Enhancements to an Undergraduate Mechanisms Course

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Introduction

   This paper covers techniques used at the University of Toronto to enhance the presentation of materials for an undergraduate mechanisms course. Some are based on the implementation visual aids in lecture presentations. The aids include the use of (i) translucent plastic models suitable for display on an overhead projector, (ii) physical models suitable for demonstration using a document camera and video projector, and (iii) computer animations which may be shown using a video projector. Examples are provided for each. The paper includes discussions of the relative merits and limitations of each of these methods of providing demonstrations, and means that the authors have employed to maximize their impact. In addition, the paper discusses the results of implementing a laboratory based on the *Working Model 2D* software.

Classroom Demonstrations

   For several years the authors have been involved in the teaching of mechanisms courses. At one time they relied solely on translucent plastic models with an overhead projector to illustrate machine motions[1]. The models included linkages, meshing of gears and gear trains. These models are limited to the demonstration of planar systems. More recently, computer software packages have been available. They permit animations of more complicated spatial systems to be developed and illustrated[2,3,4].

Many lecture rooms at the University of Toronto, Faculty of Applied Science and Engineering are now equipped with a video projector and a document camera. The authors have used this equipment to advantage in the teaching of an undergraduate mechanisms course. Both physical models and computer animations are shown to students using this equipment, which complement the theoretical lecture material. At least one animation or model demonstration is shown during each lecture. They are shown to stimulate student interest and improve their understanding.

Over the past four years, more than 70 animations have been prepared using the software entitled *Visual Nastran*. They cover a wide range of mechanical devices, mechanisms, and manufacturing operations. They complement the pictures and video segments which are shown of real machines in operation. For instance, Figure 1 depicts a gear hobbing operation. A still of a video segment is shown in Figure 1(a), and a frame of an animation developed through *Visual Nastran* is depicted in Figure 1(b). The frame from the computer animation gives a far clearer illustration of the relative motions of the hob and gear.

There is not sufficient time to show all animations during the lectures. Some are provided through the course website. However, because of the large size of many of these files, it is impracticable for students to download all of them over the web. Instead, there are plans to compile all animations onto a CD-ROM, and have them available for student use on an individual basis.

One of the advantages of using a computer animation is that components can be either added or made translucent to reveal their position relative to other components of the device. For instance, Figure 4 shows a disc clutch. Starting with two shafts from the engine and to the transmission shown in Figure 2(a), individual pieces are added one at a time to create the entire system. Figure 2(b) shows the partially completed unit, and Figure 2(c) shows the complete mechanical device. Often a computer animation is insufficient on its own to describe a mechanical device. Additional diagrams must also be provided, such as shown in Figure 3 of a cross-section of the disc clutch in its engaged and disengaged configurations.

The authors have tested different file formats to store and distribute the computer animation files, and have selected *VRML* (*Virtual Reality Modeling Language*). This has the advantages that the space requirements are generally less than other formats, and a user can control the orientation of the device during the animation. For instance, Figure 4 shows an illustration of a differential that is oriented in three different views.

A *VRML* model of a fishing reel, created using *Visual Nastran*, is illustrated in Figure 5. This is an example where it is also possible to demonstrate the physical device during a lecture. A document camera combined with a video projector can be used for such demonstrations. The authors have found that an additional video monitor can be of significant assistance. Figure 6 shows the set up for demonstrating a fishing reel using a document camera. The additional video monitor can only be seen by the demonstrator, and it shows the same image as presented to the students using the video projector. The lecturer can keep an eye on what is being shown to the students and thereby ensure that the image is in focus and within the field of view of the camera without having to look back over their shoulder to check. The arrangement allows an instructor to always face the students during a lecture.

Feedback from students obtained through the course evaluations has been very positive. They have encouraged the authors to extend their efforts of developing additional similar materials.

