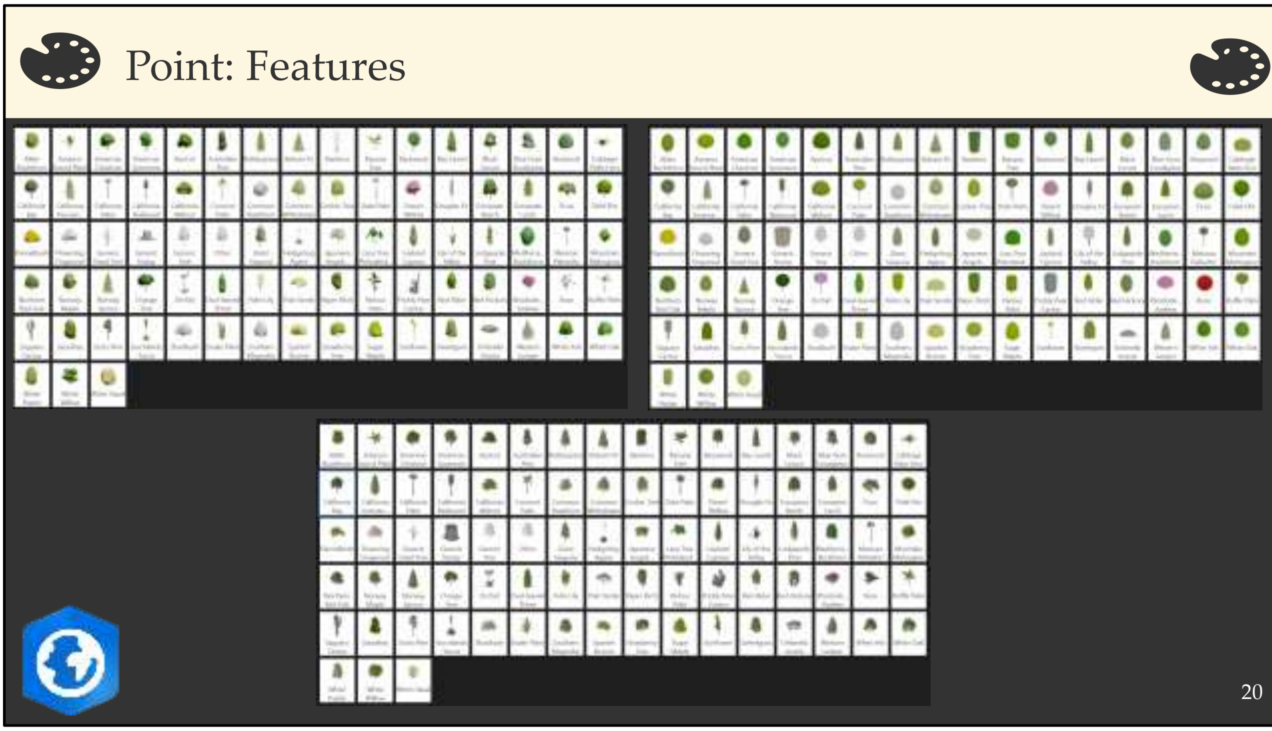
Note that it is common to have to adjust the values to obtain a reasonable range of lengths.

Points: Thematic

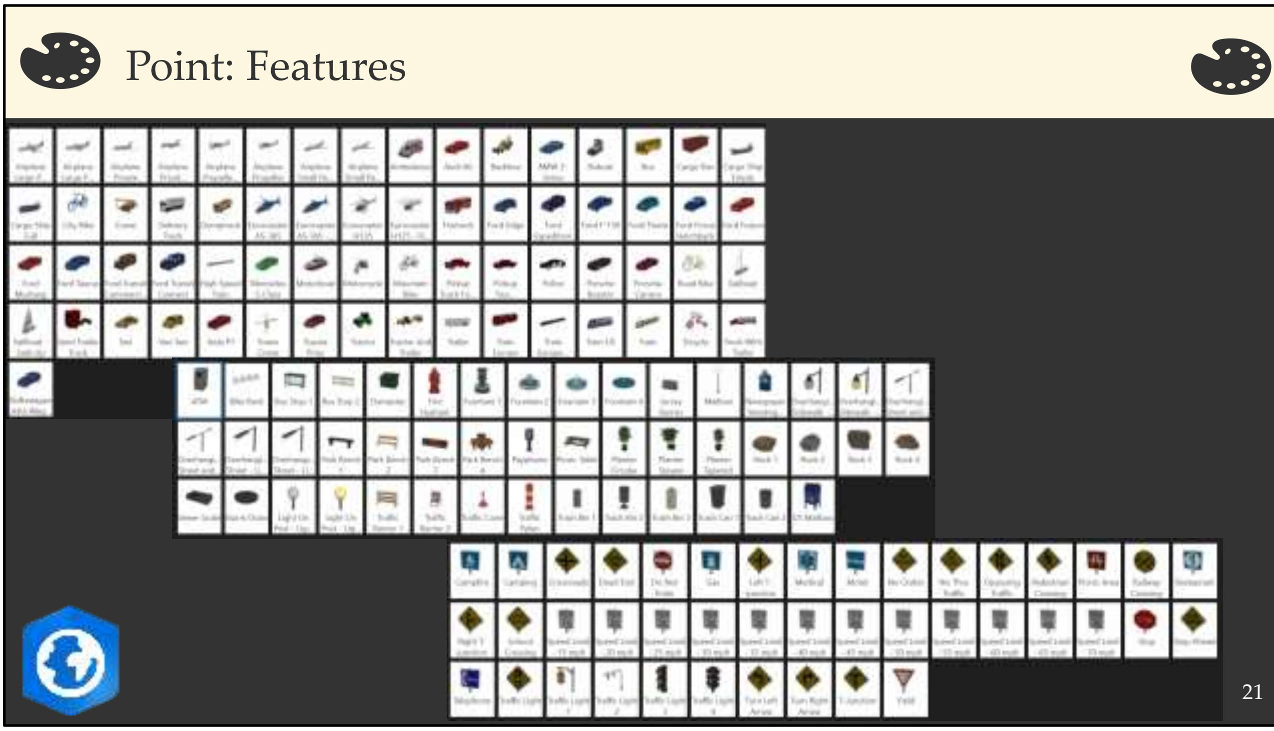


19

Point features can be symbolized thematically using various visual variables including color, size, and shape.



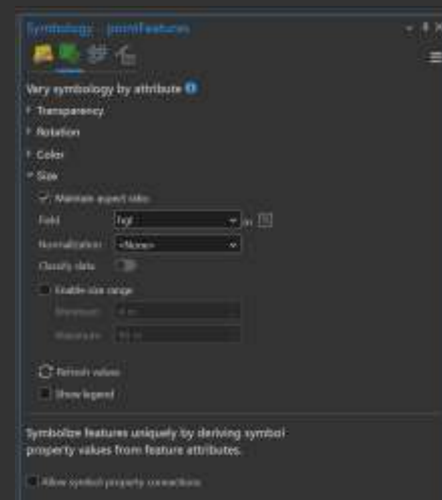
Point features can also be symbolized using categorical variations. Different symbols represent different feature classes, allowing multiple nominal variables to be displayed simultaneously in 3D space.



This slide shows some other 3D point symbol options available in ArcGIS Pro.

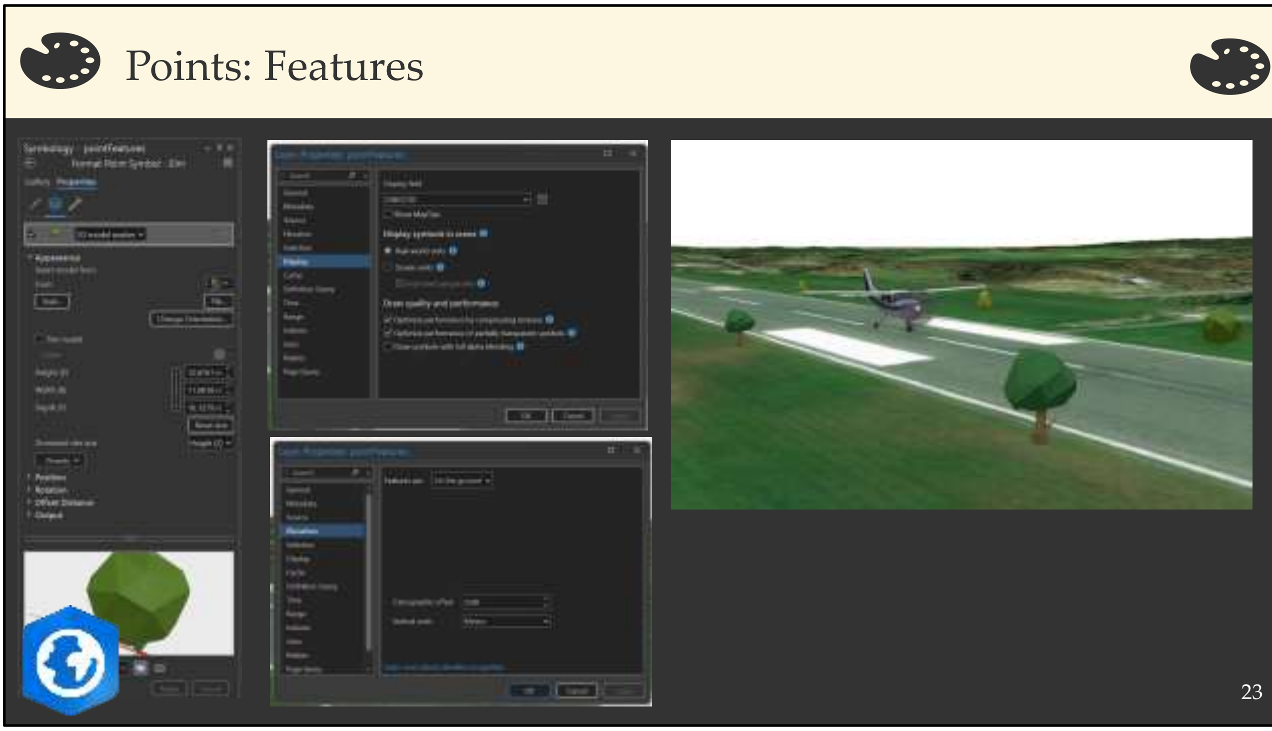
Point: Features

- Same 3D symbol for all features
- Different 3D symbol based on an attribute
- Size, height, orientation, etc. of symbol collectively
- Size, height, orientation, etc. of symbol based on an attribute



22

Point feature symbology can use a single symbol for all features, or different symbols based on attributes. Symbols can be sized, colored, or oriented based on attribute values, allowing effective representation of multivariate data in 3D space.



