

GT Beam - An Interactive Graphic Beam Analysis Program for Education

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Abstract

An interactive beam analysis program called GT BEAM, that has been developed at Georgia Tech for use in undergraduate mechanics courses, is presented. The development objectives of the program are discussed and how the program has been used effectively to increase the learning and understanding of indeterminate beam structures is presented. Practical experience with the program in two elementary structures courses is also discussed. The paper shows how graphically oriented programs can be beneficial to the education of first year engineering students by allowing them to perform 'what-if' design scenarios. The program is structured to minimize the time the instructor needs to spend in the classroom demonstrating it. The program is free to all educational institutions.

Introduction

While personal computers have greatly proliferated at universities, the actual integration of computers into mechanics of materials courses is still minimal. This is probably the cumulative result of many factors, including the lack of software for elementary structural topics, the opinion that structural theory and not computer solution methods should be taught in elementary courses, the high cost of software for a limited number of applications, and the in-class time required to teach the software operation. To overcome or minimize these obstacles, a simple yet powerful interactive graphical computer program to analysis beam structures, called GT Beam, was developed at Georgia Tech for the Macintosh family of computers. The program has been used successfully in a number of elementary structures courses over couple of years to help teach students about moment/shear and deflection diagrams for complex beams. This paper presents the basic capabilities of the program and why a graphical interface has been beneficial in helping students use the program and learn more quickly. The limitations of the program are also discussed.

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The Use of Software in the Classroom

One of the largest complaints in using canned software programs in elementary courses is that students will not learn the basic theory. If the software is used without the appropriate in-class instruction on theory then that argument would be true. However, if the theory is supplemented by the appropriate software that allows the students to go beyond the textbook examples and problems, then the software will be of great benefit in the learning process.

A second common objective in using software for engineering education is the large amount of time needed to teach the operation of the program during valuable classroom time. This concern is amplified by the current trend to reduce classroom contact hours and to introduce new engineering courses. To overcome this difficulty, the software must be easy to use and operate in a well known graphical environment such as the Apple Macintosh or Microsoft Windows. Commercial software does well in graphical interfaces, but they are generally too powerful for the couple of applications a course might have. Furthermore, the time needed to learn such complex programs is too great. On the other hand, small, topic specific programs that use standard graphical interfaces greatly reduce the learning time for the students, and thus reduce the time the instructor needs to devote to the program use. Ideally, the software should be self-explanatory, assuming the student has already learn the basic theory, and relate directly to the material learned from the textbook and instructor. The key is keeping the program simple but powerful by dealing with only one topic.

The third problem of using software is the cost. Even with large educational discounts, a single copy for each student or a site license must be obtained to use the program, which in most cases well exceeds the funds available to teach the course. Even the cost of purchasing software from nonprofit organization such as ASEE can many times become a financial burden for an elementary course. Another problem is the lack of good topic specific programs that make effective use of graphical interfaces. Topic specific programs generally do poorly in the market place because of the narrow potential customer base. The cost and availability of software is potentially the most sever problem facing an instructor for an elementary engineering course. One solution is for the instructor themselves to develop the software for the course using the school resources. Of course, complex programs would be difficult and are not desirable from the stand point that it will take classroom time to learn how to operate the program. Once developed, the software could be distributed similar to 'shareware' programs in the public domain. Promotion and dissemination of the programs could be done at conferences such as the ASEE conferences in an effort to build up a library of good topic specific software and to let other instructors what is available.

GT BEAM Development Objectives

The main purpose in developing the beam analysis program GT Beam was to give the students a simple program to do "what if" design scenarios for complex

structural beams while overcoming the above mentioned possible difficulties. Students learn how to analyze simple beams and obtain the moment, shear and deflection diagrams in the mechanics of materials courses. However, because of the time involved in solving a beam problem, only a very limited number of simple problems can be assigned in a course. This limits the type and complexity of possible beam problems that the instructor can expose the students to. The GT Beam program allows students to solve additional complex problems, such as highly indeterminate beams outside of classroom time and to go beyond the standard textbook problems. The most important reason in developing this program was to enable the students to visually see the effect of moving supports or loads in real time. The program does not show how the solution process takes places since it involves engineering principles that will not be learned until later courses.

To minimize learning time, the program layout was specifically designed around the Macintosh graphical interface. The program uses many of the same layout features that large traditional Macintosh program have. This allows the students that have used a Mac before to start using the program without extensive reading of manuals or instructor explanation. The program was original designed for the Mac mainly because all engineering students at Georgia Tech have used and have access to a Mac on campus. The program could just as easily been developed for the Windows environment that run on the Intel CPU based computers. Two surveys that were conducted found that the students spend less then 5 minutes reading the manual before running the program. About half used the manual as a reference later to clarify an operation specific points in the program.

