Animations Created in *Mathematica* for Acoustics Education

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Abstract: For the last several years the authors have integrated animations into their curricula for teaching acoustics and vibrations. The purpose of this short paper is to explain how the animations are constructed in *Mathematica*, how they are postprocessed for easy viewing, and to describe the locations where our animations are available for use by all interested individuals. For readers who may wish to build their own *Mathematica* animations, a hint for effective presentations is given from the authors' experiences. Finally, the future of such animations is projected.

BACKGROUND AND ANIMATION CONSTRUCTION

Using computer animations to teach acoustics and vibrations is not a new idea, as the late Prof. Manfred Heckl's magnificent works attest. (Dr. Heckl's movies are not widely available, unfortunately.) The present authors desired a flexible system for constructing their own animations. The *Mathematica* symbolic manipulation program made its debut in 1987, and proved to be an ideal platform for developing such animations (1). The present animations are created in a recent version of *Mathematica* (2), and then are exported as either QuickTime (3) or MPEG (4) movies. The movies can be viewed by students either directly off of the computer or on a large VCR monitor after being dumped to videotape. Some of these animations have also been incorporated into CD-ROMs developed for teaching noise control engineering (5).

A typical animation is constructed by performing a `Do[]` loop over a *Mathematica* `Plot[]` command, wherein some parameter changes, e.g., the time. For example,

```
Do[     Plot[
                Cos[x - t ], {x,0,10}, PlotRange->{-1,1}, AxesLabel->{"x","y"}
        ],
        {t, 0, 2 Pi-Pi/8, Pi/8}
]
```

produces a sequence of 16 images with t varying from 0 to 15 Pi/8. The function Cos[x - t] is plotted for $0 \leq x \leq 10$ and $-1 \leq y \leq 1$ for each value of t. This animation, obviously, represents a forward moving wave with unity speed. While not important for the present example, the PlotRange variable is explicitly set so that every frame of the animation has the same vertical scale.

Many *Mathematica* built-in plotting commands are used in our animations: `Plot[]`, `Plot3D[]`, `DensityPlot[]`, `ContourPlot[]`, `ParametricPlot[]`, and `ListPlot[]`. These functions are well described in the *Mathematica* book (2) as well as in other books on *Mathematica* graphics (6,7). However when animating small particles or discrete masses, the built in plotting commands are not sufficient, and one must program *Mathematica* using graphics primitives. For example to show a vibrating mass, one uses commands such as

```
Do[     xpos=0.5 Cos[radarg]; ypos=0.;
        Show[   Graphics[{
                        Rectangle[{-0.25+xpos,-0.25+ypos}, {0.25+xpos,0.25+ypos}]
                }],
                {PlotRange->{{-1.,1.},{-1.,1.}} }
        ],
        {radarg, 0, 2Pi- Pi/8, Pi/8}
]
```

The `Rectangle[]` command draws a rectangle using coordinates of its lower left corner and its upper right corner. Here we simply move the coordinates from left to right, by setting the x position, `xpos = 0.5 Cos[radarg]`, the while keeping the y position, ypos, constant. The `Show[]` command simply sends the graphics to the screen. Other graphics primitives, such as `Circle[]`, `Line[]`, and `Text[]`, may be used to create more complicated animations.

ANIMATION POSTPROCESSING

Once the individual frames are constructed, they may be combined into a group of *Mathematica* cells, and then played consecutively. The Macintosh *Mathematica* Front End allows one to convert such a group of cells directly to a QuickTime movie, which may be further manipulated using standard QuickTime movie editing programs. On UNIX platforms, one can use the perl program `math2html` (8) to convert an entire *Mathematica* 2.2 Notebook to a HTML document. When run with appropriate flags `math2html` will either convert a group of *Mathematica* graphic cells into an MPEG movie, or it will convert each frame in a group of graphic cells to a separately numbered GIF file; these GIF files can then be combined into an animated GIF image using a UNIX program like GIFMerge or WhirlGif (9). Animated GIFs have the advantage that most World Wide Web (WWW) browsers will display the animation automatically as soon as the image is loaded, unlike QuickTime or MPEG movies which require software to view them. However, multiple, large animated GIF files tend to be very slow whereas once a QuickTime or MPEG movie has been downloaded to the user's computer it can be played at almost any desired speed.

EXAMPLE ANIMATIONS

The author's animations are freely available. Sparrow's page is
    http://www.acs.psu.edu/users/sparrow/animations.html
Russell's animation page is
    http://www.kettering.edu/~drussell/demos.html

A HINT FOR EFFECTIVE ANIMATIONS

The authors have learned, through trial and error, that students' eyes are not always drawn to that part of the animation that we wish. To aid the student, one should carefully consider using color in such movies. A black and white animation comes alive when that portion of the plot most important to student understanding is appropriately colored.

THE FUTURE OF *MATHEMATICA* ANIMATIONS

It is clear that the animations described here only touch what will be possible in future years with expansion of the internet through the Internet 2 and Next Generation Internet projects. Such new networks will allow much larger animations to be available over the WWW. Using CGI scripts and a *Mathematica* kernel program, one soon should be able to construct animations which are **interactive**, with the student able to change critical parameters. The use of JAVAscript is also on the way. It is clear that integrating *Mathematica* animations with interactive web documents will not only make learning acoustics and vibrations more fun but also will give students the opportunity to learn the material better.

REFERENCES

1. Wolfram, S., *Mathematica*, Addison-Wesley, 1988, p. 155.
2. Wolfram, S., *The Mathematica Book, 3rd Ed.*, Cambridge U. Press, 1996.
3. QuickTime information and software available at URL: `http://www.apple.com/quicktime/`
4. MPEG information and software available at URL: `http://www.mpeg.org/`
5. See `http://www.worldcampus.psu.edu/pub/programs/nce`
6. Smith, C. and Blachman, N., *The Mathematica Graphics Guidebook*, Addison-Wesley, 1995.
7. Wickham-Jones, T., *Mathematica Graphics: Techniques and Applications*, Springer-Verlag, 1994.
8. `math2html` was written by H. Edward Donely at Indiana University of Pennsylvania. Source code and installation instructions are available from the URL: `http://www.ma.iup.edu/projects/CalcDEMma/math2html.html`
9. See `http://www.iis.ee.ethz.ch/~kiwi/GIFMerge/` and `http://www.msg.net/utility/whirlgif/`