Symbols can generally be edited, such as there size, orientation, and offset along different directions. The examples on this slide show resizing features representing a tree.

Points: Features

In this example, I am symbolizing a point layer of car positions using 3D models of cars. Different cars are used depending on a nominal attribute.

A different set of point features is symbolized as trees. The tree type is selected based on a nominal attribute.

Billboards

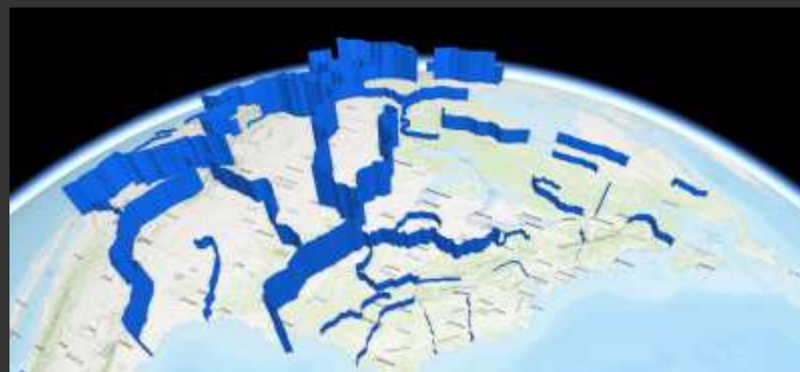
❖Flat surface that rotates to face the camera

25

Billboards are flat surfaces that always face the camera, regardless of viewing angle. This technique is commonly used for point symbols, trees, and other features where maintaining a direct view of the symbol is important. Billboards create visual impact while maintaining clarity from all viewing angles.

Lines: Thematic

- Single symbol
- Nominal variable
  - Color
- Continuous variable
  - Color
  - Height



26

Lines can be symbolized using single symbols or thematic symbols. Thematic symbology uses color or height to represent data variables. Lines can represent nominal variables using different colors or continuous variables using color or height ramps. This allows representing one or two dimensions of data per line feature.

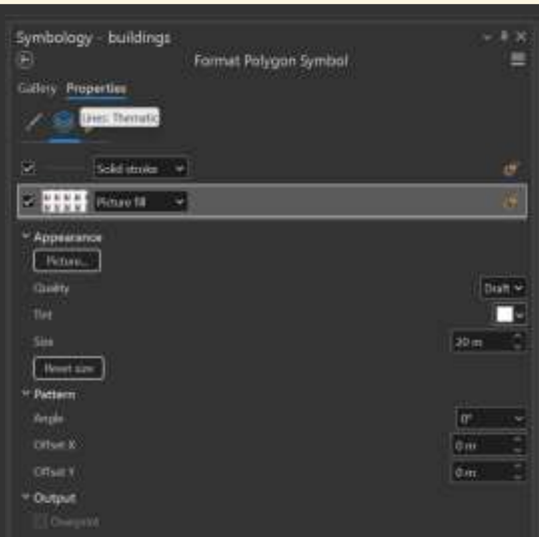
Polygons: Thematic

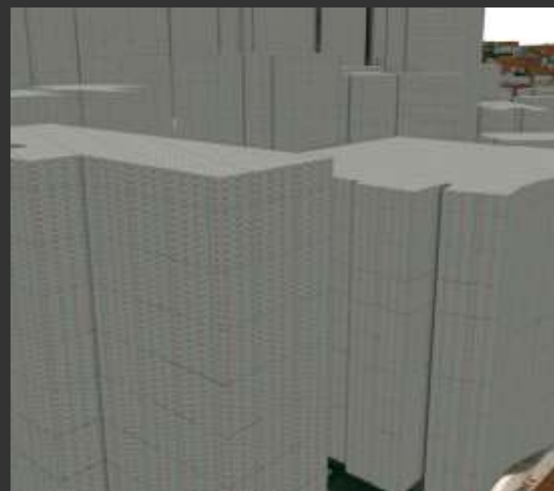
- Single symbol
- Nominal variable
  - Color
- Continuous variable
  - Color
  - Height

27

Polygons can be symbolized using single symbols or thematic symbols. Thematic symbology uses color or height to represent data variables. Polygons can represent nominal variables using different colors or continuous variables using color or height ramps.

Picture Fill

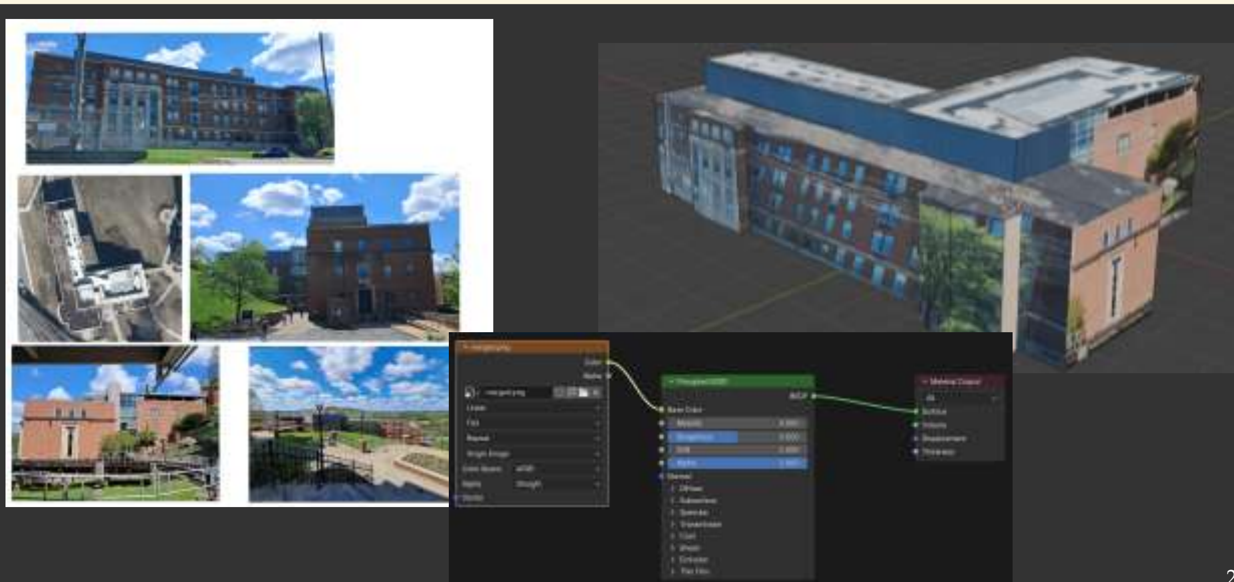




28

Picture fills allow applying photographic or graphical textures to polygon faces. This technique can add realism and detail, making visualizations more visually engaging. Textures can be repeated or stretched across polygon surfaces.

UV Map an Image



29

UV mapping allows mapping 2D images onto 3D polygon faces. Proper UV mapping ensures textures are oriented correctly and displayed without distortion.

Procedural Generation

- Can be too complex/time consuming to create symbols for all objects/faces manually
- Instead, can use rules, algorithms, and parameters to apply symbols
- Rules define how an object should be rendered
- Modify geometry (extrude, split, repeat, scale)
- Apply different textures/images to different surfaces
- Make use of feature attributes (e.g., building type and building height)
- Can incorporate randomness

https://www.youtube.com/watch?v=6oiiXkwnnJc&t=1850s

30

Procedural generation is valuable when creating symbols for many objects would be time-consuming. Rules define how objects should be rendered. Algorithms modify geometry through extrusion, splitting, repeating, and scaling. Different textures and images can be applied to different surfaces based on rules. Feature attributes like building type and height can drive the generation process. Randomness can be incorporated to create natural variation.

ArcGIS CityEngine

- Procedurally generate 3D cities
- Computer Generated Architecture (CGA) rules
- Used by urban designers, planners, architects, and 3D artists

https://www.esri.com/en-us/arcgis/products/arcgis-cityengine/overview

31

ArcGIS CityEngine is a specialized tool for procedurally generating 3D cities. CityEngine uses Computer Generated Architecture rules to automatically create buildings and urban environments. It's used by urban designers, planners, architects, and 3D artists for creating realistic 3D city models.

Rule Packages

- RPK (zipped file)
- CPA = Computer Generated Architecture
- Rule Package = Rules (CGA) + Assets (geospatial data, textures)
- Can make it so users can or cannot see code
- Written in CityEngine
- Can be used in ArcGIS Pro and shared with AGOL
- An be used for symbology and also within analysis workflows

32

Rule packages are RPK files that bundle CGA rules with assets. They can include geospatial data and textures needed for procedural generation. Rule packages can be created in CityEngine and shared via ArcGIS Online. They allow users to apply procedural generation in ArcGIS Pro and in analysis workflows. You can control whether users can see the underlying code.

CGA

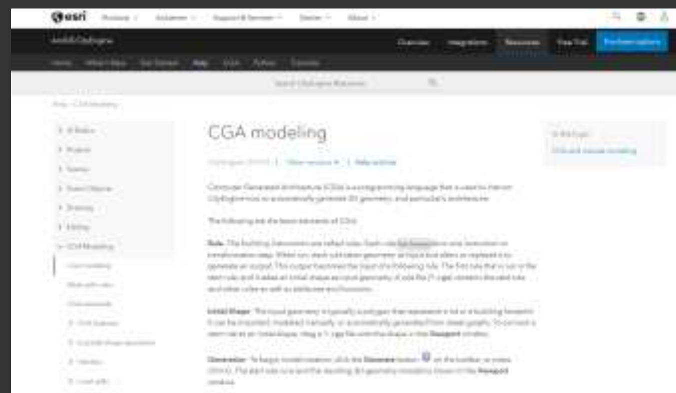
- Shape grammar programming language
- Functional programming language
- Scripting for shapes
- Process 3D geometries
- Shape = scope and geometry
  - Scope = bounding box
  - Geometry = actual geometry
- Can modify scope and geometry
- Rule = sequence of shape operations

33

CGA is a shape grammar programming language used in CityEngine. It's a functional programming language for scripting shapes and processing 3D geometries. In CGA, shape refers to both scope and geometry. Scope is the bounding box, while geometry is the actual shape. Rules are sequences of shape operations that modify scope and geometry.

CGA

❖Types of modifications:
- Move
- Scale
- Split
- Extrude
- Repeat
- Texturize
- Etc.

