Geospatial Problem Solving

Digitizing, Georeferencing, and Resampling

Image from NASA:
https://commons.wikimedia.org/wiki/File:Earth_Western_Hemisphere_transparent_background.png#filelinks

This module will explore some means by which we create and prepare geospatial data with a focus on digitizing, georeferencing, and resampling.

Module Topics

1. Creating new files and digitizing
2. Georeferencing process
3. Georeferencing algorithms
4. Georeferencing assessment with RMSE
5. Resampling methods
6. Pixel aggregation

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These are the topics covered in this module.

Ways to Create New Spatial Data

1. Field collection with GNSS
2. Collecting and georeferencing sensor-based data
   - Aerial imagery
   - Satellite imagery
   - Radar
   - LiDAR
3. Scanning and georeferencing paper maps
4. Heads-up digitizing
5. Automated extraction of features
   - Unsupervised classification
   - Supervised classification
   - Feature extraction

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Remote sensing and global navigation satellite systems (GNSS) are important data sources for GIS analysis. These methods will not be discussed here since they are discussed in other modules or courses.

Digitizing

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Digitizing Steps

1. Obtain input imagery or reference data
2. Create a new file to edit into
   - Define geometry (point, lines, or polygon)
   - Define projection
   - Create fields
3. Create attribute columns
4. Draw
5. Edit attribute information
6. Check and validate your results

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Before beginning to digitize, you will need to obtain some input imagery or other reference data.

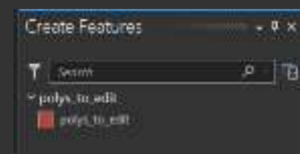
You will then need to create a new shapefile or feature class to draw into. This will require defining the geometry (point, line, or polygon), setting the projection or coordinate reference system, and creating any required attribute fields.

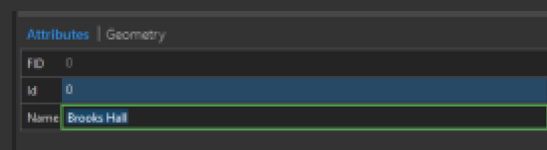
You can then draw the new features using the reference data. You will also need to edit the attribute table.

It is always important to validate your results for quality control purposes.

Digitizing in ArcGIS Pro

- Use Edit tab
- Remember to consider topology
- Remember to edit attributes
- Save often!!!!!!!





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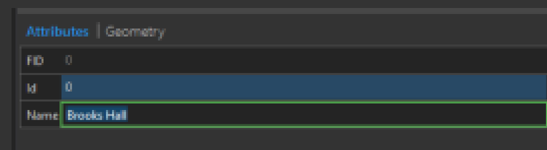
Digitizing options are available in the Edit tab.

As you edit the geometry and attributes, remember to save often so you don't lose any work.

Adding Fields

- Make sure to define the correct type



Data Type	Description
Short Integer	Integer values between -32,768 and 32,767
Long Integer	Integer values between -2,147,483,648 and 2,147,483,647
Float	Decimal values with 1-6 decimal places
Double	Decimal values with more the 6 decimal places
Text	Text strings
Date	Data info (mm/dd/yyyy)

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When creating a new field, you will need to define the field type.

Short and long integer fields can only store integer or whole number values. Long integers can store a wider range of numbers than short integers.

If you need to maintain decimal values, you cannot use a short or long integer. Instead, you must use a float or double type. Float fields can store up to 6 decimal places while double can store more than 6.

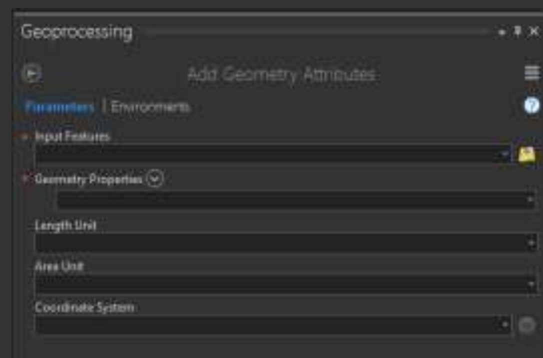
If you would like to store text or string data, you will do so in a text field. Note that numbers stored in a text field will be treated like strings. They will not be treated like numbers. For example, you will not be able to perform mathematical operations on these data.

Date fields store dates and will treat the information as dates.

Add Geometric Fields

❖Use Add Geometry Attributes Tool

Points	Lines	Polygons
X-coordinate	Start-X	Area
Y-coordinate	Start-Y	Perimeter
Z-coordinate (if z-enabled)	End-X	Centroid-X
M-coordinate (if m-enabled)	End-Y	Centroid-Y
	Mid-X	
	Mid-Y	
	Length	
	Bearing	



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Different geometric measures can be calculated and stored in the attribute table for points, lines, and polygon data.

For point data, it is possible to store the x and y coordinate. If the feature is Z-enabled, or contains elevation or height information, this value can also be calculated. If it is M-enable, the M coordinate can be calculated. M-coordinates generally relate to positions along a network.

For lines, you can calculate the x and y coordinates for the start, end, and middle of the line segment. You can also calculate the length and bearing. The bearing is the compass direction of the line and is defined as the direction of travel from the start to the end node.

For polygons, you can calculate the area and perimeter. The perimeter is the length of all the lines that make up the polygon. You can also calculate the centroid, or geometric center, coordinates. Note that centroid coordinates can sometimes be misleading. For example, for irregular or elongated shapes, the centroid may not actually occur within the polygon. For a "C" shaped feature, the centroid would occur somewhere in the middle of the "C" as opposed to within the area that makes it up. So, be careful when using centroid measures.

Impacts on Digitizing Accuracy/Precision

1. User skill, precision, and patience
2. Ease of human interpretation
3. Precision of equipment
4. Quality of reference layers
5. Etc.

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Digitizing quality can be impacted by user skill, precision, and patience.

