Civil Engineering 220 – Fall 2020

Lab #4

Differential GPS

Due Tuesday, 10/06/20 at 9:00 pm

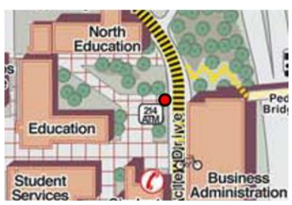
The objective of this assignment is to apply the concept of Inverse Distance Weighting to Differential GPS. The dataset you will use is:

- **campus.img** – Aerial Photograph of SDSU campus

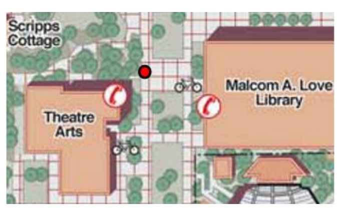
Background: Survey benchmark monuments are metal disks in the ground. They measure exact horizontal positions (latitude and longitude) and/or elevations on the Earth to give surveyors points of reference. In the United States, the National Oceanic and Atmospheric Administration's National Geodetic Survey (NGS) is responsible for managing approximately 240,000 stations established over the last two centuries. During major construction and land development, the destruction of survey monuments sometimes occurs. This destruction has increased in recent years due to rapid development. Survey markers are often used to set up a GPS receiver in a known position for use in Differential GPS surveying.

1. Normally, when this lab meets in person, students go out "in the field" with a GPS receiver to collect data. They use the GPS device to take measurements for x (longitude), y (latitude), and z (elevation in feet) at three (3) known points and one (1) unknown point on campus:

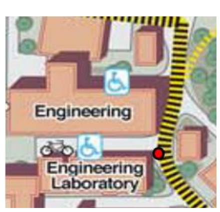
   - **Point 1 –** On sidewalk at top of stairs going down to Aztec Circle Drive near the ATM machine and coffee stand (metal disk in sidewalk).



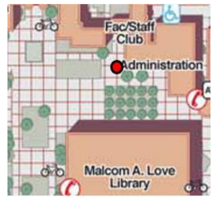
   - **Point 2 –** On sidewalk near Theater Arts building across from Love Library (metal cylinder in sidewalk 94-014). ***Note**: This survey marker is has been destroyed. Therefore, place GPS on the yellow fire hydrant in the grass next to the sidewalk.*



   - **Point 3 –** On curb/sidewalk next to the fire hydrant at the southeastern end of the lane between the Engineering Building and the Engineering and Interdisciplinary Sciences building (94-003). ***Note**: This survey marker has been destroyed. Therefore, place GPS on the "fire lane" curb.*



- **Unknown Point** – Statue: Samuel T. Black, First SDSU president; between Administration building and Love Library; Place GPS between his left foot & cane.



Since we are unable to do this, you will use the data that I provide here (use the data that corresponds to the lab section that you are registered for):

Point	Latitude	Longitude	Elevation (feet)
SECTION 1			
Point 1	32° 46′ 31.8″ N	117° 04′ 07.0″ W	461
Point 2	32° 46′ 31.5″ N	117° 04′ 19.6″ W	458
Point 3	32° 46′ 38.2″ N	117° 04′ 12.4″ W	439
Unknown Point	32° 46′ 33.3″ N	117° 04′ 16.6″ W	462
SECTION 2			
Point 1	32° 46′ 31.9″ N	117° 04′ 07.1″ W	463
Point 2	32° 46′ 31.4″ N	117° 04′ 19.8″ W	457
Point 3	32° 46′ 38.5″ N	117° 04′ 12.1″ W	436
Unknown Point	32° 46′ 33.2″ N	117° 04′ 16.7″ W	460
SECTION 3			
Point 1	32° 46′ 31.7″ N	117° 04′ 06.9″ W	466
Point 2	32° 46′ 31.6″ N	117° 04′ 19.9″ W	450
Point 3	32° 46′ 38.3″ N	117° 04′ 12.2″ W	429
Unknown Point	32° 46′ 33.4″ N	117° 04′ 16.8″ W	459
SECTION 4			
Point 1	32° 46′ 32.1″ N	117° 04′ 07.2″ W	467
Point 2	32° 46′ 31.3″ N	117° 04′ 19.5″ W	453
Point 3	32° 46′ 38.6″ N	117° 04′ 12.4″ W	433
Unknown Point	32° 46′ 33.2″ N	117° 04′ 16.7″ W	458
SECTION 5			
Point 1	32° 46′ 31.8″ N	117° 04′ 07.1″ W	458
Point 2	32° 46′ 31.4″ N	117° 04′ 19.6″ W	451
Point 3	32° 46′ 38.3″ N	117° 04′ 12.5″ W	430
Unknown Point	32° 46′ 33.2″ N	117° 04′ 16.5″ W	454

