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The Engineering Mechanics Interactive Lecture Series: Oligomedia Resources for Computer-Based Learning*

Brian Chapman
Anthony Fernando
Hugh Kelly
Phillip Tran
Quality Education at a Distance (QED) Research Unit, Monash University, Berwick, VIC 3806, Australia
QED Interactive Pty Ltd, Drouin, VIC 3818, Australia

This paper describes the features of the Engineering Mechanics Interactive Lecture Series produced for the Department of Mechanical Engineering at Monash University. Comprising twenty individual modules authored with Asymetrix ToolBook II Instructor, the series utilises large format text, two- and three-dimensional animations, mechanistic simulations and virtual experiments to create a flexible and engaging learning environment. The modules have two modes of operation: the first mode facilitates classroom lecturing by presenting the material as a sequential slide presentation; the second mode converts the modules into stand alone student tutorials. Each module also features a personalised notebook for student note-taking, and Internet access for asynchronous collaboration and consultation between students and teachers. As the modules make no educational call upon either sound or motion video resources, they are appropriately described by the term *oligomedia*.

INTRODUCTION

The Engineering Mechanics Interactive Lecture Series (ILS) is an integrated approach to teaching fundamental concepts in first year mechanical engineering. The aim of the project is to combine illustrative computer animation and mechanistic simulation with the communication capabilities of the Internet to provide students with instructional experiences that go far beyond those afforded by standard textbooks or static slide presentations.

METHODS

Following detailed comparison of Asymetrix ToolBook II Instructor, Macromedia Authoware and Macromedia Director, it was decided that ToolBook II Instructor was best suited to the development of educational packages that incorporate mathematically based simulations [1].

While many of the simple interactive exercises were implemented using ToolBook's OpenScript programming language, the more complex simulations required the use of a dedicated simulation package.

The *S*imulation *Co*ntrol *P*rogram (SCoP) provides a high level language to define and solve the fundamental equations describing a mechanism [2]. To facilitate the use of SCoP models from within ToolBook, the SCoP output was compiled into Windows dynamic link libraries (DLLs), which are accessed from ToolBook at runtime to animate ToolBook graphic objects. In addition to utilising SCoP, some simulations required additional low level code to directly access Windows Application Program Interfaces (APIs). This code was developed using the C programming language.

Most of the dynamic visualisations have thus been created by animating ToolBook objects under *OpenScript* control, sometimes supplemented by SCoP. The remainder have been assembled as *cartoon* sequences of bitmaps created either by digital still pho-

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tography or by the use of three-dimensional graphic authoring software. The three-dimensional models developed for the ILS were created using 3D Eye TriSpectives Professional and Macromedia Extreme 3D. The images were modified as necessary using Adobe PhotoShop.

Images and 256-colour palettes have been edited and managed using Equilibrium Debabelizer Pro. This was essential to allow the images created with the three-dimensional graphical authoring tools to be acceptable on a 256-colour display.

Microsoft Equation Editor was used to develop equations quickly and simply. These equations were copied, reduced to black and white using Adobe PhotoShop and pasted into the appropriate ToolBook file.

The web site associated with the system was developed using Microsoft Frontpage 97, which allows for easy moderation and maintenance of a web-based discussion forum.

As it has not been necessary to make any use of sound or motion video, it is probably more accurate to use the word *oligomedia* rather than *multimedia* to characterise the software we have created.

GENERAL DESIGN PRINCIPALS

Figure 1 illustrates a typical screen taken from the Engineering Mechanics ILS. This example illustrates a number of general design principals adhered to throughout the project:

- The font used to display textual information is 18pt regular Arial. This facilitates ease of reading when the material is presented in a lecture environment and also minimises user eye fatigue when the ILS is used as a study resource.
- Each screen contains only a small amount of text. This allows students to comprehend new concepts readily as they are presented.
- The interface is simple and intuitive. Avoidance of excessive background *decorations* and textures allows the user's focus to be drawn directly to the lecture content.
- Non-linear navigation is available from any page (slide) via the *Topics* pop-up menu.
- Except for the *forward* and *backward* navigation buttons, which are marked by universally recognised icons, all other buttons are labelled unambiguously in English, requiring no help text or further explanation.