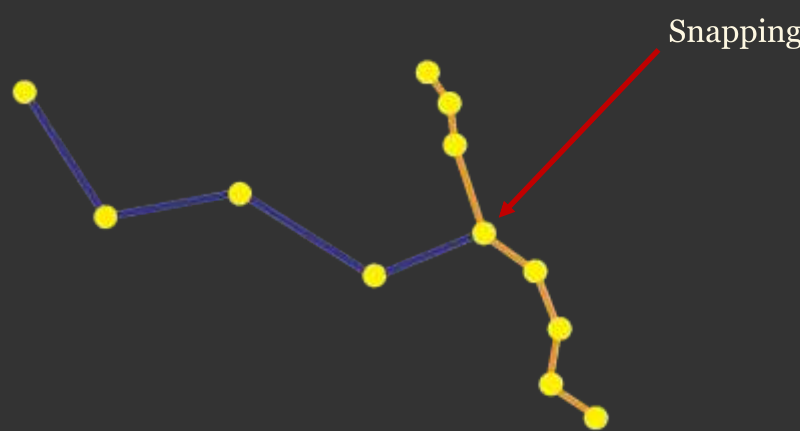
Some features are more difficult to photo interpret than others. For example, wetlands generally are more difficult to map than the location of homes and other manmade structures.

The precision of the equipment and the quality of the reference layers can also impact the product.

If the accuracy and precision of your drawn data are of importance, it is a good idea to incorporate quality control/quality assurance methods into your workflow.

Snapping

❖Causes/forces vertices to match up



If topology is important, snapping can be enabled. This will force line segments to connect if they are within a defined tolerance distance.This can be very useful for drawing road networks and other features in which topology is important.

Georeferencing

Georeferencing

❖ Process of aligning an unreferenced dataset with one that has spatial reference information

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Georeferencing is the process of aligning an unreferenced dataset with one that has spatial reference information.

As an example, you may want to use a paper map in your GIS. In order to use it effectively with other data layers, it will need to be referenced to the correct location in the map space. So, you will need to create a digital data file then apply a process to align it to other data layers in the map space. This is the process of georeferencing.

When aerial or satellite imagery are collected, they also need to be referenced to the correct location in the map space. So, this is a common preparatory task when working with spatial data.

Many GIS and remote sensing software packages provide georeferencing tools.

Scanning

Convert analog map to digital raster data

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Prior to georeferencing, analog data, such as paper maps, will need to be scanned into a computer to generate a digital raster-based file.

Scanning

- Convert analog map to digital raster data
- Resolution and quality depends on dots per inch (dpi)
- Can be converted back to vector data via tracing

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The quality of the scanned raster image will partially depend on the quality of the analog data. However, the scanning settings can also have an impact, such as the dpi used. Make sure that you use adequate settings to scan in quality data.

Once data have been scanned in and georeferenced, vector data can be generated by digitizing or tracing over the map data.

Control Points

- Used to register dataset to known location

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Control points are an important component of the georeferencing process.

Control points are used as reference and represent the same location in the data being referenced and reference data.

Control points can be created by digitizing examples on the screen.

Whenever aerial imagery is collected, it is common for ground control points to be placed on the ground prior to the data collection. These ground targets are surveyed using GPS equipment. An analyst can then use the ground targets in the image and their associated coordinates to georeference the data. This method generally produces quality results. However, this is only possible if control points can be placed in the image prior to the data collection.

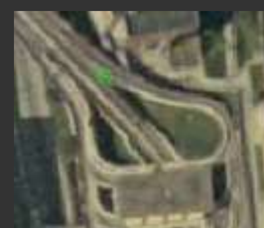
The user may also capture GPS coordinates at locations on the ground that can be easily found in the collected images, such as sidewalk crossings.

We are often forced to create control points on the computer screen and georeference our data relative to a dataset that has already been referenced, such as aerial imagery.

Control Points

Criteria for control points

1. Spread evenly around study area
2. Enough points to use the algorithm of choice
3. Use highest accuracy dataset possible
4. Use locations identifiable on both datasets (known & unknown)



- ❖ From Point = location on the data being referenced
- ❖ To Point = same location on the reference data

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Collecting quality control points is key for successful georeferencing. Here are some suggestions for collecting quality control points.

First, the control points should be spread evenly around the study area. If the control points are only collected within the center of the image, the algorithm used will have a difficult time accurately referencing the margins of the image. So, make sure to include some points in the image margins.

You should have enough points to use the georeferencing algorithm of choice. The number of points needed depends on the algorithm, which we will discuss later.

Any positional errors in the input data will impact the georeferencing result. So, it is important to use quality reference data. Generally, we rely on high resolution imagery.

Locations must be identifiable in both datasets, the data being referenced and the reference imagery.

Generally, I try to obtain as many quality reference points as possible. However, adding more points that may be suboptimal can cause issues. So, make sure the points that you use can be accurately located in both images.

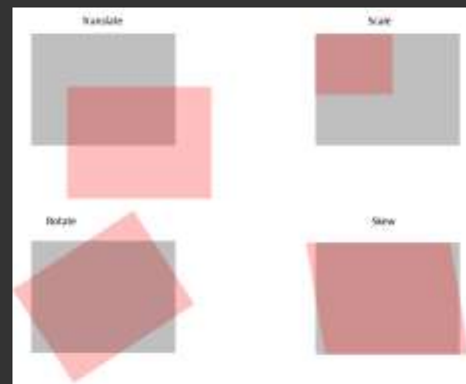
Adding points that are of low quality can decrease the quality of the result.

When defining a control point, you will need to identify it in both datasets. The From Point is the location on the data being referenced while the To Point is the location relative to the reference data. The algorithm will attempt to move the From Point location to the To Point location.

Transforming the Data

In order to georeferenced data, it may need to be:

- Translate
- Scale
- Rotate
- Skew



These transformations are applied mathematically.

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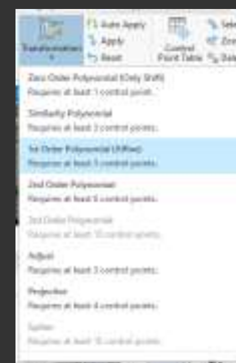
When performing georeferencing different transformations can be applied. Translation implies moving the image without changing its shape or size. Changing the scale means to change the size of the image but not the shape. Rotation will reorient the scene relative to a point of rotation. Skew is used to change or distort the shape of the data.

The transformations that can be applied depends on the algorithm used.