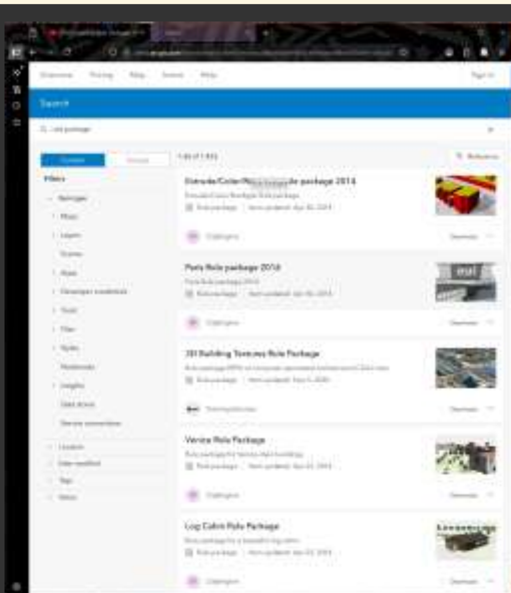


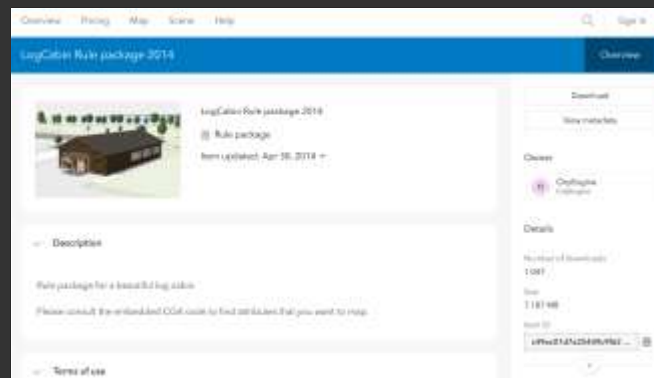
https://doc.arcgis.com/en/cityengine/2024.0/help/help-cga-modeling-overview.htm

34

CGA operations include move, scale, split, extrude, repeat, texturize, and many others. These operations can be combined in various ways to create complex 3D geometry and textures. The programming approach allows creating flexible, reusable rules for a wide variety of building types and urban patterns.

Using Rule Packages in ArcGIS Pro





https://www.arcgis.com/

35

Using rule packages in ArcGIS Pro involves accessing the 3D visualization tools and symbology options. Rule packages allow bringing procedurally generated content into ArcGIS Pro for visualization and analysis alongside other geospatial data.

Using Rule Packages in ArcGIS Pro

Symbology → Single Symbol → Properties → Procedural Fill

36

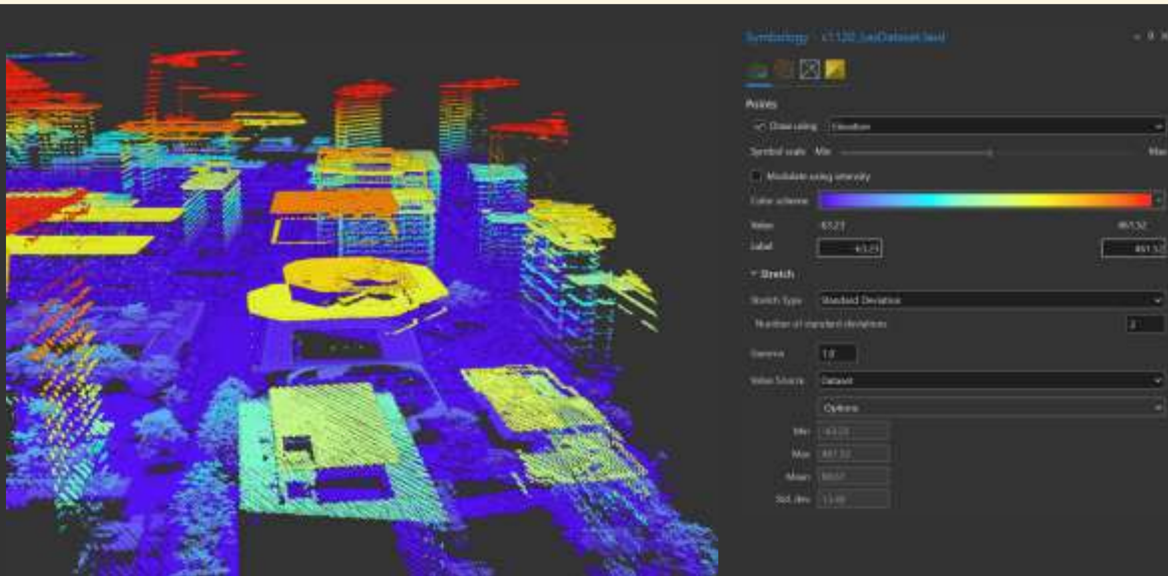
To use rule packages in ArcGIS Pro, access Symbology options and select Single Symbol or Procedural Fill. This allows applying procedural rules to features and generating complex 3D geometry automatically.

Symbology for Point Clouds

37

Point clouds are sets of points in 3D space, typically generated from lidar or photogrammetry. Point clouds can represent terrain, buildings, vegetation, and other features with dense spatial information. Point cloud visualization requires specialized techniques due to the large number of points.

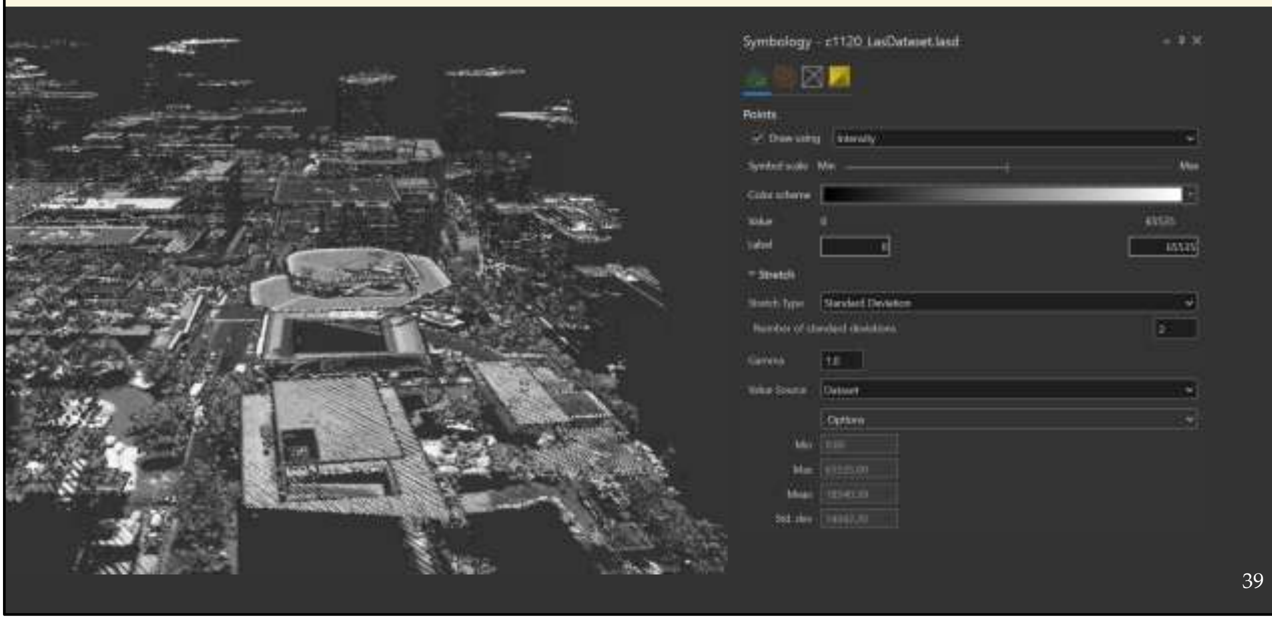
Point Style: Elevation



38

Point clouds can be styled by elevation, showing height variation through color ramps. This is particularly useful for identifying terrain features, buildings, and vegetation at different elevations.

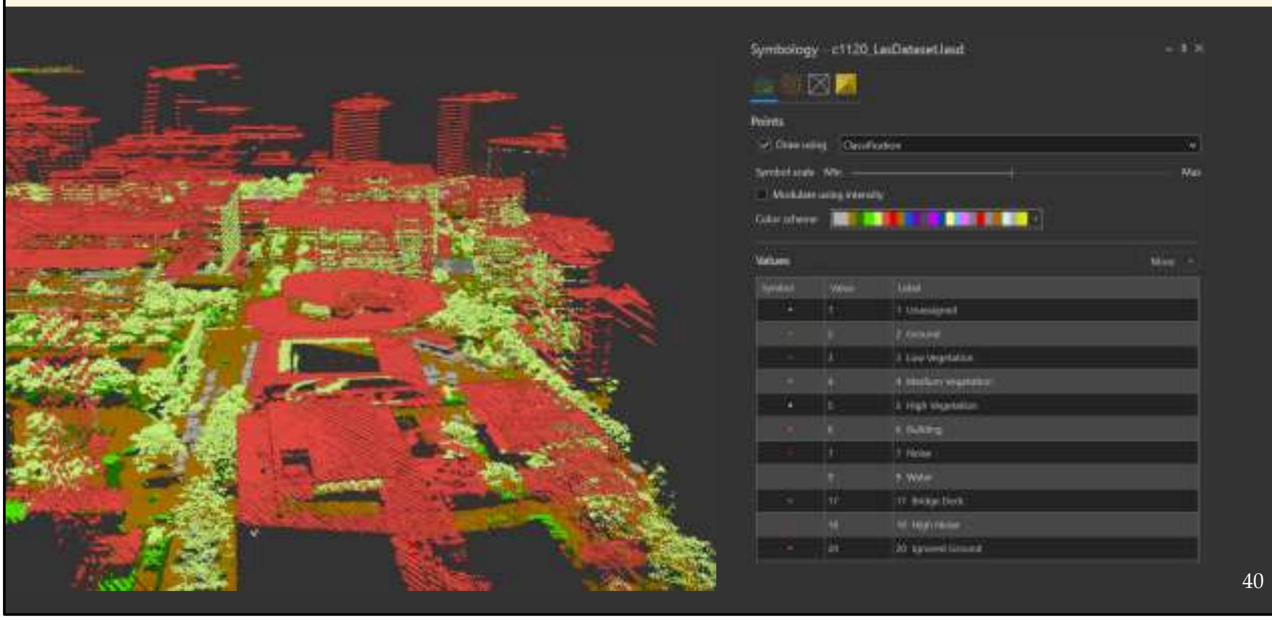
Point Style: Intensity



39

Point clouds can be styled by intensity, representing the intensity of the returned lidar signal. This indicates surface reflectivity and can help identify different materials and surface characteristics.

