Combining physical REALity with SIMulations in Pedagogical Laboratory Experiments

Edgar Berdahl, Nelson Lee, Ryan Cassidy,
and Julius O. Smith III

Center for Computer Research in Music and Acoustics (CCRMA)
Stanford University
Stanford, CA, 94305

Education in Acoustics: Tools for Teaching Acoustics
Thursday Morning at 11:20AM, June 7th, 2007

—

Special thanks to the Wallenberg Global Learning Network for supporting the REALSIMPLE project

Outline

The RealSimPLE Project

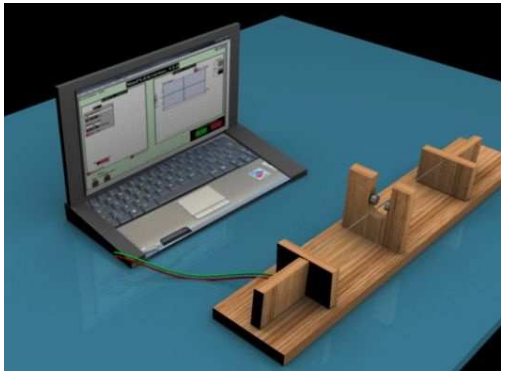
- RealSimPLE is a web-based teacher's resource for student laboratory sessions in musical acoustics.

The RealSimPLE Project

- RealSimPLE is a web-based teacher's resource for student laboratory sessions in musical acoustics.
- Music is a good way to interest young people in math, science, and engineering.

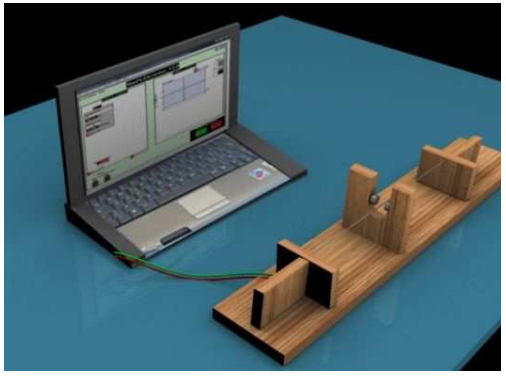
The RealSimPLE Project

- RealSimPLE is a web-based teacher's resource for student laboratory sessions in musical acoustics.
- Music is a good way to interest young people in math, science, and engineering.
- Physical experiments and pedagogical computer-based simulations of the same systems run in parallel and interconnected.



The RealSimPLE Project

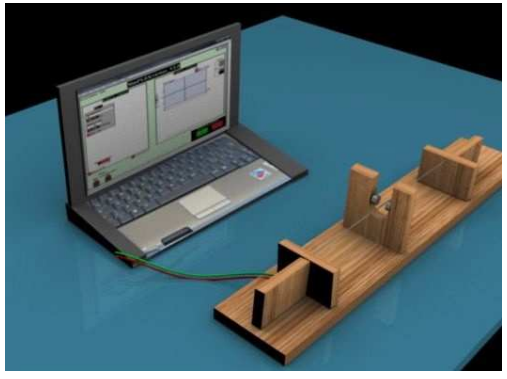
- RealSimPLE is a web-based teacher's resource for student laboratory sessions in musical acoustics.
- Music is a good way to interest young people in math, science, and engineering.
- Physical experiments and pedagogical computer-based simulations of the same systems run in parallel and interconnected.



- The traditional lab bench is enhanced rather than replaced.

The RealSimPLE Project

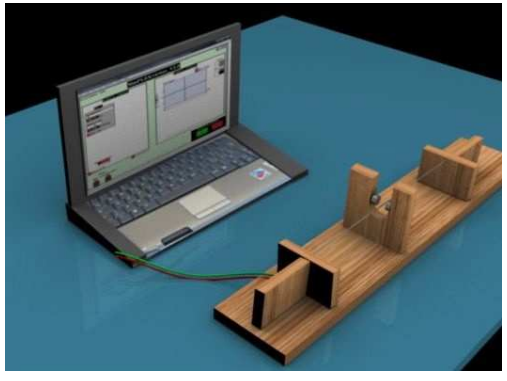
- RealSimPLE is a web-based teacher's resource for student laboratory sessions in musical acoustics.
- Music is a good way to interest young people in math, science, and engineering.
- Physical experiments and pedagogical computer-based simulations of the same systems run in parallel and interconnected.



- The traditional lab bench is enhanced rather than replaced.
- Only standard computers and some inexpensive, easy-to-build hardware are required.

