Exercise 4
Compiling a Spatial Database: Georeferencing

Due Dates:
Lab 301/302: October 8, 2018
Lab 303/304: October 9, 2018

(Total of 11 points)

1. Goals

Learning goals:

- Understand the concept of georeferencing
- Be able to georeference an image using two different approaches

For the project:

- Georeference the scanned land use map

The data layers you will be working with are topographic map of Madison with and without coordinates, and the aerial imagery of Dane County. Before you begin the exercise, **copy Lab4Data to a location on your flash drive (e.g. E:\377lab4).**

2. Georeferencing

***"Georeferencing"** (also known as "geo-registering") is the process of assigning **real-world coordinates** (such as UTM) to the points of a map or image with **local arbitrary coordinate system** (such as those of a scanner) (Figure 1). It is often accomplished using **rubber sheeting**. Georeferencing of paper maps using listed coordinates is most common but we will also look at georeferencing of datasets using a reference layer. Once a layer is georeferenced to a known real-world coordinate system (GCS, UTM, etc.) it can be properly displayed with other layers and used for further processing and analysis.*

A local coordinate system is meaningless outside of the person or machine that created it, meaning that local coordinate systems do not represent any real-world spatial location. In this exercise we will georeference a scanned map using two different methods, and then based on the lab you will practice your skills by georeferencing a land use map that will be used in our class project (project will be introduced in Lab 5).

Let's start with georeferencing a scanned topographic map using coordinates listed on the map.

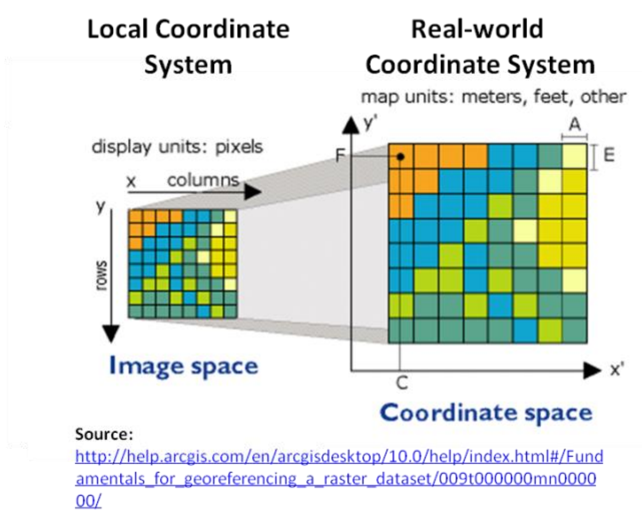


Figure 1. A simple explanation of georeferencing.

Task 1: Georeferencing using coordinates

- Open ArcMap and add ***MadisonTopoMap.tif*** from the Lab4Data folder located on your flash drive. If prompted, create pyramids which help to quickly display raster images. Also ignore the **Unknown Spatial Reference** warning if it pops up. It is the software letting you know that the data you are bringing in does not have a known spatial reference (GCS or PCS).
- Zoom in to the bottom of the map you just added. <u>What is the coordinate system that was used to make this map? Is it a geographic coordinate system or a projected coordinate system?</u>
- Right click on '**Layers**' under the Table Of Content, choose **Properties** and switch to the **Coordinate System** tab. Here we can change the coordinate system of the map document so that we can use the coordinates on the map to georeference it. Make sure you choose the correct coordinate system in <u>Projected Coordinate Systems -> State Plane -> NAD 1983 HARN (US feet) -> NAD 1983 HARN StatePlane Wisconsin South FIPS 4803 (US Feet)</u>.
- Now we have added the map that needs georeferencing and we changed the coordinate system of the map document so that it matches the one used to make the scanned map. We are ready to start georeferencing.
- Click **Customize** → **Toolbars** → **Georeferencing** to bring up the **Georeferencing Toolbar.**

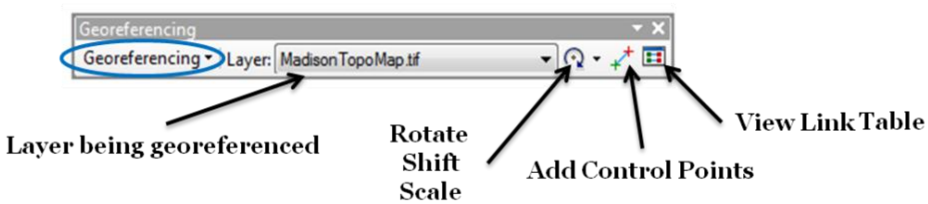


Figure 2. Georeferencing Toolbar.

