Pedagogical Efficiency of Continuous vs. Discrete User Interaction with Computer Demonstrations (Work In Progress)

Background

Computer demonstrations and simulations are well-researched tools for teaching; resources such as The Guide to Simulation Games for Education and Training have existed for half a century [1] and numerous studies have investigated the value of interactive simulations in the engineering and mathematical academic setting, for example [2]-[5]. The ubiquity of mobile computing devices, the rise of Massive Open Online Courses (MOOC), and changes as textbook publishers embrace electronic media have further spurred the use of simulations as an important method to provide an intuitive, self-guided understanding of quantitative cause-and-effect relationships [6]-[8]. Such simulations may use discrete methods to interact with them, such as setting simulation parameters, pressing a calculate button and observing the results, or they may employ a continuous method of interaction, such as dragging a slider and observing in real-time how the results are affected. Although demonstrations using continuous input methods are considerably more difficult to program, no studies have attempted to quantify the pedagogical benefits, if any, of adopting one manner of user interaction over the other.

Methods

This Work-In-Progress (WIP) paper describes a set of experiments to test the hypothesis that interactive software demonstrations using continuous input methods are more pedagogically efficient than those using discrete input methods. Two different interactive computer demonstrations were created, available at [9], each of which develops student intuition connecting a phasor representation and its time-domain sinusoidal waveform. Both demonstration programs have identical output areas displaying the sinusoid, and identically-appearing input areas showing the phasor. The discrete version requires the user to input the magnitude and angle of the phasor and press a calculate button; the continuous version uses a similar input screen but allows the user to drag a point to establish the phasor magnitude and angle. Although this pilot study examines only a pair of tightly-coupled programs, further work is planned to determine if certain subjects inherently lend themselves better to discrete or continuous input methods.

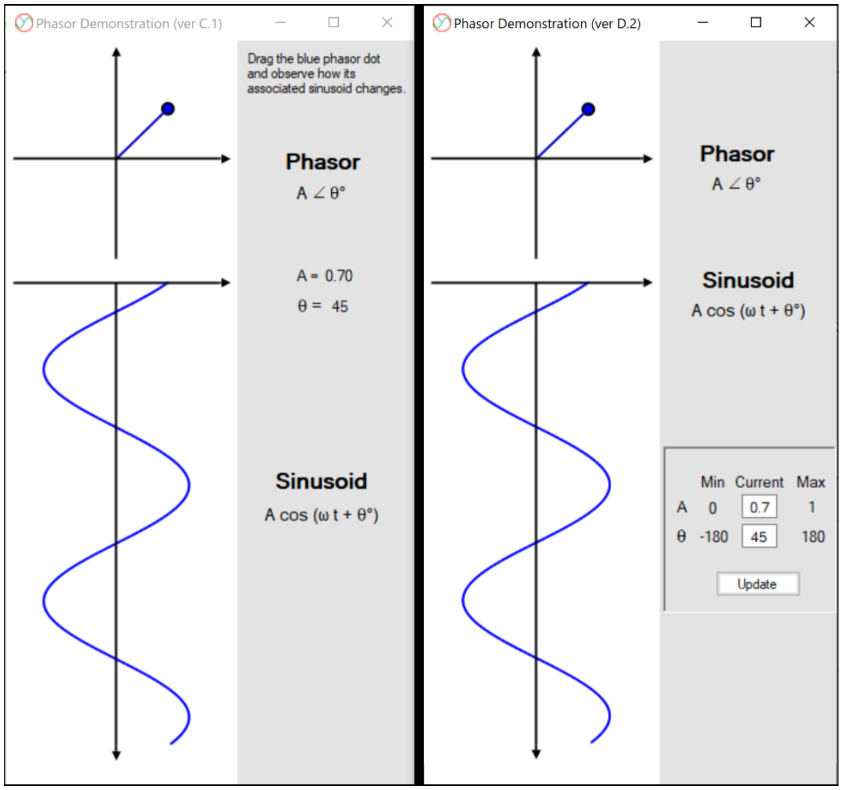

Figure 1: Two almost-identical interactive programs purporting to teach phasor concepts. The left panel shows the version designed for continuous-input and output; the learner drags the blue phasor and moves it around while observing the constantly-changing time-domain sinusoid that the phasor represents in the window below. The right panel displays the discrete-time version in which the learner enters values for the phasor magnitude and angle. In this version, the phasor is not changed until the user presses the "Update" button.