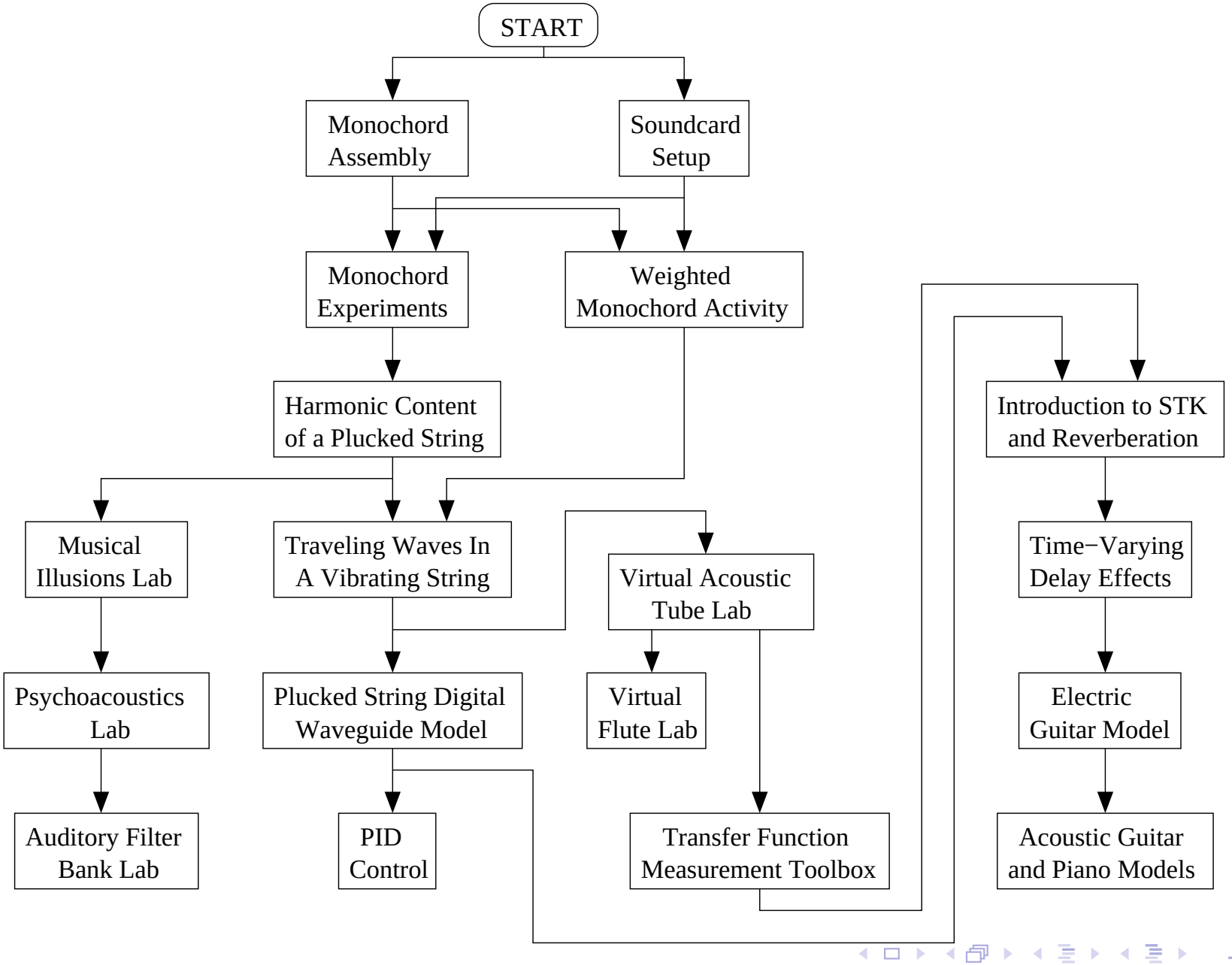
The RealSimPLE Project

- RealSimPLE is a web-based teacher's resource for student laboratory sessions in musical acoustics.
- Music is a good way to interest young people in math, science, and engineering.
- Physical experiments and pedagogical computer-based simulations of the same systems run in parallel and interconnected.



- The traditional lab bench is enhanced rather than replaced.
- Only standard computers and some inexpensive, easy-to-build hardware are required.
- The RealSimPLE Project is a collaboration between Stanford University and KTH in Sweden.

