Teaching GPS/GIS to Engineering Technology Students

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Abstract

Global Positioning Systems (GPS) and Global Information Systems (GIS) are two modern technologies that are gradually being included in engineering technology programs. These technologies were incorporated years ago into the Structural Analysis and Design Engineering Technology program offered at the University of Houston-Downtown. Students learn GPS/GIS theory and numerous applications to real design problem in their surveying course. With sponsorship of industry, students are exposed every summer to the latest technologies in total stations, GPS, and GIS. GPS and GIS have revolutionized surveying, because of the ability to quickly determine a location with high precision and obtain corresponding GIS data for the site. This paper describes some GPS/GIS applications included in UHD's Structural Analysis and Design Engineering Technology program.

The program trains students to fit the specific needs of employers and equips graduates with a bundle of advance technology training and tools that makes them immediately productive. The strong emphasis on use of modern technology provides comparative advantages to graduates of the program because they are immediately productive from day one of employment.

Introduction

Although GPS and GIS were originally developed for military purposes that included deployment of earth satellites, the technologies are now broadly available for civilian applications. GPS/GIS may include high-precision field location of monuments in surveying, location of equipment and personnel, monitoring of floating sensors for environmental monitoring over time, biomedical engineering, and other typical or non-traditional applications to real life technical problems. Diverse fields such as building and bridge construction, environmental science, safety and fire, electrical transmission lines, pipeline construction, and other applications, successfully use GPS/GIS technologies. Merging of GPS/GIS with other scientific fields, such as robotics, may yield astonishing future applications. For example, precise field locations could be set by robots through GPS/GIS transmitted data. Use of GPS/GIS is apparently limitless and many undreamed-off technical applications will surface in the future.

Use of advanced technology is also necessary and helpful to the department for the following reasons: Faculty is more productive in the delivery of educational material when up-to-date technology is used; GPS/GIS and computer simulations are tools that enhance the productivity of the faculty; and, students and faculty become highly motivated when exposed and trained in the newest technologies. GPS/GIS technology is commonly referred to as Geomatics.

Why is GPS/GIS, Geomatics, included in a Structural Analysis and Design Engineering Technology Program?

The technologies involved in Geomatics are significant for engineering technology practice because of its labor saving costs and improvements in the quality of results. Engineering firms are eager to apply Geomatics to everyday projects throughout the world. Therefore, Engineering Technology programs such as Structural Analysis and Design Technology at the University of Houston-Downtown need to expose their students to Geomatics to assure that the graduates are immediately productive after graduation. GIS and GPS are some of the most important technological advancements in the field engineering in the last fifty years. GIS is an extremely broad and complex field, concerned with the use of computers to input, store, retrieve, analyze, and display geographic information. Basically, GIS programs make a computer behave as a map: a map with wonderful powers to process spatial information and to tell its users about any part of the world at almost any level of detail¹.

While GPS is also an extremely complex system using it is simple by comparison. It allows computation of location by processing information received from satellites. Accuracy ranges from a few millimeters to somewhere around 100 meters depending on equipment and procedures applied to the process of data collection.

More advanced GPS receivers can also record location data for transfer to computers, so that GPS can determine not only the location of the receiver but also compute present and prior locations and at what velocity movement took place. Thus, GPS can serve as a means of data input to GIS. Initially, GIS used data obtained from maps and aerial photos that were scanned, or more usually digitized manually using a "puck." The puck also traced map features on a digitizer bed. With GPS, the earth's surface becomes the digitizer board; the GPS receiver becomes the puck. This approach inverts the traditional process of GIS data collection: spatial data goes directly from the environment and the map becomes a document of output rather than input².

It is important to note that the Global Positioning System is a high precision system, and originated from NAVSTAR that was developed for dynamic control of intercontinental ballistic missiles. The signal available for civilian purposes is degraded and includes errors due to interference of the ionosphere. When this signal is used for positioning, the system is operating in simple GPS mode. However, civilians have developed methods to improve the precision of the signal with systems that receive and use corrections from land stations or stationary satellites. This system with improved precision is called Differential GPS or DGPS. Improvement of precision is obtained in DGPS by calibration of the signals received from the GPS satellites with a radio signal received from a base station that computes the errors of the incoming signals.

In one specific case of environmental assessment and remediation, GPS is used to locate all agents involved in a pollution study with great precision. The agents include pollutants, sources, carriers, and resources being contaminated, such as oyster beds and sources of drinking water. GPS can also measure the dynamics of pollution measuring water and air velocities. GIS is also used in environmental studies to document the nature and location of all agents involved in a case. Colorful maps present contamination sources together with resources being polluted. A simple click of the mouse reveals the concentration of pollutants at a given point.

Based on GPS and GIS it is possible to develop computer-based models that realistically simulate spatially distributed time-dependent environmental processes in nature. These models are increasingly recognized as fundamental requirements for the reliable, quantitative assessment of complex environmental issues of local, regional and global concern. These environmental simulation models provide diagnostics and predictive outputs that can be combined with socioeconomic data for assessing local and regional environmental risks or natural resources management issues as in the case of the oysters in the Lagunas project in Tampico, Mexico³.

An expected outcome of the Lagunas Project is an environmental simulation model that allows for remediation of the two lagoons in consideration. The methodology developed in this project can be extended to cover the State of Tamaulipas. These expanded studies may respond to requests from State of Texas government (the Texas Legislature through the Texas Higher Education Coordinating Board) for participation of academic institutions in environmental studies across the US/Mexico border.