The experiment was conducted in three stages. First, students were randomly selected to be in the A or B teams, corresponding to the continuous or discrete cohorts. Both groups were given ten minutes to read identical tutorials, available at [10], that provide an introduction to the mathematics linking phasors with their time-domain sinusoids. Students were next given instructions to download the phasor application appropriate to their cohort, downloadable at [9], and given a set of identical exercises to complete requiring them to use the software application to determine relationships between various given phasors and their time-domain representations. Last, students were required to close the phasor demo applications and complete a questionnaire [11] which probed their objective understanding of the phasor concept as well as as their subjective beliefs about their understanding of phasors, and their rating of the phasor demonstration app as a learning tool. The questionnaire began by requesting their self-assessment of subject mastery, and their subjective determination of the utility of applications such as these in learning causal relationships in engineering. For example in question 6 of the questionnaire, students were asked "How well do you feel you understand the relationship between a phasor and its associated sinusoid?" Questions 8-14 were designed to measure students' objective performance in recognizing the equivalence between a phasor and its corresponding time domain signal. The final question asked the students again to provide their subjective determination of the utility of applications such as these for learning causal engineering relationships as compared to traditional methods of instruction. The comparison of the results for the discrete vs. continuous phasor apps were evaluated using the two-tailed student T distribution.

Results

A total of 91 students were involved in this Work-In-Progress study; 52 in the continuous group and 39 in the discrete group. The actual understanding of the student cohorts, based on scoring of the objective questions, are shown in Figure 2.

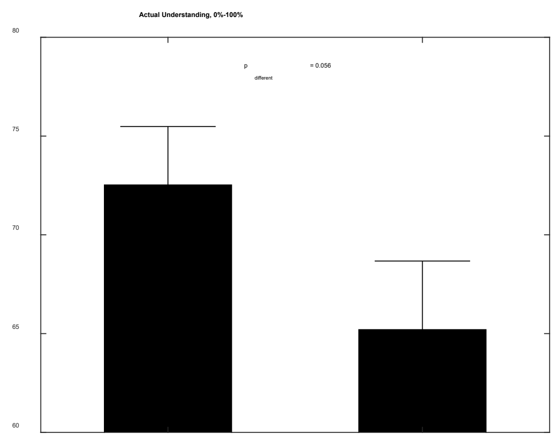

Figure 2: Comparison of the objectively-scored questions from the two cohorts. The error bars represent the standard error of the mean. In the given sample size, statistical significance at the 0.05 level is not achieved, although it is clearly close. Larger planned studies may, or may not, bridge this gap, clarifying whether or not continuous-style inputs on pedagogical programs improve learning efficacy.

Although the objective data does not quite reach significance with this N=91 sample, students' self-assessments of their learning show much stronger differences that reach statistical significance, and curiously they show the *opposite* of what appears to be the objective truth; the cohort that used the continuous applications believed they understood less than the students that used the discrete applications (Figure 3).

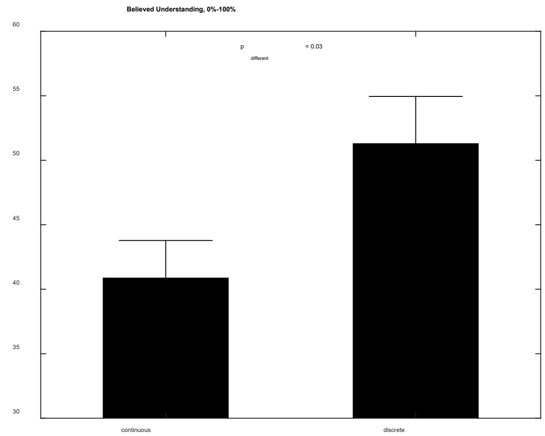

Figure 3: Comparison of the students' self-assessment of their subject mastery before they completed the objectively-scored portion. It is noticeably below the objective scores, and surprisingly show a generally opposite trend from their actual understanding in Figure 2.
This may reflect the Dunner-Kruger paradox that explains the cognitive bias which occurs when low-ability people lack the framework to assess their abilities accurately, and high-ability people overestimate the abilities of others [12],[13].

This relationship is graphically shown in Figure 4, which shows individual students' actual understanding plotted against their subjective self-assessment. Because the underlying data is strongly gridded (there are only a limited number of objective questions, and the self-assessment is a Likert-graded scale with options), the data is shown with numbers representing the count of students with identical scores. Red scores represent those from the discrete group; green from the continuous group. The data points are displayed 1 percentage point higher and lower for red and green, respectively, so their numbers do not collide on the graph. The regression line is plotted for their aggregate and the R^2 value calculated, showing a slight negative correlation as previously discussed.