RealSimPLE Laboratory Assignment Dependencies

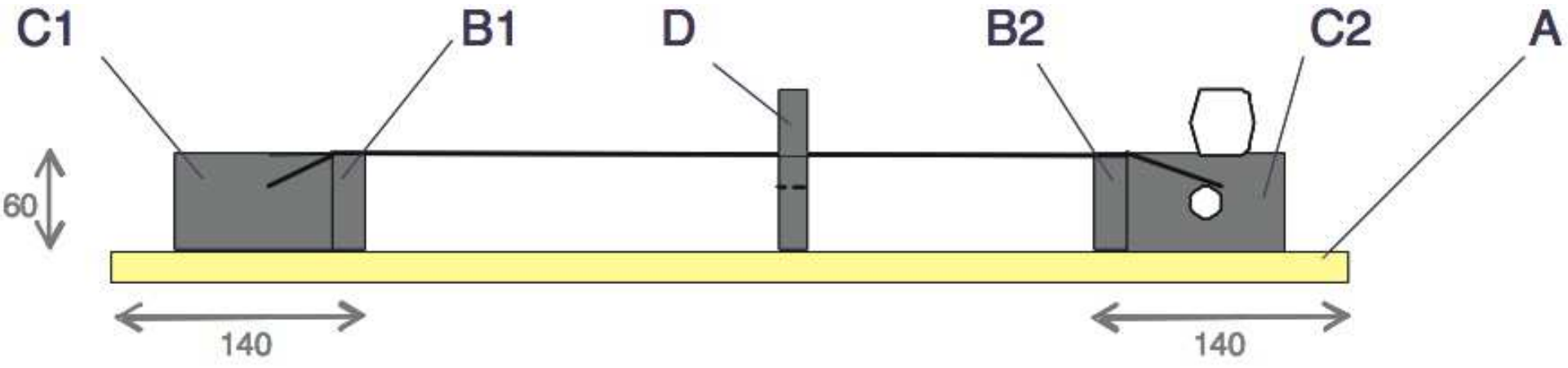


Outline

Monochord Experiments

C1, C2: longitudinal supports
D: sensor

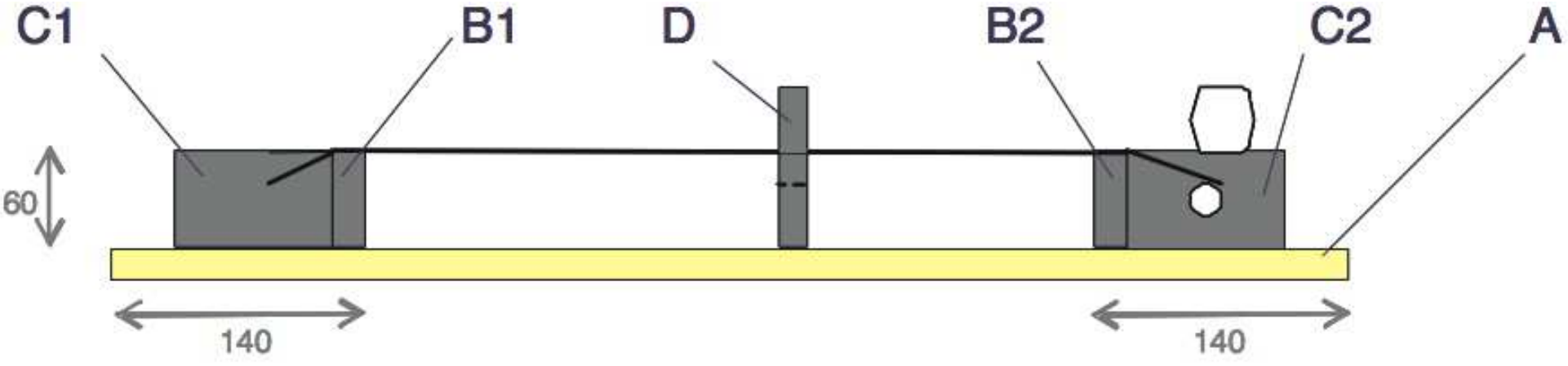
B1, B2: transverse supports
A: bottom plate



