Session 2615

Open-Ended Projects for Graduate School-Bound Undergraduate Students in Civil Engineering

Carlos Sun
University of Missouri-Columbia
Ralph Dusseau, Douglas Cleary, Beena Sukumaran, and Douglas Gabauer
Rowan University

Abstract

This paper describes a series of open-ended project classes called Junior/Senior Engineering Clinics as part of the curriculum at the Department of Civil Engineering at Rowan University. The emphasis of this paper is on projects that prepare graduate school-bound students who would benefit from a research-oriented project versus a industry-oriented project. These projects involve multi-disciplinary teams composed of undergraduate students with mixed Junior and Senior status. The purpose of this paper is to share our experiences in undergraduate research and to promote similar efforts in providing undergraduate students with graduate-school type research. Two main projects will be described in this paper. One project involves intelligent surveillance in transportation engineering by using pattern recognition techniques and video image processing. Another project involves the modeling and analysis of truss and suspension bridges in the Delaware Valley region. Both projects involve graduate-level mathematics and modeling techniques such as Linear Predictive Coding, multi-objective optimization, finite element analysis, and frequency domain analysis. In addition to the technical aspects of projects, students also experience practical aspects of research-oriented projects such as proposal drafting, project management, research report submission, conference paper writing, and weekly research meetings. The Junior/Senior Engineering Clinics provide the structure for open-ended projects to occur regularly as part of the undergraduate course study.

I. Introduction to Junior/Senior Clinic

The engineering clinic series at Rowan University are team taught by faculty from all four engineering disciplines; namely, Civil and Environmental, Chemical, Electrical and Computer, and Mechanical. All engineering students are required to take the clinic classes irrespective of their own engineering discipline. The students receive two credits per semester for the Junior/Senior clinic.

Table 1: Overview of Engineering Clinic Content

Year	**Engineering clinic theme (Fall)**	**Engineering clinic theme (Spring)**
Freshman	Engineering Measurements	Competitive Assessment Laboratory
Sophomore	Discipline Specific Design	Interdisciplinary Design Modules
Junior	Multidisciplinary Research and Design	Multidisciplinary Research and Design
Senior	Multidisciplinary Research and Design	Multidisciplinary Research and Design

Table 1 shows an overview of the engineering clinic sequence. The first two years of clinic are composed of engineering projects that are more structured These two years serve as preparation for the final two years of clinics that are composed of entirely open-ended projects. These projects are funded by industry and public agencies and are mostly multi-disciplinary projects. The industry-oriented projects are more practical in nature and are geared toward students who seek to practice as engineers with a bachelor's degree. On the other hand, the projects funded by research agencies are more theoretical in nature and are suitable for students who are bound for graduate studies. The objectives of the research-oriented projects include[1]:

- Demonstrate expanded knowledge of the general practices of engineering through immersion in an engineering project environment of moderate to high complexity.
- Demonstrate an ability to work effectively in a multidisciplinary team.
- Demonstrate acquisition of new technology skills through use or development of appropriate computer hardware, software, and/or instrumentation.
- Demonstrate effective use of project and personnel management techniques.
- Integrate engineering professionalism and ethics in their work and as it relates to the context of engineering in society.
- Demonstrate improved communication skills including written, oral, and multimedia.

Two of the logistical challenges in the Junior/Senior Clinic are getting students interested and excited in a topic that apparently may not be closely related to their own discipline and in demonstrating the *inter*- and *multi*- disciplinary nature of engineering projects.

II. Signature Pattern Recognition

The clinic project involving Intelligent Transportation Surveillance was jointly sponsored by the departments of Civil and Environmental (CEE) and Electrical and Computer (ECE) Engineering. The student research team was composed of one CEE junior, one CEE senior, and one ECE senior. This project was funded by the California PATH (Partners for Advanced Transit and Highways) Program.