Transformation Methods

- Zero-Order Polynomial = just translate the data (need 1 control point)
- First-Order Polynomial = translate, scale, and rotate (need 3 control points)
- Higher Order = more complex distortions can be corrected
  - Rarely use higher than third order
  - Need more control points
  - If raster dataset must be bent or curved, use a second- or third-order transformation



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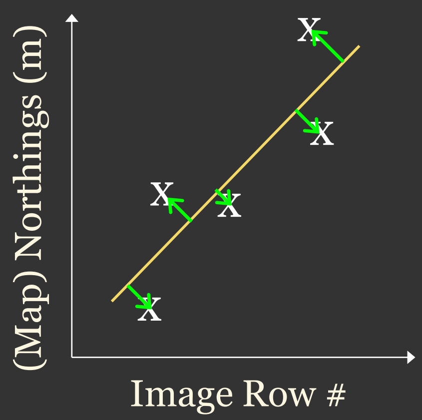
Polynomial equations can be used for georeferencing.

Zero-order polynomials can only shift or translate the image and require only a single control point.

First-order polynomials can translate, scale, and rotate the data. However, they cannot change the shape or skew the image. Three control points are required.

Higher order polynomials can apply all four distortions and require more than three control points. We rarely use higher than third-order polynomials for georeferencing.

First-Order Polynomial (Affine)



$X = Ax + By + C$
$Y = Dx + Ey + F$

X = new *x* coordinate
Y = new *y* coordinate
x = original *x* coordinate
y = original *y* coordinate

Example by Dr. Tim Warner

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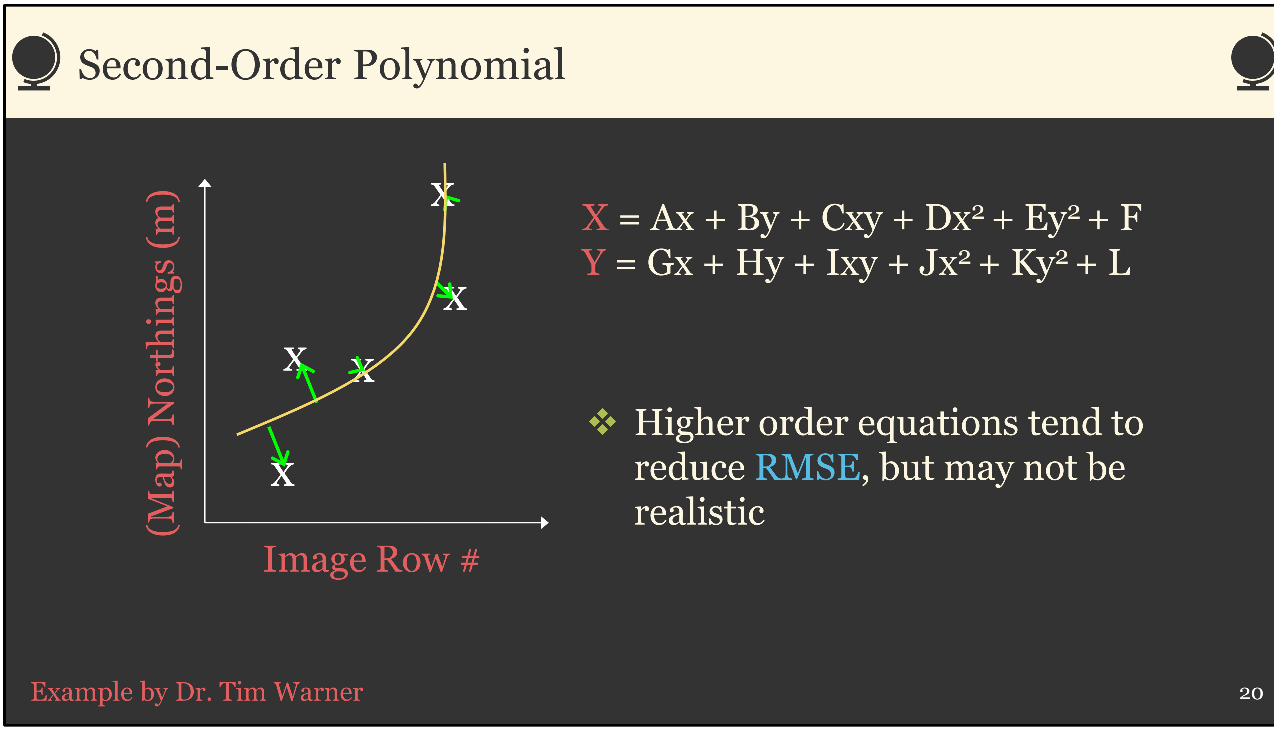
This slide provides an example of a first-order polynomial, also called an affine transformation.

Here, the new X and Y coordinates are predicted using the original x, and y coordinates. Note that both coordinates are used to predict each of the new coordinates.

The goal here is to determine appropriate coefficients to transform the data. Note that x and y are not raised to a power, as this is only first-order, so no square or cubed terms can be used.

The A term and D terms relate to changing the scale in the x and y directions, respectively. The B and E terms relate to rotation, and the C and F terms relate to translation. Again, this method does not allow for a skew to be applied.

The terms are determined using the control points and a fitting method.

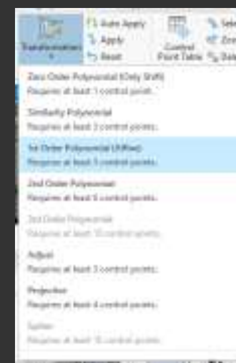


This slide shows that, as you increase the order of the equation (which determines how complex the line fitting can be – i.e. the higher the order, the more bends in the line), you automatically have the potential for less reported error (which is proportional to the green arrow length). However, it is not necessarily true that this is a more accurate representation. Note in particular that for extrapolations outside the rows/columns selected for the ground control points, very strange things can happen (as shown in this example – a high row number might map to an almost infinitely large northing!)

Note that the equations now includes square or second order terms and that a total of 12 coefficients must be learned. A second-order polynomial is capable of translation, scaling, rotation, and skewing the data.