Computer Assignment

Each year the students are assigned a computer project which involves simulating a mechanism using *Working Model 2D* software. The purpose of the project is to give students an opportunity to design a mechanism without having to build a physical prototype, and to familiarize them with mechanism simulation software. Generally students have no previous experience using this software. Therefore, one lecture session is set aside for students to be introduced to the software. Each project is designed such that it is difficult to solve analytically, thereby forcing the student to explore the software while trying to solve the project. In order to minimize the number of different solutions for each project, mechanisms for which there is just one input are used. The project is typically worth 10 percent of the final grade of a third year course in mechanical engineering. A typical project will take a student about 15 to 20 hours to complete. Four different projects are composed each year, and randomly assigned to students. Since 1997, 24 computer projects have been generated.

An example assignment is illustrated in Figure 7. This assignment asks the students to simulate an idealized automobile convertible top mechanism. In order to complete the assignment, the student will have to learn a number of aspects of the simulation software, such as drawing shapes, creating revolute joints, grounding objects, applying motors, creating output display graphs and controlling the simulation parameters. All assignments, such as the one in Figure 7, are drawn such that they illustrate the essence of the mechanism, but are not mechanically to scale. This prevents the students from simply copying the link lengths and angles from the diagram to reach the desired solution. It forces them to explore variations of the mechanism while they try to converge onto an acceptable solution, and thus gives them an understanding of the relevance of each link to the mechanism as a whole. The student cannot add or remove links, or joints when designing the mechanism. They can only vary their initial positions, lengths, and relative orientations. In addition, other constraints are specified for the project, such as overall motion workspace, trajectory tolerance, initial size and final size. The constraints are added to limit the number of correct solutions to the problem, and reflect real world constraints for similar mechanisms. For example, for the automobile convertible top project, the problem specifies that the mechanism is to begin in the 'fully extended' configuration shown in Figure 7. However, when 'fully collapsed', the mechanism must fit within a region of specified position, length and width, as illustrated by the dashed rectangle in the lower right hand side of Figure 7. Figure 8 illustrates a typical student solution to the problem given in Figure 7.

In addition to the completion of the computer simulation, each student is asked to submit a two to three page report, in which they are asked to comment on the process of solving the problem using the *Working Model 2D* software, and answer some specific questions regarding their assignment. These questions are designed to make the student explore the working mechanism that they have simulated, and learn more features of the software. Most students also use the report to comment on how they enjoyed the process of simulating a 'real world' mechanism.

The computer projects are completed through the internal Engineering Computing Facility (ECF) network within the Faculty of Applied Science and Engineering at the University of Toronto. Students must use an on-campus computer laboratory to access the software. One teaching assistant is assigned to an ECF laboratory, on a weekly basis. Students are required to submit their completed assignments electronically, to a specified folder within the ECF network.