The goal of this project is to provide an accurate algorithm to "reidentify" vehicles traveling on roadways. In context, the term reidentification refers to an ability to distinguish between and track individual vehicles from one point on a roadway to another. A wide range of techniques including video imaging, infrared, and radar technologies has been implemented to acquire traffic related data. This research, however, focuses mainly on the use of information from surface mounted inductive loop detectors. When a vehicle passes over an inductive loop detector, the metal components alter the magnetic field directly above the detector for a short period of time. Since the change in inductance is dependant on a myriad of factors including the length of the vehicle and the individual material components, each vehicle produces a unique "signature" as it passes by the detector. The intention is to accentuate the time invariant components of these signatures to provide an accurate basis for the real-time matching of vehicles traveling on roadways. An accurate procedure for matching vehicles will provide important traffic related parameters including travel time, density, origin destination demand, and lane changes.

A preliminary analysis has focused on the implementation of a platoon-matching algorithm, the discrete cosine transform (DCT), and the integration of automated video image processing. Each student was responsible for one of the aforementioned tasks.

II.A. Platoon-Based Matching Algorithms

In an attempt to improve the accuracy of the signature-matching algorithm, a platoon-based algorithm was investigated. The approach assumes that the basis for vehicle travel is the platoon and that accuracy and efficiency can be improved with the correlation of platoons of vehicles rather than singular vehicles.

In the development of a platoon matching routine, the size of a platoon is of crucial importance. Several methods can be implemented for platoon selection including a fixed vehicle number and a fixed time window. For the fixed time window method, the platoon size would be based on the traffic flow conditions at a given time. This may result in a wide range of varied platoon sizes, which may have an adverse impact on computational requirements. Using the fixed vehicle method, the time frame of the platoon would be a variable. For this preliminary analysis, a fixed number of vehicles comprise a platoon; a sensitivity analysis with regard to a varied platoon size has not been completed to date. The logic relating to the platoon-matching algorithm is presented in the outline below.

In future studies, the platoon size can vary depending on the number of lanes present, the amount of traffic, and the amount of fluctuation in traffic. Also, the size selection should be viewed in conjunction with computational considerations and an evaluation should be made regarding the platoon size, the resulting accuracy and the computational requirements.

The following outline describes the reidentication algorithm that was developed.

1. Create separate arrays for each lane of traffic (upstream and downstream)
2. Select downstream platoon vehicles using chronological selection from lane 1
    a. Sum the lengths and maximum magnitudes of the vehicles
    b. Determine time window (time of 1st & last vehicles)
    c. Determine average speed of vehicles within platoon.
    d. Store attributes of the downstream platoon in an array.
3. Set upstream time interval based on downstream time window ➔ determine time cutoffs using average speed for time shift (considering min/max travel times)
4. Check lane 1 for vehicles within time frame.
5. Add lengths of all 5-vehicle combinations and compare to downstream value
    a. If the number of vehicles < 5 from lane 1, search time window in lane 2
    b. If no 5-vehicle combination from lane matches the downstream value, search time window in lane 2

c. Set maximum number of vehicles from lane 2 to be small since the likelihood lane changes is small.

6. Add maximum magnitudes of all 5-vehicle combinations and compare to downstream.
7. Choose platoon with closest length to downstream if max magnitude check is reasonable.
8. Repeat for Lane 2 excluding those matched for platoon in lane 1.

II.B. Discrete Cosine Transform

The discrete cosine transform (DCT) is similar to the discrete Fourier transform and transforms a signal or image from the spatial domain to the frequency domain. By adding this feature check to the reidentification algorithm, we hoped to increase the accuracy.

Figure 1 shows a typical vehicle signature. As one see, the graph is extremely smooth, showing that there is very little high frequency data. Figure 2 shows the DCT of this signature. This further clarifies the small amount of high frequency data.

