Visual Transitions:
Using Multimedia to Tie Ideas Together

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Abstract

Engineering is a multitude of ideas, many of which are related to each other in some non-obvious ways. Students that see these relationships have an insight as to how things in two apparently different areas might affect each other. For example, how the positions of poles and zeros affect frequency response or how a spectrogram relates to a sound.

A visual transition is an animation whose purpose is to illustrate the ties between two entities. This paper shows four visual transitions for a new Discrete Signal Processing course. The course is designed to build sophomore students' intuition about signals and systems by relating sounds and images to their mathematical descriptions. The course uses numerous in-class demonstrations (many are visual transitions) to motivate learning. The in-class demonstrations are being captured on the World Wide Web so the students can explore them outside of class.

Introduction

Rose-Hulman now requires its sophomore computer engineering students to take a course that teaches the fundamentals of discrete time signal processing. This course is heavily based on the DSP course required at Georgia Tech for its sophomore computer engineers presented at last year's FIE[1].

This paper focuses on four of the visual transitions used in that course. Each visual transition is a QuickTime™[2] movie which is summarized in this paper by showing a few frames from each movie. The actual movies are on the FIE CD-ROM.

Phasors

This demo ties the concept of a rotating phasor with the idea that if you take the real part of the phasor and trace it out over time, the signal will be traced. Figure 1 is a frame from a movie which is for a single frequency. Figure 2 is a movie for two harmonically related frequencies; the outer phasor rotates twice as fast as the

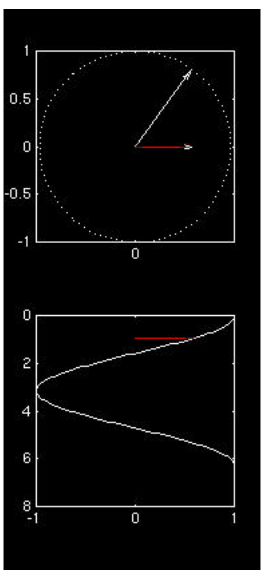

Figure 1. Top shows a phasor as it rotates and its projection onto the real axis. The bottom shows the projection moving through time as it traces out a sinusoid.

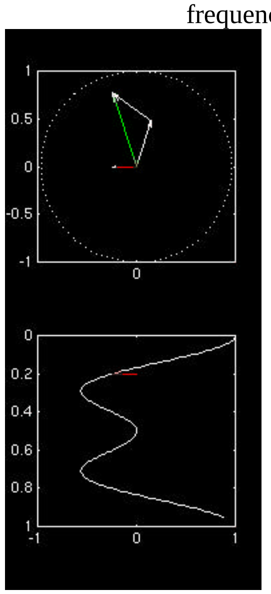

Figure 2. Like Figure 1, except the second phasor is spinning twice as fast as the first.

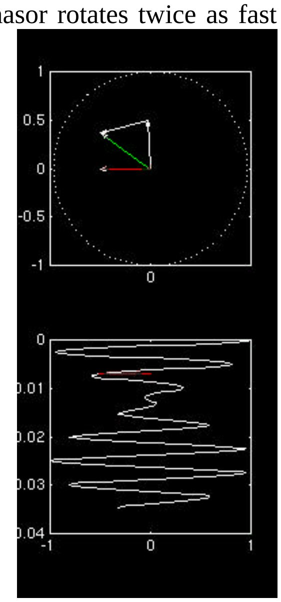

Figure 3. The second phasor is slightly faster than the first, producing a "beat" frequency.

inner. Figure 3 is for two phasor that are close enough in frequency to produce beats. The phasors actually spin in the QuickTime™ movies on the CD-ROM.

Spectrogram

The spectrum of sinusoids is emphasized heavily in this class. Figures 4-6 are frames from a movie which ties the amplitude vs. frequency plot of a signal at a given time to the frequency vs. time plot of the same signal over time. In Figure 6 the spectrogram is shown being drawn over time by the changing spectrum. See the Web page on the CD-ROM to see how these are tied together.

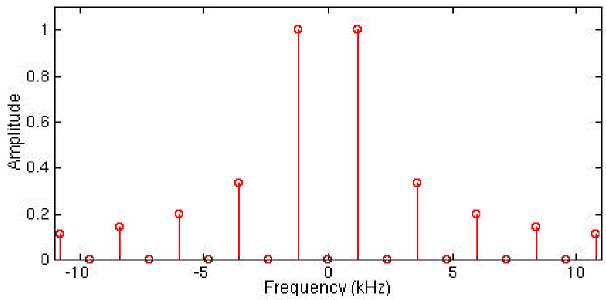

Figure 4. The spectrum, plotting amplitude vs. frequency.

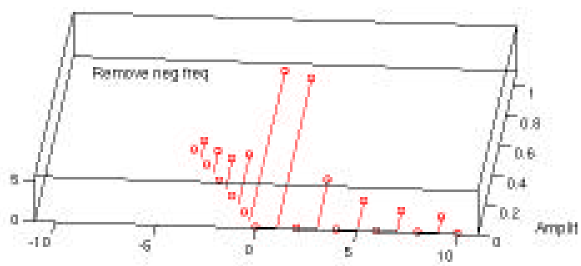

Figure 5. Showing the negative frequencies are same as the positive.