Conclusion

The use of enhanced visual aids in lectures as well as a computer laboratory has enriched the learning of the students. The *VRML* computer models used here can illustrate a mechanical concept within minutes, that would otherwise require the disassembly of a physical device, which is generally impractical during a lecture. Feedback from students has been positive which has encouraged the authors to extend these initiatives.
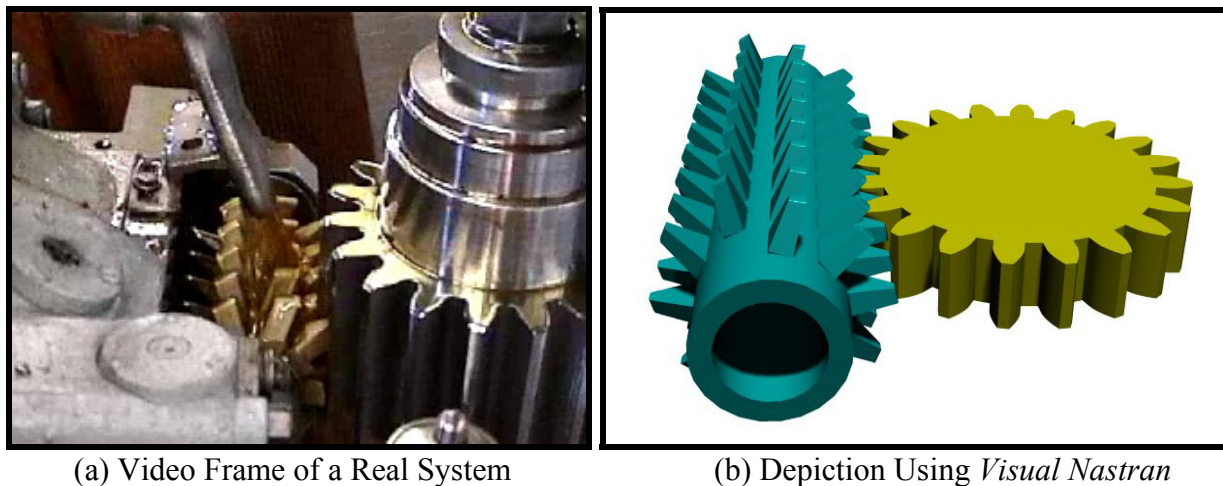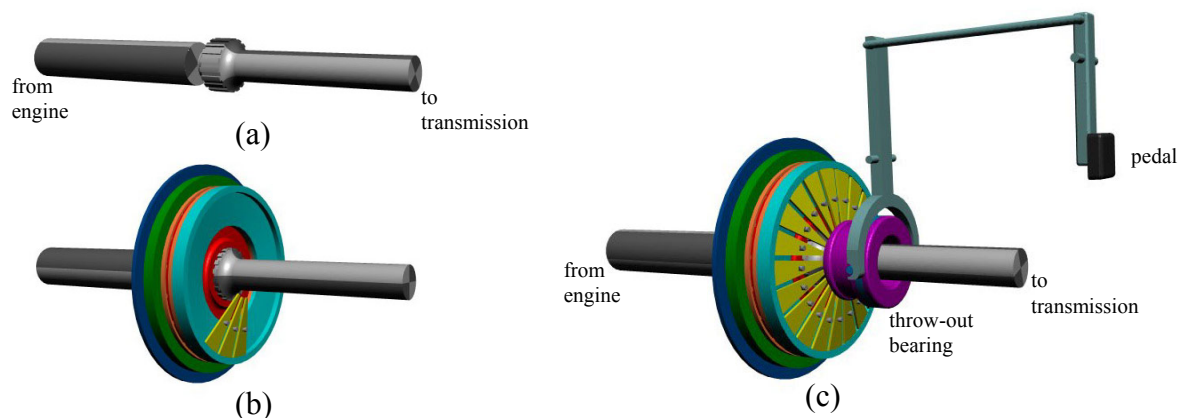

(a) Video Frame of a Real System   (b) Depiction Using *Visual Nastran*

Fig. 1 Gear Hobbing Operation

Fig. 2 Illustration of a Disc Clutch Mechanism Using *Visual Nastran*

(a) Engaged   (b) Disengaged
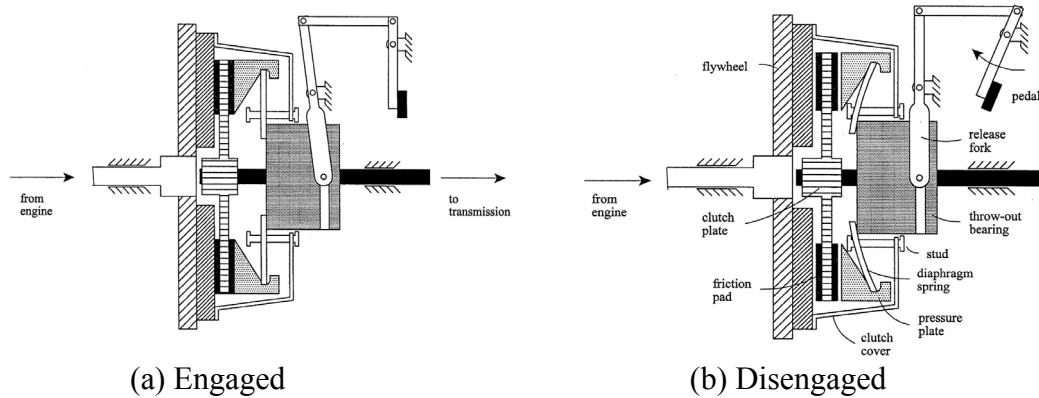
Fig. 3 Cross-Section of Disc Clutch
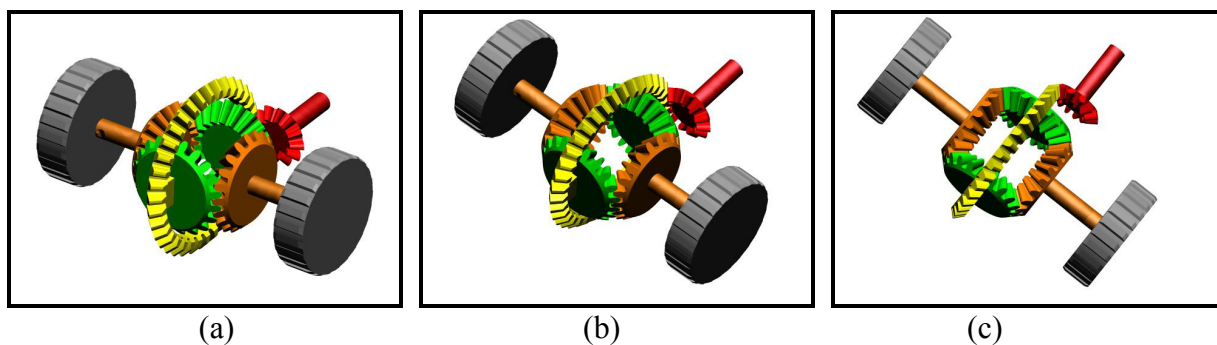