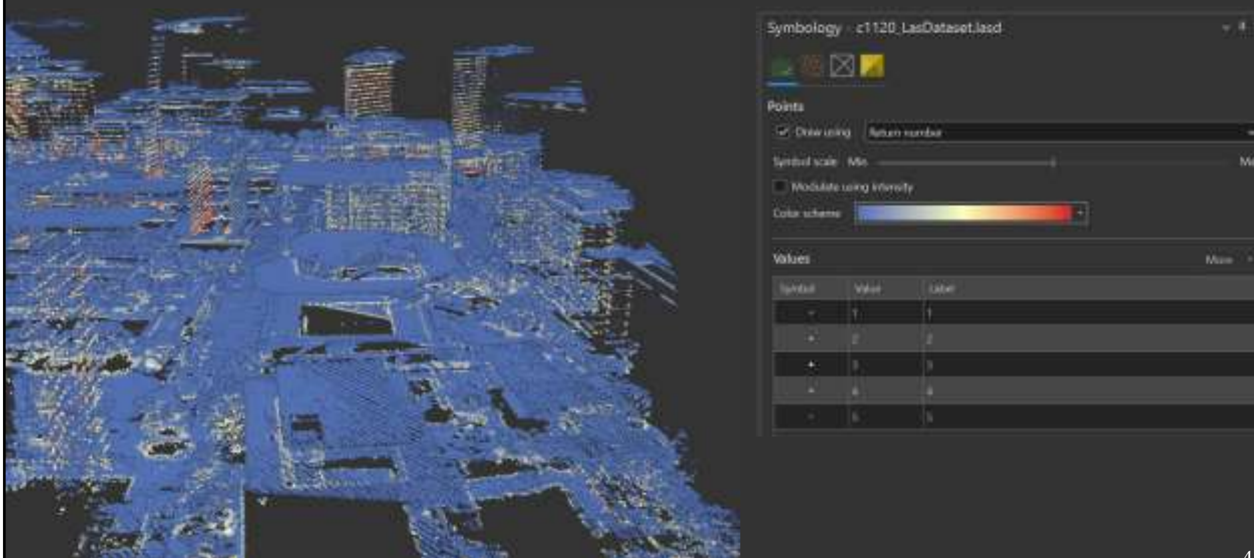
Point Style: Classification



40

Point clouds can be styled by classification, showing different feature types. Standard ASPRS classification includes ground, vegetation, buildings, water, and other classes. Classification visualization can allow distinguishing between different land cover types.

Point Style: Return Number

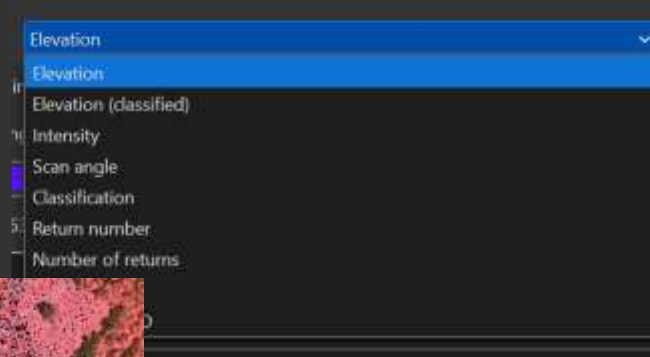


41

Point clouds can be styled by return number, showing which return in a multi-return lidar sequence each point represents. First returns typically represent canopy tops while later returns represent ground or intermediate heights.

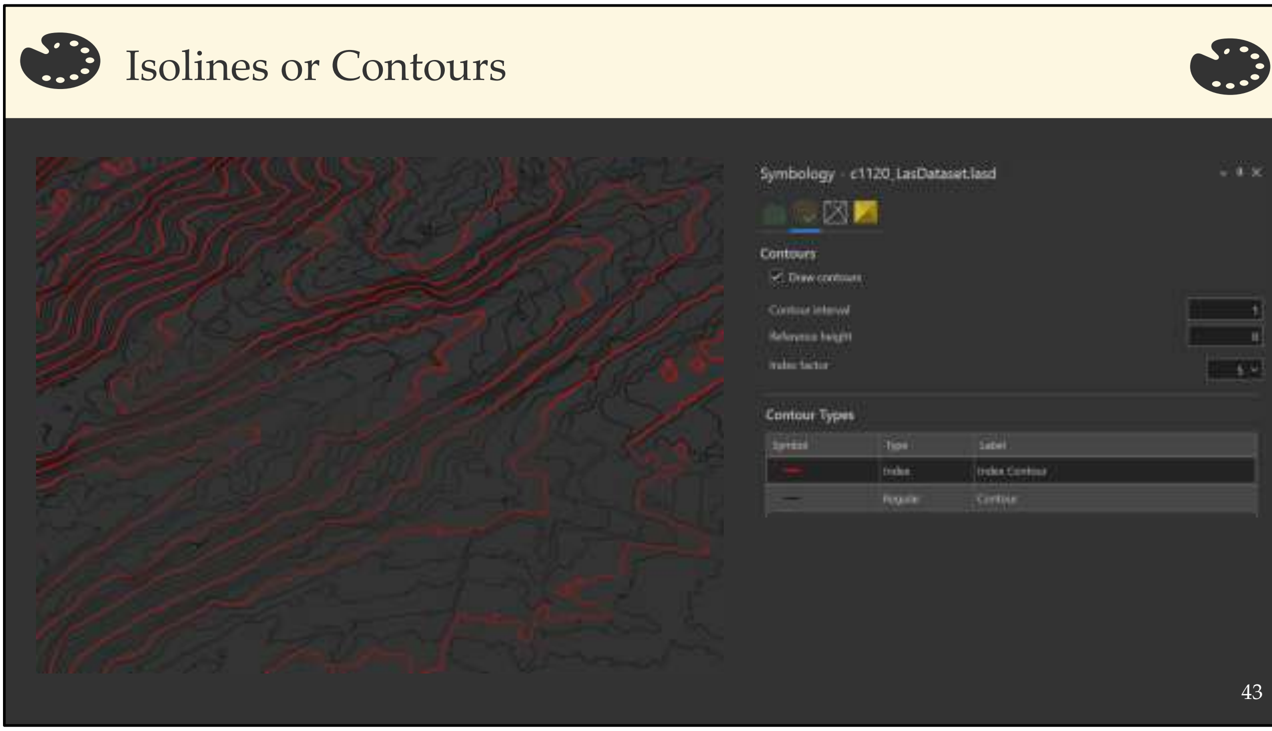
Other Attributes

- Scan angle
- Number of returns
- RGB
- RGBN



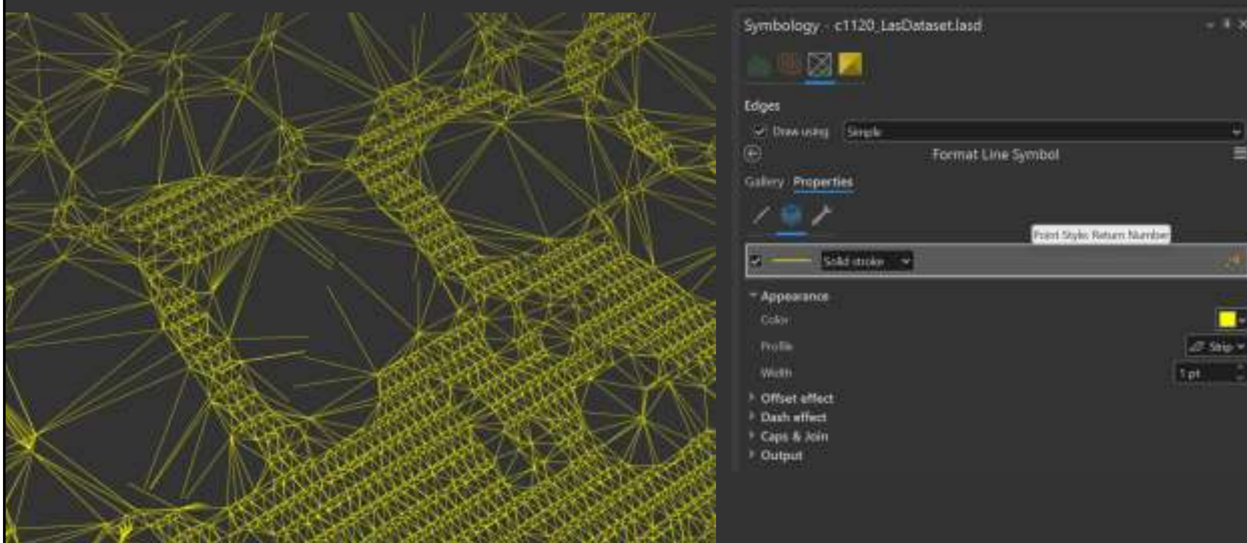
42

Additional point cloud attributes include scan angle, number of returns, RGB color from imagery, and RGBN including near-infrared. These attributes can be used for analysis and visualization.



Point clouds can be visualized as isolines or contours. This converts dense point data into more traditional contour maps.

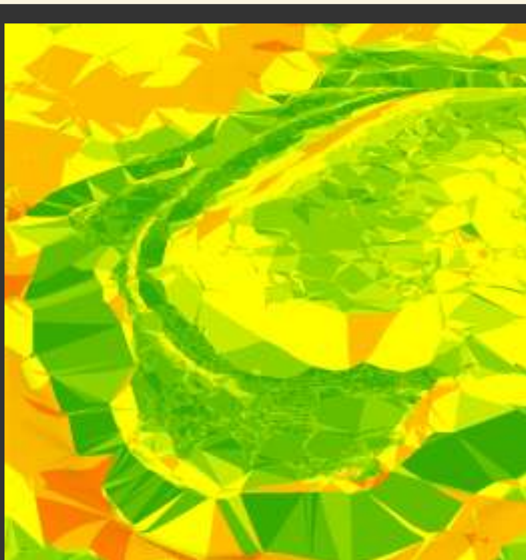
Edges



44

Point clouds can be visualized as edges, similar to a TIN surface.

As a Surface



- Elevation
- Slope
- Aspect

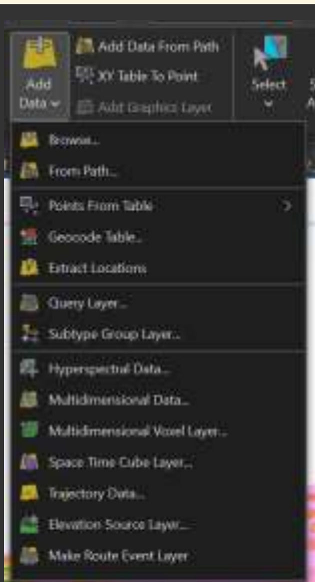
45

Point clouds can be visualized as surfaces representing elevation, slope, or aspect. Converting point cloud data to surfaces allows traditional raster analysis and visualization.