2. Create a folder named “Lab4” in the “CIVE220” folder on your drive.
3. Download the mapdata zip file from Canvas to your Lab4 folder. Extract the map data so that it can be viewed in ArcGIS.
4. Add your downloaded/uncompressed data to ArcGIS:
   a. Open ArcGIS

      Start → All Programs → ArcGIS → ArcMap 10.7

   b. In the “Getting Started” window, select New Maps → Blank Map
   c. Add your data: File → Add Data or 
   d. Connect to the folder where your map data is stored (Lab4) and select the file with the aerial photograph (campus.img).
5. Save your ArcMap project:

   File → Save As → Navigate to your Lab4 folder and save using the standard file name (CIVE220_H#_LastName_FirstName) (this will have file extension .mxd)

Lab 4 – Homework Tasks and Questions:

This week you will submit an **Excel** file as your homework.

i. Open Excel and save a blank file in your Lab4 folder using the standard file name:

CIVE220_H#_LastName_FirstName (this will have file extension .xlsx)

ii. In your Excel file, insert a text box with the following standard heading:

Name
CIVE 220, Fall 2020
Homework #4 (Section #)

iii. Perform the following tasks and answer the questions in your Excel file. As needed, provide supporting window captures, measured values, calculations and discussion. Make sure each question number is clearly indicated and present your answers in full sentences.

1. Create a table in Excel with the latitude (y), longitude (x), and elevation (z) values of the 3 known points and the unknown point that were obtained from the GPS. Label the table as appropriate and be sure to include units.

2. Convert the longitude and latitude values from Degrees-Minutes-Seconds (DMS) to Decimal Degrees (DD) in Excel (using a formula). Display 8 decimal places.

3. Create an input file to import the GPS data into ArcGIS:
   a. Open Notepad (type Notepad in the search field next to the Windows button to find the application)
   b. Type the word SITE_ID and press Tab; type the word Latitude and press Tab; type the word Longitude and press Tab; type the word Elevation and press Enter
   c. Type a description for the first SITE_ID (e.g., Point1) and press Tab
   d. Type latitude value (in DD) for Point 1 with 8 decimal places and press Tab
   e. Type longitude value (in DD) for Point 1 with 8 decimal places and press Tab
   f. Type elevation value (in feet) for Point 1 with no decimal places and press Enter
   g. Repeat steps c-f for the remaining points (4 total)
   h. Take care not to put any extraneous keystrokes in your Notepad file (e.g., spaces, tabs, enters, extra text). **The columns will not necessarily line up!**
   i. Save As "GPSpoints.txt" in your Lab4 folder and close Notepad

4. Add the GPS coordinate file that you just created to ArcMap.
   a. In order to see your points on the map, you must select Display XY Data.
      - Specify the fields for the X, Y, and Z coordinates
      - The Coordinate System of Input Coordinates is: GCS_WGS_1984 (because it is GPS data). If this is not the coordinate system specified in the "Display XY Data" window, you must press edit and select the correct coordinate system (Geographic Coordinate Systems ⇨ World ⇨ WGS 1984).
   b. You may wish to change the size/shape/color of your symbols so that the points are easier to see.
   c. Create a screen capture (PrtScr) showing the four GPS points displayed on the campus map with your filename visible at the top of the image. Paste the image in your Excel file.

