Feeling is Believing: Teaching System Dynamics through Haptic Rendering

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Objective

Providing a cheap, engaging, and personalized laboratory learning experience is one of several challenges facing effective undergraduate education in STEM disciplines and has been identified as one of 14 Grand Challenges for Engineering in the 21st century by the National Academy of Engineering [1,2].

Overall Objective: Determining the impact that directed hands-on activity with haptics technology will have on engineering education is the ultimate goal of this study. Specifically, we are interested in discovering innovative ways to improve the modeling and design intuition of engineering students in a way that helps them relate theoretical systems seen in the classroom to physical systems found in everyday life, such as a raquet and ball.

Photo courtesy of The Telegraph®

Hypothesis: We believe that integrating haptic rendering into the traditional engineering curriculum will provide a learning experience that will help students relate mathematical modeling concepts to real life experience.

We will test this hypothesis using a novel apparatus that provides haptic information to the user to enhance their learning experience and engage their intuition.

The "Cigar Box"

The primary apparatus which enables the present experiment packages various electrical and mechanical components within a 6"x9" cigar box from which the device derives its name. Because we use a variety of cigar boxes (acquired from a local smoke shop) every kit is unique and appealing.

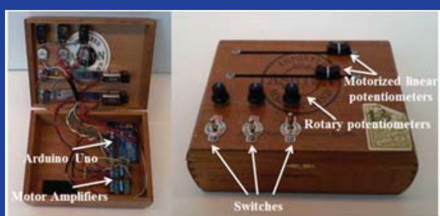


Figure 1. Annotated views of the cigar box apparatus (open and closed).

Components:

- Arduino® Uno microprocessor
- Motorized linear faders (Motorized linear potentiometers)
- Switches
- Motor amplifiers
- Rotary potentiometers
- Battery-powered or standard outlet connection

Figure 2. Cigar boxes come in a variety of shapes and sizes.

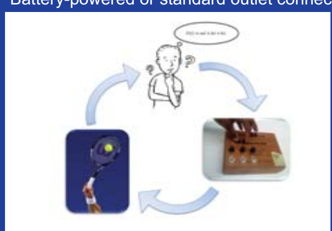


Figure 3. Schematic diagram showing the link we are trying to establish between physical phenomena (interactions between a racquet and a ball, for instance) and mathematical equations using the box as an intermediary agent.

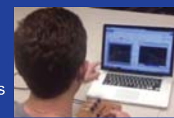
The cigar boxes can be programmed and used in a variety of activities ranging from haptic rendering course projects to musical instruments and more!

Methods

Quantitative assessments (ten minute written quizzes) were administered to students following interventions using take-home assignments that integrated the cigar box (cigar box assignments). Qualitative feedback (in the form of a written survey) was collected at the study's conclusion.

General Procedure:

- Class is divided into two groups (Groups A and B) with students in each category forming 3-4 person subgroups
- Assessment I is delivered to the class
- Intervention 1: Group A is given the cigar box assignment while Group B is given the complementary written assignment
- Assessment II delivered to the class
- Intervention 2: Group A is now given the written assignment while Group B is given the cigar box assignment
- Assessment III is delivered to the class
- Survey administered



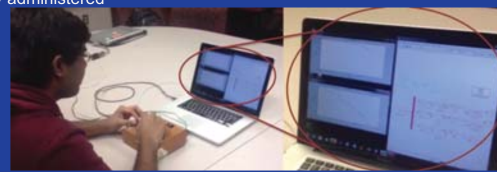


Figure 4. Cigar box assignments (top to bottom): haptic paddle, spring-mass-damper, frequency response.

Preliminary Analysis

Quantitative Assessment:

- Designed to reinforce concepts that would normally be taught in the course
- Scores derived from quiz performance
- Mean scores increased from Quiz 1 to Quiz 2 but are within error

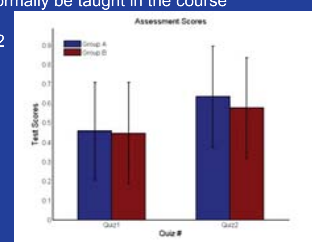


Figure 5. Mean test scores for quantitative assessments (quizzes) 1 and 2. Error bars +/- 1 standard deviation.

Figure 6. Screenshot of survey provided to students at conclusion of the study.

Qualitative Survey:

- Combination of discrete-response and open-ended questions
- Administered at conclusion of study

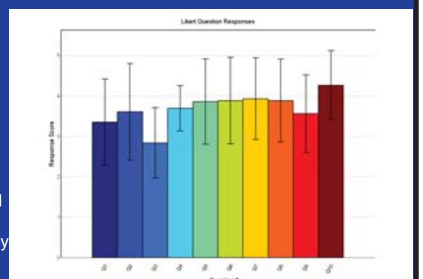


Figure 7. Mean response score to Likert scale survey questions. Error bars +/- 1 standard deviation.

- Responses to Q4 and Q10 above neutral
  - o Students thought it was relevant to the course material
- Big jump in mean responses between Q3 (mastery of frequency response before using the Box) and Q4 (mastery after using the Box)

Student Feedback

"I don't think the ME dept. gives us enough exposure to physical systems so we can work on more real-world (not necessarily ideal) situations. I liked seeing the theory applied to a real thing instead of a vague set of variables. "

"Definitely incorporate the cigar box into the class, I found it very useful. If not lab classes, at least discussion after class covering what the code does and why unit conversion are needed."

"I believe near the end of the semester I learned a great deal b/c I was forced to implement 461 ideas into the code."

"I think most ME's in this school have almost no diagnostic skill, this starts to build that experience."

"Cigar box helped me learn frequency response easily."

"It helped me to be able to understand the concept of feedback controls and haptic control."

"I think the in class discussions pre & post cigar box were the best learning portion. It helped me visualize Bode plots."

"I enjoyed working on the cigar box, it was a good supplement to the HW's, & lectures. It could be taught in a separate cigar box lab section to supplement what we do in class."

Conclusions

- More sensitive measures are needed to quantify impact
- Qualitative feedback indicates students largely appreciate hands-on activity
- Further refinement of methods and procedure is needed

Future Work

- Develop new assessments that are more sensitive to impact of cigar box
  - o Incorporate physical object exploration with pencil-and-paper quizzes. Have students identify properties.
- Continuous improvement of next generation cigar box models
  - o Development of "frictionless" model
  - o Incorporate flat voice coil motors
  - o Improve wiring harness

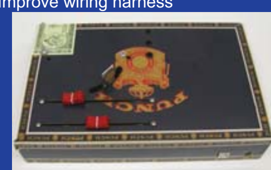


Figure 8. Next generation of cigar box ("frictionless" model) incorporates flat voice coil motors acquired from computer hard drives.

- Debug and extend software repository for cigar box assignments
- Adapt apparatus for use in other courses

References

[1] Fox, M., & Hackerman, N. (2003). Evaluating and improving undergraduate teaching in science, technology, engineering, and mathematics. Washington, D.C.: The National Academies Press (National Research Council).

[2] Grand Challenges for Engineering, (2008). A report published the National Academy of Engineering, Washington, DC