2006-2170: STRATEGY TO INCORPORATE GIS AND GPS APPLICATIONS INTO CONSTRUCTION EDUCATION

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Strategy to Incorporate GIS and GPS Applications into Construction Education

Abstract

This paper presents the strategy to teach undergraduate students GIS and GPS knowledge through several related courses in a construction engineering and management (CEM) program. This information could be disseminated through typical CEM courses such as Surveying, Construction Planning and Scheduling, Construction Contract and Field Management, and a senior level Special Topics in Construction course. The students will be exposed to the latest spatial technologies including GIS, GPS, laser scanning, aerial photography and satellite imagery, and will learn how they can develop fully integrated spatial applications and solutions in a wide variety of construction planning, decision, implementation, and management areas. Besides basic knowledge, in the senior level, students would be able to use GIS applications to enhance construction process visualization with such tools as 3D animation. The sequence of topics, course sequencing, software licensing, and laboratory development will be discussed in the paper along with a proposed project example. After students obtain these basic skills, they will be able to graphically simulate and the operate construction process with spatial construction data in a simple, accurate, safe, and effective way. The prerequisite knowledge for these courses and the way to bring industry practice into this course is discussed as well.

Introduction

Recently, Geographic Information Systems (GIS) and Global Positioning Systems (GPS) are becoming increasingly useful and beneficial in construction engineering and management field due to their increasing availability due to the evolution of these technologies. With the current trends in 4D CAD, more construction companies are integrating GIS with scheduling. Therefore, more and more contractors and transportation agencies are expecting the GIS and GPS knowledge and capability from new graduates of construction engineering and management programs. Introduction of GIS and GPS to the undergraduate students in construction engineering and management program will bring them a positive element for their career in future. Some programs of civil engineering have incorporated GIS courses in their curriculum[1; 2]. In the area of undergraduate construction education, however, it is very hard if not impossible to establish an independent undergraduate level course or short training of GIS and/or GPS applications in construction education under the current curriculum system. The strategy described in this paper will allow introducing undergraduate students the GIS and GPS and its applications step by step through several related courses in the construction engineering and management program.

GIS/GPS Basic

Numerous books and papers can be referenced for the basic concepts of GIS and GPS[3]. To summarize, GIS is a decision support tool for organization, analysis and modeling, displaying spatial data over time, and then analyzing potential impacts and outcomes of alternative decisions[4]. This is based on GIS capability of queries pertaining to location, condition, and patterns in any location. GIS has been in use since 1950s[1]. However, only recently, GIS has been applied considerably by federal, state and local government on data capture and processing due to the availability of advanced computer technology and software packages, and especially due to the increased accuracy in GPS equipment. These governments include, for examples, departments of transportation, and land administration. Also, private sectors such as real estate management have already had GIS application.

One of the best versions of GIS software is ArcGIS, which is made by ESRI[5]. ArcGIS includes ArcView, a full-featured GIS software for visualizing, managing, creating, and analyzing geographic data, allowing users to see relationships and identify patterns, make better decisions and solve problems faster. With ArcView, users can

- Leverage geographic data to make better decisions.
- View and analyze the spatial data and build new geographic data sets quickly and easily.
- Manage all the files, databases, and Internet data resources from a single application.
- Customize the user interface around the tasks that users need to accomplish

ArcView is the most widely used desktop GIS software in the world due to its capability of creating high-quality maps with a large array of symbols and cartographic capabilities. ArcView makes data management and editing a painless task because data can be integrated from almost any source. ArcView simplifies complex analysis and data management tasks by allowing users to visually model the task in a logical work flow through data integration and spatial analysis using industry-standard programming languages[5].

The nature of construction – large amount of field data, changing of location, changing over time – best meets the data requirements of using GIS/GPS. With increasing of demands from construction industry, the education of GIS/GPS for construction graduates is not adequate. Students must learn two major concepts: one is about GIS/GPS operations, and the other is about spatial data management. However, the focus of applications should be on enhancing students' background to meet construction activities requirements. It is intended for students to apply the basic principles and techniques of the GIS/GPS applications for construction activities with an emphasis upon data management.

Outcomes and Course Frame

The prime objective of incorporating the GIS/GPS into construction education is to expose construction students to the basic concepts and practices involved in applying and using

GIS/GPS applications to construction activities such as surveying, planning, field management and process simulation. As mentioned above it will not be a good practice to set up just one independent course of GIS/GPS. Instead, several related courses in the construction engineering and management program should be used to teach undergraduate students this advanced technology. The courses being involved are typically, in general, Surveying, Construction Planning and Scheduling, Construction Contract and Field Management, and Special Topics for senior. The students will exposure to the latest spatial technologies, including GIS, GPS, laser scanning, aerial photography and satellite imagery and how they can interface to develop fully integrated spatial applications and solutions in a wide variety of construction planning, decision, implementation, and management areas. Besides the basic knowledge, in the senior level, students should be able to use GIS to use GIS applications to enhance construction process visualization with such tools as 3D animation.

Different teaching strategies should be applied in each of courses above, including formal lecture, laboratory, and comprehensive/intern projects. While the detailed technical description is being discussed in the following section, the knowledge points in the proposed courses can be divided into three major steps/components:

- Step I – Basic GIS/GPS concepts: This step allows students to learn the basic GIS/GPS concepts, spatial data management, and prepare to obtain the potential benefits for construction. Usually, students should be able to attend a pure GIS class from other programs such as Geography or a short training course offered by computer support center. However, considering these courses are not required by curriculum (i.e., not all students are willing to attend these elective courses), a review or short introduction of basic GIS/GPS concepts must be provided in the first course involving GIS/GPS. The best place is course of Surveying.
- Step II – Applications in Construction: This step focuses on applying theoretical GIS/GPS with available software and hardware to solve issues in construction. These applications include the construction field data collection, data management and integration of construction activities. The courses involved in this step are Construction Surveying, Construction Planning and Scheduling, Construction Contract and Management of Construction.
- Step III – Advanced Projects: This step will give those students who have learned the GIS/GPS basic applications separately an opportunity to integrate various parts together into a comprehensive or real construction project. The best course for this step is special topics or senior design in construction, or senior internship. This step will also allow students integrating GIS/GPS with other newer technology such as laser scanning and 3D/4D animation to simulate the construction process

Upon completion of the learning activities through various courses, the students should be able to:

- Understand the basic concept of GIS/GPS and its capability to meet some construction needs.