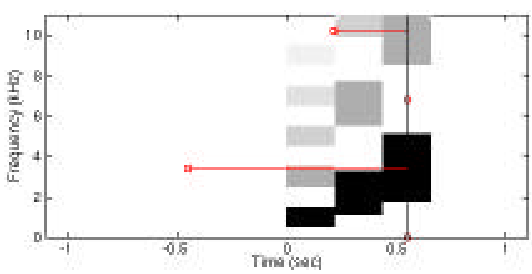

Figure 6. "Drawing" the frequency vs. time spectrogram.

Aliasing

If you are going to do discrete signal processing, you have to know about aliasing. Our students have not had Fourier Transforms, so we address aliasing from the time domain. Figure 7 is a frame from a demo tying a continuous signal to its reconstruction from sampling. This QuickTime™ movie has an audio track which describes what is happening.

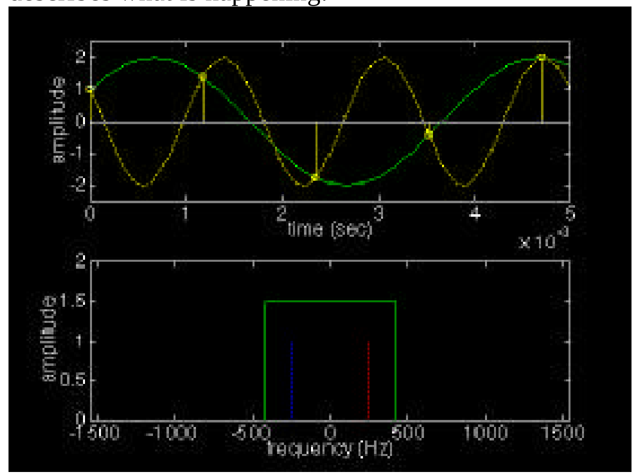

Figure 7. A continuous signal at 600 Hz is aliased to 250 Hz.

Poles and Zeros

The tie between the location of the poles and zeros of a system and the frequency response of that system is an important one. Figures 8-12 are frames from a visual transition that makes the tie via two approaches. Figure 8 show the poles and zeros for $H(z) = \frac{1}{1+z^{-1}+z^{-2}}$. Figure 9 shows the corresponding frequency response. Figures 8 and 9 are tied together in two different ways.

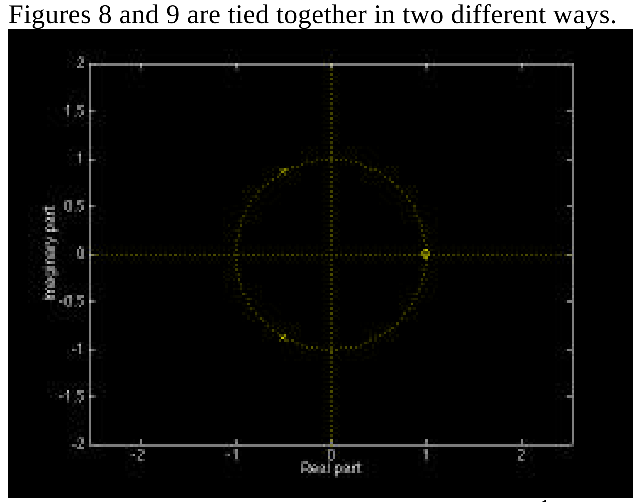

Figure 8. The pole/zero plot for $H(z) = \frac{1}{1+z^{-1}+z^{-2}}$

Figure 10 shows how the pole/zero plot relates to the complex z-plane plot of $H(z) = \frac{1}{1+z^{-1}+z^{-2}}$ by plotting the pole/zero plot over the complex z-plane plot.

Figure 11 ties the two together by running an arrow around the unit circle and recording its altitude as it goes, thus tracing the frequency response. (See the movie on the CD-ROM)

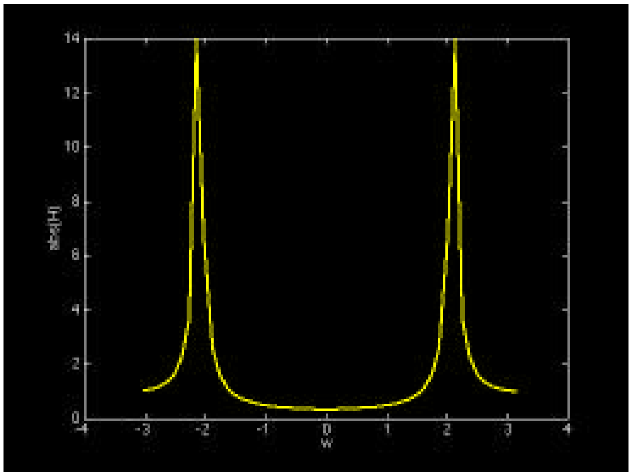

Figure 9. The frequency response of $H(z) = \dfrac{1}{1 + z^{-1} + z^{-2}}$.