- Explore the toolbar so that you become more familiar with the buttons and tools (Figure 2). To learn more about Georeferencing Toolbar see http://desktop.arcgis.com/en/arcmap/latest/manage-data/raster-and-images/georeferencing-toolbar-tools.htm
- To register (geo-reference) a map, you need points whose coordinates are known in both coordinate systems (in our case in the State Plane with feet as units) and in the arbitrary, scanner coordinate system (pixels as units). These points are called **control points**. The control points are marked by cross-hair squares and their coordinates in State Plane can be figured out based on the grid on the scanned image.
- Zoom to the top right corner of the scanned Madison map, where we will place the first control point.
- In the **Georeferencing Toolbar** select the **Add Control Points**  tool.
- Left click on the intersection of 2,160,000 feet and 440,000 feet. Once you left click the cross-hair turns green and stays in place. Now right-click and choose **Input X and Y**. Type in 2160000 for X coordinate and 440000 for Y coordinate (Figure 3).

- If you click in the wrong place, you can right click and choose **Cancel Point**.

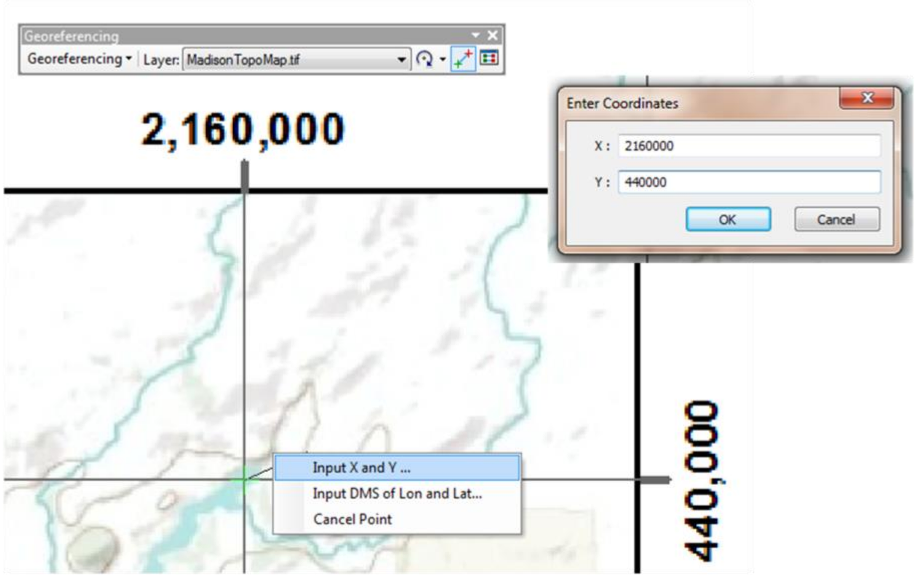


Figure 3. Adding control points.

<u>**Question 1.**</u> When using "**Add Control Points**" tool, describe what the initial left click on the map is providing and what the Input X and Y is accomplishing. (1pt)