LECTURE MODE VS STUDY MODE

To cater for the differing needs of students and lecturers, the Engineering Mechanics ILS provides two separate modes of operation, lecture mode and study mode. A keyboard toggle (Ctrl + Shift + S) is used to switch between these modes, depending on the environment in which the material is being examined.

In lecture mode, each left-click of the mouse button displays a single block of information and the user steps through the lecture point-by-point in a manner similar to a conventional slide show in a lecture presentation. Switching to study mode transforms the modules into stand alone student tutorials featuring a page-by-page display that allows for effective student revision and private study.

INTERACTIVE EXERCISES

Each lecture contains a number of simple interactive exercises to reinforce student understanding. When utilised within the lecture environment these exercises become virtual demonstrations that can be used to heighten student interest and initiate group discussion. Figure 2 (a-c) illustrates one such exercise taken from Lecture 1, Elasticity and Springs. This exercise allows the user to investigate the consequences of stretching a wire by varying degrees. When stretched within its elastic limit, the wire is seen to snap back to its original length (2a). When the wire is stretched past its elastic limit, it is permanently deformed and does not return to its original length (2b). Finally, if the wire is stretched beyond its plastic limit, it is seen to break (2c).

Another kind of interactive exercise is shown in Figure 3, using drag-and-drop techniques to reinforce a summary of classifications and criteria. When a label is dragged to its correct location, its position is confirmed with a green tick; if the chosen position is incorrect, a temporary red cross appears as the label is *floated* back to its starting position.

These tasks can be made obligatory, if required, by restricting the user's navigation options until they have been completed. However, no such *linear* constraints have been included in the current Interactive Lecture Series.

ILLUSTRATIVE ANIMATIONS

Throughout the lecture series, two- and three-dimensional animations are utilised to provide students with a visual representation of the concepts under investigation.

The example shown in Figure 4 deals with an object's degrees of freedom. After studying a textual description of the concepts, students may click the

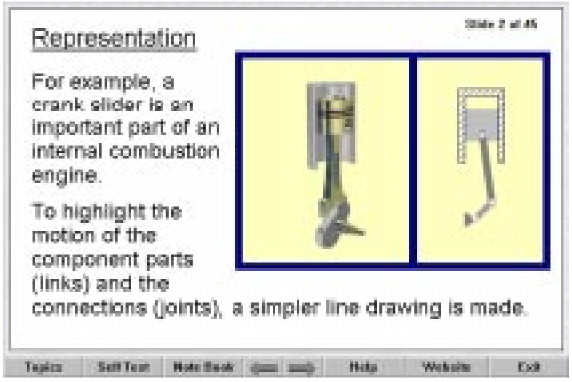
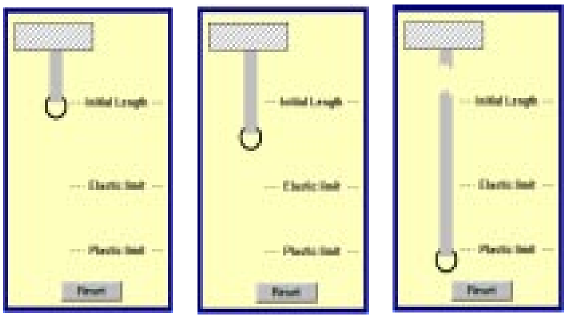


Figure 1: Sample screen from Engineering Mechanics.



a b c

Figure 2: Elasticity interactive exercise.

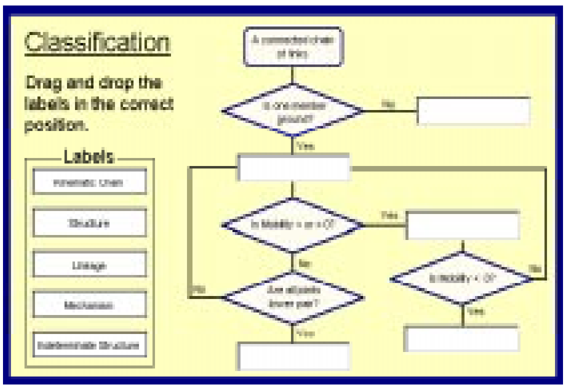


Figure 3: Drag-and-drop interactive exercise.