Monochord Experiments

C1, C2: longitudinal supports
D: sensor

B1, B2: transverse supports
A: bottom plate

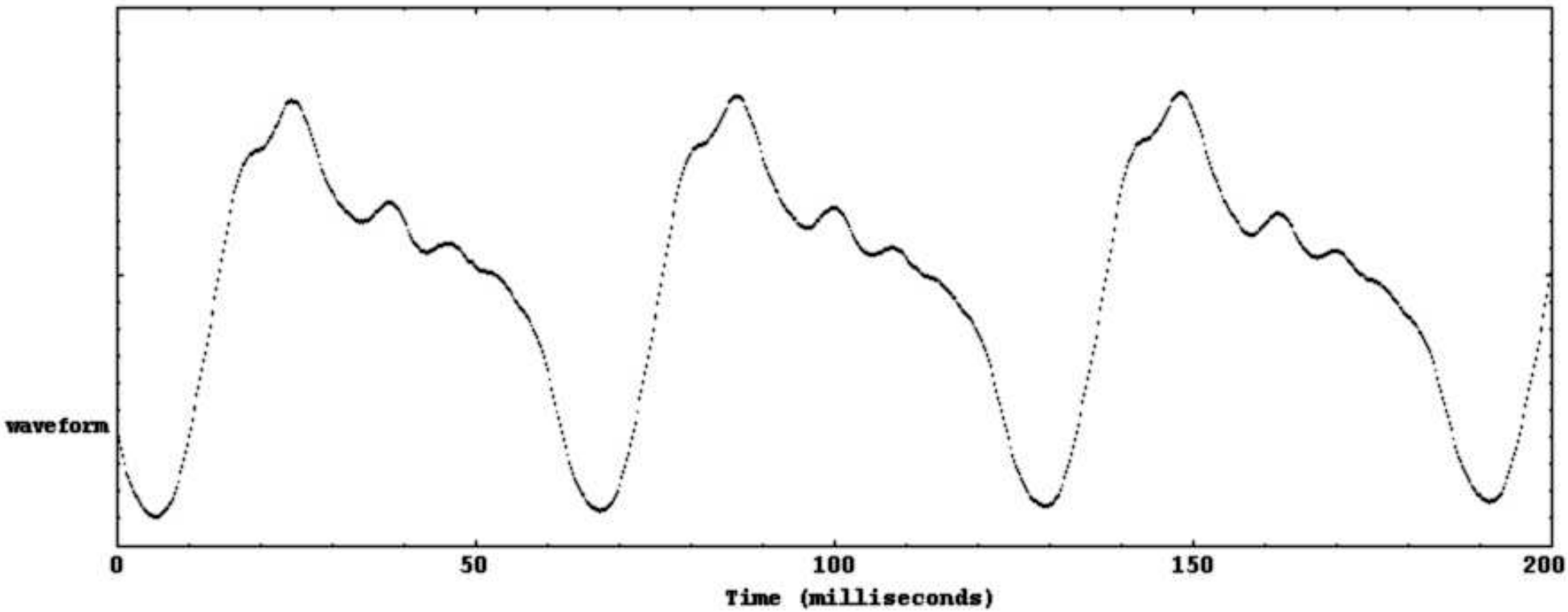


Measurements And Analysis With Pure Data

- Pure Data is an open-source graphical signal processing language.

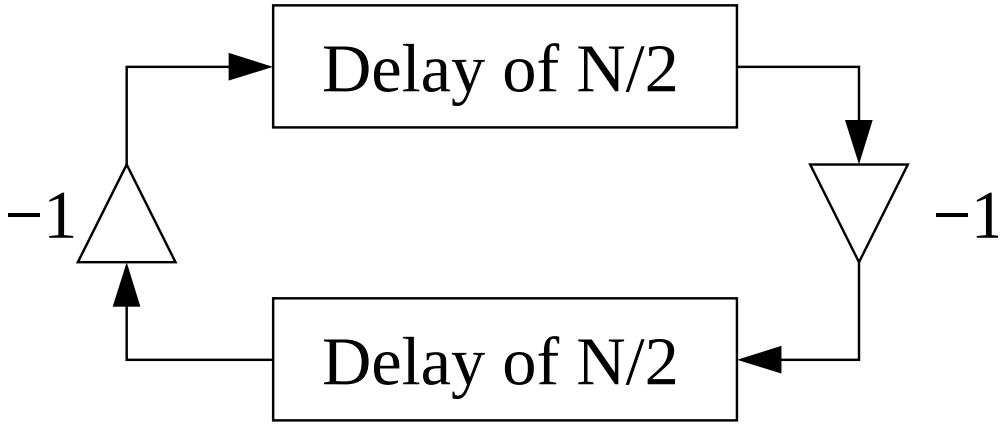
Measurements And Analysis With Pure Data

- Pure Data is an open-source graphical signal processing language.
- For instance, students can record the sound of a pluck and find the period graphically.