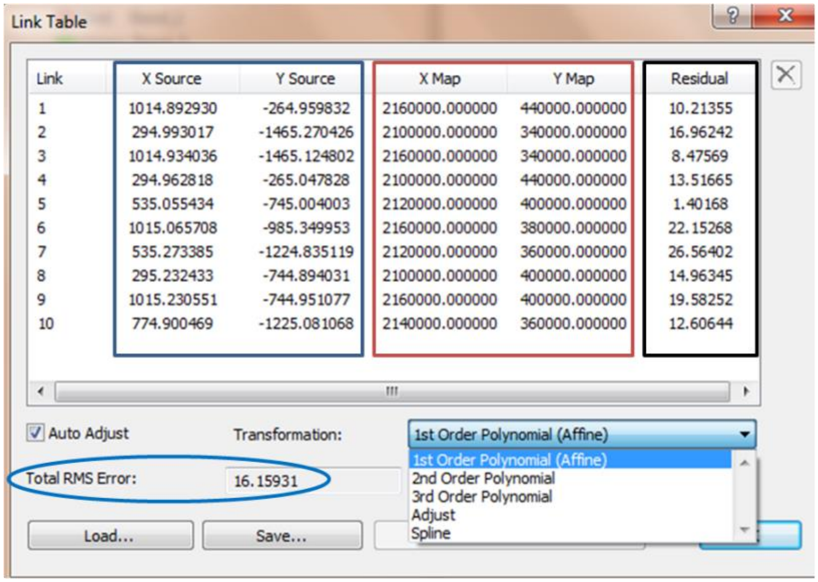
- Click OK. After inputting the first point, you may see that your map has disappeared. In fact, it has just been repositioned based on the coordinates you just entered. To view the map in its entirety, right-click on its name in the TOC and choose **Zoom To Layer** or click **Full Extent**  icon in the Tools toolbar.

Note: Don't quit your work until you finish this whole task. Otherwise, the information you have entered won't be saved!

- Repeat the last two steps for other control points. Use the following **basic rules** for selecting initial **control points**:
  - <u>Use points that are easy to identify</u> such as grid intersections
  - <u>You need at least 6 control points</u> – the number of points will be a balance between cost or time and accuracy
    - The goal for this map is to have **10** control points – this is enough to accurately georeference this map without spending too much time doing it
  - <u>Distribute points evenly on the image</u> – this ensures that the whole map is accurately georeferenced not just a part of it.
    - To distribute points evenly ensure that you have placed reference points roughly in all four quadrants of the map as well as in the center.
- To increase the speed of this process, use the keyboard shortcuts for zooming and panning. They are **Z** (zoom in), **X** (zoom out), and **C** (pan). If you use the **Add Control Points** tool with the mouse, you can toggle between it and the pan and zoom tools using your left hand on the keyboard.
- If you make a mistake typing in a number, your map will become skewed or twisted. Go to **View Link Table**  in the **Georeferencing Toolbar** to delete or edit the problem point.

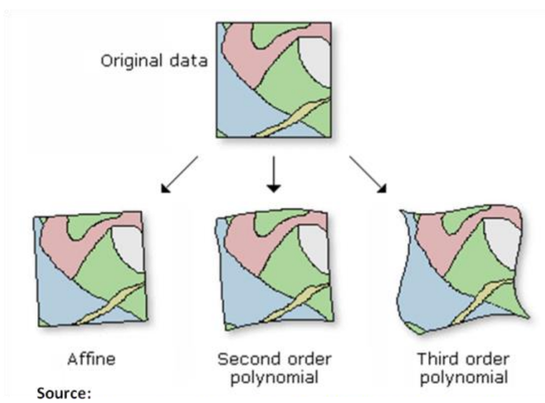
Question 2. Explain what the columns **X Source**, **Y Source** and **X Map**, and **Y Map** in the link table represent. (1pt)

- Once you have 10 control points, in **Georeferencing Toolbar** click the **View Link Table** button and examine the columns (Figure 4).



Link	X Source	Y Source	X Map	Y Map	Residual
1	1014.892930	-264.959832	2160000.000000	440000.000000	10.21355
2	294.993017	-1465.270426	2100000.000000	340000.000000	16.96242
3	1014.934036	-1465.124802	2160000.000000	340000.000000	8.47569
4	294.962818	-265.047828	2100000.000000	440000.000000	13.51665
5	535.055434	-745.004003	2120000.000000	400000.000000	1.40168
6	1015.065708	-985.349953	2160000.000000	380000.000000	22.15268
7	535.273385	-1224.835119	2120000.000000	360000.000000	26.56402
8	295.232433	-744.894031	2100000.000000	400000.000000	14.96345
9	1015.230551	-744.951077	2160000.000000	400000.000000	19.58252
10	774.900469	-1225.081068	2140000.000000	360000.000000	12.60644

Figure 5. Link Table.



Source:
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Fundamentals_for_georeferencing_a_raster_dataset/009t000000mn000000/

Figure 4. Types of transformations.