Symbology for Voxels and Multidimensional Raster Grids

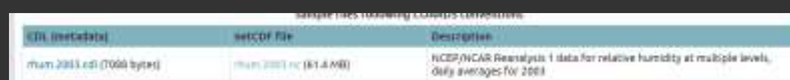
Voxels are three-dimensional pixels representing values assigned to volumes in a 3D grid. Voxel and multidimensional raster grids allow representing multivariate spatial data across three spatial dimensions and often time.

Adding Voxel Data in ArcGIS Pro



- ❖Multidimensional Data
- ❖Multidimensional Voxel Layer
- ❖Space Time Cube Layer

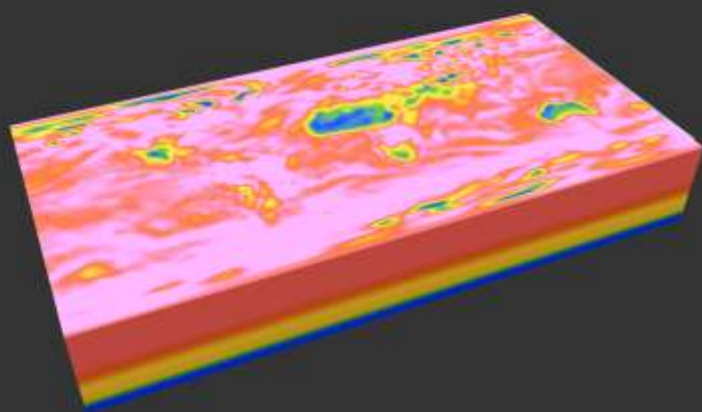
Example data used here from:
https://archive.unidata.ucar.edu/software/netcdf/examples/files.html



47

Adding voxel data in ArcGIS Pro involves creating multidimensional voxel layers or space-time cube layers. These layers allow visualizing complex, multidimensional datasets including climate, atmospheric, and oceanographic data.

As a Cube or Volume

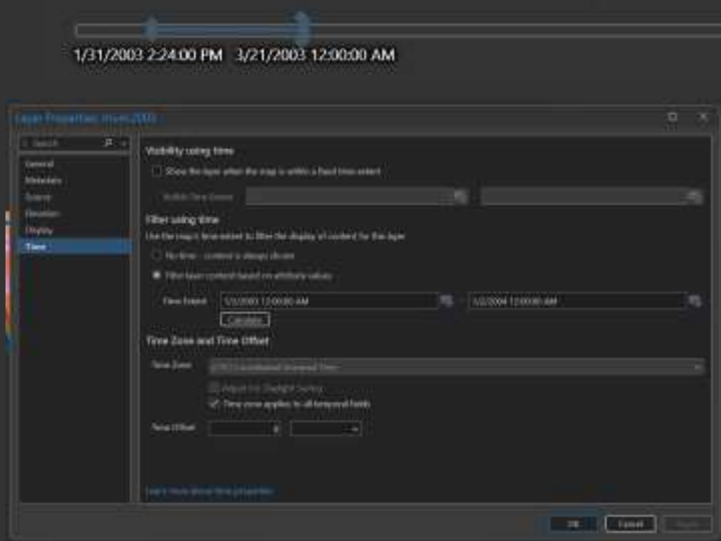


- *x*, *y*, *z* (depth or altitude)
- Variable mapped to color ramp
- Could be continuous or discrete

48

Voxel data can be visualized as a cube or volume where x, y, z coordinates define position and a variable is mapped to color. Variables can be continuous or discrete depending on the data characteristics.

Time Slices



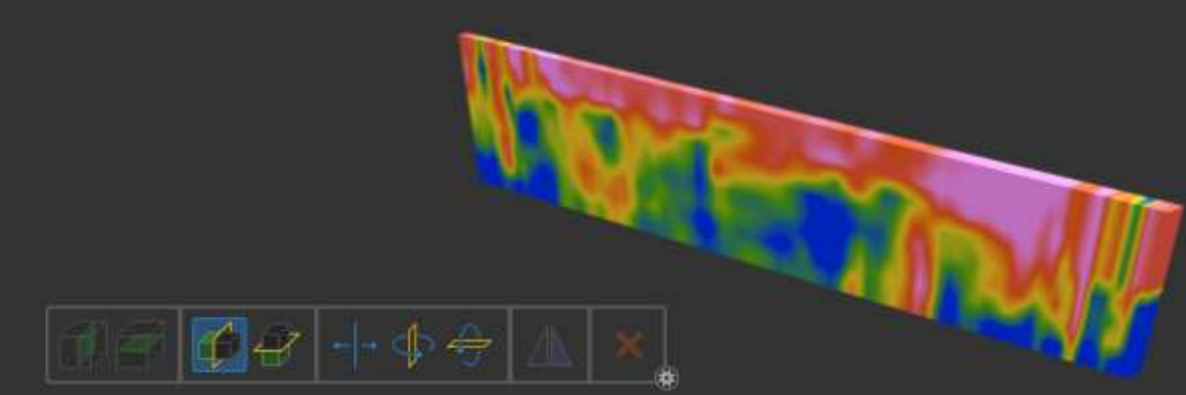
- User slider or animation to show change over time
- Can combine with time series graphs

49

Time slices allow viewing specific time steps from multidimensional data. Users can interact with sliders or animations to show how values change over time. Time series graphs can be combined with spatial visualizations.

Spatial Slices

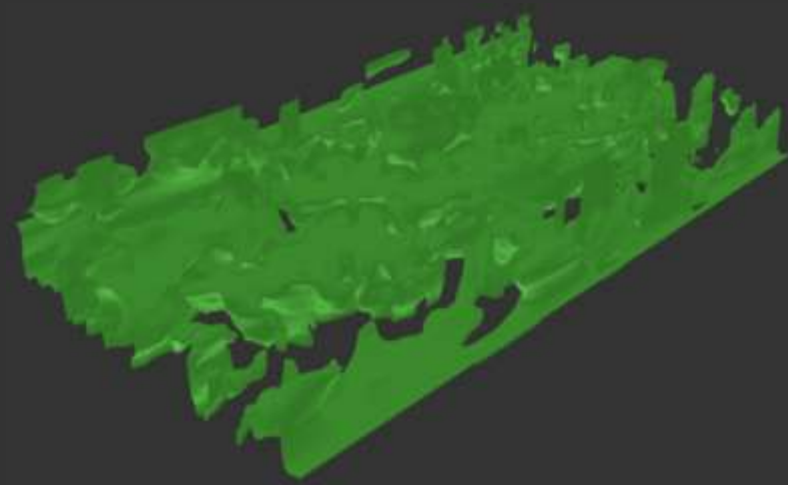
- Can be vertical, horizonal, or oblique



50

Spatial slices show cross-sections through 3D data. Slices can be vertical, horizontal, or oblique depending on the analysis question. This technique helps visualize spatial patterns within 3D volumes.

Isosurface

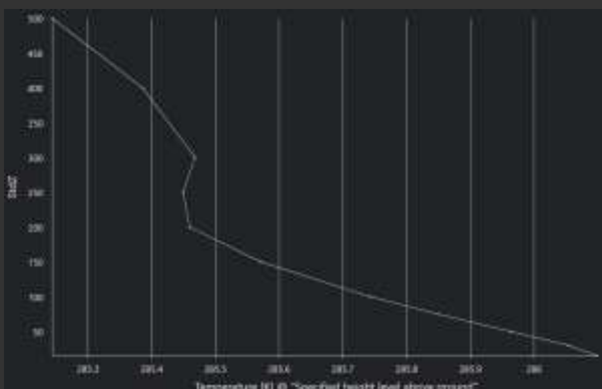


- Surface representing locations with the same value

Isosurfaces are surfaces representing locations with the same value. This technique allows visualizing 3D patterns and thresholds, making it easy to identify regions meeting specific criteria.

Graphs

- **Profiles** with altitude or depth at a pixel location



- **Time series** of value at pixel location

52

Graphs can show profiles with altitude or depth at a specific pixel location, or time series of values at a pixel. These complementary visualizations provide both spatial context and detailed value information.

3D Labeling

53

3D labeling places text annotations in 3D space to identify and provide information about features. Effective 3D labeling requires careful consideration of placement, size, orientation, color, and visibility.

In Scene vs. On Screen

- In Scene
  - Treated like object that consumes space in 3D view
  - Can be obstructed by other objects in the view
  - May use distance-based rendering or multiple LODs
  - Often attached or associated with objects

- On Screen
  - Separate layer of content
  - Does not interact with content in the view
  - May use distance-based rendering
  - Used to help with general navigation or when associated with features covering a wide area

54

3D text can be positioned in scene, where it consumes space and can be occluded by other objects, or on screen, where it's a separate layer and doesn't interact with scene content. In-scene text can use distance-based rendering or LODs. On-screen text helps with navigation and remains visible regardless of scene content.

Font

- Rules for 2D maps generally apply
- Match font to theme of the scene

55

When selecting fonts for 3D scenes, apply traditional 2D mapping font rules, as already discussed in this course. Match the font to the theme of the scene. Choose legible fonts that work at the intended size and viewing distance.

Text Color

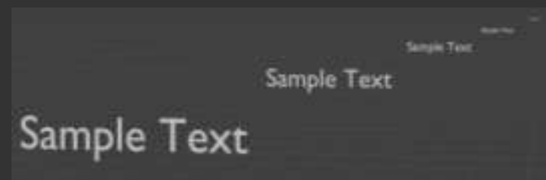
- Selecting an appropriate color can be tricky since the background may change as the user navigates
- When using realistic content and textures, bright colored text is preferred
- For thematic data, text color should contrast with the colors used to display the map features
- Can use halos or background fills to improve legibility
- Can apply transparency
- In scene text will be impacted by lighting configuration

56

Text color selection is tricky in 3D because background colors change as users navigate. With realistic content, bright colored text is preferred. With thematic data, text should contrast with displayed colors. Halos or background fills improve legibility. Transparency can be applied. In-scene text is affected by lighting configuration.

Text Size

❖ Real-world size
- Get larger as user gets closer
- Resizes with other objects in the scene
- Can be hard to read at different distances



❖ Screen-Space-Size
- Take up consistent area on screen
- Same size with changing distance
- Look artificial/lack of depth perception

57

Text size can be real-world size, getting larger as users approach and resizing with other scene objects, which can make text hard to read at different distances. Alternatively, screen-space-size maintains consistent screen area regardless of distance, but can look artificial and lack depth perception.

Placement

❖ Stand-Alone-Text
- Treated as its own independent object
- Positioned relative to a source feature
- Often used for point features
- Can be billboarded

❖ Embedded Text
- Draws directly on a scene object
- Text and object treated as one feature
- Need surface area on which to add text

58

Text placement includes stand-alone text positioned relative to features, and embedded text drawn directly on scene objects. Stand-alone text is common for point features and can be billboarded. Embedded text requires surface area and is treated as part of the feature.

