Cross Pollination between Surveying and CAD

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Abstract

I am fortunate that I have been able to teach the surveying course and CAD course to support a civil engineering technology program at the University of Houston – Downtown. To make these two courses more interesting and further the learning, I have embedded surveying principles and practices in the CAD course and embedded CAD and mapping applications such as Google Earth and Earth Points into the survey course. This paper is about presenting these innovative modules that the author believes have made a rather dry course such as Surveying more interesting and provided some preparation for surveying while the students are still taking CAD.

Some of the learning modules discussed will include

- CAD students preparing property drawings from surveyor notes
- CAD students learning about the Public Land Survey System and legal descriptions to draw a property from a legal description
- CAD students converting geodetic coordinates to state plane coordinates to complete a property description using Google Earth, Earth Points, and Auto-CAD
- Surveying students using Google Earth to estimate the surveying markers in a local surveying area, converting geodetic coordinates to state plane coordinates and providing the bearings and distances between points of the resultant traverse
- Surveying students using Auto-CAD to find a missing point from a GPS/RTK Network Survey using resection techniques
- Surveying students comparing the results of distances measured in Google Earth versus a taping survey between points in the local surveying area
- Surveying students completing much the same final project as the CAD students

As part of providing these learning modules, transparent learning assessment (TLA) has been incorporated, which is defined below.

"Transparent assignment design refers to teaching practices aimed at making learning processes more explicit for students. A growing body of research indicates that incorporating elements of transparent assignment design, such as clearly communicating the **purpose**, **task**, and **criteria**, into student assignments, can:

- Serve as a 'road map' for students, providing them with a greater opportunity for successfully meeting the expectations of the assignment.

- Benefit all student groups, with particular benefit to underrepresented student groups, in terms of achievement, retention and graduation rates, and students' confidence and sense of belonging.
- Demystify the learning process for students who may be less familiar with college success strategies.
- Provide faculty with opportunities for reflection on their assignments and how they meet student outcomes." [1]

Introduction

The CAD course that is offered at the University of Houston – Downtown (UHD) is a course solely for Structural Analysis and Design students who are essentially Civil Engineering Technology students. Given this fact, the course has been tailored to the needs of civil engineering technology students and all drawings are civil engineering drawings.

Embedded in some of these drawings are the principles and practices of Surveying, which is another course I taught this semester (Fall, 2022). I have embedded into the Surveying Course CAD drawings and Mapping applications such as Google Earth and Earth Points.

These various learning modules are shown below.

Surveying Principles and Practices within the CAD course

1. Property Drawing from Surveying Notes
2. PLSS Lecture and Earth Points
3. Drawing from Legal Description
4. Final Project – CAD: Use of Google Earth and Earth Points for final project

Auto-CAD and Mapping Applications within Surveying Course and Laboratory

1. Property Drawing from Surveying Notes
2. Use of CAD to determine bearings and lengths of a closed traverse
3. Google Earth, Earth Points, and CAD to determine lengths and bearings of a closed traverse
4. Resection Survey that involved a combination of Google Earth, Tape Survey, and Auto-CAD
5. Drawing circles using a compass to find resection point on a given map with existing points in State Plane Coordinates and using this as a basis to a discussion on GPS and triangulation
6. Drawing from Legal Description
7. Final Project – Survey: Errors associated with One Zone SPCS PA versus Two Zone SPCS – what's the Auto-CAD or Mapping portion of this?
8. Final Project – Surveying Lab: Determining how accurate distances are in Google Earth

Each of these learning modules will be discussed below and implications for transparent learning explored.

CAD Course, Property Drawing from Surveying Notes

The fourth drawing in this course comes from a drawing with surveyor notes (please see **Figure 1**).

