Abstract
At Pennsylvania College of Technology, an affiliate of The Pennsylvania State University, we believe in current technical education with an emphasis on practical applications. Our portfolio of programs includes Civil Engineering Technology (CT) and Surveying Technology degrees and a new four year Civil Engineering Technology degree (BCT). The Civil Engineering Technology (CT) and Surveying Technology (SU) Associate degrees are ABET accredited.

We recently received a National Science Foundation (NSF) Curriculum (ILI) grant. The major thrust of implementation reflects the revolution caused by technology in civil engineering and survey. We give each student not only the theory but also actual experience with the projects and equipment that are the "bread and butter" of civil engineering practice. Laboratories in cartography, photogrammetry, surveying and civil engineering are designed to integrate experiences in this new technology.

In the area of Geographic Information Systems (GIS), the merger of information from different sources, often in different formats, is the norm in civil engineering technology practice, using GIS-based systems. We must recognize and keep up with this trend. We purchased the Modular Geographic Information System (GIS) Environment (MGE) system from the Intergraph Corporation, which we feel best suits our educational needs.

This presents course designers with the requirement to balance education in the basics with training in the most modern applications. As a project in the second semester, we construct a Digital Terrain Model (DTM) and a map, produced at engineering scale (about 1 inch equals 35 feet with half foot contours) for an area of four acres controlled by traverse stations, also observed and reduced by students. The technique used is a modification of the old standby, stadia mapping. This paper discusses the application of GIS technology to that exercise.

Introduction
At Pennsylvania College of Technology, an affiliate of The Pennsylvania State University, we believe in current, applications-intensive technical education. Our portfolio of technical programs includes a two-year Civil Engineering Technology (CT) Program, with an emphasis in surveying, a two-year Surveying Technology degree and a new four year Civil Engineering Technology degree. We feel that in our programs we
teach the art and science of the application of abstract principles to the real world. While the techniques change, the basic ideas remain and explain why we do what we do. A good understanding of the basics alone is not enough. Today's Engineering professionals must understand modern applications as well. So nothing we teach is purely theoretical, just as nothing is taught as pure application without the basic knowledge to understand it. Our Civil Engineering Technology (CET) and Surveying Technology (SU) Associate degree programs follow the Accreditation Board for Engineering and Technology (ABET) standards. Both the CET and SU programs are ABET accredited.

We recently received a National Science Foundation (NSF) Curriculum (ILI) grant. The major thrust of the grant implementation reflects the revolution caused by electronics, satellite based measurement, and computer technology in civil engineering and survey. Concurrent with improved measurements is an increase in productivity. To start the implementation we purchased the Modular Geographic Information System (GIS) Environment (MGE) system from the Intergraph Corporation, which we feel best suits our educational needs. This system allows us to teach fundamentals while using the MGE to illustrate those fundamentals. As an educational institution, we were not interested in a one step "field-to-finish" blackbox approach so common in production programs.

The problem we now face is how to give each student not only the theory but also actual experience with the projects and equipment that are now the "bread and butter" of Civil Engineering practice. The solutions should be performed on modern equipment with techniques used in today's practice. Students in our programs are provided opportunities for hands-on experiences and real problem-solving using industry standard equipment. Field-based laboratories and laboratories in cartography, photogrammetry, surveying, and civil engineering design were upgraded to include experiences in this new technology. Students are currently required to respond to competency-based curricula where they demonstrate ability in the use of essential pieces of equipment and the related supportive technologies.

In addition, we need to overcome the "fragmentation" experienced by students as a result of their exposure to coursework specific to surveying, highway design and land use. Improvements and integration include improved synthesis/integration of multiple source data through application of Geographic Information System (GIS) technology and improved survey measurement precision. Above all, we need to integrate these technologies and their use so students understand information and data base use for engineering and surveying problem solution.

With Geographic Information Systems (GIS), the merger of information from different sources (e.g. surveying, Global Positioning System and Photogrammetric activities), often in different formats, is the norm in civil engineering technology practice. Such information is used in the design of subdivisions, location of parks, design of transportation networks, and the husbandry of the environment. Most government and
private engineering entities have switched to GIS-based systems and our educational institutions must recognize and keep up with this trend.

The implication is that greater quantities of information must be integrated to provide civil engineers, planners, and others with greatly enhanced predictive and planning capacities. Our students must understand that the information upon which decisions are based will have multiple and correlated inputs. This will improve the efficiency of designs, identify long term problems, and reduce costs. The capacity to integrate large quantities of information can greatly reduce the cost of major building and construction projects. The high cost of capital and the duration of a major project prior to completion both raise total cost. By reducing the time needed for planning, development and construction, up front costs are lowered. Information systems can greatly enhance the speed and accuracy of development and ensure that design expectations are more fully met. Students must understand the concept of flexibility in design and construction because of the availability of rapid response to "what if" alternatives GIS provides.

**Student Project Chosen**

Decisions about the apportioning of education in the basics as opposed to training in the most modern applications always present course designers with a problem. Both the CET and SU programs require a four-semester series in surveying, with an emphasis on land and civil engineering applications. This was the first area in which we decided to apply the GIS. As a project in the second semester, our students make observations to construct a Digital Terrain Model (DTM) from which a map is produced at engineering scale (about 1 inch equals 35 feet with half foot contours). The area of the map (see Figure 1) is the open area in the upper middle of the aerial view, taken looking roughly south. It is about four acres and is surrounded by traverse stations, also observed and reduced by students. The technique used is a modification of the old standby, stadia mapping.