Transformation Methods

4. Adjust = combines polynomial and triangular irregular network (need 3 control point)
5. Similarity = first order transformation which tries to preserve the shape of the original raster (need 3 control points)
6. Projective = commonly used for image data (need 4 control points)
7. Spline = uses rubber sheeting (need 10 control points)



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Other methods are available that do not rely on or solely rely on polynomial equations. This slide provides some examples. Again, different methods require different numbers of control points. The optimal method will depend on the data being referenced, the control points used, and the required transformations.

How do we assess the quality of our georeferenced result?

Root mean square error (RMSE)

$$RMSE_x = \sqrt{\Sigma(x_{predicted} - x_{actual})^2/n}$$

$$RMSE_y = \sqrt{\Sigma(y_{predicted} - y_{actual})^2/n}$$

$$RMSE = \sqrt{(RMSE_x{}^2 + RMSE_y{}^2)}$$

- Measure of how well the now-referenced data matches with the source
- Obtained by comparing the known location of the control point with the computed coordinates of the control point.

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Georeferencing is generally assessed using the root mean square error, or RMSE, statistic.

This measure provides an assessment of how well the now referenced data matches the source or reference image.

It is generally calculated by comparing the known location of the control point with the computed coordinates of the control point.

The predicted x and y coordinates are subtracted from the correct location to obtain a residual or error. The residuals are then squared, summed, then divided by the number of samples. Lastly, the square root is taken. This will provide an RMSE for the x and y directions. These measures can then be combined to obtain a total RMSE.

RMSE will be reported in the map units or as number of pixels. Lower RMSE is better.

How do we assess the quality of our georeferenced result?

Correct X	Correct Y	Predicted X	Predicted Y	X residual	Y residual	X residual squared	Y residual squared
513,126.80	4,101,294.60	513,127.30	4,101,293.40	0.5000	-1.2000	0.2500	1.4400
513,123.20	4,101,303.40	513,118.10	4,101,302.10	-5.1000	-1.3000	26.0100	1.6900
513,203.80	4,101,209.10	513,203.10	4,101,207.20	-0.7000	-1.9000	0.4900	3.6100
513,182.60	4,101,377.80	513,181.60	4,101,379.90	-1.0000	2.1000	1.0000	4.4100
513,217.60	4,101,403.60	513,216.10	4,101,405.20	-1.5000	1.6000	2.2500	2.5600
						RMSE X	2.45
						RMSE Y	1.66
						RMSE	2.96

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This slide provides an example RMSE calculation.

The correct and predicted x and y coordinates are differenced to obtain a residual. The residuals are then squared, summed, then divided by the number of samples. The last step is to take the square root. Once the RMSE is obtained in the x and y directions, they can be combined to obtain a total RMSE.

In this example, the total RMSE is 2.96 meters. This suggest that each pixel is, on average, 2.96 meters from its correct location.

What is considered an acceptable RMSE? This depends on many factors. For example, coarser spatial resolution data will tend to have a larger RMSE than fine spatial resolution data as the larger pixel or cell size will result in some spatial ambiguity. For imagery, our goal is generally to obtain an RMSE that is smaller than the dimensions of a pixel or cell.

Some mapping tasks may require better georeferencing results than others. There will always be some georeferencing or positional error in your data.

RMSE Interpretation

- The residuals is the difference between the predicted x and y coordinates and the actual coordinates, as specified with the control point
- Low RMSE can be misleading if the quality of the control points is poor
- Sometimes the algorithm overfits to the control points, so the RMSE can be misleading
- For imagery, we generally want the RMSE to be lower than the size of the pixel

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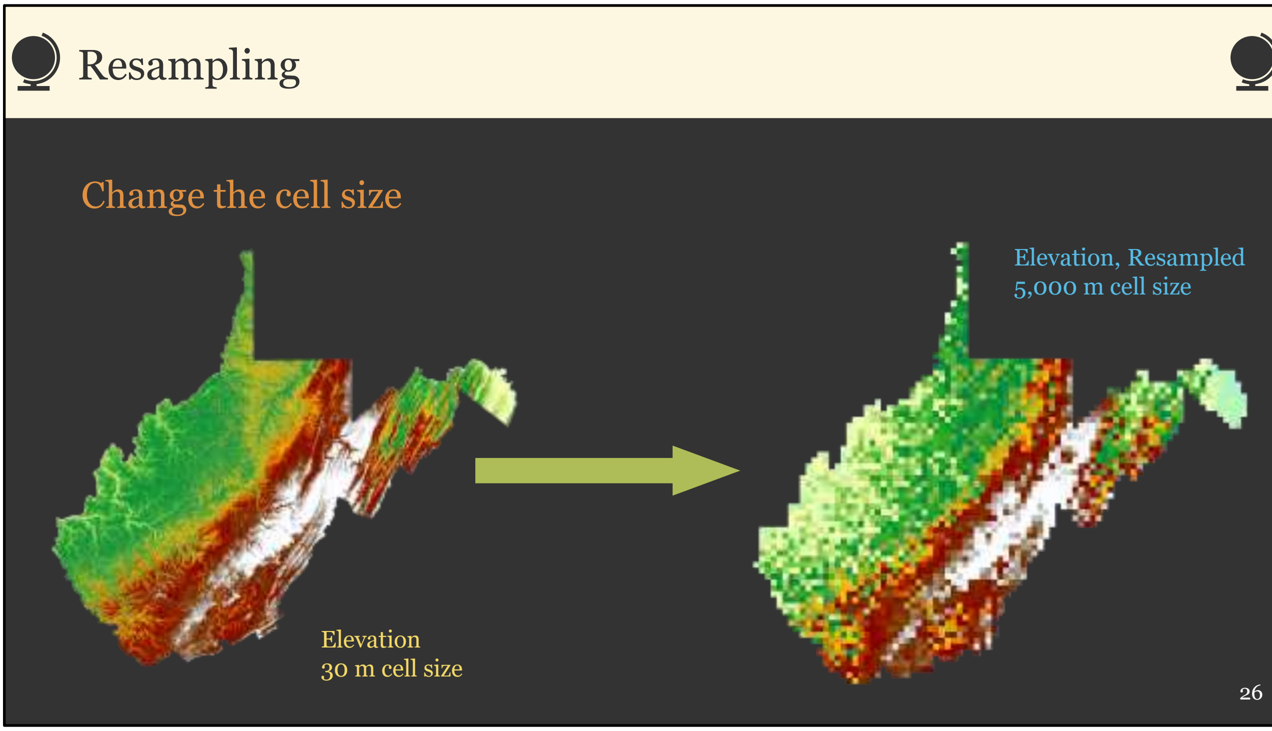
Here are some other notes regarding interpreting RMSE. Note that RMSE can be misleading if the quality of the control points is suspect or poor. Also, algorithms commonly overfit to the control points. So, if control points are used to calculate RMSE, the accuracy can be inflated. It is best to withhold data points and calculate RMSE relative to these new locations.

