Virtual Disk Drive Design Game with Links to Math, Physics and Dissection Activities

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Abstract *- The Multimedia Virtual Disk Drive Design Studio is an engineering design case study using interactive multimedia courseware for undergraduate engineering and science students. The purpose of this multimedia case is to introduce students to the world of mechatronics and multidisciplinary design in the form of a disk drive. Students play the role of a project engineer for the ACME disk drive Company and are asked to mine out the necessary information from a multimedia archive in order to build a new disk drive model. Students can build on three different kinds of learning styles: (1) literature search and abstract theory, (2) consultations from experts and (3) design studio. Students are asked to launch their new disk drives in a certain time frame, simulating the idea of time-to-market. They must also keep track of the development and production costs. This interactive disk drive case study is ideally complemented by hands-on mechanical dissection of actual disk drives. The Western Digital Corporation provided the mathematical model for performance calculations and IBM Almaden Research contributed in the form of technical literature and expert opinions. The CD ROM version was implemented in Macromedia Director, running under Windows, NT and Apple Mac operating systems and was a recipient of one of the 1997 NEEDS Premier Courseware awards. Further additions include a web version with links to math and physics modules in Matlab. The courseware has been used and evaluated in multidisciplinary Freshman Design, Materials, and Product Development courses as well as in K-12 pre-engineering courses. This paper will summarize key design, implementation, student testing, and instructional issues.*

Introduction and Objectives

The Virtual Disk Drive Design Studio (VDDS) uses multimedia tools and a game format to teach students about the design process. The program gives a simplified example of the design process, highlighting the pressures an engineer might see in the workplace. The main issue that the student must face relates to design tradeoffs. Other issues include a budget and time schedule that should be maintained.

The game format of the VDDS is designed to make students think about the choices necessary in design within an entertaining and educational environment. This is accomplished by an interactive setting, which allows the student to choose the form of instruction they want. When used in combination with a disk drive dissection activity the VDDS can be a valuable introduction to engineering. [1]

The VDDS design will ideally be used in a scaffolded learning framework. In this framework the activities are designed to have goals which build on students everyday experiences and encourage autonomous learning. The scaffolded knowledge integration framework (SKI), developed by Linn, also emphasizes using a variety of strategies to approach a problem rather than enforcing the idea of a single right answer or method for a solving a problem. [2]

Design and Implementation

The VDDS CD-ROM was originally designed by David Yu.[3] The game begins with an introduction from the ACME president (Figure 1) explaining the student's role as a product engineer for ACME corporation. The student's task is to design a disk drive for the computer market that meets certain performance specifications (seek time and power use, for example).

Figure 1: The ACME president

The student then proceeds to a tutorial that explains the navigation system for the game. Once the student has been introduced to the design goals and the navigation system, a display of the disk drive divided into five subassemblies appears. Figure 2 shows this image as well as the user interface used in the program. The user interface has the navigation tools on the right side and allows free movement between the five subassemblies of the disk drive.

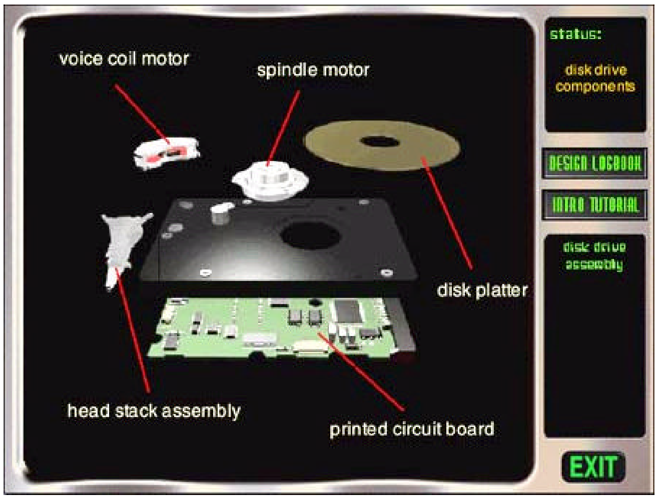

Figure 2: Assembly view

For each of the subassemblies of the disk drive, the student has three options (Figure 3). These options are the Literature Search, Consult Experts, and Design Studio. In the Literature Search, the student can read information about the subassembly. If the student selects Consult Experts, a short video of an experienced engineer will appear. The video contains tips on the importance of certain design goals within that particular subassembly.

Figure 3: Navigation Options

In the Design Studio the student designs each subassembly by choosing from several options the parts which make up the subassembly. Generally the choices offered will include an inexpensive, lower quality option, a mid-range option, and a more expensive, higher quality choice. For each of the five sub-assemblies, the student can go through as few or as many of the options as they choose. The multimedia libraries can also be accessed in any order to accommodate a student's learning style. The student must go through the Design Studio for each subassembly in order to compile a final design, but the background research is decided upon by the student.