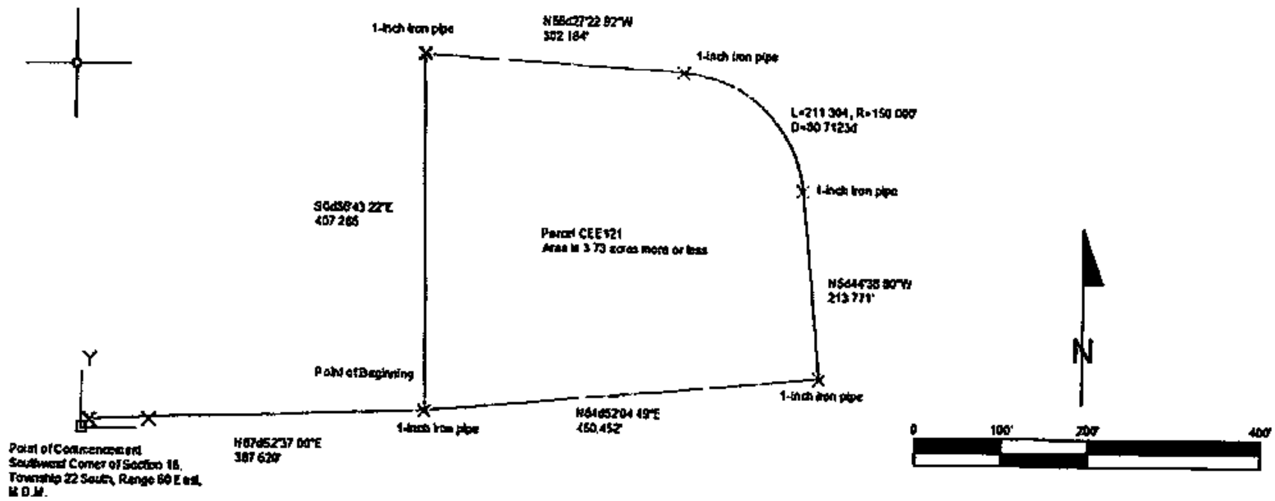


Figure 1 – Drawing from Surveyor Notes [2]

CAD Course, PLSS Lecture and Earth Points

The same lecture that I give in the Surveying Course is provided to the CAD students and covers the basics of the Public Land Survey System and details on a legal description. The presentation goes on to show how the PLSS can be utilized as a point of commencement, and this becomes the basis to a final project discussed below.

CAD Course, Drawing from Legal Description

The students are given a legal description much like what is given below and from this legal description they are required to complete a drawing and determine the area enclosed within the property (see **Figure 2**).

....

Parcel CEE121
All of Parcel CEE121 being that portion of the southwest quarter of Section 10, T22S, R60E of M.D.M., described as follows:
COMMENCING at the southwest corner of said Section 10 given as a 1-inch iron pipe and thus the POINT OF REFERENCE:
THENCE N87d52'37.00"E for a distance of 387.620' to the POINT OF BEGINNING given as a 1-inch iron pipe;
THENCE N84d52'04.49"E for a distance of 460.452' to a 1-inch iron pipe;
THENCE N5D44'38.80"W for a distance of 213.771' to a point of curvature along the eastern boundary of said parcel and given as a 1-inch pipe;

THENCE northwesterly an arc distance of 211.304' along a tangential curve, concave toward the southwest, radius 150.000', and a central angle of 80.7123d, to a point of curvature given as a 1-inch pipe and along the northern boundary of said parcel;
THENCE N86d27'22.92"W a distance of 302.164' to a 1-inch iron pipe;
THENCE S0d36'43.22"E a distance of 407.286' to the POINT OF BEGINNING, which is given as a 1-inch iron pipe.
The area of Parcel CEE121 is given as 3.67 acres.

....

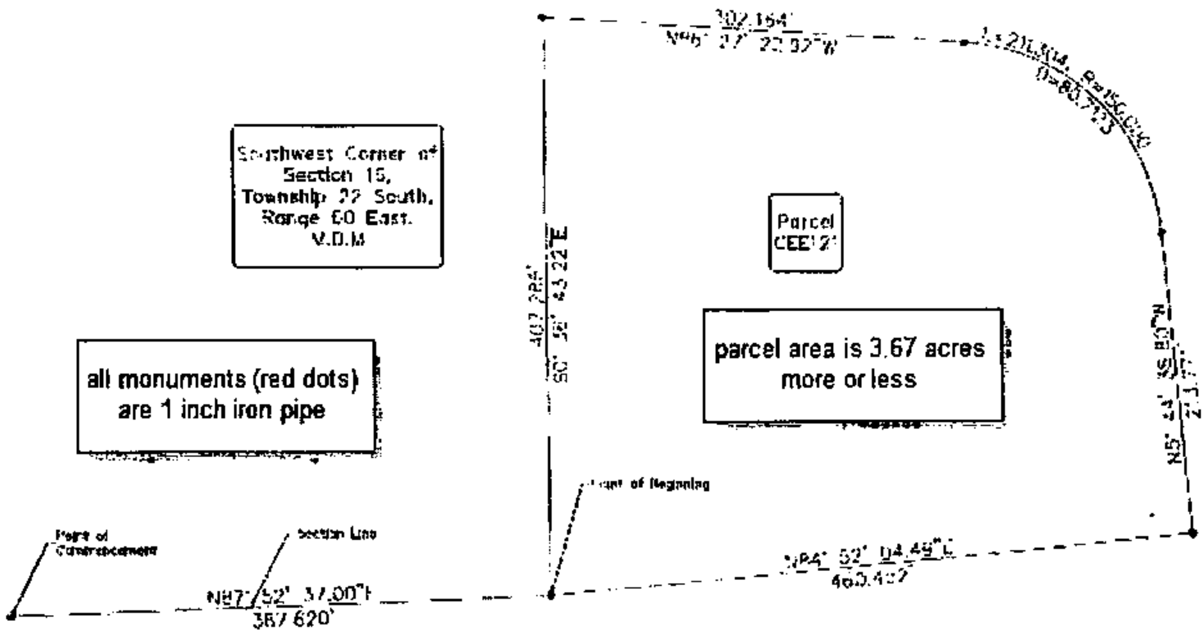


Figure 2 – Drawing from legal description [2]

CAD Course, Final Project

Given below is the Final Project for the CAD course.