(a)   (b)   (c)

Fig. 4 Views of a Differential Using *VRML*
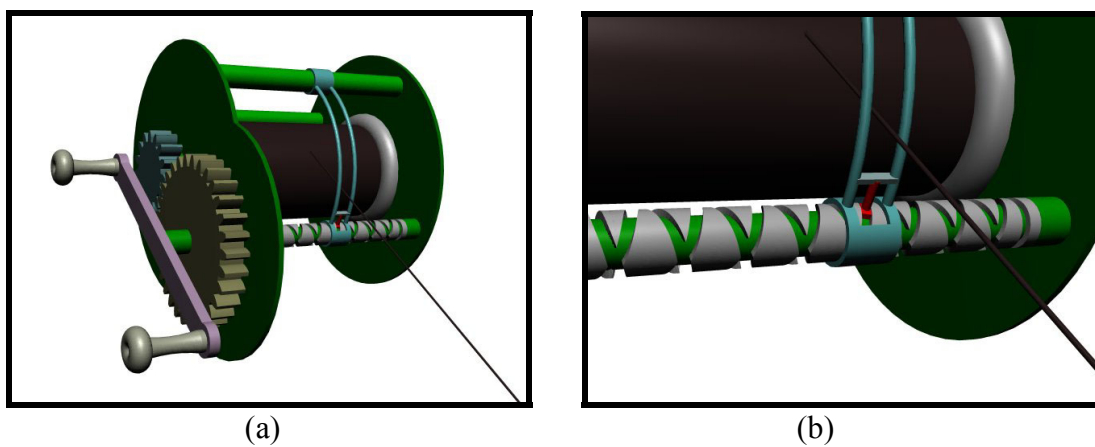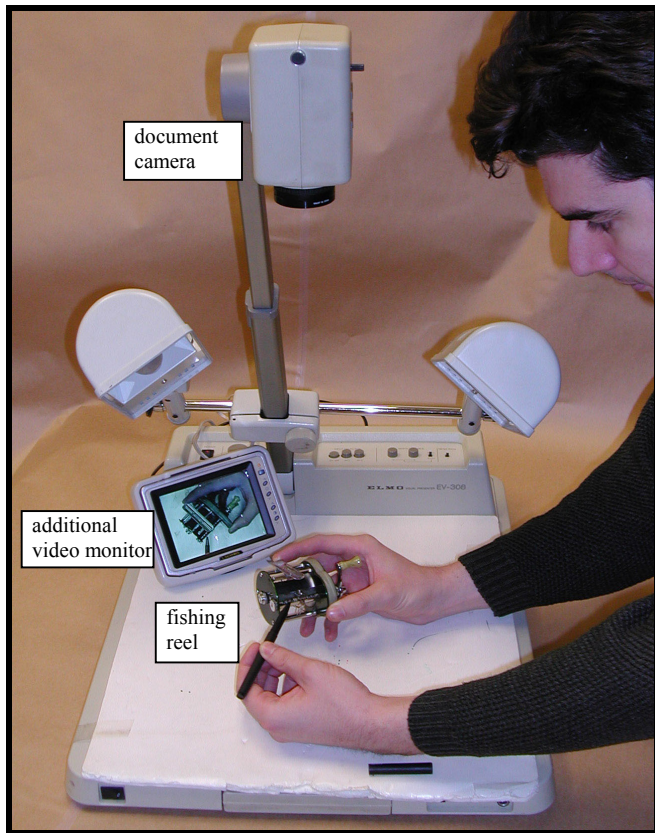