After the student has made selections for all five features, the design is evaluated and compared to the design goals set out at the beginning of the program. The evaluation will then display the performance specifications of their design compared with the desired specifications of the company. The student can then go back and make adjustments or release their product as is. If the student decides to go back to make adjustments a short video will give them tips on what they should work on.

Once the student releases the product, the president returns to give a simulated performance evaluation. If the student has done well and has met the goals and time constraints the product launch is successful. If the product was late or is lacking in features it can result in loss of market share and a loss for the company.

Additional Matlab Exercises

In the updated web version of the VDDS, a Matlab exercise has been developed to illustrate the physics principles of seek time. With this module, students can see a simulation of the read/write head scanning a disk. They can adjust the same parameters they see in the VDDS game and see the effects on the displacement error of the read/write head.

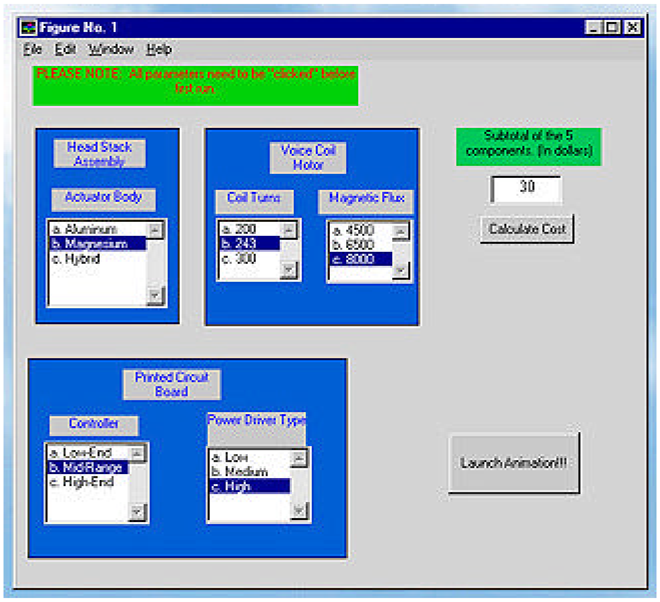

Figure 4: Matlab menu

Figure 4 shows the first window of the Matlab exercise in which the student can choose the same options available in the game. The program then adds up the cost of the chosen features and runs the simulation.

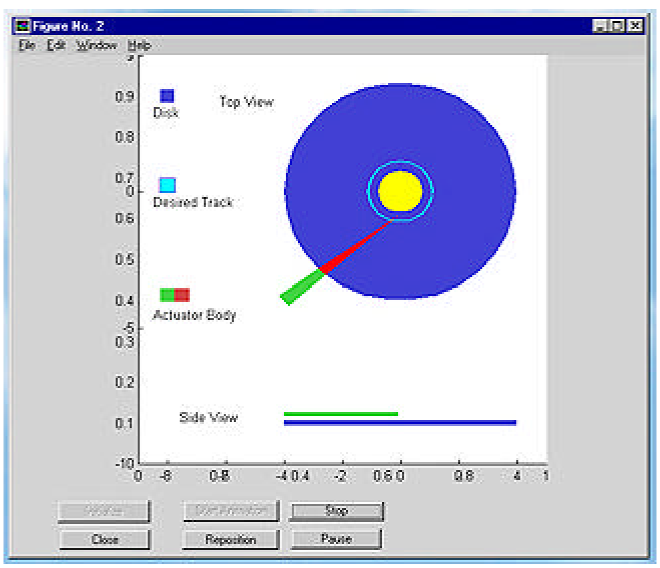

Figure 5: Seek Time Animation

Once the student begins the animation, a second window (shown in Figure 5) appears. The animation shows a disk with a highlighted track (the Desired Track) and a read/write arm (the Actuator Body). Once the animation begins, the arm travels on a path to get to the desired track.

When the animation is completed and the window is closed, a results window appears. The results include a graph of the tracking error of the read/write head (determined by the radial position of the head) as well as a graph of the glide height error (determined by the height of the head off of the disk).

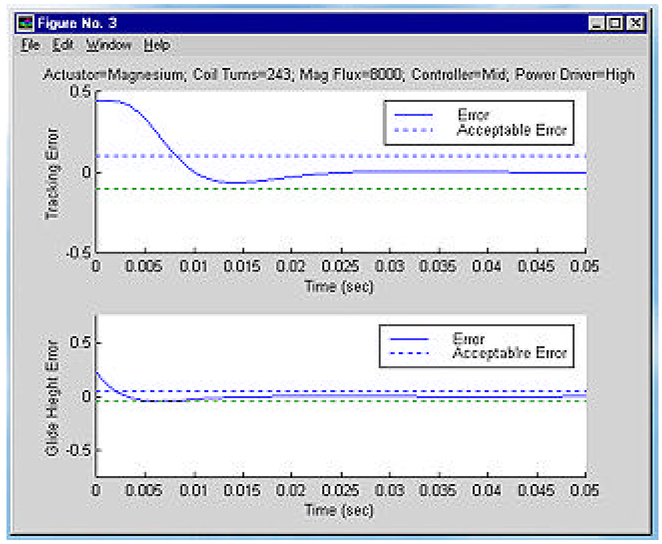

Figure 6: Matlab results

With these demonstrations the student can compare the options for design features and their resulting errors and costs.