Final Project

You are a professional land surveyor who has been asked to survey my property and you've provided a tentative legal description and map prepared from using Google Earth and Earth Points. You are required to turn in for a grade by the last class day the report given below. I've listed the steps required to succeed.
I'm in the process of getting the class a subscription to Earth Points to provide an overlay of the PLSS system and a more convenient means of getting properties corners in state plane coordinates.

Final Project Steps

1. Open Google Earth and make sure PLSS overlay is on
2. Open given "KMZ" file on Blackboard
3. Note nearest PLSS section to property

4. Note "BC" and "EC" are estimated beginning of curve and end of curve; you'll have to include more points to get a better estimate of the highway curve.
5. Using "property" find the latitude and longitude of all boundary points to include corners "SW", "NW", and "SE."
6. Using calculator convert these points to state plane coordinate system for the south Louisiana region (see Earth Point).
7. Open Auto-cad, units -> Decimal and Surveying Angles to the appropriate level of accuracy
8. Incorporate all points into Auto-Cad and connect all points with lines and curves.
9. Using "property" in Auto-Cad find distances and azimuths.
10. Finish your drawing and prepare a legal description from the drawing to include vicinity portion and estimate of enclosed area.
11. Provide a report that includes the following
    a. Letter of Transmittal
    b. Bill of Work
    c. Legal Description
    d. Drawing (Map) of Property

The solution involves utilizing Google Earth, Earth Points and understanding the PLSS (see **Figure 3**).

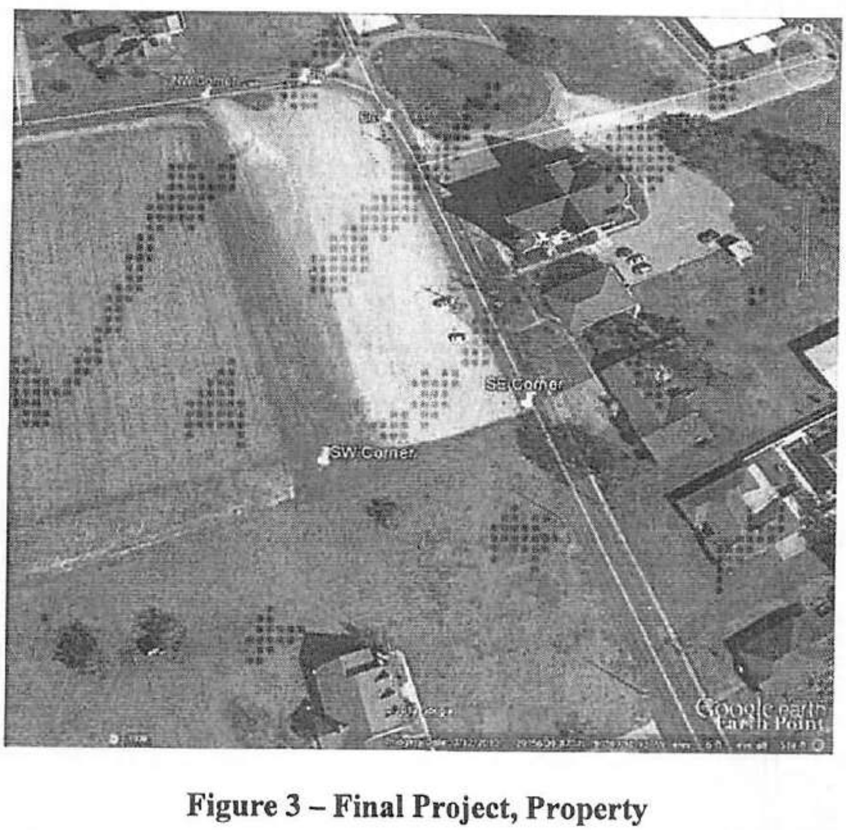


Figure 3 – Final Project, Property

Surveying Course, Property Drawing from Surveying Notes

This is a repeat of what was done in the CAD course.

Surveying Course, Use of CAD to determine bearings

The process of understanding the mechanics of a closed traverse to include

- Going from Bearings to Azimuths
- Getting the Azimuths of a closed traverse when knowing one bearing line and all interior angles
- Determining Departures and Latitudes
- Correcting for Misclosure

Is a process that takes several weeks, and the first part is to determine the azimuths of a closed traverse when knowing one bearing line and all interior angles (see **Figure 4**).