GPS/GIS Laboratories and Equipment at the University of Houston-Downtown (UHD)

The GPS/GIS Laboratory at UHD has excellent GPS equipment that is used for educational purposes. Figure 1 shows a partial view of the laboratory at UHD. The GPS equipment consists of the OMNISTAR DGPS receiver. This receiver has the capability to collect signals from 12 satellites and at the same time a signal from a stationary satellite that applies all necessary corrections. This system has sub-centimeter capabilities defined as the ability to determine latitude and longitude of a point with errors of less than one-centimeter. The system is used in a stationary manner to teach GPS in the laboratory where a stationary antenna was installed at the top of the building. This GPS can also be transported and used in the field for precision measurements.

Figure 1 – GPS/GIS laboratory at UHD

The lightweights Trimble GPS receivers are ideal for mapping applications that do not require high precision. They can also operate in DGPS mode for improved precision in locations and measurements of velocities of water streams and air balloons. Positions determined with these units have a probable error of less than 30 meters operating in GPS mode and 3 meters in DGPS. Figure 2 shows GPS receivers in use. The portable GPS units are used to map all resources and

sources of pollutants. The location of homes, industries, wastewater points of discharge, and marine life are necessary for construction of the GIS models⁴.

The GPS systems at UHD have the capability to determine velocities based on changes in position and time. This technique, known as RTK (ReaTime Kinematics), are used to measure magnitude and direction of the velocity of water. A buoy carrying the GPS equipment floats in the body of water transmitting data to base computer.

Figure 2 - GPS receiver in use

The GPS/GIS laboratory has a Global Information System based on Arc View⁵. The GIS system allows construction of three-dimensional models using the module 3D Analyzer. This module plays an important role in development of three-dimensional models for the movements of water in bodies of water. Figure 3 shows UHD students and Adjunct faculty working in the determination of latitude, longitude and elevation of a location.

Figure 3- Determination of Geomatics coordinates.

GPS/GIS in the Bachelor of Science in the Engineering Technology Curriculum

GPS/GIS is used in several courses in the program. Examples are:

- In the Senior Steel Design course structures are surveyed and evaluated for repair⁶.
- In the Senior Concrete Design course students locate the final layout of their projects in the field. Based on a GIS drawing, the foundations of a project are localized in a field near the university.
- The Finite Element Analysis of Structures where students measure actual deflections of bridges to compare them with the theoretical values computed in class.
- Measurement of velocities and accelerations of streams of water in the bayous of the Houston Area, are also examples of the application of GIS/GPS technologies in the program.

Actual Applications of GPS/GIS

Faculty contacts with industry are of great benefit for applied disciplines and technologies such as Geomatics. The Adjunct faculty member of Geomatics in our department is in continuous contact with providers of equipment and services in the field. These providers are interested in presenting their products to students. Figure 4 shows the representative of a manufacturer of robotic equipment used in Geomatics explaining the characteristics and operation of the robots to one of the many women students in Structural Analysis and Design.

Adjunct faculty teaching engineering technology at the University of Houston-Downtown are professional engineers successful in their careers and willing to share with students professional experiences accumulated over many years of practice. Most students at the Engineering Technology Department are employees of the petrochemical industry in the Houston Area. Figure 5 shows faculty and students in fieldwork.

Figure 4- Instruction in robotics for Geomatics.

Figure 5- Adjunct faculty and students in field practice.

The university environment allows for experimentation and testing of new techniques that have not been applied in private industry. Faculty at UHD in the field of GPS/GIS have developed novel techniques for measurement of currents in water streams that may be used by industry.

Figure 6- Geomatics buoys for environmental studies.

Figures 6 and 7 shows students using buoys equipped with GPS units and sonar devices for complete analysis of velocities of streams in the Houston bayous. The university also provides the opportunity to develop and test new computer techniques useful to industry.

Figure 7- Buoys equipped with GPS and sonar devices.

Figure 8 shows a graphic database of water flow created in the GPS/GIS laboratory of in a bayou adjacent to the University of Houston-Downtown. Engineering technology students in a surveying course developed the database using ArcView software.

Figure 8- Water Flow Database created in a Surveying Course.

Conclusions

- Geomatics is a new technology developed in industry and used extensively at present in many civil engineering projects.
- Graduates of Structural Analysis and Design, are highly desirable to industry, have a choice of employment, and are successful in reaching responsible positions in industry and government.
- The Engineering Technology Department at the University of Houston-Downtown focuses on unique programs relevant to the Houston, Texas area. Structural Analysis Design was designed to meet the needs of the community at-large.
- The strong emphasis on computer technology provides comparative advantage to graduates of the program because they are immediately productive after employment.
- The program trains students to fit the specific needs of the Houston area and equips the graduates with a bundle of advance technology training and tools that makes them immediately productive.
- Use of advanced technology is necessary and advantageous to the department since faculty members become more productive in the delivery of educational material.

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Alberto Gomez-Rivas is Professor of Structural Analysis and Chair of Engineering Technology. Dr. Gomez-Rivas received Ph.D. degrees from the University of Texas, Austin, Texas, in Civil Engineering and from Rice University, Houston, Texas, in Economics. He received the Ingeniero Civil degree, with Honors, from the Universidad Javeriana in Bogotá, Colombia. He also served as Chief of Colombia's Department of Transportation Highway Bridge Division.

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