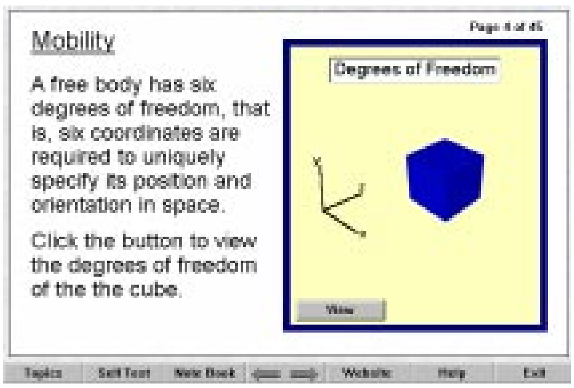


Figure 4: Mobility illustrative animation.

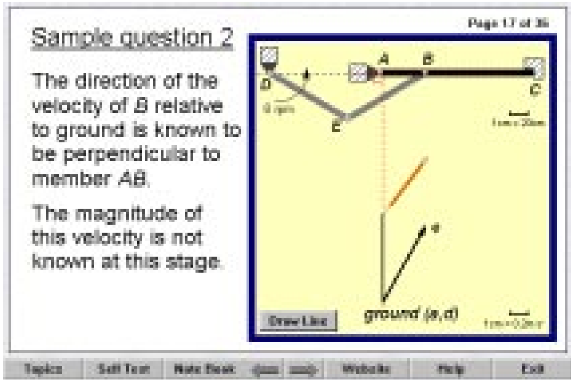


Figure 5: Velocity diagram illustrative animation.

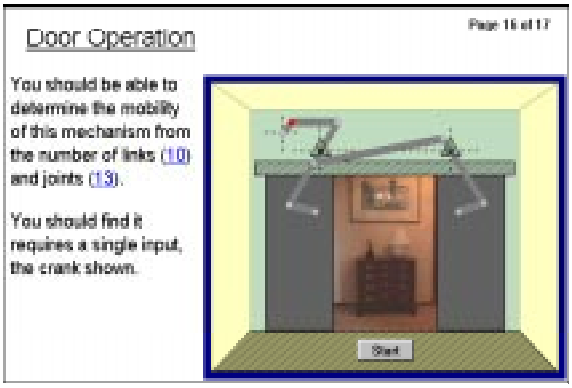


Figure 6: Illustrative animation of a lift door mechanism.

View button to watch as the three-dimensional cube undergoes translation along the x, y and z axes and is then seen to rotate about each axis.

The next example (Figure 5), illustrates the process of drawing a velocity diagram. The student is presented with a description of each step in the process and then has the option to observe the line being drawn by a pencil in much the same way as they would be required to do so if addressing a problem in the real world. By allowing students to visualise otherwise abstract concepts, animations of this type have been shown to enhance student comprehension [3].

This principle is extended further in the example shown in Figure 6, which illustrates a lift-door mechanism. When the *Start* button is clicked, the mechanism undergoes a stereotyped animation involving one complete rotation of the crank. However, the upper left pin is actually a *hot* pin that can be dragged in either direction of rotation by the user, giving a more direct feel for the behaviour of the mechanism. This simulation requires numerical solution of six non-linear algebraic equations that describe the motion of the linkages, taking the user-determined position of the *hot* pin as the input to the algorithm for Newton's iterative method of solution.

Figure 7 shows an illustrative animation assembled from a series of digital still images of a worm and wheel gearing model. The animation is set in motion by successively hiding and showing each of the bitmaps in the sequence. This method produces a significantly faster response time than the use of motion video in .avi files.

MECHANISTIC SIMULATIONS

Mechanistic simulations differ from cartoon animations in that the motion of animated objects is based on mathematical equations that describe the fundamental nature of the system under investigation [4]. Each lecture module of the Interactive Lecture Series contains a number of mechanistic simulations. These simulations allow both lecturers and students to conduct virtual experiments by adjusting various system parameters.