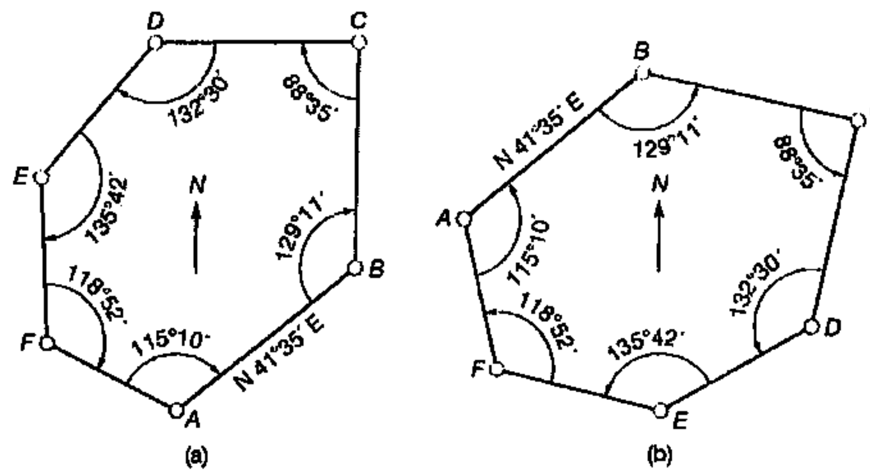


Figure 4 – Azimuths from one bearing line and interior angles [3]

The students are shown how to solve this problem by hand but they also they can check there answers using Auto-CAD.

This process starts by using the correct units where the angles need to be surveyor's units and to the nearest whole second.

The first bearing line is drawn as

```
>line
>0,0
>@100<N41d35'E
```

This original line is then copied unto itself and rotated through a negative angle equal to the next interior angle

```
>rotate
>[pick working end of line]
>-129d11'
```

A new line is created, and the interior angle is dimensioned. This process goes on until you have the following (see **Figure 5**). Even as the traverse does not close, you'll notice that the last line and first line are parallel to each other, and it can be shown both lines have the same bearing.

The last step is to draw all lines starting from originally line and going in a counterclockwise direction starting from the origin and using properties to determine the bearings for all lines.

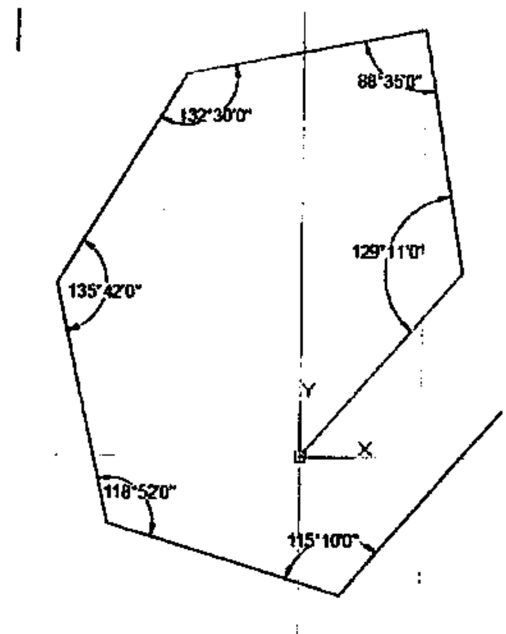


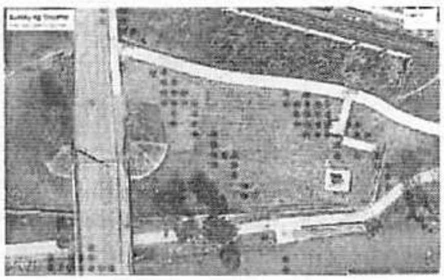
Figure 5 - Auto-CAD Drawing for Determining Bearings

Surveying Course, Google Earth, Earth Points, and CAD to determine lengths and bearing of a closed traverse

In Week 4, I established six points in the local surveying area (see **Figure 6**). Associated with these points in Google Earth is a latitude and longitude. Using Earth Points [4], the appropriate state plane coordinates were determined and then put in a set of local coordinates.

From these local coordinates, the corners of the closed traverse were established (see **Figure 7**) and distances and bearings between points were determined from Auto-CAD.

Point	Latitude Degrees	Minutes	Seconds	DD	Longitude Degrees	Minutes	Seconds	DD	Earth Points Output	Easting [feet]	Northing [feet]	Easting' [feet]	Northing' [feet]
P-1	29	45	56	29.76556	95	21	37.93	-95.36054	4204 3122977.285UsFtE 13843867.608UsFtN	3,122,977.285	13,843,867.608	87.935	162.814
P-2	29	45	55.7	29.76547	95	21	36.15	-95.36004	4204 3123136.858UsFtE 13843839.833UsFtN	3,123,136.858	13,843,839.833	247.508	135.039
P-3	29	45	55.34	29.76537	95	21	35.91	-95.35998	4204 3123157.016UsFtE 13843804.079UsFtN	3,123,157.016	13,843,804.079	267.666	99.285
P-4	29	45	55.23	29.76534	95	21	36.29	-95.36008	4204 3123125.644UsFtE 13843792.188UsFtN	3,123,125.644	13,843,792.188	236.294	87.394
P-5	29	45	54.94	29.76526	95	21	35.89	-95.35997	4204 3123161.432UsFtE 13843764.198UsFtN	3,123,161.432	13,843,764.198	272.082	59.404
P-6	29	45	54.84	29.76523	95	21	37.94	-95.36054	4204 3122981.019UsFtE 13843747.667UsFtN	3,122,981.019	13,843,747.667	91.669	42.873
Bottom, Left Corner	29	45	54.44	29.76512	95	21	39	[illegible]	4204 3122869.350UsFtE 13843704.794UsFtN	3,122,869.350	13,843,704.794	0	0