- Recognize the scope of construction activities for GIS/GPS are applicable.
- Select appropriate software and hardware for applying GIS/GPS knowledge to improve construction performance.
- Design a basic spatial data management system after further self-study and obtain advice from experienced engineers.
- Locate the future study direction if more knowledge is needed for applications in this area.

In summery, students should know how to analyze construction operations using GIS/GPS knowledge to simplify and improve the critical construction process.

Integration of GIS/GPS in the construction curriculum

According to the frame described above, several courses in the construction curriculum can be integrated with GIS/GPS applications.

Surveying

In current construction curriculum, the construction engineering and management program usually shares the surveying course with civil engineering program. Therefore, the integration of GIS/GPS application in a surveying course can be somewhat similar to the practice done by the Civil Engineering program at University of Hartford[1] with necessary modification.

With the prerequisites of computer-aided design and appropriate computer programming courses (used to develop students' ability to recognize the computer knowledge and software structure), a four-credit surveying will be established with spatial data management and GIS/GPS concepts and basic applications as well as traditional surveying methods. This course will be placed in the first semester of the sophomore year. As the first point students encounter the GIS/GPS the surveying course is also a time point to be familiar the required GIS/GPS software and hardware. The best combination is the ArcGIS system[5] and the Trimble GPS system[6]. The software ArcGIS license can be obtained from ESRI.

In this stage, the homework and laboratory questions should be based on the basic tutorial material and the use of equipment. However, the class final project should be related to construction site layout. Recommended supplemental text is *Introduction to ArcGIS*[7].

Construction Contract and Field Management

Within one combined or several separate courses of construction contract, management of construction, construction planning and scheduling, the GIS/GPS components and applications will be added in following topics:

- Subcontractor selection and management

As a part of contract management and bidding, subcontract selection is important for a general contractor. Subcontractors' qualification data and analysis and related

management can be enhanced by applying GIS system. To teach students with this application, an instructor needs to establish the simulated subcontractors' data first and then require student to input and analyze the data using GIS system. Finally, the best subcontractor and other alternatives can be produced.

- Construction Site Layout

Utilization of GIS can make an automated site layout[8]. GIS applications improves the site planning efficiently by eliminating the need for extracting data from various resources such as drawings, specifications, schedules and estimates. GIS/GPS based data management system provides an effective foundation for planning construction activities. In order to teach GIS applications in these courses, the instructor needs to set up several functions before give students the lab work such as (1) temporary facility library; (2) GIS database such as construction site geographies table and the feature attribute table; and (3) database and graphic queries. The lab exercise for students can focus on (1) spatial data analysis; (2) potential site layout generation; and (3) identify the optimal site layout.

In this stage, some real industry data can be used in the class.

Advanced Projects

As mentioned above, in a course of Special Topics or Senior Design in Construction, or Senior Internship, the students can be given an opportunity to simulate the construction process with GIS data and other technologies. Current research[9] shows GIS based visual simulation can dynamically and graphically simulate the complex construction process. The simulation output is helpful for engineers to understand construction process quickly and more comprehensively. The construction process is complex and fragmented. As new technology is developed and implemented, the industry is in a constant state of change[10]. It is valuable and beneficial to bring construction data of real projects to the classroom. It is important to bring student to the construction site to visit the applications of those technologies. This stage will involve other advanced technologies and industry information described in following sections. In the senior level, students should be able to use GIS applications to incorporate site line with a visualization tool such as 3D/4D animations and then make a walk/fly-through construction environment

Other Advanced Technologies

After the GIS/GPS and current applications are taught, some other advanced technologies are ready to be introduced into class in order to simulate the construction process. Laser scanning allows users to graphically catch existing projects or current construction sites and gather as-built graphical data to help the design process and construction management. Construction simulation systems such as STROBOSCOPE (State and Resource Based Simulation of Construction Processes)[11] is to allow students graphically simulate the construction process before the actual activities happen in the real world. The reason to bring STROBOSCOPE to the class is that it can be used to model extremely complex operations by using more advanced features.

One example of laser scanning, Leica 3D HDS Laser Scanning System[12], consists of a HDS (3000 or 4500) scanner, a laptop computer, and Software. The HDS system captures 3D surface

geometry of complex structures and sites with an unprecedented combination of completeness, speed, accuracy, and safety. Complete surface geometry of exposed surfaces is remotely captured in minutes. The scanner can be rotated or moved around the site to capture entire scenes. As soon as scanner has scanned a structure or site, software lets users use the 3D point clouds for a wide variety of applications, including those that require export to different formats so that GIS system can build a database.

Conclusion

The strategy described in this paper features an integrated and incremental exposure to the GIS/GPS and its applications that teaches construction engineering and management students GIS/GPS technology. The knowledge and skills gained in the class will help students graphically simulate and operate construction process in a simple and effective way. The practice of class projects give students the encouragement to pursuit the further study related to advanced technology. Through the exposure to these advanced technologies, the students will gain the solid foundation to the construction process. The benefits for their future career are expectable.

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