Parametric Case Studies - Closing the Loop

Wade C. Driscoll
Industrial and Systems Engineering
Youngstown State University

Abstract

Traditional case studies have proven to be effective means for teaching engineering design. Unfortunately, traditional case studies, in which all students in a class simultaneously work on the same case study, may result in inappropriate levels of student interaction. A parametric case study is a generalization of a traditional case study in which problem parameters vary from one student to another. This ameliorates the problem of inappropriate student interactions, since each student works on a different problem. This advantage accrues at the cost of an additional burden on the instructor who evaluates the students' work. This paper reports on research that was performed to investigate the feasibility of having the microcomputer - the platform used to deliver the case study to students - also serve to generate base-line solutions to the multitude of problems that result.

1. Introduction

This paper is organized as follows. The next section relates the student outcomes attending traditional case studies to those specified in Engineering Criteria 2000. Section 3 provides an example of a parametric case study and describes a platform for its delivery. Then Section 4 demonstrates proof of concept for the ideal of having the same computer platform that delivers a parametric case study also generate the means to conveniently find baseline solutions for it. A summary, conclusions and extensions appear in the final section.

2. Engineering Criteria 2000 and Traditional Case Studies

The ABET Engineering Criteria 2000 [3] may be paraphrased as specifying that engineering programs must demonstrate that their graduates have an ability to

- apply knowledge of mathematics, science, and engineering;
- design and conduct experiments, as well as to analyze and interpret data;
- design a system, component, or process to meet desired needs;
- function on multi-disciplinary teams;
- identify, formulate, and solve engineering problems;
- communicate effectively; and
- use the techniques, skills and modern engineering tools necessary for engineering practice.

In addition, Engineering Criteria 2000 also specifies that engineering programs must also demonstrate that their graduates have

- an understanding of professional and ethical responsibility;
- the broad education necessary to understand the impact of engineering solutions in a global/societal

context;

- a recognition of the need for an ability to engage in lifelong learning; and
- a knowledge of contemporary issues.

The congruence of the outcomes specified in Engineering Criteria 2000 with those achieved via case studies supports their continued use. Case studies can require students to apply knowledge, design and conduct experiments, design systems, work on teams, identify problems, etc. A year seldom passes without the publication of papers in the ASEE and other journals (for example, see [4]) citing favorable experiences with case studies. Many engineering educators who use case studies agree that, in addition to their power in contributing to the outcomes specified in Engineering Criteria 2000, they also have the following advantages:

- The instructor knows in advance the aspects of design that the case study is likely to cause to surface.
- The instructor knows in advance the levels of maturity and expertise that are required for the problem.
- The instructor does not have to rely on forces outside of his or her control to supply a suitable problem that is consistent with the educational aims of the lesson.
- The instructor does not have to respond to pressures from the workplace in establishing deadlines for student work. That is, the project can be managed according to educational objectives rather than enterprise objectives.
- The instructor does not have to be concerned that a shift in company priorities may result in a lack of support.
- The instructor does not have to be concerned that the company may redefine the student's participation so that it is limited to clerical work, rather than engineering design.

Of course, proponents of "live" project from industry have corresponding lists of advantages for the medium of engineering design with which they have had the most success. They may contend that well defined, well structured (closed-ended) engineering problems with predictable results tend to have relatively low design content. However, the reader may consider the possibility that differences in experience, expertise and perspective may allow a problem - which appears to an expert to be closed-ended - to present an abundance of engineering design experiences to an undergraduate student who doesn't have the resources of the expert. A person whose experiences include taking graduate courses, completing research investigations, and rendering consulting services in an area relevant to a case study may well view as closed-ended a problem that seems bewilderingly open-ended to an undergraduate student without those advantages. Live projects from industry will certainly remain an important part of the education of engineers. However, there should be agreement that a balance of case studies, live projects from industry, and other vehicles for the delivery of engineering education will result in the effective development of essential engineering skills.