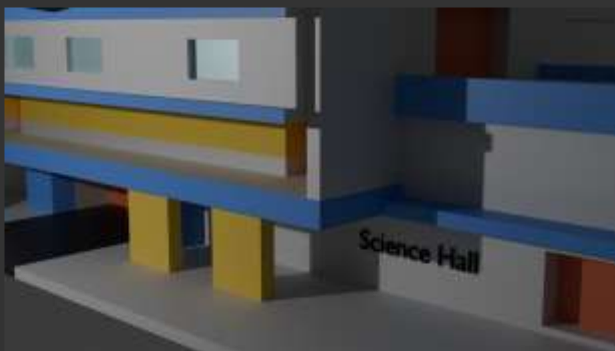
Stand-Alone Text

- When billboarding, use the same plane as the symbol
- Place above, on, or below symbol
- Can vertically offset to minimize overlap
- Can add leader line with increased vertical offset
- Set priorities to minimize conflict

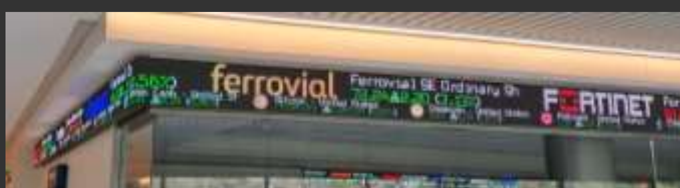
59

When using billboarded stand-alone text, use the same plane as the symbol. Place text above, on, or below the symbol. Vertical offset can minimize overlap. Leader lines with increased vertical offset clarify associations. Priorities minimize text conflicts.

Embed in Feature



- Reduces ambiguity
- Text does not add to space taken up by the feature
- Must have enough surface area
- Only readable from some angles
- Consider a ticker-tape effect



60

Embedding text in features reduces ambiguity and doesn't add to feature size. However, it requires sufficient surface area and is only readable from some angles. Consider ticker-tape effects for continuous text.

Embed in a Surface

- Best when
  1. Text physical at the location
  2. Only text used in scene
- Generally, more legible with flatter terrain

61

Embedding text in surfaces works best when text is physically at a location and is the only text in the scene. Generally, such text is more legible within flatter terrain.

Text Orientation and Direction

- Billboarding
  - Most common way to orient text in 3D
  - Can lock so rotation can only occur relative to certain axes
  - Works for real-world-size and screen-space-size
- Along a line
  - Sometimes used for linear features
  - Can use real-world size text that decreases in size with distance
  - Works for real-world-size
- Constrained to a virtual shape
  - Use spheres, cubes, or cylinders
  - Works for real-world-size (sometimes screen-space-size)

Text orientation options include billboarding, which can be locked to specific axes. Along-a-line orientation works for linear features with real-world-size text decreasing with distance. Constrained-to-shape orientation uses spheres, cubes, or cylinders.

As a 3D Object

- Volumetric
- Can be shaded
- Can cast shadows
- Can navigate through or around letters
- Cinematic
- Works for real-world-size

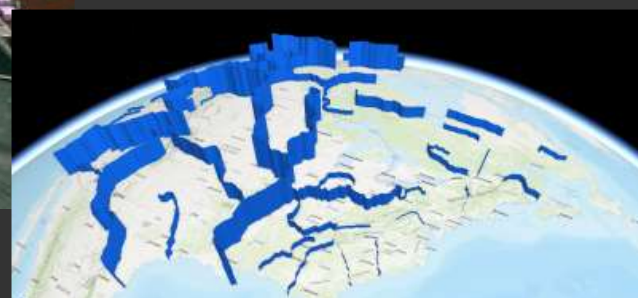
Text as 3D objects can be volumetric, shaded, cast shadows, and allow navigation through and around letters. This cinematic approach works for real-world-size text and can create a dramatic effect.

Sharing and Viewing 3D Data

64

We will now discuss some methods for sharing and viewing 3D data.

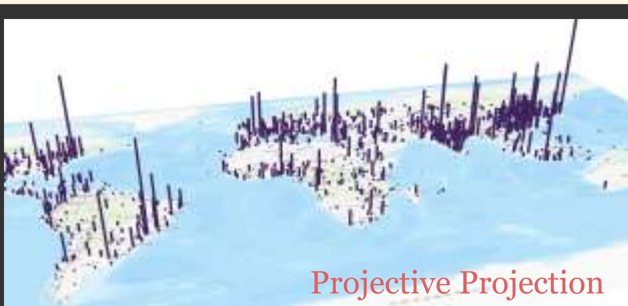
Local vs. Global Scene

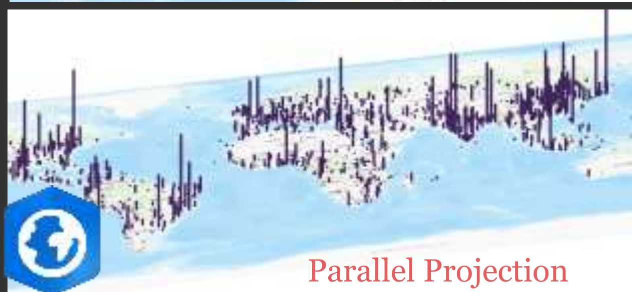


65

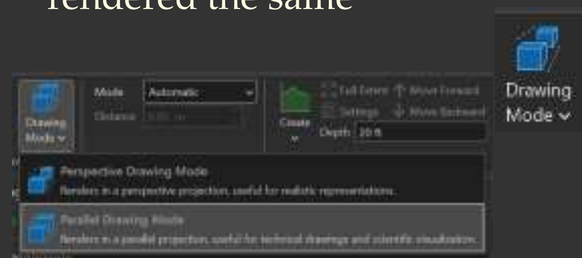
A local scene uses a projected surface or Cartesian space as opposed to a digital globe, as is used by a global scene. Local scenes are generally used for larger scale products, such as those covering individual cities, portions of cities, or sites whereas digital globes and global scenes are used for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

Drawing Mode





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



66

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 or when users will interpret or compare the relative sizes or heights of features.

Options

1. Web apps
2. Still images
3. Animations/Video Flythroughs
4. Interactive/Video Game Engines
5. Virtual/Augmented Reality

There are multiple options for viewing and sharing 3D data. In the following slides, we will focus on web apps, still images, and video flythroughs.

Web Apps

Layer Types

- ESRI Environment
  - Publish as a hosted 3D layer from a scene layer package (SLPK)
  - 3D tiles package as .3tz

https://www.esri.com/arcgis-blog/products/arcgis-online/3d-gis/3d-object-layer-a-comprehensive-overview

https://doc.arcgis.com/en/arcgis-online/reference/scene-layers.htm

69

3D layers for use in web scenes can be published from ArcGIS Pro or created in ArcGIS Online. You can publish data as a hosted 3D layer from a scene layer package (SLPK) file or as a 3D tiles package in .3tz format. Different layer types have different capabilities and support different publication methods and data sources.

Layer Types

- 3D Object = similar to a multipatch feature class
- 3D Point = large set of point features with automatic thinning
- Building = complex digital building models
- Gaussian Splat Layers = realistic visualization of 3D geometry
- Mesh = integrated meshes on the web
- Point Cloud = point clouds
- Voxel = raster-based

3D layer type	Supports associated feature layer (editable)	Supports SLPK (read only)	Supports 3tz (read only)
3D object	Yes	Yes	Yes
3D point	Yes	Yes	No
Building	Yes	Yes	No
Gaussian splat	No	No	Yes
Mesh	No	Yes	Yes
Point cloud	No	Yes	No
Voxel	No	Yes	No

https://www.esri.com/arcgis-blog/products/arcgis-online/3d-gis/3d-object-layer-a-comprehensive-overview

https://doc.arcgis.com/en/arcgis-online/reference/scene-layers.htm

70

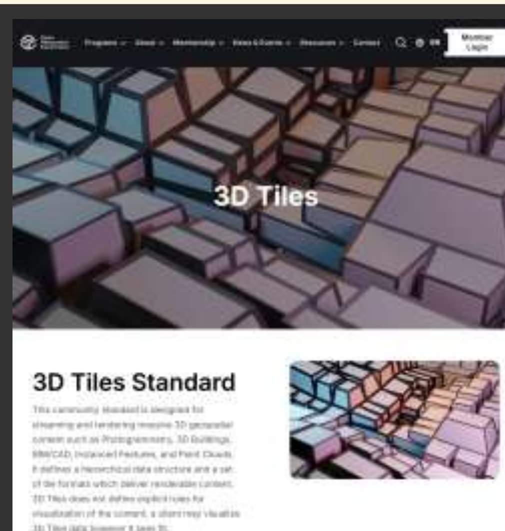
Several 3D layer types are available for web scenes. 3D Object layers are similar to multipatch feature classes and support associated editable feature layers, SLPK, and 3tz formats. 3D Point layers represent large sets of point features with automatic thinning for performance. Building layers contain complex digital building models. Gaussian Splat layers provide realistic visualization of 3D geometry using gaussian splatting. Mesh layers represent integrated meshes on the web. Point Cloud layers display point cloud data. Voxel layers represent raster-based 3D data. Each layer type has different capabilities for editing, storage, and representation.

Open Standards

❖3D Tiles

https://docs.ogc.org/cs/22-025r4/22-025r4.html

https://www.ogc.org/standards/3dtiles/



Open Geospatial Consortium

71

3D Tiles is an open standard developed by the OGC (Open Geospatial Consortium). This standard is increasingly important for web-based 3D visualization and is supported by many tools and platforms. Understanding 3D Tiles is essential for working with modern 3D geospatial data.

Types

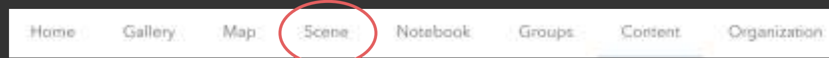
- Can make Local or Global Scenes

72

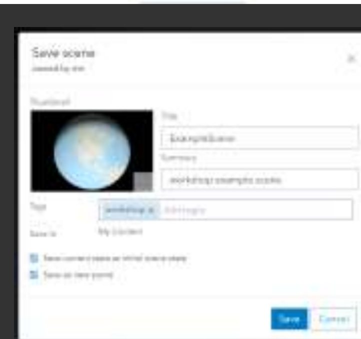
Web scenes can be either local or global. Local scenes are projected and centered on a specific geographic area. Global scenes use geographic coordinates and represent the entire Earth using a digital globe. The choice between local and global scenes depends on the geographic extent and nature of your data.