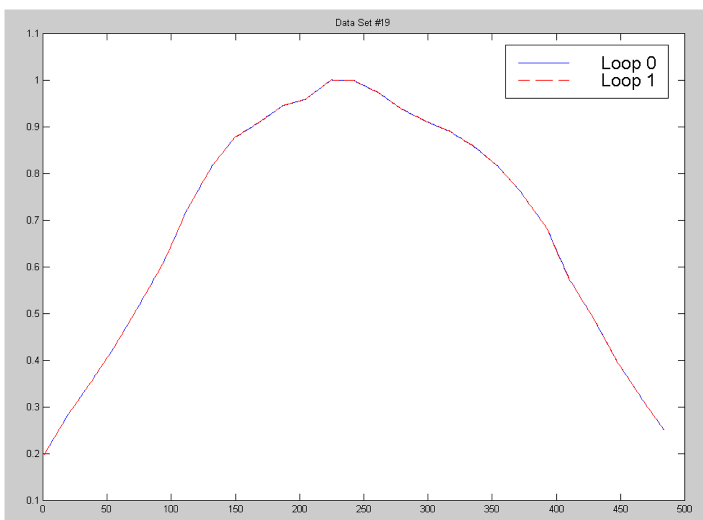

Figure 1: Typical Vehicle Signature

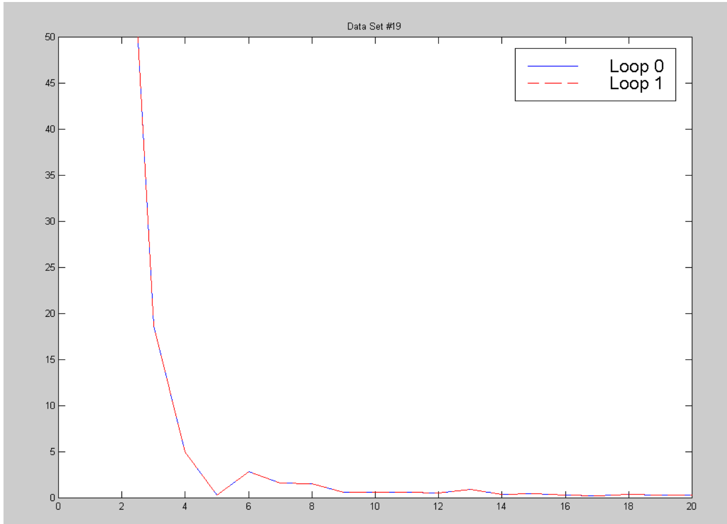

Figure 2: DCT of Typical Signature

The excessive low frequency data made it hard to match DCT's of signatures. To help remedy this problem, we implemented a high pass filter in the DCT routine. This filter essentially blocks all low frequency and DC frequencies. By doing this, the low frequencies no longer dominate the frequency response, and more high frequency characteristics can be obtained from each vehicle signature.

When analyzing the results obtained from the DCT algorithm, the data show that many of the misses were extreme. For example, the routine would match vehicle 21 with vehicle 109. It is highly improbable that these vehicles could be the same, since the vehicle 28 would have to be traveling at a very slow rate of speed to cross the next downstream loops after such a long period of time.

To solve this problem, we decided to try and implement a time window feature. This time window would eliminate a number of the possible matches. Besides making our matching more accurate, it would also speed up the routine since only a few cars would have to be compared to each other.

II.C. Video Image processing

In order to exploit the benefits of detector fusion, video images were used in conjunction with inductive loop signatures. The goal is to use the color feature vector to augment existing algorithm results.

The concept of "background subtraction" is used in deriving chroma. Background subtraction will take an image with a vehicle in it, and "subtract" from an image of the background without a vehicle. This will ideally eliminate all of the image that is not the vehicle. For instance, if the RGB values for the background image are within +/-20, that pixel will be set to black, otherwise, the pixel will remain unchanged. This comparison process will repeat for each pixel in the image, and the result should be a black background with a vehicle as the only non-black part of the image. From this, the most predominant color, other than black can be taken, and this will be the color of the vehicle. In the case that the vehicle is black, another restriction will be put on the function to compensate for this possibility. Several problems could be encountered with this part of the process, such as the presence of more than one vehicle per image, the time of day (lightness/darkness), and the time it might take to go pixel by pixel through an entire image.