Unfortunately, potential users of case studies may be deterred by their inherent difficulty in achieving suitable levels of student interaction. When an entire class simultaneously considers a single traditional case study, it may become difficult to determine when appropriate levels of student interaction are transcended. Class and smaller group discussions of case studies have the advantages of developing teamwork, leadership and project management skill among students while undermining the deleterious notion that engineering work is done without social interaction. However, these discussions require students to make decisions regarding the appropriateness of their level of interaction that they may not have the background, judgement and/or inclination to evaluate. The range of individualities of student work may range from the extreme exemplified by the student who doesn't share his ideas, doesn't benefit from the ideas of others, doesn't contribute to group activities, and does little or nothing to develop his or her communications and/or teamwork skills. Another extreme may be exemplified by the student who makes minimal contributions to group efforts, manipulates others to do the bulk of the work, and attempts to take credit for more than his or her own accomplishments. Often the instructor must make difficult judgements about the level of appropriateness of the interaction of students on traditional case studies. Parametric case studies ameliorate this disadvantage of traditional case studies while retaining their merits in helping to achieve the outcomes given in Engineering Criteria 2000.

3. Parametric Case Studies

The text of the Outboard Boat Case Study which follows this paragraph illustrates the principles of parametric case studies. Bold and italic type emphasizes those problem parameters which change from one student to another.

Outboard Boat Company

Version 1

The Outboard Boat Company manufactures motorboats. The company needs a production plan for the year for its Spring Valley, Tennessee plant. Demands by month are given in the following table.

Month	Demand	Month	Demand	Month	Demand
1	***230***	5	***720***	9	***455***
2	***110***	6	***1060***	10	***275***
3	***250***	7	***1530***	11	***170***
4	***405***	8	***1175***	12	***320***
				Total	***6700***

The total production for the year must equal its total demand. However, a boat used to meet the demand for a particular month need not necessarily have been produced in that month. The boat could have been made in an earlier month and held in inventory. The inventory holding cost for a boat increases proportionately with the number of months it is kept in inventory. Company officials estimate the constant of proportionality to be ***$60*** per boat per month. Similarly, demand can be 'carried over' from one month to the next at an estimated cost of ***$210*** per boat per month. However, this carryover cannot occur at the end of the year. A conversion factor between workers employed and boats produced on regular time, obtained by dividing the number of boats produced by the number of workers required to produce them, equals ***2.3*** boats per employee-month. Unfortunately, the factor declines to ***2.2*** boats per employee-month for overtime. The labor agreement requires overtime for a person working more than 40 hours per week; it allows the company to insist upon as much as ten overtime hours per employee per week. The company may request a person to work more than ten overtime hours in one week. However, the request may be accepted or rejected at the discretion of the worker. Regular time averages to ***$2100*** per worker-month. A premium of 50% for overtime wages results in an 'overtime only' cost of **$3150** per worker-month. It has been said that the cost of hiring a worker averages to ***$1200***, and the cost of laying off a worker averages to ***$2800***. The workforce at the beginning of the year consists of ***150*** employees. There are initially ***50*** boats in inventory.

The reader will note that most of the text of the parametric case study remains invariant. Consequently, all students confront problems having the same structure. However, specific parameters vary from student to student, resulting in unique designs for each.

Although a parametric case study can be distributed to students entirely on paper, the author has found their delivery via a microcomputer platform to have many advantages.

- It is more efficient in terms of the use of the instructor's time.
- It enables additional instantiations of the case study to be generated with no significant additional effort on the part of the instructor.
- It may be conveniently adapted to distribution over the WWW.
- It encourages students to use the computer.
- Students have a head start in documenting the problem that they solved, since text from the parametric case study can be copied from the Windows application defining their case study to their report of their results.
- Students need not reenter the data defining their parametric case study. They can simply copy data from the application that generates their case study to the application (e.g., a spreadsheet) that is being used to generate design alternatives.
- It provides a unique opportunity for the instructor to generate base-line designs for the multiplicity of case studies that result.