(a)   (b)

Fig. 5 Illustration of a Fishing Reel Using *Visual Nastran*

Fig. 6 Demonstration of a Fishing Reel Using a Document Camera

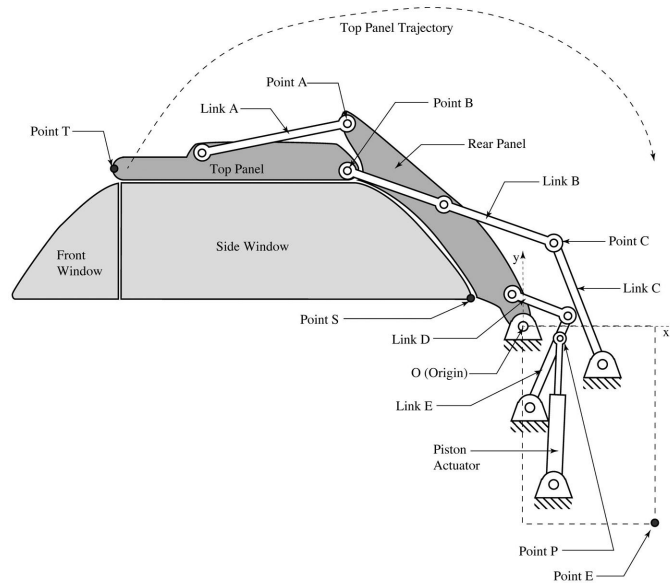**Fig. 7** Definition Diagram of an Automobile Convertible Mechanism

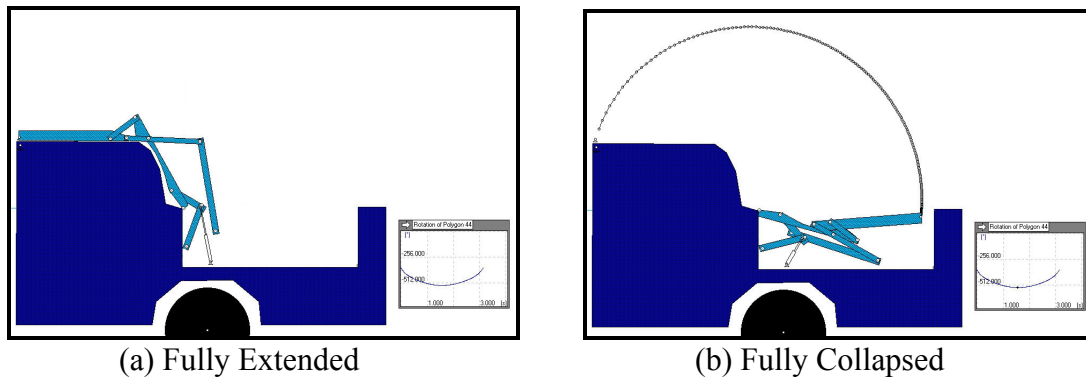| (a) Fully Extended | (b) Fully Collapsed |

Fig. 8 Configurations of an Automobile Convertible Top Mechanism Using *Working Model 2D*

References

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NIKOLAI DECHEV graduated from the Department of Mechanical Engineering, University of Toronto. He is currently working on his Ph.D. from the same department. His research involves precision mechanism design, and the development micro-electromechanical systems (MEMS) design. He has been a contributor to the development of the computer laboratory and the *VRML* mechanism models.