Resampling



Resampling is used to change the cell size of raster data. Generally, cells are made larger, or the data are coarsened, since making the cells smaller will not really add information but will just duplicate existing values. You can't increase the detail by simply resampling a coarser dataset to a finer spatial resolution.

You may resample raster data to make it easier to process over large extents or to change the cell size to match other inputs in an analysis.

We will now explore methods used to resample raster data.

Resampling Methods: Majority

- Majority Resampling
- Resamples using the most common cell value
- Good for categorical data

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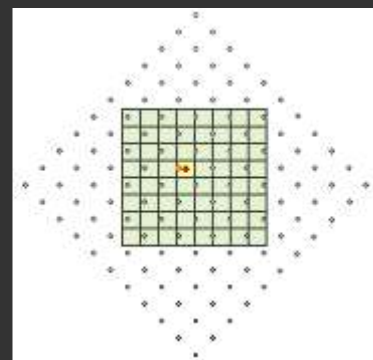
Majority resampling will assign the most common cell value of the original cells that fall within the new cell to the new cell.

This method is not generally used for continuous data. It is more commonly used for categorical data.

For example, if a land cover categorical raster grid was resampled using this method, each new cell would be assigned the majority land cover class from the smaller original cells that fall inside of it.

Resampling Methods: Nearest Neighbor

- Nearest Neighbor
- New value will be the value of the original cell closest to the center of the new (larger) cell
- Good for categorical data



http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm

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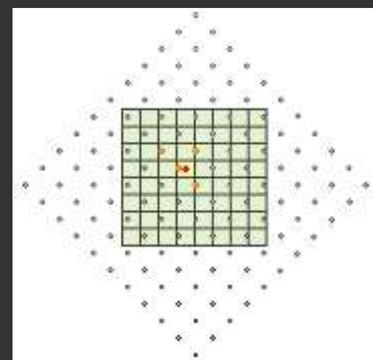
Nearest neighbor resampling assigns the closest cell value from the original raster grid to the new cell.

No averaging is performed, so this method can be used to resample both categorical and continuous data.

Resampling Methods: Bilinear Interpolation

- Bilinear Interpolation
- Uses the inverse distance-weighted average of the four nearest pixel values to estimate a new pixel value
- The four cell centers from the input raster that are closest to the cell center for the output processing cell will be weighted based on inverse distance and then averaged
- Good for continuous data
- Creates a smoothed surface



http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm

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Bilinear interpolation uses the inverse distance-weighted average of the four nearest pixel values in the original grid to estimate the new cell value.

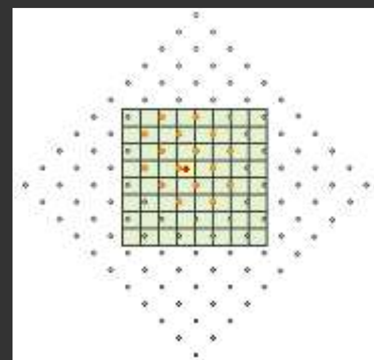
The four cell centers from the input raster that are closest to the cell center for the output processing cell will be weighted based on inverse distance and then averaged. So, nearer cells will have a larger weight in the calculation than cells that are further away.

Since averaging is performed, this method is not appropriate for categorical data. However, it can be used for continuous data.

This method tends to smooth the image or raster data.

Resampling Methods: Cubic Convolution

- Cubic Convolution
- Similar to bilinear interpolation, except the 16 nearest input cell centers and their values are used
- Tends to sharpen edges
- Good for continuous data



http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm

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Cubic convolution is similar to bilinear interpolation except that the nearest 16 cells are used as opposed to the nearest 4. Since it makes use of averaging, it is also not appropriate for categorical data but can be used for continuous data.

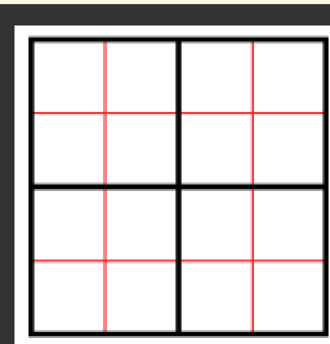
This method tends to sharpen edges more than bilinear interpolation.

Bilinear interpolation and cubic convolution are both commonly used to resample image data.

Bilinear interpolation tends to smooth raster data because each output cell is calculated as a weighted average of the four nearest input cells. This averaging reduces abrupt local variation and pulls extreme values toward surrounding values. Cubic convolution uses a larger neighborhood of cells and fits a curved surface through the nearby values, allowing it to better preserve local gradients and detail. As a result, bilinear interpolation often produces a smoother output, while cubic convolution often produces a sharper-looking output, although it may introduce slight overshoot or values outside the original data range.

Pixel Aggregation

- Generates a reduced-resolution version of a raster grid
- Each output cell contains the Sum, Minimum, Maximum, Mean, or Median of the input cells that are encompassed by the extent of that cell



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Another option to change the cell size is to use pixel aggregation. This is also sometimes referred to as image degradation.

When using this method, a statistic from the cells that fall within the new larger cell is calculated and returned to the new cell.

Examples include sum, minimum, maximum, mean, or median.

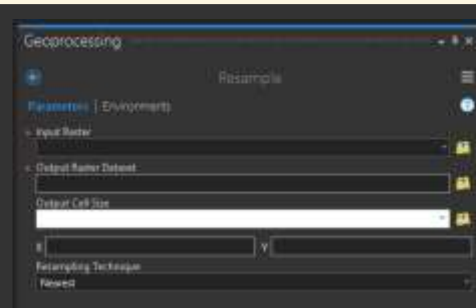
The raster data can only be reduced in spatial resolution in such a manner that a whole number of input cells will fall perfectly within a new cell. For example, a 2-by-2 meter raster grid could be converted to a 4-by-4 meter grid but not a 3-by-3 meter output.