State Plane Coordinate System (earthpoint.us)

dX	[feet]	159.573
dY	[feet]	-27.775
Distance	[feet]	161.97

0.525

Scale = 308.52

Figure 6 – Determining the local coordinates of points within a traverse given latitude and longitude

Point	Bearing	Distance [feet]
P-1		
	S78d15'25"E	161.65
P-2		
	S29d5'55"E	43.382
P-3		
	S72d7'20"W	35.378
P-4		
	S48d20'59"E	41.55
P-5		
	S87d47'53"W	169.608
P-6		
	N3d46'11"W	114.662
P-1		

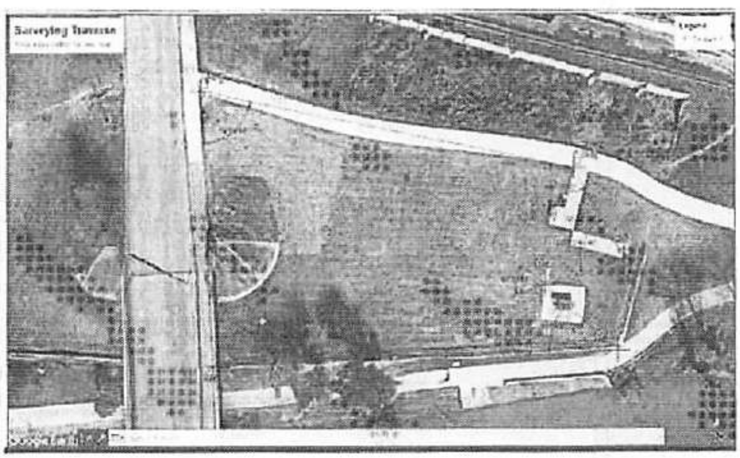


Figure 7 – Completing the Traverse in Auto-Cad knowing the local coordinates of traverse corners

Surveying Course, Resection Surveying that involved a combination of Google Earth, Tape Survey and Auto-CAD

We had the opportunity to use a base and rover GPS (Trimble R12 and R12i) to determine the state plane coordinates for the eight established surveying points in our local surveyor area (see **Figures 8** and 9). Unfortunately, we missed "Point 3" and a resection survey was done using tapes from three adjacent points (Points 2, 4, and 6).

The results of this resection survey were determined in Auto-CAD and given in **Figure 10**. We were pleasantly surprised at how well the resection survey actually went and the Auto-CAD drawing explicitly shows the level of precision.

Point	Easting	Northing	Elevation	Observation Class	H.Precision	V.Precision	Comments
	[feet]	[feet]	[feet]		[sft]	[sft]	
4	3,123,019.820	13,843,851.549	24.166	Network RTK	0.033	0.058	Point 1
5	3,123,136.522	13,843,836.744	22.176	Network RTK	0.038	0.065	Point 2
6	3,123,136.112	13,843,804.758	21.308	Network RTK	0.033	0.06	Point 4
7	3,123,163.928	13,843,798.742	20.621	Network RTK	0.043	0.086	Point 5
8	3,123,125.446	13,843,772.967	20.827	Network RTK	0.026	0.048	Point 6
9	3,123,157.842	13,843,770.721	20.28	Network RTK	0.028	0.052	Point 7
10	3,123,101.695	13,843,763.840	20.188	Network RTK	0.026	0.05	Point 8