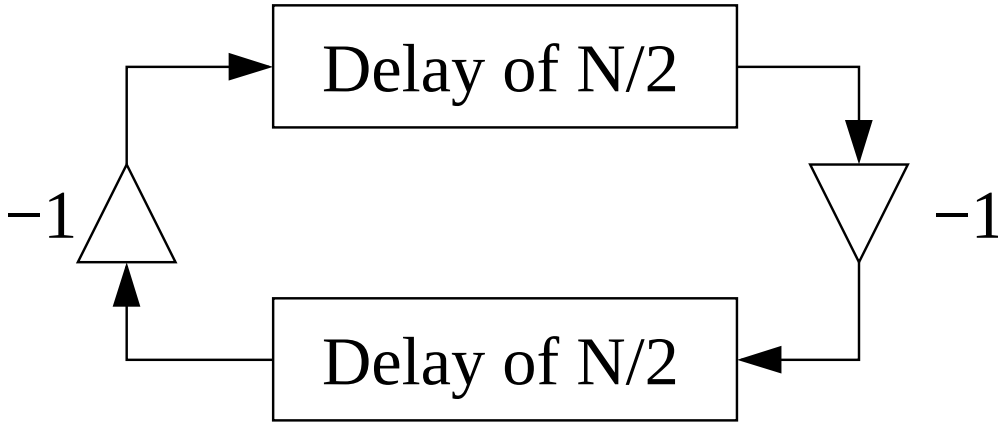


Outline

Monochord Digital Waveguide Simulation

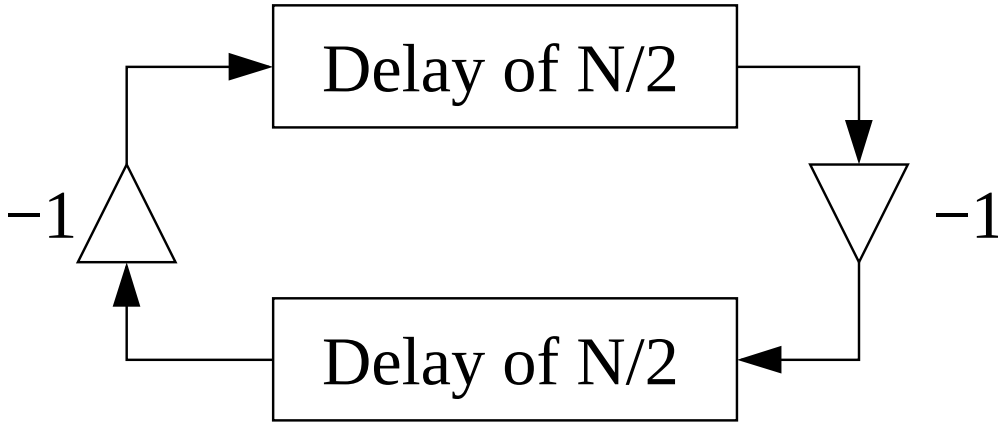


Monochord Digital Waveguide Simulation



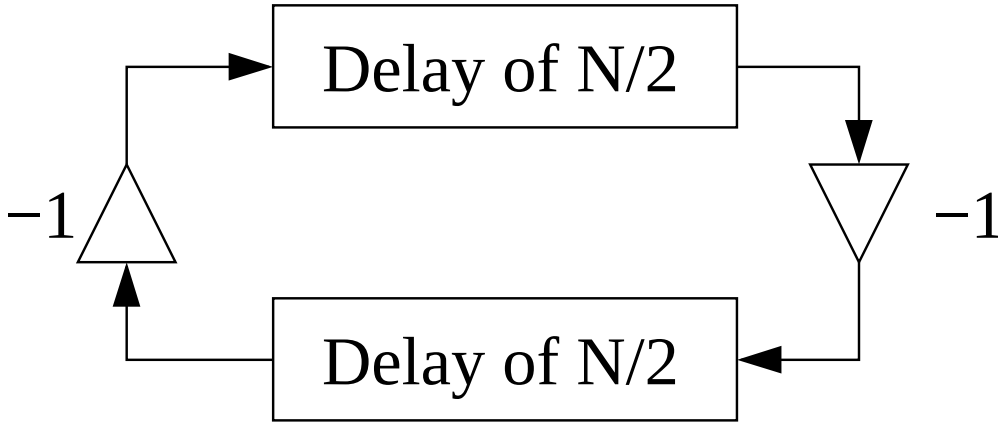
- The upper delay line models waves traveling to the right.

Monochord Digital Waveguide Simulation



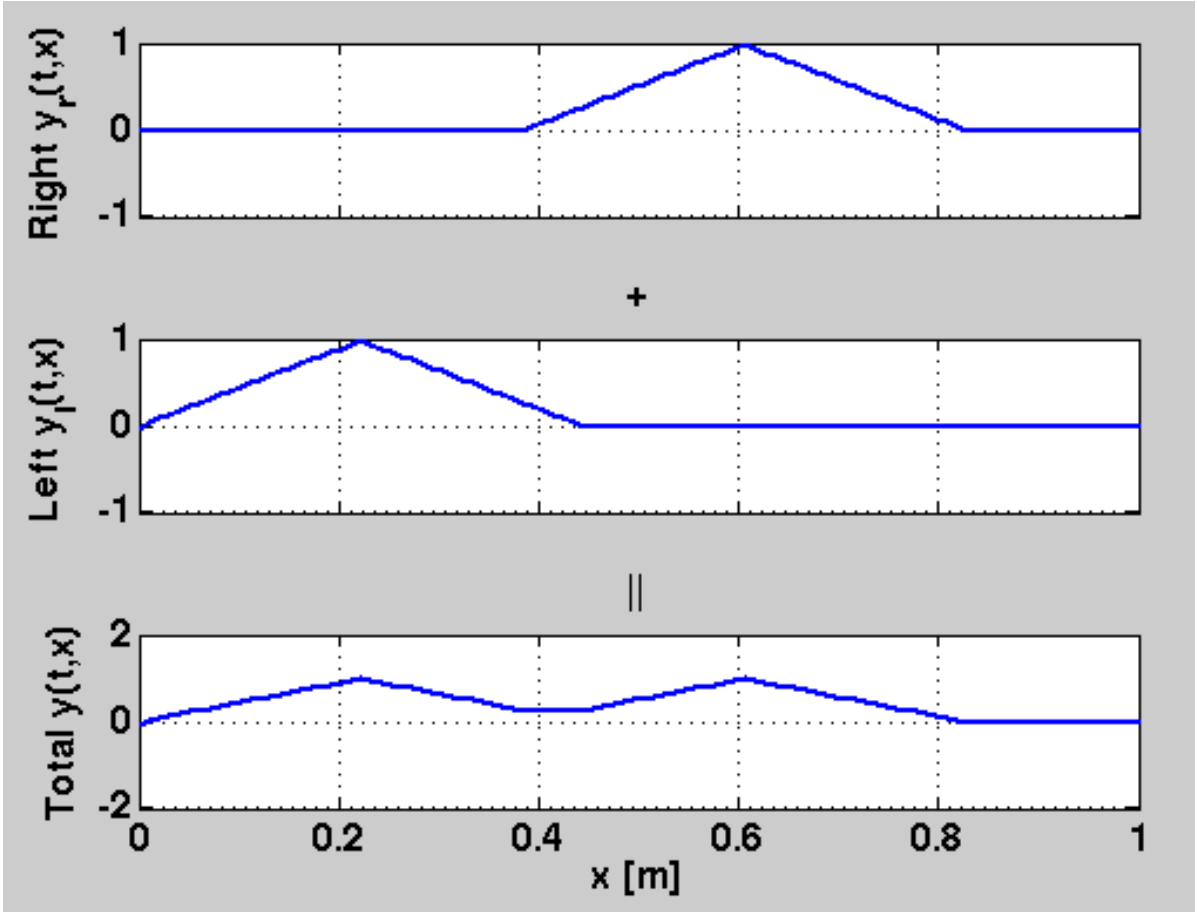
- The upper delay line models waves traveling to the right.
- The lower delay line models waves traveling to the left.