Since the program is designed for educational purposes and is topic specific, i.e. beam analysis only, the usefulness of the program outside of the course is of course limited. It could be used in other courses as a quick and easy way to get moment and deflection information similar to an engineering handbook. To make the program more useful in future courses and after graduation, more topics would need to be included such as shear stresses, but then the program would require classroom time to teach the operation of the program. For that same reason, 2-D structures such as trusses were not included. It would be possible to write additional software to cover those topic, but they should not be linked into a 'do-everything' program that one sees at the commercial level. Furthermore, the simplicity of the program allowed the author himself to do the programming. More complex programs generally require a group of software developers, which then dictates that the program must be a commercial program to recover development costs.

Operation Summary of GT BEAM

The actual GT BEAM program closely resembles current Macintosh draw programs, as shown in Fig. 1. There are various drawing tools located at the left of the screen and the user simply uses the mouse to pick the desired tool by clicking on it. The basic operations of the GT Beam consist of three items: 1) the initial construction of the beam, loads, and supports, 2) modification of the loads,

supports and the beam properties, including their location and magnitude, and 3) the calculation and graphing of the moment, shear, rotation, and deflection. All of these operations are done primarily with the mouse. The program begins with a basic simply supported beam which can then be modified to construct the desired beam type and desired loading. Since the interface is highly interactive and does not require node or element numbering, students can quickly do multiple "what if" design scenarios and thus enhance their structural design engineering intuition.

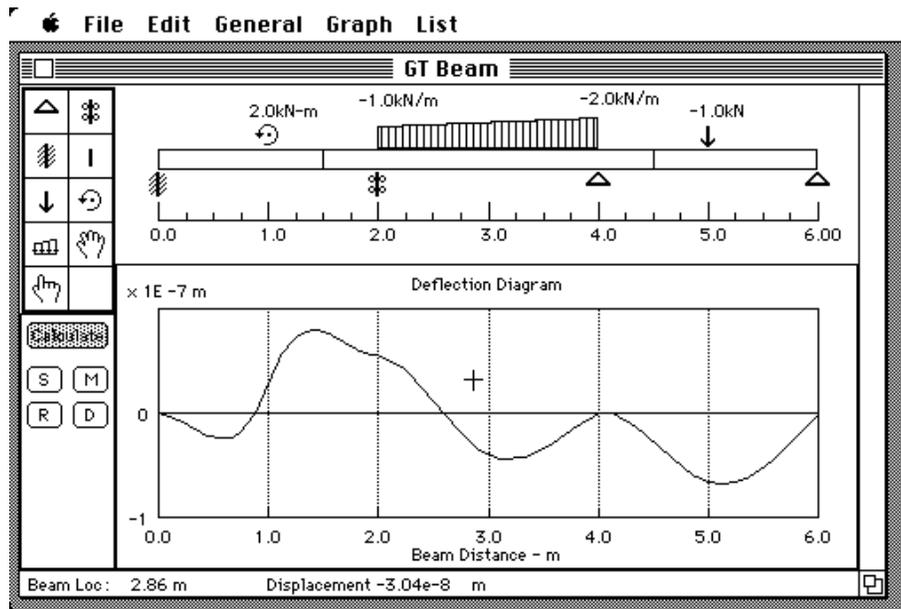


Fig. 1 Main Design and Graphing Screen.

The loads and supports are added by first clicking on the appropriate tool in the tool palette on the left side of the working area and then clicking slightly above the desired point on the beam for the loads, and slightly below the beam for the supports. There are three types of loads available, point force, point moment, and distributed loads. Also, there are three type of supports, simply supported, fixed, and sliding joint. The loads and supports are moved with the hand tool by clicking on the item and holding the button down as the item is moved to the new location. The load magnitudes (and locations of both supports and loads) are modified through dialog boxes that are accessed by double clicking on the item with the pointing hand tool. A typical dialog box is shown in Fig. 2.

Modify Distributed Load	
Left Side of Load	0.50 m
Left Side Magnitude	-1.00 kN/m
Right Side of Load	1.75 m-4
Right Side Magnitude	-2.00 kN/m
<input type="button" value="OK"/> <input type="button" value="Delete"/> <input type="button" value="Cancel"/>	

Figure 2. Distributed Load Dialog Box.

Other features of the program include modification by the user of the ruler and sign convention. The units for loads and material properties can also be changed through dialog boxes as shown in Fig. 3. In addition to visual solutions in graph form, numerical values can be displayed by using the List menu command or by moving the cursor to the point of interest and reading the values at the bottom of the screen.