III. Seismic Analysis of Delaware Valley Bridges

The goal of this project is to perform modeling and seismic analysis on three of the four main Delaware Valley bridges; namely, the Betsy Ross, the Ben Franklin, and the Walt Whitman bridges. The first step is to analyze the Betsy Ross bridge. The project team is composed of faculty and undergraduate and graduate students from the departments of Civil and Environmental, Mechanical, and Electrical and Computer Engineering. Because of the advanced nature of this project, the tasks are divided among undergraduate students, graduate students, and faculty. The undergraduate students include mainly juniors and seniors, and most of them have had several structures and geotechnical courses. Some have also taken the Advanced Finite Element Analysis course which is open to undergraduates. Some tasks such as the coding of the bridge superstructure and research on area seismic characteristics are more suited for undergraduate students. There are also special seminars scheduled where industry experts come to Rowan University to present their experiences on bridge seismic analysis.

In order to understand a Seismic Analysis of the Betsy Ross Bridge Superstructure, one must first learn about the superstructure itself and understand how it functions under various types of loadings. This would include the components of the structure, how and why they are used, and how each component of the bridge affects one another. For reasons of this nature, research was performed on the steel truss bridge in areas such as the finite element analysis, seismic analysis, strength and stiffness, damping effects, and vibration. Moreover, ductility of steel truss members plays an important factor in seismic analysis. The ductility of a bridge plays an important factor in how the bridge can react or respond in an earthquake with various types of ground motion.

While the research was being compiled, steps were taken to understand the plans of The Betsy Ross Bridge. The bridge was redrawn using AutoCAD 2000 and imported into SAP 2000. SAP 2000 is a program that can perform finite element analysis and will show the effects and reactions of the bridge as it is being put through various ground motions.

Examination of the approach structure was conducted from the east abutment to the main span pier. The basic philosophy for analysis of the east approach is to first construct a 3D-model in AutoCAD, second import the drawing into Microsoft notebook, third edit the contents, fourth import the model into SAP 2000, and lastly assign member properties.

The components of the bridge drawing are the following:

- Curvature of roadway
- Slope of roadway
- Crown in the roadway
- Width of the deck
- Stringer Shape
- Diaphragm Shape
- Stiffeners
- Copying of Spans
- Pier Shape
- Connectivity

Frame elements are used to model beam-column and truss behavior in planar and three-dimensional structures. A frame element is modeled as a straight line connecting two joints. Each frame element may be loaded by self-weight, multiple concentrated loads, and multiple distributed loads. End offsets are available to account for the finite size of beam and column intersections. These end offsets were to be the next thing tackled in the project, however time constraints did not allow for this. In the models, the elements were made with lines not accounting for any thickness or overlap. These end offsets would account for this. Element internal forces are produced at the ends of each element and at a specified, equally spaced, points along the length of the element.

A frame section is a set of material and geometric properties that describe the cross-section of one or more frame elements. The frame section defines the cross-sectional dimensions of an element. Material properties for the Section are specified by reference to a previously defined material. Basic geometric properties are used, with the material properties, to calculate the stiffness of the section. They are the cross-sectional area, the moment of inertia, the torsion constant, and the shear areas.

In dynamic analysis, mass of the model is used to compute the internal forces. Self-weight loads, concentrated span loads, and distributed span loads may also be applied to the structure. Self-Weight Load can be applied in any Load Case to activate the self-weight of all elements in the model. The Concentrated Span Load is used to apply concentrated forces and moments at various locations on Frame elements. Distributed span loads are used to apply distributed forces and moments on Frame elements, which have six degrees of freedom.