This method can be used for both categorical and continuous data depending on the statistic returned.

Resampling in ArcGIS Pro

❖A good resource:

http://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/performing-analysis/cell-size-and-resampling-in-analysis.htm



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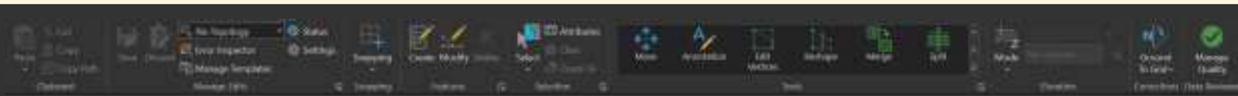
If you would like to read more about resampling, check out this ESRI link. Note that resampling is made available in a variety of GIS and remote sensing software packages.

Digitizing, Georeferencing, and Resampling In ArcGIS

Editing Tab



- Create, Modify, Delete
- Topology Rules
- Snapping Rules
- Editing Tools
- Save/Discard

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The Editing tab provides tools and options for digitizing new features in ArcGIS Pro.

Editing Tools

- Move
- Annotate
- Edit Vertices
- Reshape
- Merge
- Split
- Rotate
- Scale
- Transform
- Align Features
- Move To
- Replace Geometry
- Generalize
- Clip
- Explode
- Divide
- Buffer
- Mirror

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A variety of tools are available for editing data that have already been drawn.

Create New Layer

- Geoprocessing → Data Management → Create Feature Class
- Creates a feature class if saved to a geodatabase
- Creates a shapefile if saved to a folder
- Specify
  - Geometry
  - Coordinate Reference System

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Before creating new features, you will need to create a new layer to draw into. The Create Feature Class tool can be used to create a new feature class in a file geodatabase or a shapefile outside of a geodatabase. You will need to define the geometry type and datum/projection for the layer.

Digitizing Steps

1. Obtain input imagery or reference data
2. Create a new file to edit into
   - Define geometry (point, lines, or polygon)
   - Define projection
   - Create fields
3. Create attribute columns
4. Draw
5. Edit attribute information
6. Check and validate your results

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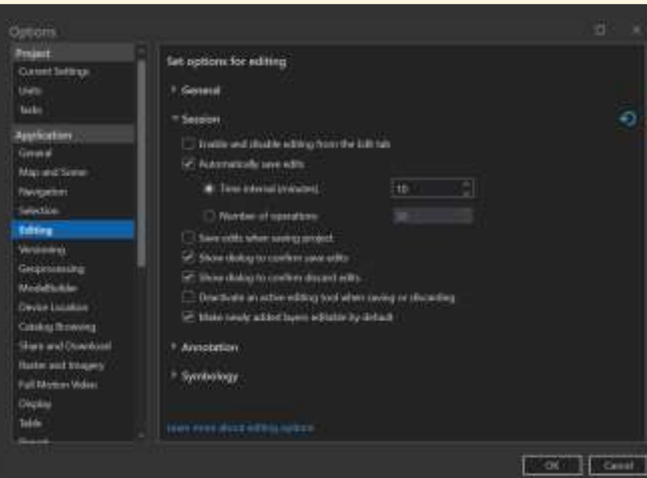
Before beginning to digitize, you will need to obtain some input imagery or other reference data.

You will then need to create a new shapefile or feature class to draw into. This will require defining the geometry (point, line, or polygon), setting the projection or coordinate reference system, and creating any required attribute fields.

You can then draw the new features using the reference data. You will also need to edit the attribute table.

It is always important to validate your results for quality control purposes.

Turn On Auto Saving



❖ Project → Options → Editing → Automatically save edits

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You can turn on auto saving during editing under Project tab → Options → Editing. I highly recommend turning on auto save since a software crash can cause you to lose unsaved work.

Create New Feature Class

1. Choose one of the drone images that you would like to digitize features from and navigate to the associate map. (either the digitize1, digitize2, or digitize 3 map). Choose a type of feature that you would like to digitize in the map extent as polygon features (buildings, trees, vehicles, athletic fields, ponds, etc.).
2. Navigate to the Analysis Tab and click on the Tools icon to open the Geoprocessing Pane. Search for the Create Feature Class Tool (Data Management Tools → Feature Class → Create Feature Class)
3. Create a new feature class with a polygon geometry. Make sure to use the same projection as the reference drone image.

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The following exercises ask you digitize new features over drone data.

Add Attributes

1. Once your new feature class is created and loaded into the map, right-click on it is the Contents Pane and select Attribute Table. This will open a view of the attribute table.
2. Use the Add button in the attribute table to add at least two fields to the table. Make sure to use an appropriate field type and set an alias name.

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Digitize Features

1. Edit the polygon layer symbology to make it easier to edit. We recommend using a hollow symbol with an easy to see outline color that contrasts well with the background.

2. Navigate to the Edit Tab and click the <u>Create</u> icon. This will open the Create Features Pane.

3. Draw a few example features.

4. Edit the associated attributes (this can be accomplished using the Attributes Pane available in the <u>Selection</u> section of the Edit Tab.

5. Make sure to save your edits. This can be accomplished by clicking the <u>Save</u> icon in the Edit Tab.

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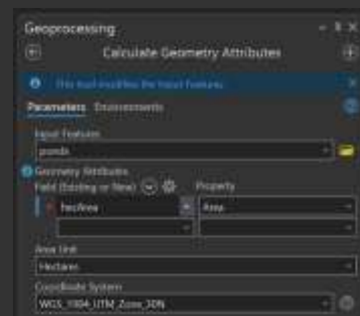
Calculate Geometry Attributes

1. In the Analysis Tab, click on the <u>Tools</u> icon to open the Geoprocessing Pane.
2. In the Geoprocessing Pane, search for the Calculate Geometry Attributes Tool (Data Management Tools → Features → Calculate Geometry Attributes)
3. Configure the tool as follows:
   - **Input Features** = your polygon layer
   - **Geometry Attributes**
     - **Field** = *hecArea*
     - **Property** = *Area*
   - **Area Unit** = *Hectares*
   - **Coordinate System** = *should be same as the layer*
   - Click <u>Run</u> to execute the tool.