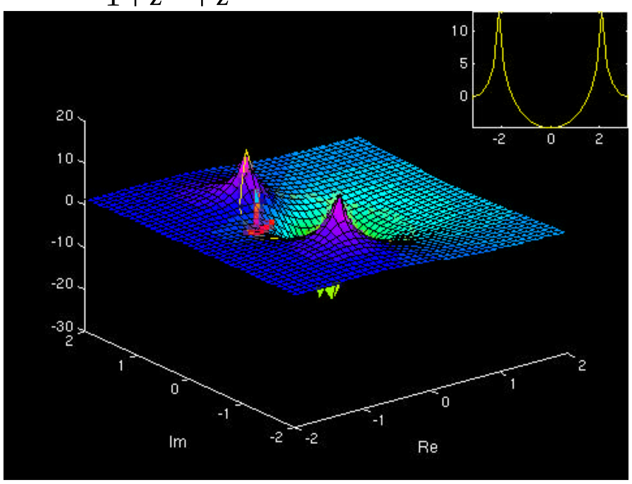

Figure 10. A visual tie between the pole/zero plot and the complex z-plane plot of $H(z) = \dfrac{1}{1 + z^{-1} + z^{-2}}$.

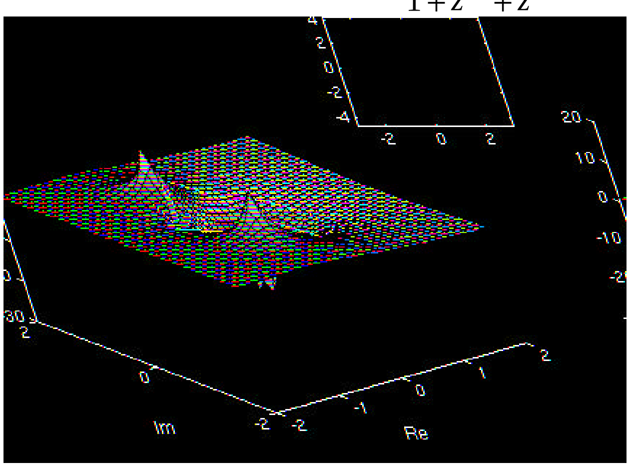

Figure 11. A frame from the movie showing the arrow moving around the unit circle and recording its altitude (frequency response) in the upper right corner.

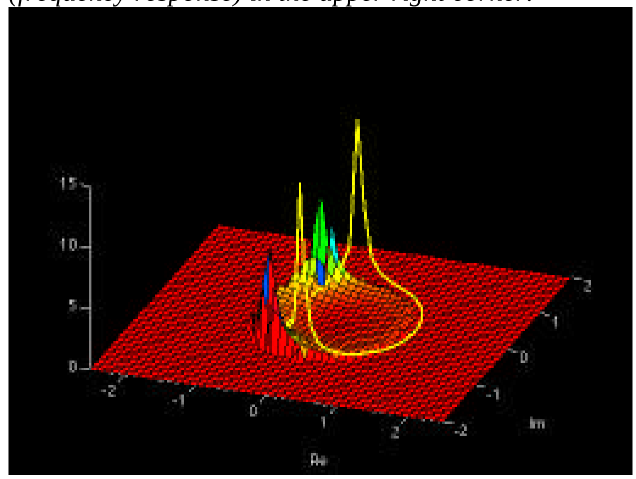

Figure 12. Another way of visualizing the frequency response. This time by "pealing" the unit circle off the surface.

Figure 12 shows the unit circle trace being "pealed off, resulting in the frequency response.

Student Responses

No formal assessment has been used to attempt to measure the effectiveness of these exercise. However, many informal responses show that the students feel the demos are helpful. The pole/zero animation in particular has received many positive responses.

Conclusions

Visual transitions are an effective use of multimedia that helps students to see the ties between related concepts. Four such examples were presented here. Our success so far makes us highly optimistic that more of such demos can be created to help further student understanding.

These demos and others will soon to be published in "DSP FIRST: A Multimedia Approach"[4] by Prentice Hall. Check http://www.prenhall.com/~dspfirst for further information on the project.

Links:

- QuickTime Movies

References

1. Mark A. Yoder, James H. McClellan, Ronald W. Schafer, "Using Multimedia and the Web to Teach the Theory of Digital Multimedia Signals," *Proceedings of Frontiers in Education, 25th Annual Conference*, Nov 1-4, 1995, Atlanta, GA.
2. QuickTime™, registered trademark of Apple Computer, Inc.
3. Matlab, registered trademark ofMathWorks, Inc.
4. Jim McClellan, Ron Schafer, and Mark Yoder, "DSP First: A Multimedia Approach", published by Prentice Hall, 1997.