Shell elements are used to model shell, membrane, and plate behavior in planar and three-dimensional structures. This is what was done in analyzing the girders. The shell element is a three-or-four-node formulation that combines membrane and plate-bending behavior. Plate bending behavior includes two-way, out-of-plane, plate rotational stiffness components and a translation stiffness component in the direction normal to the plane of the element. Shell elements always activate all six degrees of freedom at each of the connected joints. A shell section is a set of material and geometric properties that describe the cross-sectional of one or more shell elements.

Joints are very important when it comes to the analysis of any structure. They have six degrees of freedom and are the primary locations in the structure at which the displacements are known or are to be determined. In the future, there is a possibility of placing springs at the joints and performing the analysis that way. Any of the joints in the structure can have translation or rotational spring support conditions. The springs connect the joint to the ground in an elastic manner.

Constraints are used to enforce certain types of rigid-body behavior, to connect together different parts of the model, and to impose certain types of symmetry conditions. A constraint consists of a set of two of more constrained joints. The displacements of each of the pair of joints are related by constraint equations. Constraints can be enforced on the following types of behavior: rigid body, rigid diaphragm, rigid plate, rigid rod, and rigid beams.

The gusset plates were an additional structural element of importance. The gusset plates are found at each major node of the bridge structure connecting the bridge members. The size, weight, and strength of these pieces of the puzzle are of significant importance when it comes to analyzing the seismic endurance of the entire bridge. The gusset plates transfer energy from one member to the others that share the same node. This is significant because the plates have to endure all the different strains from any member attached to it from different angles. This establishes a tremendous need for strength at the nodes. Each plate was hand measured one by one from the scaled drawings in the plans.

Initial investigation of the supporting pier structures revealed that additional calculations would be required in order to take into account the effects of any seismic activity subjected to them. These additional calculations are required to determine the maximum allowable load applied and deflection of the individual pier structures at the point of concrete failure.