Create a Scene

- Log into ArcGIS Online (https://www.arcgis.com/index.html)
- Click on Scene



- Click Save and Open Icon
- Save as
- Provide title, save location, tags, and summary
- Click Save



73

You can generate web scenes using ArcGIS Online. Scenes are viewed and created under the Scene tab. They are saved as items to your ArcGIS Online content.

Tour of Scene Viewer

- Add data to Scene
- List of Layers
- Access or capture Slides
- Change Scene properties
- Save
- Create an app

- Search
- Layer List and Legend
- Basemap
- Illumination and weather
- Analyze/Measurement
- Share
- Graphic settings

*Tools on right are for data layers

74

Scene are viewed in the Scene Viewer as opposed to the Map Viewer. The tools available for scenes are different from those for Maps.

The icons on the left-side allow for adding data to the scene, viewing the layer list and accessing layers, accessing or capturing slides, changing the Scene properties, saving the Scene, and creating an App from the Scene. Slides serve a similar purpose as Bookmarks in a 2D map. They store a camera position and view of the scene from a specific vantage point and scale.

Tools on the right-side allow for searching, viewing, and manipulating the Layer List and Legend; changing the base map; changing the simulated illumination and weather conditions; performing analyses and measurements; and changing the share and graphics settings.

Publish 3D Layers from ArcGIS Pro

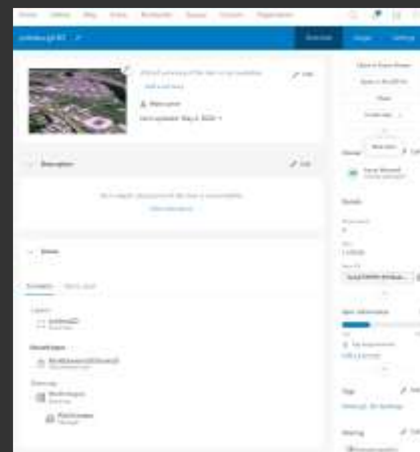
- Can publish scene + data or just data
- Provide a summary and tags
- Set share settings
- Can configure symbology and pop-ups in ArcGIS Pro
- 3D data published as hosted 3D object

75

Publishing 3D layers or scenes from ArcGIS Pro allows sharing your work with broad audiences. You can publish a scene plus associated data, or just the data without the scene. You can provide a summary and tags to describe your content, set sharing settings to control who can access your data, and configure symbology and pop-ups before publishing. 3D data are published as a hosted 3D object layer in ArcGIS Online.

3D Scene Item

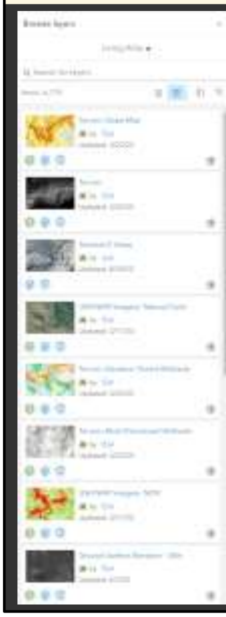
- Drop pages created for scene and data
- Can update sharing from these pages



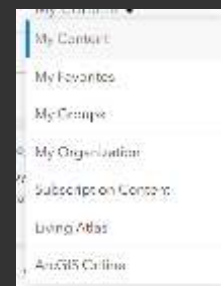
76

When you publish a scene, a 3D scene item is created in ArcGIS Online with associated drop pages showing the scene and data. These pages can be used to preview your content and update sharing settings.

Connecting to Other Layers



- My Content = your ArcGIS Online content
- My Favorites = often or recently used layers
- My Groups = from group in which you are a member
- My Organization = shared within your organization
- Subscription Content (not free)
- Living Atlas = ESRI Living Atlas
- ArcGIS Online = shared publicly by others via ArcGIS Online

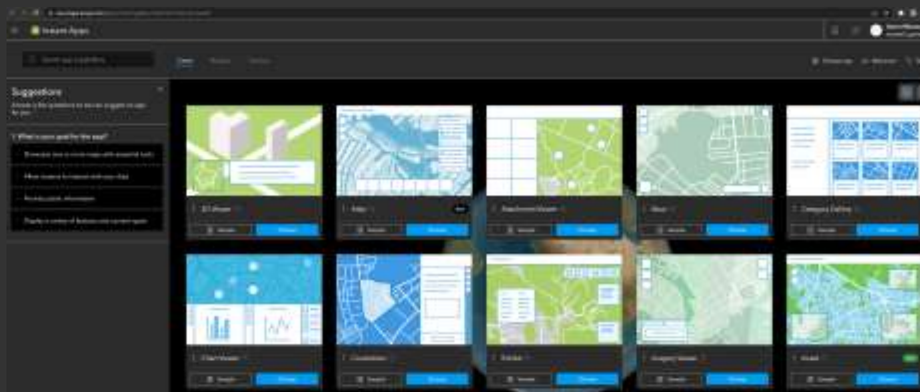


77

When connecting to other layers in ArcGIS Online, you can access content from various sources. My Content shows your own ArcGIS Online content. My Favorites shows frequently or recently used content or layers. My Groups provides layers from groups you're a member of. My Organization provides content shared within your organization. Living Atlas provides ESRI's Living Atlas content. ArcGIS Online provides publicly shared content. Subscription content provides additional premium data.

App with Instant Apps

- Instant Apps = pre-made applications that you can load your layers into



78

Instant Apps are pre-made applications that you load your layers into. With Instant Apps, you choose from available templates and configure settings without coding. Apps are created quickly and can be customized for your specific data.

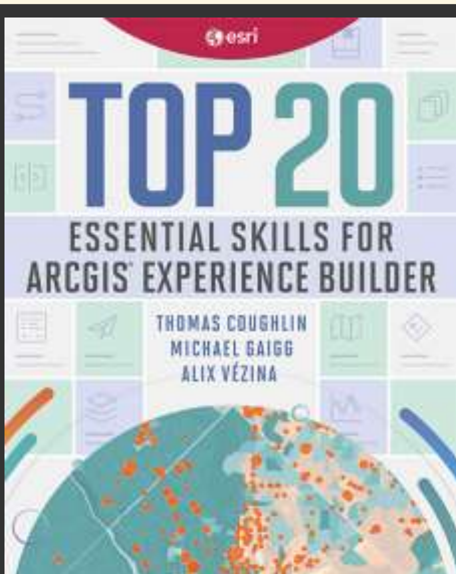
App with Experience Builder

- ArcGIS Experience Builder = web-based tool for generating multi-page websites that do not need to be centered around a map

79

ArcGIS Experience Builder is a web-based tool for generating multi-page websites that don't need to be centered around a map. Experience Builder provides more flexibility than Instant Apps for creating custom web experiences.

Book Recommendation



Top 20 Essential Skills for ArcGIS Experience Builder

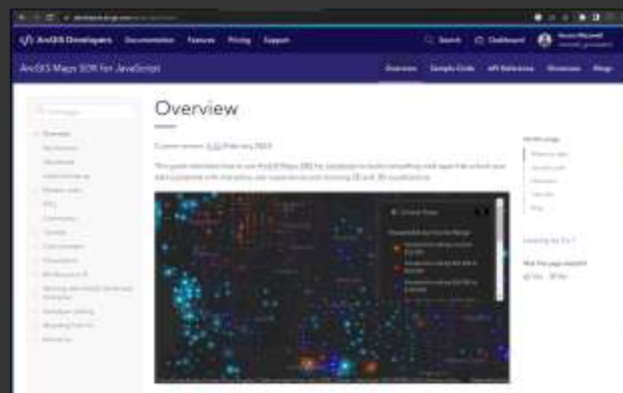
By Thomas Coughlin, Michael Gaigg, and Alix Vézina

- Design and create visually stunning and highly functional map apps with *Top 20 Essential Skills for ArcGIS Experience Builder*.

If you are interested in a book focused on Experience Builder, I recommend the text referenced on this slide and published by ESRI Press.

App with ArcGIS Maps SDK for JavaScript

- ArcGIS Maps SDK for JavaScript = offers fully customizable web maps and apps (requires coding)



https://developers.arcgis.com/javascript/

81

The ArcGIS Maps SDK for JavaScript offers fully customizable web maps and apps but requires coding knowledge. This is the most flexible approach for developers who want complete control.

App with CesiumJS

- Cesium Ion: store 3D tiles
- Cesium for Unity: integration with Unity engine
- Cesium for Unreal: integration with Unreal engine
- CesiumJS: JavaScript library for creating 3D web scenes

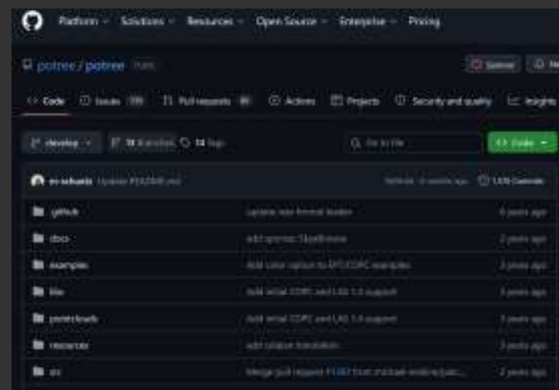
https://cesium.com/

82

CesiumJS is a JavaScript library for creating 3D web scenes. Cesium Ion provides cloud storage for 3D tiles. Cesium has integrations with Unity and Unreal for game engine applications.

Point Cloud Viewing on the Web

- Potree
- Free and open-source WebGL-based point cloud renderer for large points clouds



https://github.com/potree/potree

83

Potree is a free, open-source WebGL-based point cloud renderer excellent for visualizing large point cloud datasets on the web. Potree is particularly useful when you have massive point cloud data that needs to be viewable via a web browser.