Monochord Digital Waveguide Simulation

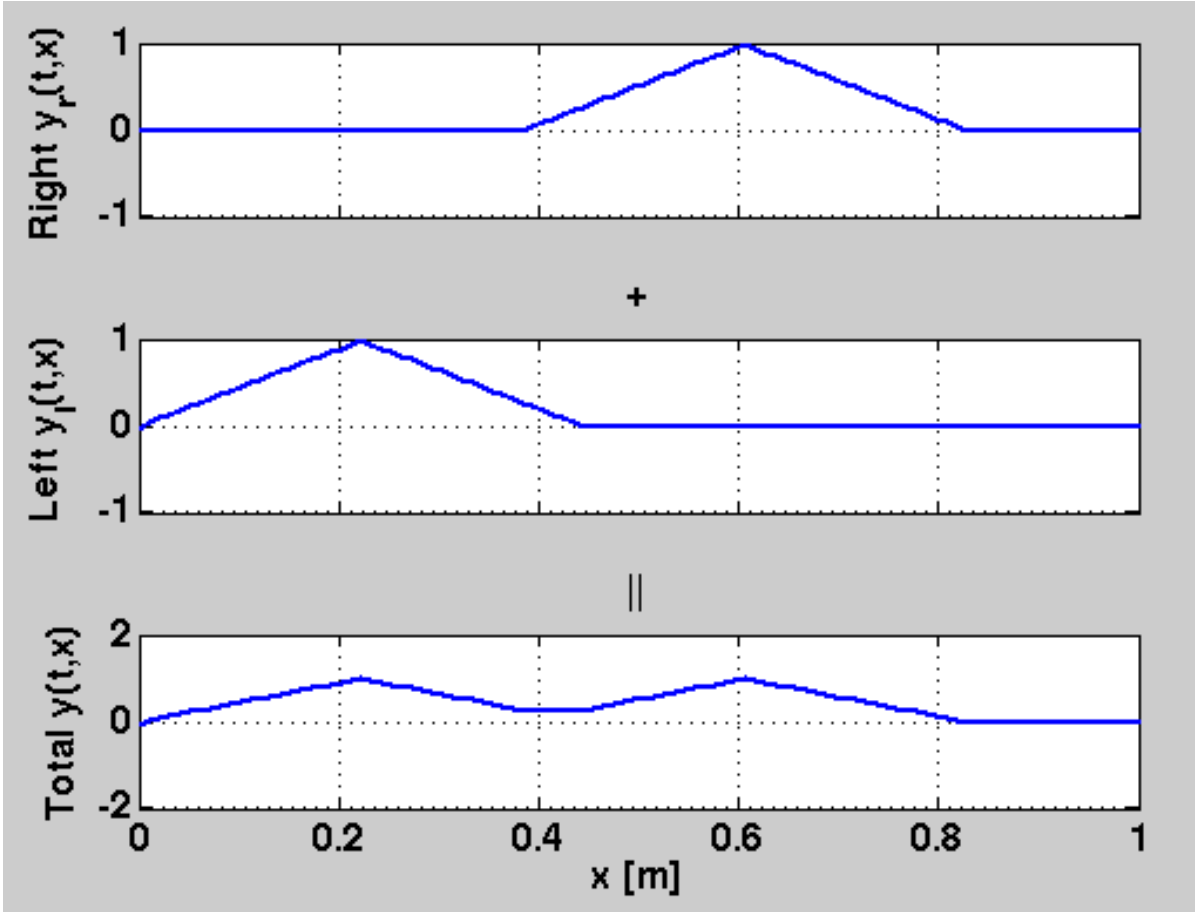


- The upper delay line models waves traveling to the right.
- The lower delay line models waves traveling to the left.
- The total loop delay is N samples.