Question 3. Explain what a **residual** is. What is it a measure of? What measuring unit is it in? Hint: Think about the unit for **X, Y Map** columns. (1pt)

Question 4. When number of control points reaches 4 or more, you get an **RMS Error** measure. Explain why. How is RMS Error related to the number of control points? (0.5pt) Hint: refer to the lecture notes if needed.

Refer to the help documents for more info about georeferencing images, the different types of transformations, etc: http://desktop.arcgis.com/en/arcmap/latest/manage-data/raster-and-images/fundamentals-for-georeferencing-a-raster-dataset.htm

- Check the **Total RMS Error** field in the **Link Table**. If the value in this field is less than 20 feet, then you can go to the next step. Otherwise, delete the control points with highest residuals (amount of error) and add new control points more accurately.
  - There are different types of transformations. Each one minimizes the residual errors differently however each needs a certain amount of control points to work properly. For now, we will stay with **Affine Transformation** which simply scales, shifts and rotates an image to georeference it. Read the help documents for details on the other types of transformation (Figure 5).

Question 5. How are the residuals and the Total RMS Error related? (0.5pt)

- The last step is rectifying your image. Go to **Georeferencing** → **Rectify** in the **Georeferencing Toolbar**. Change the **Output Location** to your Lab4Data folder and rename the file *MadisonTopoMap_georef.tif*. Keep the other fields as default (Figure 6). Click Save.
  - This rectification process determines the relationship between the scanner coordinate system with the State Plane coordinate system through the set of control points.
- Add the georeferenced image to your map document (don't worry if the colors look different than the original map) and check its **Properties**. What is the Spatial Reference of this map?

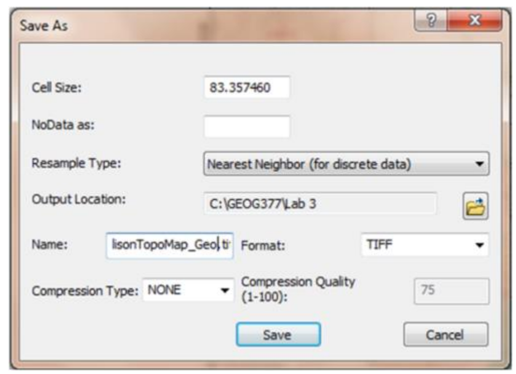


Figure 6. Save As dialog box.

Question 6. In a few sentences explain the *concept* and *process* of georeferencing. (2pt)

Now, let's try a slightly different method. This time instead of using coordinates listed on the map we will use aerial photography as our reference.

Task 2: Georeferencing using a reference layer

- Open a **NEW** map document and add *DaneCounty.sid* image from Lab4\DaneCounty. What is the coordinate system of this image?
  - This is 2010 NAIP (National Agriculture Imagery Program) aerial imagery acquired during growing season.
  - Because this imagery has a spatial reference and is the first file to be added to a new map document, the whole document will now use the coordinate system of this file.
- Add *MadisonTopoMap_nogrid.tif*. Click OK on the **Build Pyramids** window and the **Unknown Spatial Reference** warning. This is the same scanned map we used in Task 1, however this one does not have the State Plane grid with coordinates on it. Is the topo map overlaying the aerial imagery? Why or why not? Think back to lab 3.

- Change the coordinate system of the map document to **match the coordinate system listed on the topo map that was used to create it.** Refer to the 3rd bullet point in Task 1 for the details on how to accomplish this.
- Zoom in to the scanned map and choose a point that you can also easily recognize in an aerial photo, for example Picnic Point on the UW campus, or a major road intersection. Use **Zoom to Layer** (right click on the name of layer) as well as other zooming and panning tools and shortcuts to navigate between the two layers.
- In the **Georeferencing Toolbar** make sure that *MadisonTopoMap_nogrid.tif* is the layer set to be georeferenced. Select the **Add Control Points** tool and left click on the point on the map you choose.
- In this case we can't input x and y because we do not know what they are. Instead zoom to the corresponding point on the aerial photo and click again. Did you notice how your map shifted to the new location, just as it did previously? That is because we just assigned a real-world coordinate to the point on the scanned map.
    - **Note that the first click will always be on the layer that is being georeferenced (source – topo map) and the second on the layer is used for georeferencing (target – aerial)**
- After adding the first control point, your scanned map will shift as in Figure 7. It is the correct geographic space, but only for the one control point.