Table 1 – GPS/RTK Network Survey

Figure 8 – Surveying Points in GPS/RTK Network Survey

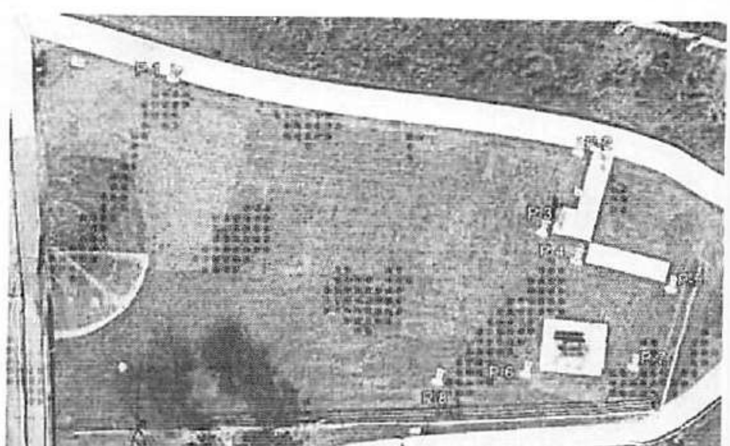


Figure 9 – Google Earth Image with All Surveying Points in local surveying area

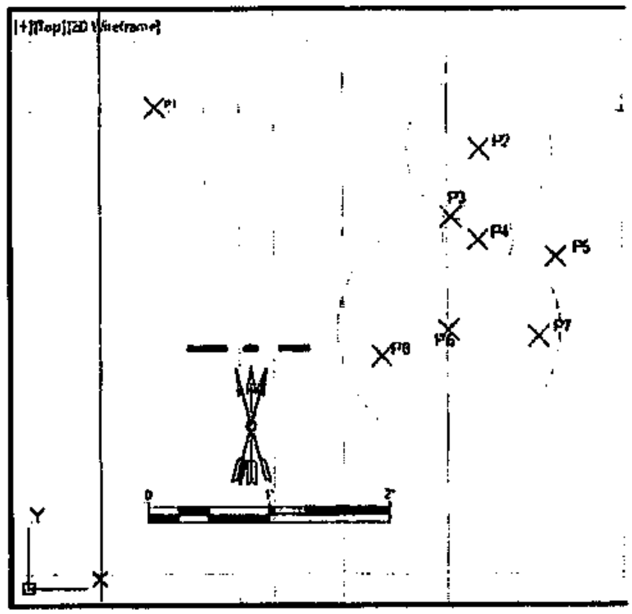


Figure 10 – Resection Survey (Auto-CAD)

Surveying Course, Drawing Circles using a compass to find resection point on a given map with existing local coordinates and using this as a basis to a discussion on GPS and triangulation

A simpler resection survey was done with pencil and compass (see **Figure 11**). The students are given three known points and distances to the unknown point and with a compass, they mark out the intersection point of the three arcs. The results are again surprisingly precise.

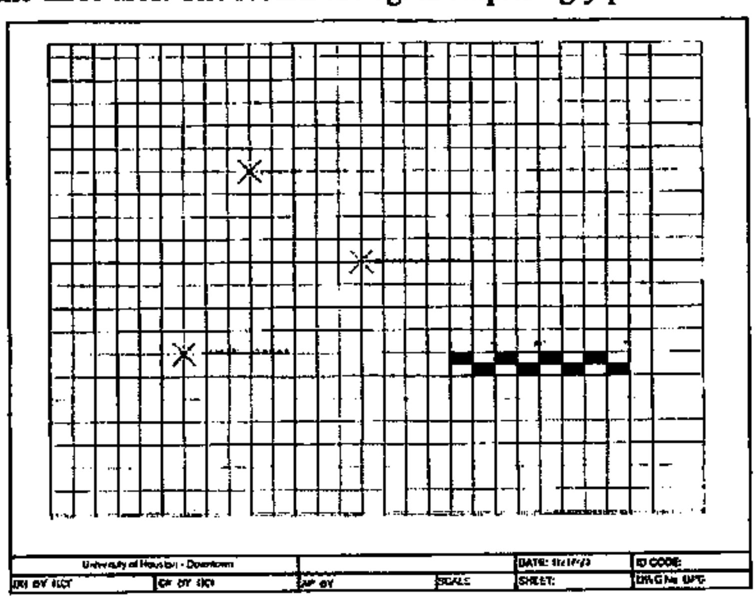


Figure 11 – Resection Survey (Hand Drawn)

The resection survey shown in **Figure 11** became the basis to a general discussion about triangulation and this was followed by a presentation on GPS.

Surveying Course, Drawing from a legal description

This is a repeat of what was done in the CAD course.

Surveying Course, Final Project for Surveying Course

Purpose

You will work with a buddy on determining the merits of a one zonal SPCS for Pennsylvania versus the current two zonal SPCS. Your findings will be written up as a technical memo to include **Figure 12** and **Table 2.**

You will be given the following resources…

1. A model that converts from geodetic coordinates to {X, Y, Z} for both an ellipsoid and sphere
2. A model that calculates {Easting, Northing} for a particular state, map projection, input parameters, and {Latitude, Longitude}
3. A lecture on Map Projections, Conformal Mapping, and State Plane Coordinate System (SPCS)
4. A word document that follows (3)
5. In-Class Assignment to determine from zonal constants the Easting and Northing (see below)

What you need to do is calculate the scale factor at the various latitudes along the central meridian for one zone SPCS, PA and two zone SPCS, PA.