Animations of Traveling Waves in a Vibrating String

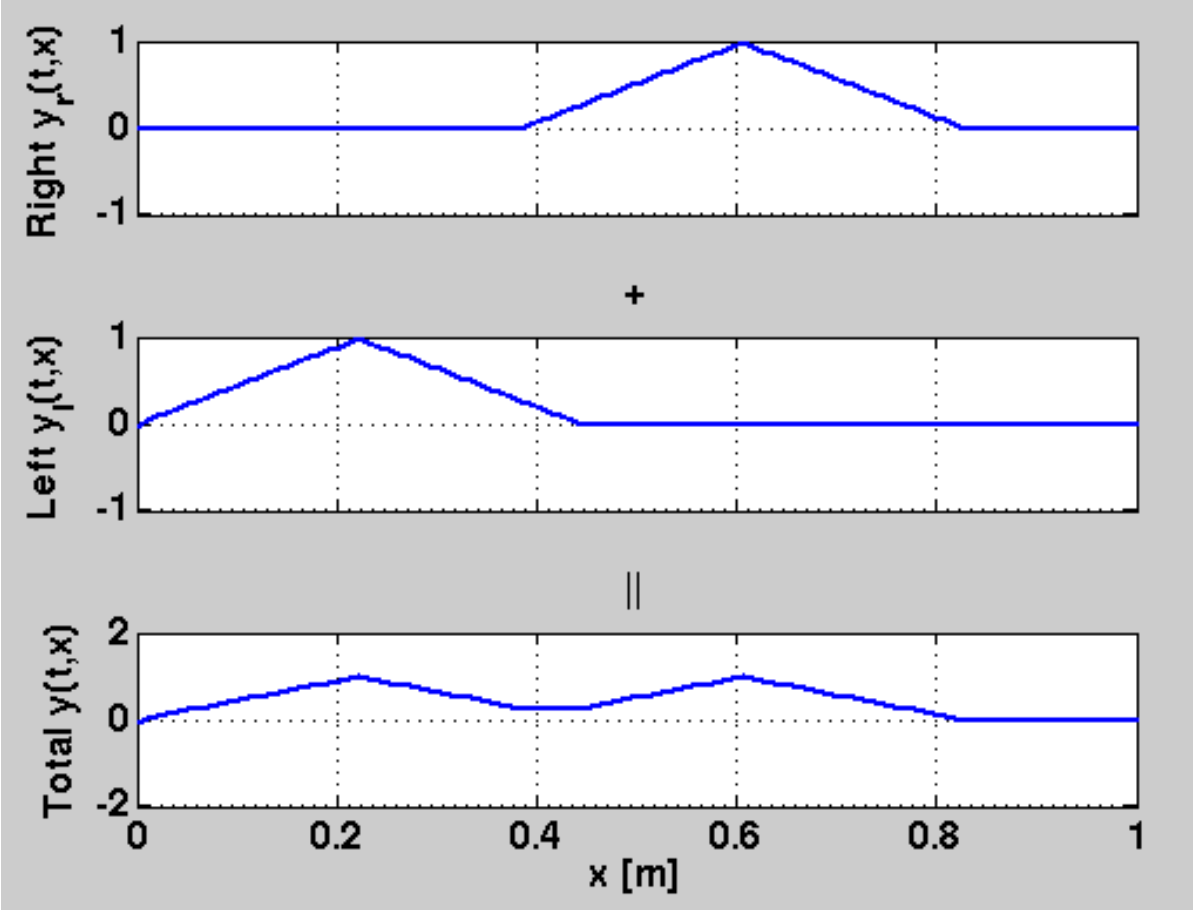


Animations of Traveling Waves in a Vibrating String



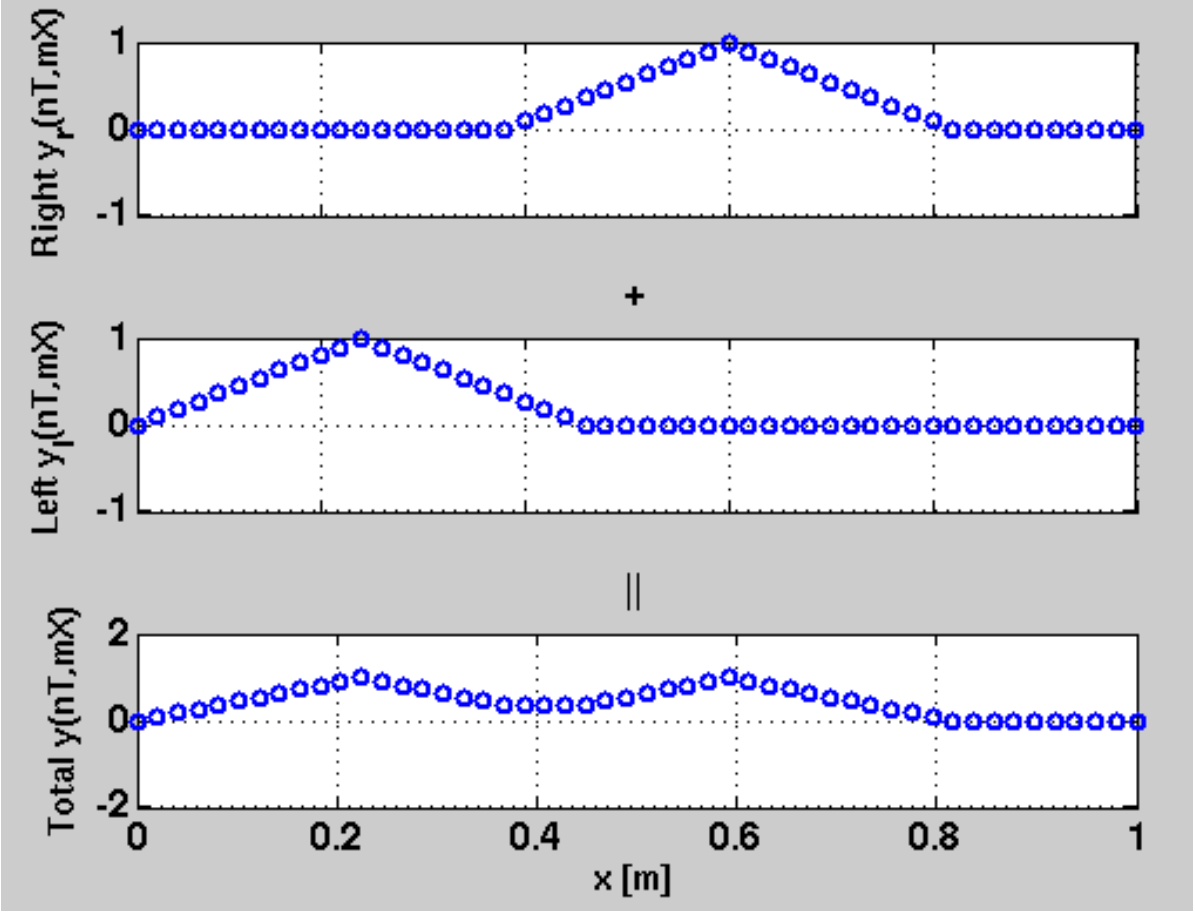
- Animations can display fast processes in slow motion.