The properties of the beam, such as the beam length, Young's modulus, and the moment of inertia are changed in a dialog box that appears when the pointing hand tool is double clicked on the beam. The beam joint tool (looks like a straight vertical line) is used to make different beam sections, each of which can have different cross-sectional properties.

Units for Input and Output (Don't mix SI and US Units)				
Length	<input type="radio"/> ft	<input type="radio"/> inch	<input checked="" type="radio"/> m	<input type="radio"/> mm
Force	<input type="radio"/> kip	<input type="radio"/> lb	<input checked="" type="radio"/> kN	<input type="radio"/> N
Moment	<input type="radio"/> lb-in	<input type="radio"/> lb-ft	<input type="radio"/> N-mm	<input type="radio"/> N-m
	<input type="radio"/> kip-in	<input type="radio"/> kip-ft	<input type="radio"/> kN-mm	<input checked="" type="radio"/> kN-m
Distributed Load	<input type="radio"/> lb/in	<input type="radio"/> lb/ft	<input type="radio"/> N/mm	<input type="radio"/> N/m
	<input type="radio"/> kip/in	<input type="radio"/> kip/ft	<input type="radio"/> kN/mm	<input checked="" type="radio"/> kN/m
Modulus	<input type="radio"/> KSI	<input type="radio"/> MSI	<input type="radio"/> MPa	<input checked="" type="radio"/> GPa
Moment of Inertia	<input type="radio"/> in-4	<input type="radio"/> ft-4	<input type="radio"/> mm-4	<input checked="" type="radio"/> m-4
Rotation	<input checked="" type="radio"/> Rad	<input type="radio"/> Deg		
<input type="button" value="OK"/>				

Figure 3. Unit Selection Dialog Box.

The actual calculation is done by first clicking on the 'CALCULATE' button with any tool. By clicking on the 'S', 'M', 'R', or 'D' buttons, the shear, moment, rotation, and deflection diagrams will be displayed, respectively. The horizontal beam location and calculated parameter value is displayed at the bottom of the working screen as the mouse is moved.

The program solves the beam by first splitting the main beam into a series of smaller beam members between each load, support or beam section joint. These beam members, along with the end load conditions, are then used in a matrix stiffness solution method to solve for the shear, moment, rotation, and deflection at each beam member end. This information is then used to develop exact fourth order equations for the shear, moment, rotation, and deflection for each beam member. The effects of shear deformation was not included.

The program was developed at Georgia Tech at minimal cost through a grant from the Georgia Tech Center for the Enhancement of Teaching and Learning. This eliminated the need use internal instructional funds to purchase a similar commercial program that would have probably been to complex to use in an introductory course. The current program version is being distributed free of charge as public domain software and can be obtained from the author by sending a blank disk and stamped self-addressed envelope.

Learning Impact of the Program

As like all teaching and learning evaluations, it is difficult to judge if a particular program is successful. Similarly, in the case of GT Beam, it is hard to know if the students knowledge and engineering skills actually improved or not by using GT Beam. However, two written surveys were conducted to evaluate the students perception of the program and if it helped then learn beam analysis. The results of the survey results are summarized in the following paragraphs.

1. The majority of students thought the program was easy to use. On average it took 10 minutes for the student to start using the program to solve the homework assignment. Only half used the manual to do the assignment.
2. Most students indicated that their understanding of moment/shear diagrams did improve through the use of the program. Some mentioned that they were better able to comprehend the relationships between particular load types and their respective moment/shear diagrams.
3. Over 90% of the students thought that their time was well spend in using the computer. Most thought it was a good supplement to the book and instructor. They also indicated that they would like to see more useful computer assignments and programs.

4. About half of the respondents mentioned that they plan to use the program in other classes and after graduation as a reference tool for beam moments and deflections.

The overall results of the survey indicated that the students did increase their understanding of beam analyses through the use of GT Beam. It should also be noted that other professors that have used the program as part of their classes have also commented favorably about the program.

Summary

The main objective of developing and implementing GT Beam into mechanics of materials courses was to enhance the students understanding of simple beam design and analysis through the application of simple, easy to use, topic specific software program running on the Macintosh computer system that is available to all students. The standardized Macintosh graphical environment allowed students to use the program quickly without the instructor using valuable classroom time. The software was not used in the actual teaching of problem solving, but instead was used after the students fully understood the theory of beam bending to design complex beams and to gain an intuition of beam theory that is only possible after dealing with the design of many beam problems. This allowed students to analysis a large number of beams in a relatively short period of time and will allow them to do "what-if" design scenarios to increase their engineering ability.

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