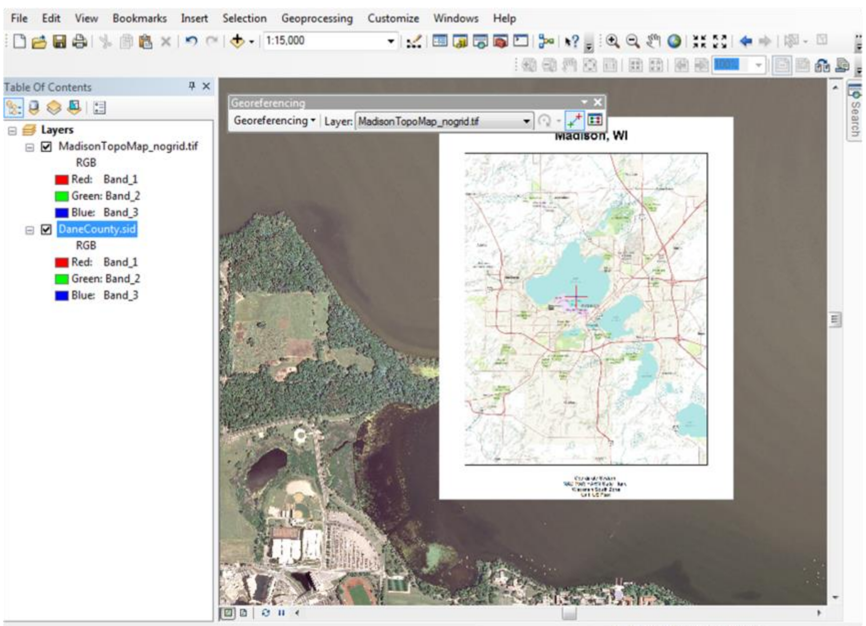


Figure 7. Georeferencing a map to an aerial image.

- Pick at least 9 more points (for 10 control points total) by following the same rules as listed in Task 1. Remember that the first cross-hair should come from the scanned map and the second from the aerial. Once you have at least two points, the scanned map will cover the aerial underneath it so you'll need to turn the layers in the TOC on and off to pick control points.
    - When using **Add Control Points** tool you can switch back and forth between the tool and the zoom and pan tools without losing your control points.
    - When adding points on one of the two layers, check off the visibility of the other layer.
- Once you have at least 10 control points, check the **Link Table** for **Residual** errors and **Total RMS**. This method of georeferencing might be less accurate depending on how much care you take when assigning your control points, therefore try to keep Total RMS less than **50** feet.

Follow the same steps for improving your RMS as described in Task 1. What was your final Total RMS error? (You will need this number for Question 7)

- If you are satisfied with your Total RMS, repeat the same steps for rectifying the image as in Task 1. Name your output *MadisonTopoMap_Geo2.tif*.
- Add the georeferenced image to the map document and check its coordinate system. What is it? Remove the original map.

Question 7: Take a screenshot of your **georeferenced map** correctly overlaying the aerial imagery and include it in your report. List your final **Total RMSE** for Task 2. (1pt)

Question 8: Using one of the two methods explored in tasks 1 and 2, georeference *basemap.jpg* by the next lab period. Use UTM coordinates to define 10 control points, and make sure that your total RMS error is less than 1 meter. Take screenshots of your final **Link Table** as well as the location of **control points** on the map and include them in your report. Rectify the image and save it as *rectifiedbasemap.tif* on your flash drive. You will need this completed in order to be able to work on Lab 5. (1.5pt)
Which geo-referencing method did you choose and why? (0.5pt)

Question 9: When defining control points in Question 8 you used UTM coordinates instead of GCS that were also listed on the map. Explain why from the perspective of the different types of coordinate systems. (1pt)

3. Lab Assignment:

- Typed answers to the questions including the screenshots for questions 7 and 8.
  - 9 questions total for 10 points (attendance +1 pt)

Note that you will need the georeferenced map from question 8 to be able to proceed with Lab 5.