The example shown in Figure 8 illustrates the simulation of a machine featuring a rotating mass. The simulation describes a mechanism that starts from rest, accelerates through resonance, remains at a uniform operating speed for a set period of time and then slows to rest. By adjusting the parameters of spring stiffness, rotor mass, damping coefficient, time to stop and time to full speed, the user is able to investigate the phenomenon of resonance through interactive virtual experimentation. The animation and graphical display are calculated dynamically at runtime by numerical integration of the system's second-order ordinary differential equation of motion.

A simple, though educationally powerful, mechanistic simulation is shown in Figure 9. This example allows virtual experimentation with the parameters determining the stiffness constant of a spring.

It is worth noting that the only virtual procedure in this example that can be easily replicated on the laboratory bench is variation of the force applied to the spring. The remaining procedures are either physically impossible, unsafe, or too difficult to afford a practicable form of learning.

Thus, this simple example illustrates an extremely powerful feature of these techniques, that is, the ability for computer-based virtual experimentation founded on mechanistic simulation to transcend the physical, logistical, financial and even ethical limitations that constrain traditional laboratory teaching.

REVIEW QUESTIONS

At any time, the student can navigate to a series of lecture-specific multiple choice questions (Figure 10). These questions are cross-referenced with the lecture material such that an incorrect answer provides

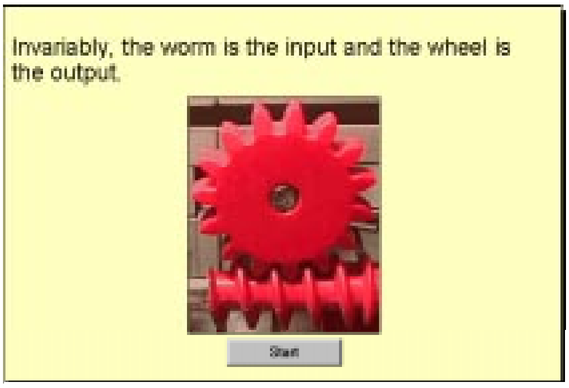


Figure 7: Illustrative animation of worm and wheel gearing using cartoon animation of digital photographs.

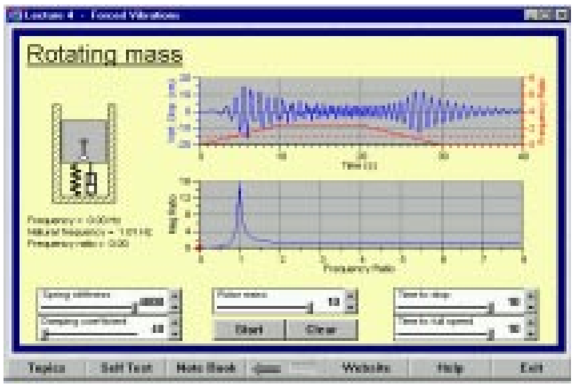


Figure 8: Rotating mass mechanistic simulation.

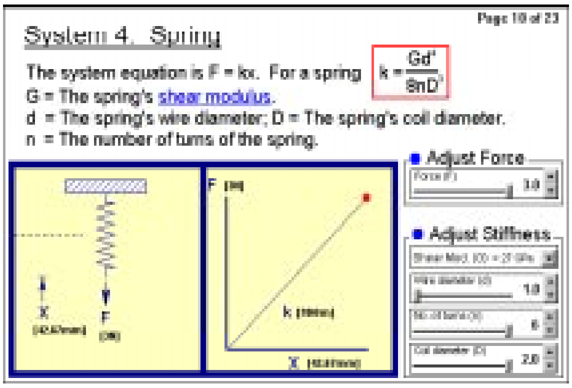


Figure 9: Mechanistic simulation of a spring.