A new field should be added to your polygon layer that provides the land area of the features in hectares. You can check by opening the attribute table.



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Georeferencing

❖ Process of aligning an unreferenced dataset with one that has spatial reference information

Available under Imagery Tab

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Georeferencing options/tools are provided under the Georeferencing tab. This tab can be instantiated by selecting Georeference under the Imagery tab when a raster layer is selected in the Contents pane.

Load Unreferenced Image

1. Navigate to the georef map and the Map Tab.
2. Click the Add Data icon. Add the venice2.jpg image from the rawFiles folder. The added layer does not have a spatial, so a warning message is provided. It will not draw at the correct location.

3. Make sure the venice2.jpg image is selected in the Contents Pane and navigate to the Imagery Tab.
4. Click on the Georeference icon in the Imagery Tab. This will load the Georeference Tab.

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The following exercises step you through the georeferencing process.

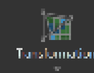
Add Control Points

1. Use the Add Control Points icon to add control points. You first need to find a location that is obvious in both the venice2.jpg image and the reference base map imagery. Select the location on the venice2.jpg layer first followed by the associated point in the reference data. You can navigate between the layers using Zoom to Layer and the map navigation options. It is also helpful to turn the venice2.jpg layer off as needed.

2. Collect at least 5 control point pairs. Try to spread them out over the extent of the image you are georeferencing. If you need to delete control point(s), you can open the control point table using the Control Point Table icon in the Gereferencing Tab. A delete button is provided in the table.

Save Georeferencing Result

1. Once you are done collecting control points, navigate to the Georeferencing Tab and select the Transformation icon. Make sure the transformation type is set to First Order Polynomial (Affine).



2. Click on the Save as New icon in the Georeferencing Tab. This will launch the Export Raster Tool. Name the output raster and click Export to save the georeferenced version of the historic image. The new georeferened layer should be added to the georef map.

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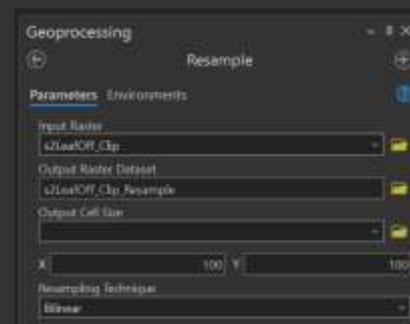
Resample Raster Grid

1. Navigate to the rasterSummarize map.
2. use the Resample Tool to coarsen the clipped version of the s2LeafOff layer to a 100 m spatial resolution using the following settings:
   - **Input Raster** = s3LeafOff (clipped version)
   - **Ouput Cell Size** = *100 m*
   - **Resampling Technique** = *Bilinear*



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This exercise asks you to resample multispectral imagery.

Digitizing, Georeferencing, and Resampling In QGIS

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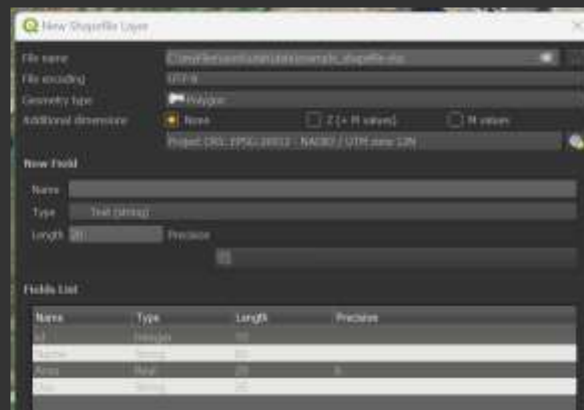
Digitizing: Create New Layer

- Layer → Create Layer
- Settings vary by file type
- Considerations
  - Geometry type
  - Z values
  - M values
  - Coordinate reference system
  - Fields
  - Field types
  - Field settings



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In QGIS, a new layer can be created under the Layer menu. Different options are available for different file types.

Digitizing: Draw New Feature

- Right-click layer
- Toggle Editing
- Left-click to add vertices
- Right-click to close feature
- Fill out attributes
- Click OK
- Save Layer Edits

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This slide describes how to draw new features into a layer.

Digitizing: Edit Existing Features

- Select feature
- Tools
  - Vertex Tool
  - Modify Attributes
  - Delete
  - Cut
  - Paste

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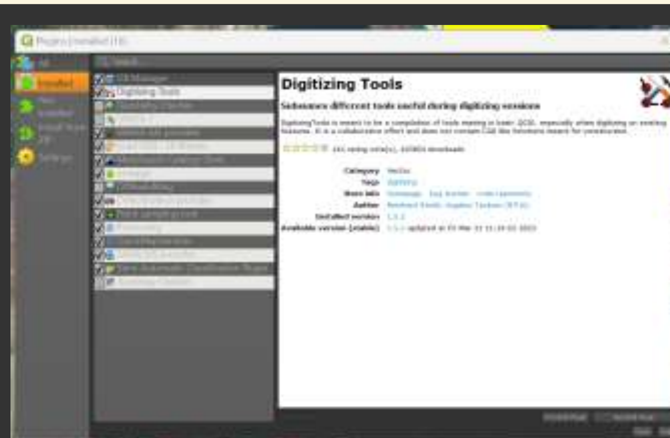
There are also tools available to edit or modify existing features.

Digitizing: Digitizing Tools Plugin

- Split multi-part to single-part
- Split feature
- Merge multiple features
- Copy attributes
- Cut feature with polygon
- Clip feature with polygon
- Donut holes
- Fill gaps



https://github.com/bstroebl/DigitizingTools

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Additional editing tools are provided by the Digitizing Tools plugin.