5. Project the GPS coordinates from **GCS_WGS_1984** (Geographic Coordinate System – World Geodetic System of 1984) to **SPC_NAD83** (Projected Coordinate System – State Plane Coordinates, North American Datum of 1983, US Feet): **NAD_1983_StatePlane_California_VI_ FIPS_0406_Feet**

a. The Projection Tools are found in ArcToolbox (ArcToolbox window → Data Management Tools → Projections and Transformations).

b. In a text box, answer the following: Is this vector or raster data? Which projection tool should you use? Why do we have to project this data?

c. Name your new file ("Output Dataset or Feature Class") the same as the original with the ending "_SPC" appended (for State Plane Coordinates). Be sure to put the file in the Lab4 folder with your other map data. (**DO NOT accept the default name in the "Output Dataset" field. Click on the folder icon to the right of the field and browse to the correct folder**.)

d. Geographic Transformation – leave blank.

6. Determine the x, y values for each point in **meters** (Refer to lab notes for additional instructions on Attribute Tables):

a. Right click on projected GPS coordinates layer and choose "Open Attribute Table."

b. From Table Options menu, choose "Add Field."

c. Name your field x_GPS and choose:

- Type – "Double"
- Precision (maximum total number of digits) – 10
- Scale (number of decimal points) – 2

d. Add another field for y_GPS (repeat steps b and c).

e. Calculate x values in **meters**: Select x_GPS field, right click on field name and choose "Calculate Geometry." Repeat to calculate y values.

7. Use the following information to determine your GPS error: (x,y values in CA State Plane for San Diego (NAD_1983) linear units in meters; z values are ground elevation in feet above mean sea level/Geoid).

Points	x (m)	y (m)	z (ft)
Control Point 1	1,923,300.42	567,828.38	453
Control Point 2	1,922,980.17	567,806.34	436
Control Point 3	1,923,164.53	568,024.33	422

a. Enter the table above into your Excel file. Label the table as appropriate and be sure to include units.

b. Create a similar table for all four points with your x, y, and z values obtained by GPS and calculated in step 6.

c. What is your GPS error (in the x, y, and z directions) at each of the three control points? Assume errors are based on: $ERROR_{GPS,i}$ = $(x, y \text{ or } z)_{GPS,i}$ - $(x, y \text{ or } z)_{Control,i}$. Calculate the errors in each direction, for each control point, in Excel.

d. In a text box, answer the following: Which point has the smallest error (absolute value) in the x direction? Which point has the smallest error in the y direction? Which point has the smallest error in the z direction?

8. In Excel, calculate the distance in meters from the unknown point to each of the three known point using your GPS coordinates. Use the distance formula: $d = \sqrt{\Delta x^2 + \Delta y^2}$

9. Using **Inverse Distance Weighting Squared (with α =2)** and the errors you measured in the x, y, and z directions for your three known points, calculate your adjusted x, y and z values at your unknown point (x*, y*, z*). Below are the sample equations for the x-direction (equations are similar for the y and z directions). Show all work in Excel.

a. **Weighting factor**: $w_i = \frac{\left(\frac{1}{d_i^2}\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^2}\right)}$ where **d** is calculated from the distance formula

b. **Correction:** $E_x^* = \sum_{i=1}^{n} w_i E_{x,i}$ where $E_{x,i} = x_{GPS} - x_{Control}$

c. **Adjusted x value:** $x^* = x_{GPS,Unknown} - E_x^*$

10. Create a Layout View in ArcMap showing all layers zoomed to full extent, and with your attribute table for the projected GPS coordinates layer displayed:

a. Page orientation - Portrait

b. Insert the standard heading in a Text Box above your map.

c. Insert ESRI North 91 Arrow in the lower left corner.

d. Insert Scale Line 1 Metric with units of meters in the lower right corner.

e. Move and resize elements within the layout window to best display the content.

f. From Layout view, create a screen capture; make sure your filename is visible at the top of the image; and paste the image in your Excel file.

11. Save all work and submit your Excel file on Canvas.