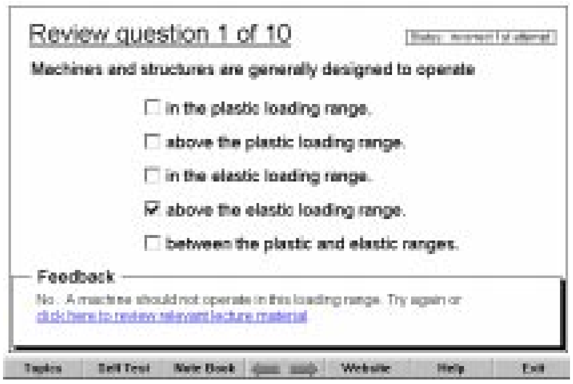


Figure 10: Review question page.

the student with the option to review the relevant lecture material before proceeding to the next question. The software monitors student progress based on the first response to each question. At the conclusion of the test questions the user's score is displayed.

PERSONAL NOTEBOOK

The Interactive Lecture Series also provides students with a Notebook facility (Figure 11). This notebook allows students to record personal observations and comments to disk for later review or printing.

INTEGRATED INTERNET CAPABILITY

In recent times there has been a great deal of discussion relating to the distribution of multimedia content material over the Internet. While this is a very appealing concept, the present reality of the situation is that the Internet simply does not provide the necessary bandwidth for online distribution of graphically-intensive applications.

The Engineering Mechanics Interactive Lecture Series circumvents these bandwidth limitations by presenting the content material on CD ROM and utilising the Internet solely for the purpose of communication between students and staff.

Clicking the *Website* button on any page in any of the modules causes the ILS to open the default web browser and navigate to a web page associated with the subject (Figure 12). This website provides students with the opportunity to post questions to an asynchronous forum and to contact fellow students and staff via email.

DEVELOPMENT PROCESS

Because the content specialists and the development team were based at different physical locations throughout the development of the Engineering Mechanics ILS, we formulated a distributed production process that utilised various forms of modern day communication. This process generally had a number of stages:

- At the commencement of each unit the development team received either typed lecture notes or an existing set of Powerpoint slides that formed the basis of the content for the module.
- The team then identified areas in which illustrative animations or mechanistic simulations could be utilised to enhance student understanding.
- Prototype screens of the lecture's simulations and/or animations were faxed to the content specialists for comment and approval.
- The lecture was then implemented and made available to content specialists for review via ftp.
- Comments and amendments were communicated via phone and email, and the appropriate changes were made.

It should be emphasised that each member of the development team, ie each of the four authors of this paper, is trained in the basic sciences. This is crucial to our development strategy, which involves our mastering all aspects of the development work: the academic content, the instructional design, and the design and scripting of interactive tasks, animations and simulations. Only in regard to C programming did any part of the work become the exclusive province of a single team member (Hugh Kelly). In fact, the only parts of the entire package that were outsourced were some of the decorative graphics on the title pages.

This strategy proved to be highly cost effective and totally free of the cost-overruns, extended deadlines and failure of project management that so often plague developments in educational *multimedia*. It is significant that the first eleven modules were completed by the team at QED Research Unit between March and December 1997, while the remaining nine modules were completed by QED Interac-

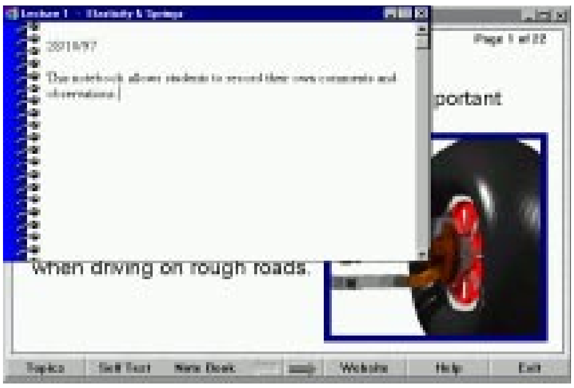


Figure 11: Student notebook.

Figure 12: Web site.

tive Pty Ltd in a period of seven weeks during January and February 1998, following the unit's privatisation.

This same *oligomedia* approach has also been applied successfully to other educational developments, with proven cost effectiveness in the areas of electronics engineering [5][6] and economics [7].