The principles of the technique are presented for completeness. The students use an electronic theodolite, Philadelphia rod and cloth tape. Student groups set up on one of the already coordinated (Pennsylvania State Plane (1983) North Zone (3701)) traverse stations and set the azimuth of an adjacent station on the horizontal plate of one of our electronic theodolites in lower motion. When the instrument is placed in upper motion in the direct position, the horizontal plate reads azimuth. This is called placing the instrument “in meridian”. Since the observer is a student, Top, Middle and Bottom wires, rather than interval, are observed, along with zenith distance (vertical angle) and azimuth. The height of the instrument above the station is measured with cloth tape for each observing session. Appendix A shows the mathematical algorithm for conversion of these observations into (X,Y,Z) coordinates.
Figure 1. The Penn College Campus. Area mapped is in the upper middle of the image and is about 4 acres in size. Note that the picture predates the construction of the College's Victorian House shown in Figure 3.

Each group annotates their field book’s “remarks” column so that points observed which are not on the ground, such as the tops of walls, can easily be identified and later segregated. From this, the students produce planimetric and topographic ASCII files of observations (see Figure 2).

Instructional time is devoted to the standard file exchange protocols ASCII and .DXF, so students understand the process involved in converting observations to (X,Y,Z) coordinates and going from one application to another using .DXF files. Although they are capable of computing the (X,Y,Z) coordinates by hand, to save time, they use a program written by the faculty to make this transformation. The program also tests the half-intervals (Top - Middle and Middle - Bottom) to detect blunders. Agreement of 0.01 ft is required for the point to be accepted.
Figure 2. An example of a student ASCII data file prepared from the fieldbook, done in the Notepad editor. Order of data for each point is Point #, Top, Middle and Bottom wire readings made on the level rod, Zenith Distance in degrees-minutes-seconds format and Azimuth in that same format. Note that observation 94 does not meet the (top-middle) to (middle-bottom) criterion.

Figures 3a and 3b show examples of the program produced files of (X,Y,Z) coordinates and the accompanying “hardcopy” students use to check accuracy of input data. It is the (X,Y,Z) coordinate files that the students edit and copy-concatenate into planimetric and topographic coordinate files.
They then use an MS-DOS application called LI Contour (A B Consulting Co., Inc) to preview their work for completeness and for blunders previously undetected. The (X,Y,Z) coordinates can also be edited in the program, if necessary. The student groups then produce preliminary plots of planimetric detail, again to ensure completeness. Preliminary plots of the hypsographic information are also produced to ensure adequate density of data and as a blunder check. Once they check these data, the program produces a .DXF file of the planimetry showing point location and point name and another showing the location of hypsography points and their elevation.
Figure 3b. Students receive a paper copy of each instrument position from the coordinate program. Note that observation 94 is marked as rejected. Students can then decide if they have made an entry error in their ASCII files or an error in observing in the field.

The MGE System is an enhancement to Microstation (Bentley Systems Inc), although this is akin to saying an automobile is an enhancement of the wheels and tires. The planimetric file is imported into an already set up project in Intergraph MGE. The layers of the .DXF file containing the point names appear as “tags,” in Intergraph MGE and Microstation parlance. Students then manipulate line weights and place lines, curves and text to produce the planimetric detail. They show buildings as line polygons. The students symbolize the locations of trees, lightposts, walkways, fire hydrants, drains and other utilities. The .DXF file image containing this information is then deleted, leaving the linework and symbols. The students then import the .DXF file containing the elevation data and spot high and low points are noted and symbolized. This .DXF file image is also deleted. Using an application called Modeler, elevation data are read directly into the project and contour lines are cast at half foot intervals. The students then construct a legend and plot the project at the desired scale. Figure 4 illustrates that graphic.
We have also integrated the GIS into instruction in our photogrammetry course, required for SU students, using the same techniques with the output from our analytical plotter. Students also do an analysis, using GIS and its query language, for a civil engineering project in our Topographic and Cartographic Drafting Course.

**Conclusion**

Not only do our students gain an appreciation for modern techniques applied to classic mapping and Civil Engineering problems, but they also gain an understanding for the need and use of a series of applications. These applications, made by different entities, using different terminology, are all needed to produce the final product: the ASCII DTM and paper map, in the case of the surveying project. Our emphasis on fundamentals equips our students to perform these processes and other surveying or civil engineering tasks with the applications we use or with any others they will come across in what they call “the real world.”
Appendix A - Conversion of Observations into Point Coordinates

For each point to be mapped, the group observes Horizontal plate reading (Azimuth), Vertical angle and Philadelphia rod readings, Top, Middle and Bottom reticule wires.

Known from previous work are the station coordinates for the station over which the instrument is set. The half-intervals are computed and compared ([Top-Middle] and [Middle-Bottom]). If acceptable, the following are computed:

\[ H \text{ (the horizontal distance)} = K \times (\text{Top-Bottom}) \times \cos^2 \text{(Vertical angle)} \]

\[ V \text{ (the vertical distance)} = \frac{1}{2} \times K \times (\text{Top-Bottom}) \times \sin(2 \times \text{Vertical angle}) \]

where \( K \) is the Stadia Interval Constant, usually 100 in most modern instruments. Note the Stadia Constant, i.e. the distance from image convergence to plumb point, is zero in most modern instruments. Then:

\[ X \text{ (easting)} = X_{\text{instrument}} + H \times \sin \text{(Azimuth)} \]

\[ Y \text{ (northing)} = Y_{\text{instrument}} + H \times \cos \text{(Azimuth)} \]

\[ Z \text{ (elevation)} = Z_{\text{instrument}} + \text{Instrument Height} + V - \text{Middle wire reading} \]

These coordinates are associated with the point description from the Remarks column of the fieldbook for later plotting in the CAD.

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