The allowable error is 1 part per 10,000 parts and in terms of scale factor this means

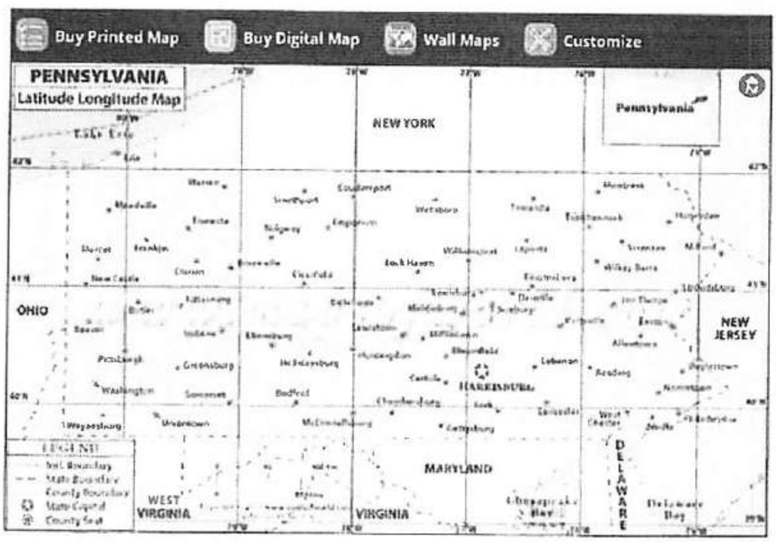


Figure 12 – State of Pennsylvania

Latitude	One Zone Scale Factor	Two Zone Scale Factor	Comments
42d North			
41d45' North			
41d30' North			
41d15' North			
41d00' North			
40d45' North			
40d30' North			
40d15' North			
40d00' North			
39d45' North			
39d30' North			

Table 2 – Scale for One Zone and Two Zone SPCS, PA

Task

(Equation 1)

$$1 < k < 1.0001$$

Or

(Equation 2)

$$.9999 < k < 1$$

When these conditions are exceded it needs to be noted and we'll draw this as a graph of PPM versus Latitude where

(Equation 3)

$$PPM = abs(1 - k) * 1e6$$

PPM is parts per million and when $PPM > 100 \rightarrow exceeded\ allowable\ error$

The technical memo needs the following elements

- Introduction to Problem
- Method of Solution
- Results to include **Figure 12, Table 2,** and a graph of PPM versus latitude for one zone and two zone SPCS, PA
- Discussion/Conclusion
- References

The results of the analysis showed that when utilizing a one zone for PA the allowable error of 100 PPM was exceeded across the middle third of the state and would be a reason for not going to a one zone SPCS for PA.

Surveying Course, Final Project for Surveying Laboratory

The purpose of this final project was to determine how accurate are the distances measured in Google Earth compared to using tapes.

Each team will complete this assignment and turn in a group report. I would suggest providing the report to me for comment prior to the actual turn in for a grade – this makes your report that much stronger.

By an appropriate surveying means, I want to know how accurate are the lengths in Google Earth for the following points (see **Figure 13** and **Table 3**) that make up a six sided traverse.

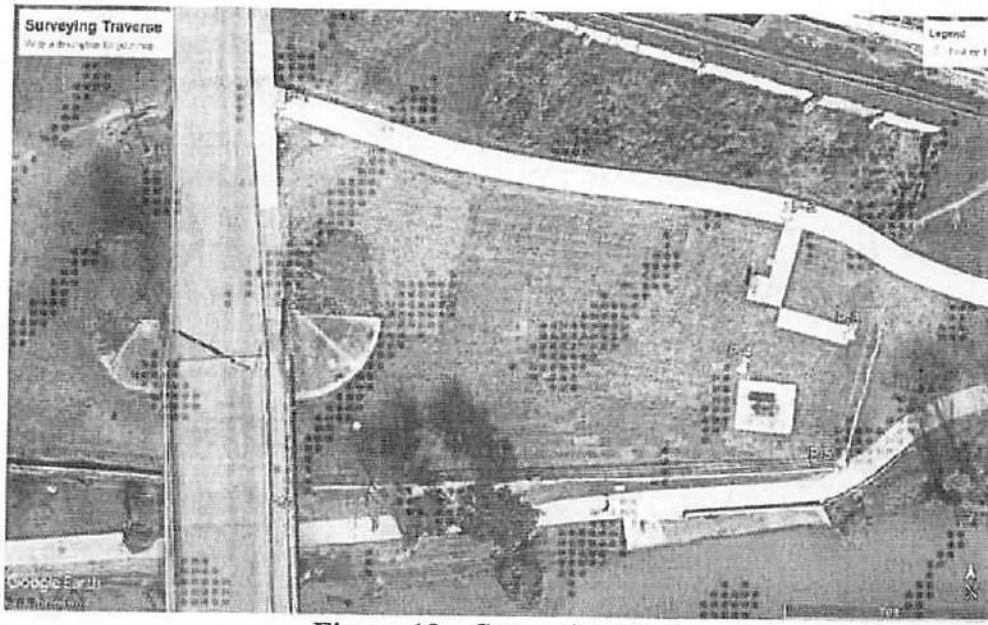


Figure 13 – Surveying Park

Point	Description
P-1	Corner where road sidewalk meets sidewalk on north edge of Park
P-2	Corner where north edge sidewalk meets sidewalk running to bench slab
P-3	Southeast corner of slab
P-4	Northwest corner of slab
P-5	Outer edge of fence corner