CONCLUSION

The Engineering Mechanics Interactive Lecture Series is an attempt to integrate various emerging technologies in a manner that best exploits the unique capabilities of each particular medium. Highly interactive simulations and illustrative animations are delivered on CD ROM, while the Internet is utilised for rapid and effective communication. This integration and the aforementioned features of the ILS result in a product that offers both students and lecturers a valuable new tool for exploring concepts in engineering mechanics.

We believe that we have barely begun to scratch the surface of the limitless possibilities for enhanced virtual experimental learning that these *oligomedia* techniques afford.

ACKNOWLEDGEMENT

The academic content experts for the material developed in this Engineering Mechanics Interactive Lecture Series were Associate Professors Robin Alfredson and Terry Berreen of Monash University's Department of Mechanical Engineering. It is with great pleasure that we acknowledge the efficiency with which they organised their material, the clarity with which they issued their instructions and the patience with which they answered our questions.

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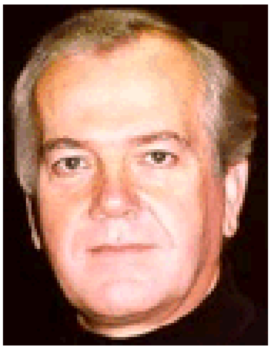
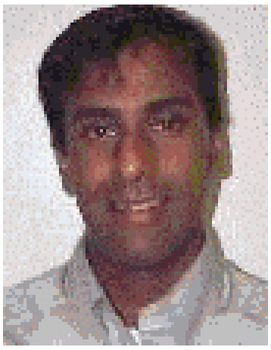
BIOGRAPHIES



Brian Chapman graduated from Monash University with a Bachelor of Medical Science and Doctor of Philosophy, majoring in muscle physiology with particular interests in energy metabolism, thermodynamics and membrane transport. He has published over 30 scientific research papers and has pioneered the use of mechanistic computer simulation as a tool for research in theoretical physiology. As director of Monash University's QED Research Unit (1994-97) his interests in simulation became focused on application to teaching through development of computer-based resources for self-directed experimental learning. During this period he led a development programme that produced 24 new titles in physiology, pharmacology, medicinal chemistry, economics, electrical engineering and mechanical engineering. His largest development project to date has been an entire first-year university subject entitled *Economics: An Interactive Study Guide*, published by Addison Wesley Longman in 1997. These development activities are now being continued through a private company called QED Interactive Pty Ltd of which Brian is managing director.

He is also a part-time professional concert pianist and has released recordings on both vinyl and compact disc as well as distance education products for music students on audio cassette.



Anthony Fernando is an Honours graduate from Monash University, where he was awarded the Dean's List Fellowship for academic excellence. He is experienced with a wide range of development tools having worked as a multimedia developer with QED Research Unit at Monash University during 1997 and being currently employed as a developer with Andersen Consulting. His main interest is the utilisation of leading edge technology for the development of high quality educational software. In his spare time he enjoys playing the saxophone and clarinet, hiking and cycling.

Hugh Kelly has a Bachelor of Applied Science from Monash University. He has wide experience in several computer programming languages and particular expertise in the creation of new simulation software. His experience with the Simulation Control Program (SCoP), dating from the 1980s, is now applied to the development of Windows dynamic link libraries (DLLs) based on the SCoP software. Having worked at Monash University's QED Research Unit until its closure in 1997, he is currently employed by Monash University's Distance Education Centre while completing a postgraduate diploma in software engineering, specialising in Java.

Phillip Tran is currently a third-year medical undergraduate at Monash University. His introduction to the work of Monash University's QED Research Unit came when he enrolled in the Unit's course option for medical students, *Electronic Authoring with Asymetrix ToolBook II,* presented by Brian Chapman. This led to his being invited to work with QED Research Unit during the summer vacations of 1996 and 1997, this employment being continued with the newly privatised QED Interactive Pty Ltd during 1998. His creative interest in computer programming has led to his co-authorship of several software titles, including Monash University's *Engineering Mechanics* CD-ROM and QED Interactive's *Virtual Experiments in Electronics Engineering* CD-ROM.