The students not only have the opportunity to see the simulation, but they have access to the governing equations as a separate instruction module in the web version. These equations model the actuator body (which carries the read/write head) as a rod with a torque applied at one end. The actuator body can be seen in Figure 5. The angular position of the actuator body determines the position of the read/write head. The equations are derived from mechanics equations found in freshman physics courses. They are:

$$a = \frac{t}{I}$$

$$w = w_o + a(\Delta t)$$

$$q = q_o + w(\Delta t) + 0.5a(\Delta t)^2$$

where a is the angular acceleration, t is the torque applied by the voice coil motor, I is the moment of inertia of the arm, w is the angular velocity, q is the angular position, and Δt is the time interval used for numerical integration. The value for the moment of inertia and torque are those used in the VDDS calculations.

These equations will give the student a clearer demonstration of how the design trade-offs are affected by mass and power. The result will be a better understanding of how mathematics and physics are actually used in an engineering environment.

Web Page Additions

The web version of the VDDS expands on the existing CD version by including more information on engineering terms as well as a thorough explanation of how the game relates to engineering practice. This information will describe criteria for design choices as well as methods for making design decisions. Like the other resources in the game, this information is easily accessible for those interested but is not required for completing the exercise. These additions give the students better understanding of the results of design decisions.

In order to make the web format more accessible many of the animations and videos from the CD-ROM have been adjusted to suit modem-based access of a web page. The web version has less animation in order to decrease download time. Also, the videos are optional and are accompanied by a transcript. This decreases download time as well as making the game accessible to hearing impaired students.

The web version also adds more collaboration than its CD-ROM predecessor. The web page includes places for real-time chats so students can discuss their work with each other and instructors. Also included are links, which will allow the students to email designers and engineers to ask them questions about the disk drive design and the process of engineering.

The web version also gives instructors and researchers the ability to track students as they play the game. The results will give instructors an understanding as to how various students approach the problem. This can be valuable for learning about individual students as well as for general research.

Student Testing

The VDDS CD-ROM was completed in 1997 and has been used in several classes including freshman/sophomore design seminars, multimedia case study classes, and pre-college programs.[5]

The student feedback from these courses has been very positive. Many students had no previous background in engineering or design. They showed signs of greater understanding of engineering and design trade-offs after using the courseware. The most positive comments related to the engagement of the game. Used along with a disk drive dissection in an Introduction to Engineering course during the summer of 1997, one student commented:

"This was also one of my favorites. In this class I learned about the components of a computer. About all the little itty bitty pieces of silicon and the drives in the computer. The activity was designing a disk drive in the computer simulation. That was my favorite. On my first try, my partner (Rob) and I achieved the requirements right away!"

The enthusiasm for the game and the sensitivity of students to key design issues indicates the value in an educational tool like the VDDS. The comments about the CD-ROM version also indicated several areas that could be improved. These include making transcripts available for hearing-impaired students, making the time table more understandable, and having a "notebook" online to keep track of the work done and time used along the way. These issues will be addressed in the web version, as will the issues tying design in with mathematics and physics, an issue raised by some educators. The Matlab exercises and web version of the VDDS will be tested throughout the spring, summer, and fall of 1999.

Instructional Issues

The Virtual Disk Drive Design Studio was designed so that it could be used as a stand-alone addition to a design or introduction to engineering course. However, it would optimally be used in conjunction with an actual disk drive dissection. Artifact dissection was developed by Prof. Sheppard from Stanford University as a way to introduce students to design and mechanical systems by exposing them to the mechanical systems around them. By reasoning about how objects are designed and built, students learn more about the design process. In combination with the VDDS game, students not only reason about how objects are built but participate in building one in simulation. In this way the students can get both a qualitative idea of the design process through the game and practical experience with the results of the design process through the dissection. When used in the scaffolded learning environment, the VDDS also builds on students intuitions and introduces a diversity of methods from which a student can draw new knowledge.

Summary and Future Work

The success of the VDDS with students who are new to engineering suggests that interactive case studies can be valuable for sparking student interest in the subject of engineering. However, an explanation of why certain design decisions may be better than others is missing in the CD version. In the Matlab exercises and the web version, the VDDS will be able to provide a more detailed look into the reasoning behind design choices. These math, physics, and design extensions will strengthen the educational value of the Virtual Disk Drive Dissection Studio. [7]

Acknowledgements

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