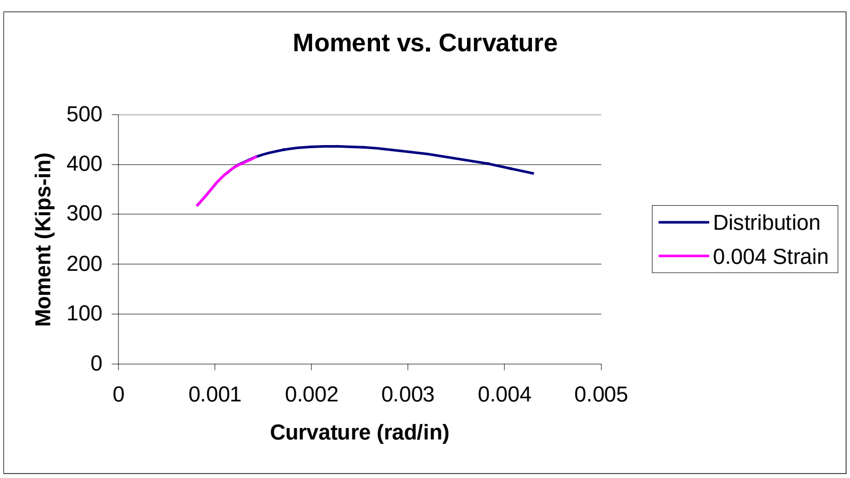

Figure 3. Moment vs. Curvature

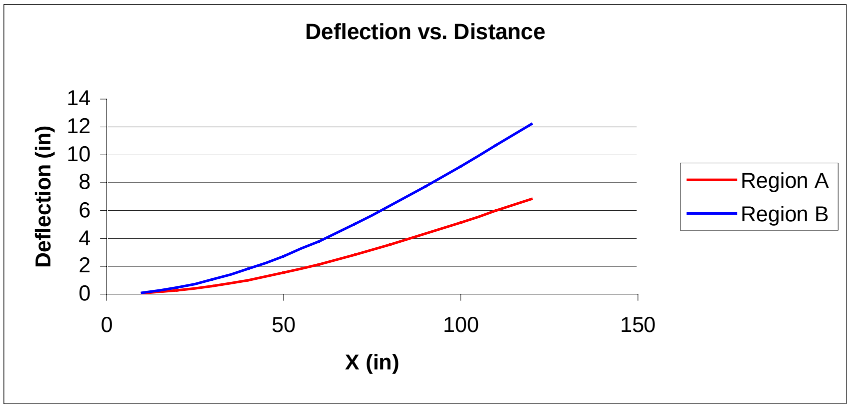

Figure 4. Deflection vs. Distance

Figures 3 and 4 show selected examples of bridge modeling. Figure 3 shows the moment vs. curvature curve. Figure 4 shows a graph of the elastic curve with region A being when concrete reaches a crushing strain of 0.004 and region B being when the maximum moment is developed regardless of the crushing strain

IV. Conclusion

The Junior/Senior Clinics provide the opportunity for graduate school-bound students to participate in open-ended projects that are research-oriented. These courses provide a regularly scheduled sequence of project classes for junior and senior level students.

There are many characteristics of the clinics that are similar to graduate-level projects. First, the teams are highly multi-disciplinary and force students to delve into new engineering areas. Second, the open-ended research problems that are tackled in clinic emulate the level of difficulty that is encountered in graduate-level projects albeit at a lower intensity. The nature of these problems forces students to think critically, analytically, and creatively. Third, the funding agencies involved usually fund graduate-level research projects and expect the same kind of quality in the deliverables. Along those lines, the students are required communicate well to the sponsors in both written and verbal forms.

Despite the positives associated with offering such projects, there are also many challenges. First, it is sometimes difficult to motivate students in disciplines that are not their own. Second, the students do not have the full set of undergraduate engineering tools at their disposal; therefore, they proceed at a much slower pace than graduate students. The technical abilities of the students also limits the complexity of the problem that can be tackled. Consequently, interesting research issues are sometimes avoided instead of investigated.

Two particularly successful examples of Junior/Senior clinic projects are presented in this paper. One involved the use of advanced technologies and mathematical algorithm development. The other involved the modeling and simulation of bridge structures using finite element analysis. Both projects required the students to study the theory behind engineering tools and methods. And both projects gave students valuable experience in preparing them for graduate studies and research.

Acknowledgement And Disclaimer
The research reported in this paper was supported by the California Department of Transportation (Caltrans), PATH (Partners for the Advanced Transit and Highways) and DRPA (Delware River and Port Authority). The contents of this paper reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or New Jersey. This paper does not constitute a standard, specification, or regulation.

Bibliography

1. 1. College of Engineering, Rowan University. Senior and Junior Engineering Clinic I Syllabus. Glassboro, NJ. (2000)

Biographical Information

CARLOS SUN

Carlos Sun is an Assistant Professor of Civil and Environmental Engineering at the University of Missouri-Columbia. Dr. Sun received a B.S. in Electrical and Computer Engineering, and M.S. and Ph.D. in Civil Engineering from the University of California at Irvine in 1990, 1993, and 1998, respectively. Previously, he was an assistant professor at Rowan University, a postdoctoral researcher at the University of California at Berkeley, and an instructor at the University of Southern California.

RALPH DUSSEAU

Ralph Dusseau is the Professor and the DRBA Chair in the Department of Civil and Environmental Engineering at Rowan University. Dr. Dusseau graduated from Michigan State University and was previously a faculty at Wayne State University.

DOUGLAS CLEARY

Douglas Cleary is an Associate Professor in the Department of Civil and Environmental Engineering at Rowan University. He obtained his Ph.D. from Purdue University and was previously with Black and Veatch Engineering. He specializes in the area of structures.

BEENA SUKUMARAN

Beena Sukumaran is an Assistant Professor in the Department of Civil and Environmental Engineering at Rowan University. Her area of expertise is geotechnical engineering. She was previously a research fellow at the Norwegian Geotechnical Institute.

DOUG GABAUER

Doug Gabauer is an undergraduate research assistant at Rowan University.