Digitizing in QGIS 1

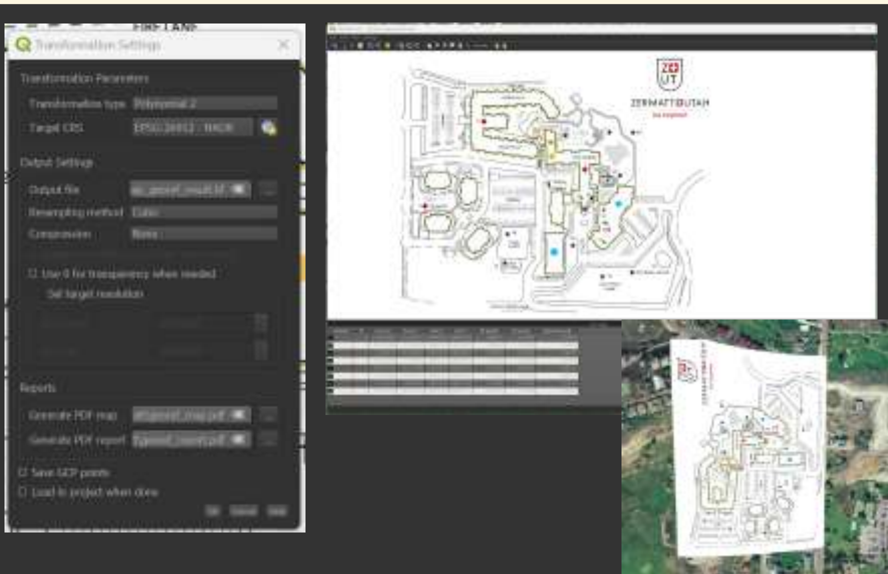
- Use the zermett project.
- Create a new polygon layer
- Add a Name field to the polygon layer (text data type)
- Add a Type Field to the polygon layer (text data type)
- Use the aerial imagery and the Zermatt-Utah-Property-Map.pdf file as a guide to:
  - Digitize the following Buildings: Chateau Villas, Hotel Baer, Matterhorn Conference Center, Bernese Event Center. Include the name of the building and the type ("Hotel" or "Conference") in the attribute table.
  - Digitize the following additional features: tennis courts, sand volleyball, gazebo, carousel. Include the name of the feature and define the type as "Attractions".

These exercises ask you to draw new features and create a map layout of your results.

Digitizing in QGIS 2

- Use the zermett project.
- Create a map layout of your Zermott digitizing results.
- The layout should include the map, a north arrow, a scale bar, a legend, and a title. The legend should differentiate the features by type.
- Make sure the layout uses space effectively and is well defined.
- Export your map as a PDF file.

Georeferencing



- Layer → Georeferencer
- File → Open Raster
- Settings → Transformation Settings
- Collect ground control points
- Start georeferencing
- Can save ground control points

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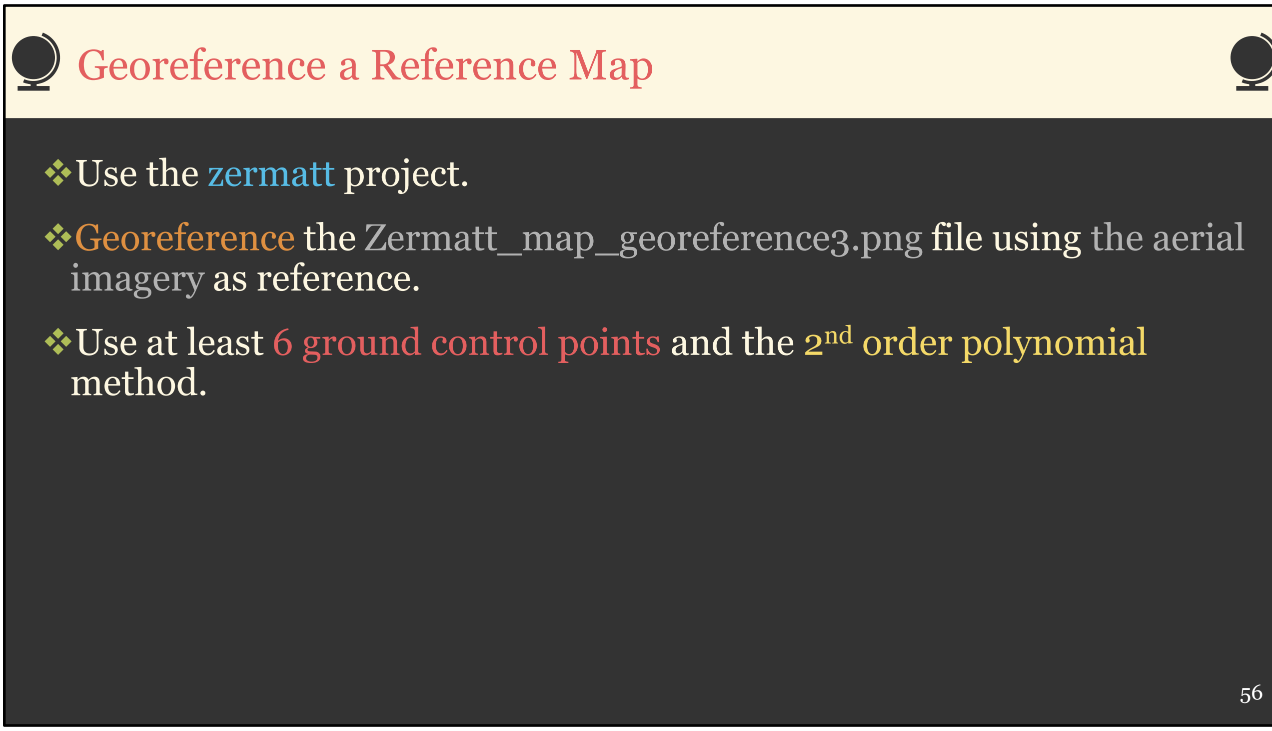
This slide describes how to initialize a georeferencing process in QGIS.



This exercise asks you to georeference a reference map image using QGIS.

Resampling in QGIS

- Processing Toolbox → GRASS → Raster → r.resample
- Processing Toolbox → SAGA → Raster-Tools → Resampling

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In QGIS, raster data can be resampled using several tools. The most common is the Warp/Reproject tool, which can change a raster's coordinate reference system, cell size, extent, and resampling method. The Align Rasters tool is useful when multiple raster grids need to share the same resolution, extent, CRS, and grid alignment. The Translate tool or Export → Save As option can also be used to create a new raster with a different resolution.

Methods are also made available through GRASS and SAGA.

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.