Still Images

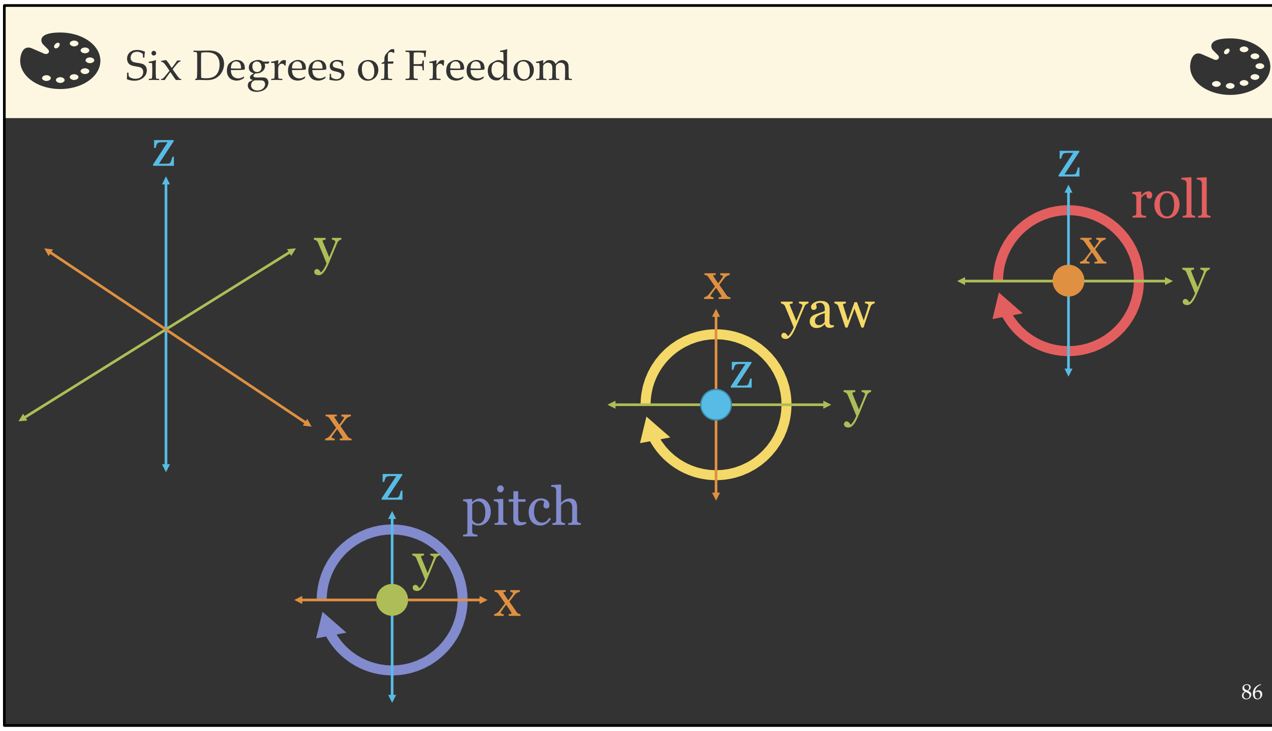
84

Key Considerations

- Viewing extent
- Camera position/composition
- Lighting
- Use of color/shadow
- Aspect ratio
- Depth of field simulation

85

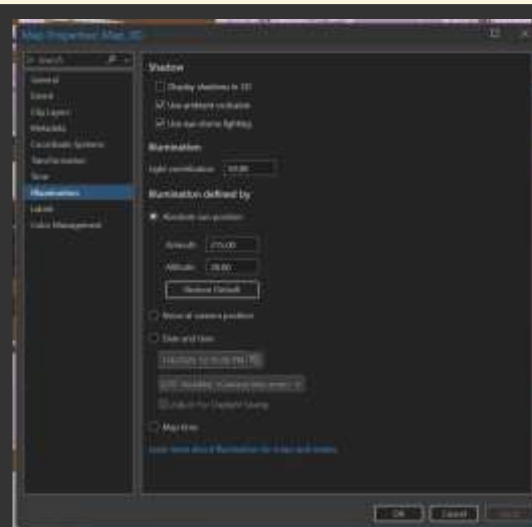
When creating still images from 3D scenes, several key considerations impact the visual quality and effectiveness of your composition. The viewing extent determines what portion of the scene is visible. Camera position and composition affect how the viewer perceives the scene. Lighting is crucial for mood and visibility. The use of color and shadow guides viewer attention. Aspect ratio affects how the image is perceived. Depth of field simulation controls focus and emphasis.



Relating to positioning the virtual camera, 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.

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



87

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.

Video Fly-throughs

88

Video Fly-Through

- Similar to animation
- Primarily keyframing the camera

https://pro.arcgis.com/en/pro-app/latest/help/mapping/animation/overview-of-animation.htm

89

Video flythroughs in geospatial visualization are similar to animation in general but primarily involve keyframing or moving the camera rather than objects. This creates smooth navigation through data.

Types of Camera Animations

- **Fly-through** = Navigate through a map or scene smoothly as if you are following a route or path.
- **Tour** = Fixate on points of interest. Each destination typically has a Hold keyframe Hold Keyframe inserted to pause and observe it. Each transition typically uses the Hope type to emphasize zooming in to a location and zooming out to the next one.
- **Fly-around** = Rotate around a key position in the scene to visualize it from all directions. This mode is well-suited to showcase a single location or feature in great detail.
- **Fly-along** = Step along the vertices of a single linear feature as you follow the path. For best results, it is recommended that the linear feature be simplified and flow in one direction.

https://pro.arcgis.com/en/pro-app/latest/help/mapping/animation/animate-the-camera.htm

Several types of camera animations exist. Fly-through navigates smoothly as if following a route. Tour fixates on points of interest with hold keyframes to pause. Fly-around rotates around a key position to visualize from all directions. Fly-along steps along linear features following a path.

Creating Video Fly-Through in ArcGIS Pro

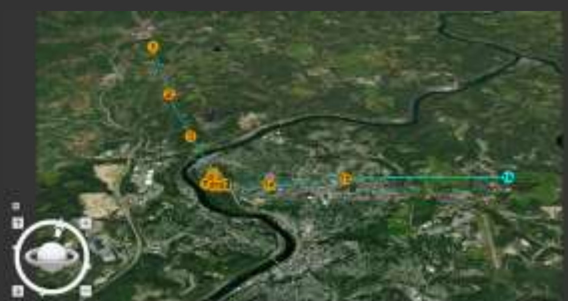
1. Create a Local or Global Scene
2. Go to View Tab
3. Select Add from the Animation section
4. New Animation Tab will load

91

To create video flythroughs in ArcGIS Pro, create a local or global scene. Go to the View Tab and select Add from the Animation section. A new Animation Tab will load where you can set up your animation.

Flight Path

- Add keyframes to control motion
- Keyframes can be added, deleted, updated, and edited

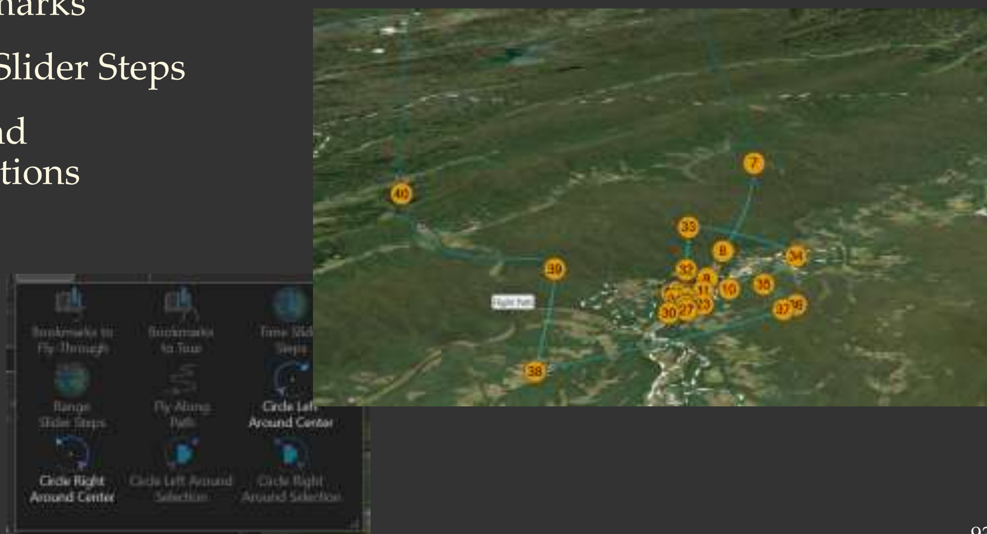


92

Add keyframes to control motion. Keyframes can be added, deleted, updated, and edited. The flight path shows the path between keyframes.

Import Key Frames

- From Bookmarks
- From Time Slider Steps
- Circle around objects/selections

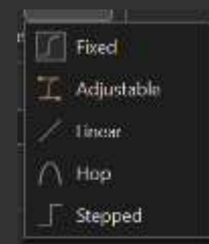


93

Import keyframes from bookmarks, time slider steps, or by circling around objects or selections. This provides quick ways to set up keyframes.

Interpolation between Keyframes

Fixed	Create a path with smooth, tightly controlled turns between keyframes. This is the default type for camera navigation.
Adjustable	Create a configurable curved path between two keyframes. This method uses a Bezier curve with adjustable control points.
Linear	Create a straight path between keyframes. This is the default type for layer transparency, time, and range properties.
Hop	Create a path with configurable bounces between keyframes.
Stepped	Create a path that cuts between keyframes. This is the default type for time or range properties that are



https://pro.arcgis.com/en/pro-app/latest/help/mapping/animation/essential-terminology-list-for-animation.htm

https://pro.arcgis.com/en/pro-app/latest/help/mapping/animation/animation-transitions.htm

94

Interpolation between keyframes affects the path and motion. Fixed creates smooth, tightly controlled turns. Adjustable creates configurable curved paths using Bézier curves. Linear creates straight paths. Hop creates bouncing paths. Stepped cuts between keyframes.

Properties at each Keyframe

❖ Can augment camera properties

95

You can augment camera properties at each keyframe, controlling not just position but also camera settings like focal length and depth of field.

Overlays

- Text
- Images
- Logos

96

Overlays add text, images, and logos to your video. Overlays provide context and branding.

Export

- ❖Often slow to render
- ❖Best settings generally depend on use case
- ❖Things to consider:
  - File type
  - Frame rate
  - Range of frames to render
  - Resolution
  - Quality

97

Animations often render slowly, and best settings depend on the use case. It is important to consider file type, frame rate, range of frames, resolution, and quality settings.

Interactive, Virtual, and Augmented Reality

Unity

- Cross-platform game engine
- Released in 2005
- Indie game development
- 2D and 3D game development
- Interactive simulation development

Unity

https://unity.com/

99

Interaction and moving within a 3D environment is often achieved using gaming engines. Unity is a commonly used gaming engine.

Unreal Engine

- Game engine
- Developed by Epic Games
- Used for 2D and 3D game development, film and cinema, and VR/AR development

https://www.unrealengine.com/

100

Unreal Engine is another commonly used gaming engine.

Cesium

- Cesium Ion: store 3D tiles
- Cesium for Unity: integration with Unity engine
- Cesium for Unreal: integration with Unreal engine
- CesiumJS: JavaScript library for creating 3D web scenes

https://cesium.com/

101

The Cesium products are used to represent 3D data on the web. Cesium Ion allows you to store 3D tiles on the web for use in applications. Cesium has been integrated into Unity (Cesium for Unity) and Unreal Engine (Cesium for Unreal). CesiumJS supports the creation of 3D web scenes displayed in view port on a web page.

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.