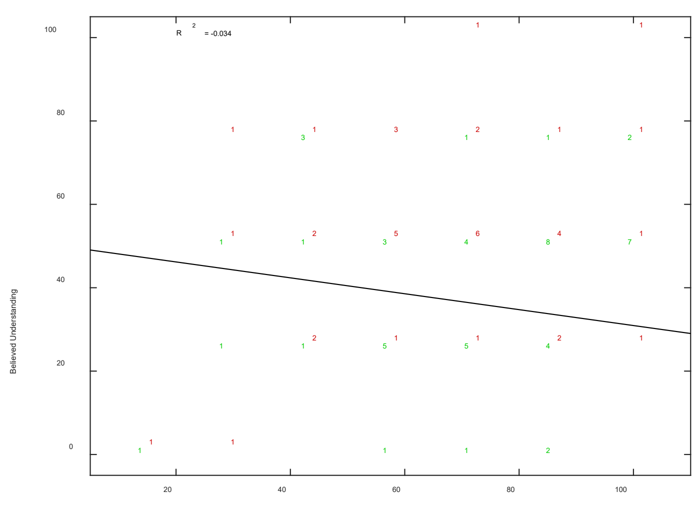

Figure 4: Student self-assessed understanding compared with their objectively-determined understanding shows a negative correlation. Values from the continuous cohort are shown in green; the discrete cohort data is shown in red.

Students were asked to rate their perceived utility of interactive applications for teaching causal engineering relationships both before and after the students completed the objective assessment part of the test. Unsurprisingly, among most of these categories there were no significant differences observed, but the continuous cohort showed a significant ($p = 0.032$) increase in their ratings of the utility of these types of teaching tools when asked after they completed their objective testing. Larger cohort sizes with specific follow-up questions will be needed to understand what are causing these differences, since with the current cohort sizes we cannot yet determine if there is a difference between objective learning in the two cohorts (Figure 2).

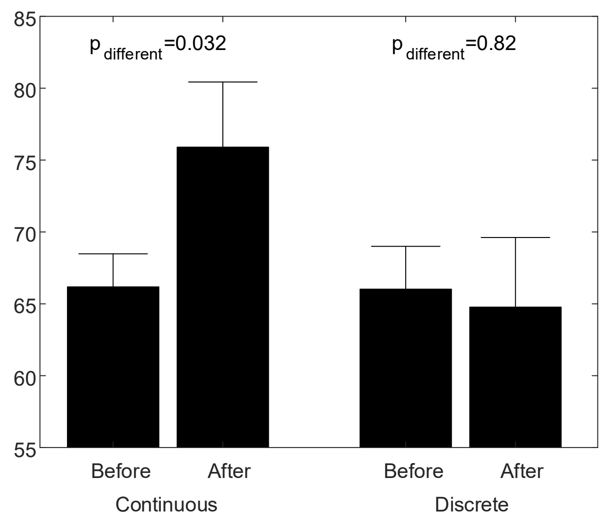

Figure 5: Cohorts were asked to rate the pedagogic utility of interactive learning applications to understand causal engineering relationships such as they examined. The question was asked both before and after they completed the objectively-scored mastery test. Surprisingly, the continuous cohort who were asked the question after they completed the objectively-scored portion showed a statistically-significant difference from the other three categories.

Conclusion

The pilot data reported in this Works in Progress shows more data is needed to determine if the central hypothesis can be proven: that application programs whose inputs are continuously-variable and have constantly-updated outputs provide a more effective learning tool than applications that provide discrete inputs and push-to-update outputs. Specifically, greater numbers of students will need to be tested using the applications reported in this paper to determine if statistically-significant differences can be reached. Further, several different applications will need to be designed to determine if the results reported in this study can be generalized, since it is possible that certain subjects are inherently better suited to continuous vs. discrete simulation patterns. Initial data suggests that differences in student learning between these modalities do indeed exist, and that although student self-assessment is a poor tool, it may be helpful to include subjective assessments both before and after the objective assessment.

If larger subsequent studies show significant and generalizable difference occur between pedagogical applications that use continuous graphical inputs and constantly-updated outputs rather than text-box inputs and push-to-update output methods, it may have an impact on future pedagogical engineering simulation designs.

References

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