Table 3 – Points on Traverse

Steps

1. Determine a surveying method that will accurately measure the distance between points, which may be the steel tape, total station, or GPS receiver. If need be, use Earth Points to convert from latitude/longitude to SPCC.
2. Provide an error as parts per 10,000 for each side of the traverse and get a mean and standard deviation for the error.

3. Write this up as a report with the following sections
    a. Problem Statement
    b. Method of Solution
    c. Results
    d. Discussion/Conclusions
    e. References
    f. Appendices

Your report should include **Figure 13, Table 3** and **Table 4** given below.

Points	Google Earth Distance	Surveyed Slope Distance	Estimated dZ	Surveyed Horizontal Distance	Difference	Parts per 10,000
	[feet]	[feet]	[feet]	[feet]	[feet]	
1						
			1.99			
2						
			1.555			
3						
			-0.206			
4						
			0.547			
5						
			3.886			
1						

Table 4 – Google Earth, Surveyed Distance, and Error

An average relative error associated with using Google Earth's distance tool versus taping for short distances (under 250 feet) was about 5% with a standard deviation of 3%, which would be good enough for mapping but not accurate enough for surveying applications.

It needs to be noted that the average relative error varied from group to group and ranged from less than 1% to as high as 9%.

We'll likely look at longer distances by measuring distances between benchmarks established on metro Houston bridges where a database [5] has been provided by Harris County Flood Control District.

Use of Transparent Learning Assessment in a Surveying Course

I provide what are called Spot Checks. These are quizzes for no grade and the students don't put their names on them. It is an opportunity for the students to see what I find important about the course and for both the students and I to see how well a particular concept we are exploring is understood.

There were at least two spot checks where I utilized Transparent Learning Assessment (TLA).

A comparison of a spot check without TLA and with TLA is given as **Appendix A**. As part of the discussion, the TLA method will be discussed.

Discussion

I believe any time you can provide computer applications of concepts your teaching and those computer applications are visual in origin then you're doing a service for the students. In this paper, a cross pollination between CAD and surveying was explored for 12 learning modules. Along with the learning modules TLA was explored.

TLA is further discussed below.

I wholeheartedly agree that an assignment should provide the "Purpose", "Task" and "Criteria for Success" to both inform and motivate the student. My concern though is that we may be providing too much of the solution and hand carrying the elements of the solution instead of having the students seek out the answer through lecture notes, the book, and other resources. The search is when the body of knowledge is actually mastered.

In the presentation to accompany this paper three documents are discussed

- Spot Check without TLA
- Spot Check with TLA
- Grade Sheet for Final Exam

I believe the spot check that has incorporated TLA does provide more guidance and there is a concern on how much guidance to provide; the world is not cookie cutter.

A grade sheet for the final exam was also provided. Should this grade sheet be attached to the student's final exam to provide them a clear rubric on how they'll be graded? If it is, it also provides ample hints on how to complete the final example problems? Should this be allowed?

Conclusions

This paper has shown how CAD and mapping tools can be utilized in an introductory surveying course and how elements of surveying can be incorporated into a CAD course for civil engineering technology students. Twelve learning modules have been shown and TLA explored.

This paper has also explored elements of TLA and the author is still deciding on how much TLA should be incorporated into his courses.

One criticism of TLA states [**6**],

> On the one hand, research has shown that explicit criteria may positively affect student performance, reduce their anxiety, as well as support students' use of self-regulated learning strategies. On the other hand, there are fears that explicit criteria may have a restraining influence on students' learning, as well as limiting their autonomy and creativity.

Where to draw that line is the aspiration of a future ASEE GSW paper.

References

[1] Washington State University, Office of Assessment for Curricular Effectiveness, https://ace.wsu.edu/assignment-design/transparent-assignment-design/, accessed 11/2/2022.

[2] https://www.cadtutor.net accessed 1/10/2023.

[3] Ghilani, C.D. (2017). Elementary Surveying: An Introduction to Geomatics, Pearson, 15th Edition.

[4] https://www.earthpoint.us accessed 1/10/2023.

[5] https://www.hcfcd.org/Resources/Interactive-Mapping-Tools/Harris-County-Floodplain-Reference-Marks accessed 1/10/2023.

[6] Jonsson, Anders (2014). "Rubrics as a way of providing transparency in assessment"; *Assessment and Evaluation in Higher Education*, v. 39, n. 7, pp. 840 to 852.

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