Parametric case studies ameliorate difficulties in achieving appropriate levels of student interaction to a large extent. When each student has a unique instantiation of the problem, they can discuss design alternative, solution methodologies, and project management strategies with reduced risk of transcending appropriate levels of interaction, since eventually each must ultimately take responsibility for his or her unique problem. Verbatim copying of another's results will often result in faulty designs. Unfortunately, this advantage is attended by the requirement to evaluate multiple instantiations of design problems, rather than the one problem required by a traditional case study.

4. Generation of Base-Line Solutions to Parametric Case Studies

Engineering design problems by their very nature defy unique solution. It is quite possible for two engineers practicing in differing contexts to design vastly different systems for the same design problem. Engineering judgement about the resources available, the time constraints to be met, and the economic forces to be considered, etc., may result in different assumptions being made, which in turn lead to different designs. However, the information defining a parametric case study may be used to generate a *baseline* solution to the problem against which other alternatives can be compared. Since all of the information required to describe the case study is in its computer implementation, one would surmise that it would be possible (conceptually, at least) to use the same means to contribute toward its solution.

The author established proof of concept for this approach for the Outboard Boat Case Study described earlier. Readers may recognize, possibly after some reflection, that the Outboard Boat problem may be analyzed via linear programming. This suggests that a linear programming model be developed from the data in the case study without human intervention. With this in mind, the author developed software that interrogates the data base describing an instantiation of that problem, processes that information, and develops the text describing a linear programming model of the problem under a given set of assumptions. Then, when evaluating a student's design, the instructor causes the model to be generated, uses the resulting text file as input to a linear programming application package, and obtains a baseline solution to the problem. Consequently, the reasonableness of a student's design can be evaluated in consideration of an existing design alternative, and the burden of evaluating students' work is lessened.

Modern computer hardware and software enable this to be done in a manner that takes advantage of a Windows environment. That is, the application that generates the case study can also be used - via password, of course - to generate its baseline model. For example, the Outboard Boat Windows application produces the text file is condensed below.

```
..title
  Outboard Boat, Data Set 1
..objective minimize
CIL1 + CIS1 + ERTC1 + EOTC1 +  1200 NEH1 +  2800 NEF1 + CIL2 + CIS2 + ERTC2 + EOTC2 +  1200 NEH2 +  2800
NEF2 + CIL3 + CIS3 + ERTC3 + EOTC3 +  1200 NEH3 +  2800 NEF3 + CIL4 + CIS4 + ERTC4 + EOTC4 +  1200 NEH4
+  2800 NEF4 + CIL5 + CIS5 + ERTC5 + EOTC5 +  1200 NEH5 +  2800 NEF5 + CIL6 + CIS6 + ERTC6 + EOTC6 +  1200
NEH6 +  2800 NEF6 + CIL7 + CIS7 + ERTC7 + EOTC7 +  1200 NEH7 +  2800 NEF7 + CIL8 + CIS8 + ERTC8 + EOTC8
+  1200 NEH8 +  2800 NEF8 + CIL9 + CIS9 + ERTC9 + EOTC9 +  1200 NEH9 +  2800 NEF9 + CIL10 + CIS10 + ERTC10
+ EOTC10 +  1200 NEH10 +  2800 NEF10 + CIL11 + CIS11 + ERTC11 + EOTC11 +  1200 NEH11 +  2800 NEF11 +
CIL12 + CIS12 + ERTC12 + EOTC12 +  1200 NEH12 +  2800 NEF12 + 0 ( NE0 + IL0 + IS0 ) + 0 ( NE1 + NEOT1 + PRT1
+ POT1 + P1 + IL1 + IS1 ) + ... (Ten months of similar variable definitions omitted) + ... +0 ( NE12 + NEOT12 + PRT12
+ POT12 + P12 + IL12 + IS12 )
..constraints
IL0 =  50                           IS0 =   0                      NE0 =  150
NE0 + NEH1 - NEF1- NE1 = 0          NEOT1 -0.25 NE1 <= 0           .435 PRT1 - NE1 <= 0
.455 POT1 - NEOT1 <= 0              PRT1 + POT1- P1 = 0            IL0 - IS0 + P1- IL1 + IS1 =  230
CIL1 -  60IL1 = 0                   CIS1 -  210 IS1 = 0            ERTC1 -  2100 NE1 = 0EOTC1
EOTC1-  3150 NEOT1 = 0              (Ten  months of similar constraints not shown)
NE11 + NEH12 - NEF12- NE12 = 0      NEOT12 -0.25 NE12 <= 0     .435 PRT12 - NE12 <= 0
.455 POT12 - NEOT12 <= 0                PRT12 + POT12- P12 = 0         IL11 - IS11 + P12- IL12 +
IS12 =  320
CIL12 -  60IL12 = 0                 CIS12 -  210 IS12 = 0      ERTC12 -  2100 NE12 = 0
EOTC12 -  3150 NEOT12 = 0           IL12 =  50                 IS12 = 0
```

Consequently, the instructor faced with evaluating a plethora of instantiations of a parametric case study may generate base-line solutions for each with reduced effort. Thus a major deterrent to the use of parametric case studies is overcome.

6. Summary, Conclusions, and Extensions

Traditional case studies have many widely recognized advantages in engineering education. Parametric case studies, as a generalization of traditional case studies, share all of these features. They also have additional advantages related to student collaboration, computer use, reduction of the data entry burden for students, and ease of distribution. However, these advantages accrue at the cost of greater difficulty in evaluating student work.

The results of this investigation establish proof of concept for a method of mitigating this disadvantage. The investigation demonstrated that the data base for the description of a case study can be interrogated to build a model which is then used in obtaining a base-line solution to an instantiation of the design problem. Thus the instructor has the means to easily obtain base-line solutions to the multitude of solutions that may result from a class of students. This "closes the loop" on parametric case studies by using microcomputers to generate both the problems and their base-line solutions.

Opportunities for further work abound. The author continues to abstract the essential features of current engineering problems encountered in engineering practice into case studies, and then to adapt them to the parametric case study mode. Each such parametric case study results in an opportunity to use the methodology which proved successful in the Outboard Boat Case Study to automatically generate base-line solutions to the resulting problems.

The approach may also find application in distance learning, in computer-aided instruction, in asynchronous learning, and on the WWW. One method of providing real-time examinations and their evaluation depends upon access to problem statements and solutions on file. The randomness of an examination relies upon the random selection of problems and their solutions, both of which are stored a priori. The experiences with parametric case studies suggest that a powerful alternative consists of the random generation of problem parameters with the automatic computation of their solutions.

References

[1] Driscoll, Wade C., "Parametric Case Studies for Teaching Engineering Design", ASEE Annual Conference Proceedings (1992)

[2] Driscoll, Wade C., "Parametric Case Studies with Interactive Data Acquisition for Teaching Engineering Design", ASEE Annual Conference Proceedings (1993)

[3] Engineering Accreditation Commission of The Accreditation Board for Engineering and Technology, *Engineering Criteria 2000*, 111 Market Place, # 1050, Baltimore, MD 21202 (1996)

[4] Bell, Peter, and C. H. Von Lanzenaeur, "Teaching MS/OR with Cases", ORMS Today, (October 1996)

WADE C. DRISCOLL earned engineering degrees from Penn State, New York University and Case Western Reserve University. His research and teaching interests reside in modeling, simulation, and operations research.

As described in [1], a parametric case study is a generalization of a traditional case study in which problem parameters vary from one student to another. Microcomputer software has been effectively employed in delivering parametric case studies. This paper reports results from an investigation made to determine the possibility of also using a microcomputer to ease the evaluation burden attending parametric case studies by contributing to the generation of their base-line solutions.

Proponents of case studies may contend that even those case studies in which a preponderance of experienced college professors tend to agree upon the essentials of good design provide ample opportunities for an undergraduate student to perform engineering design.