Animations of Traveling Waves in a Vibrating String

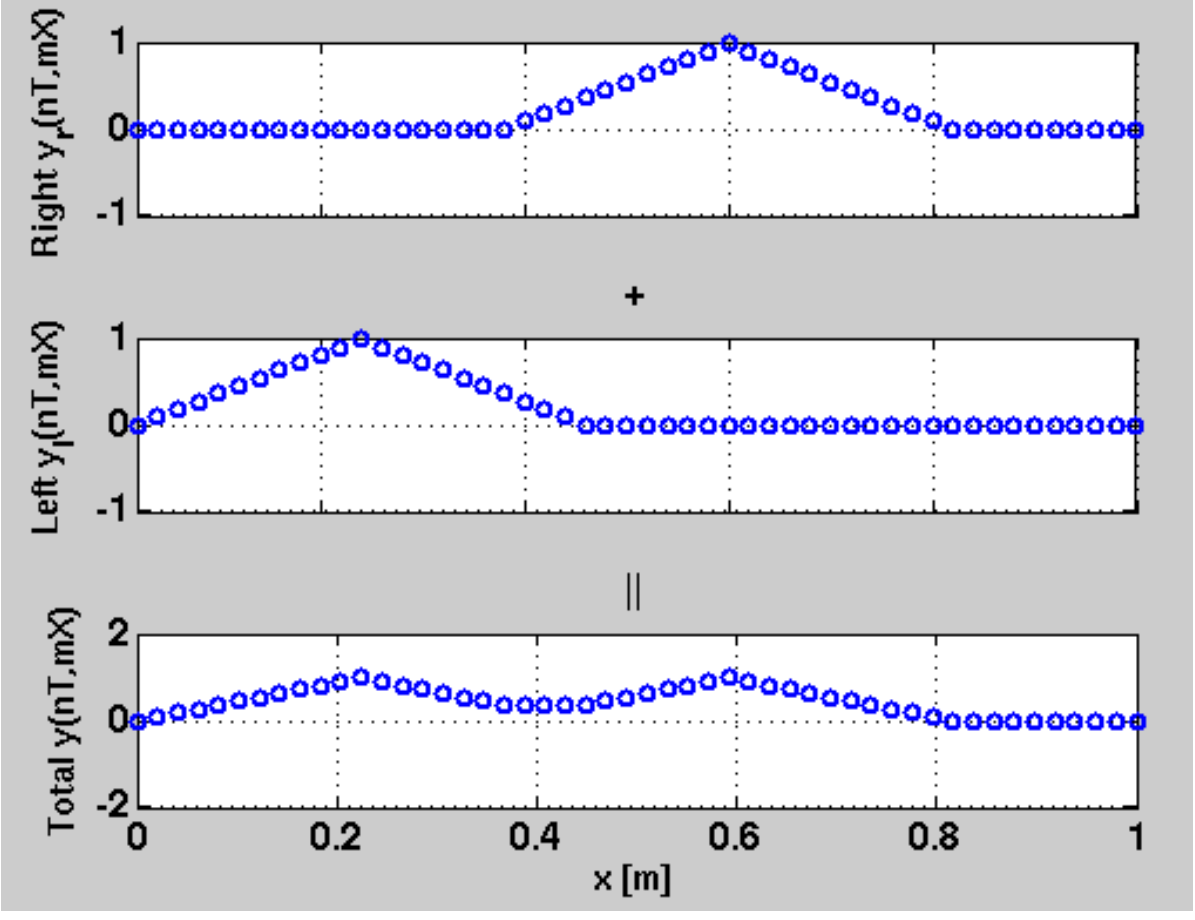


- Animations can display fast processes in slow motion.
- Animations can call greater attention to detail.

Animations of Sampled Traveling Waves

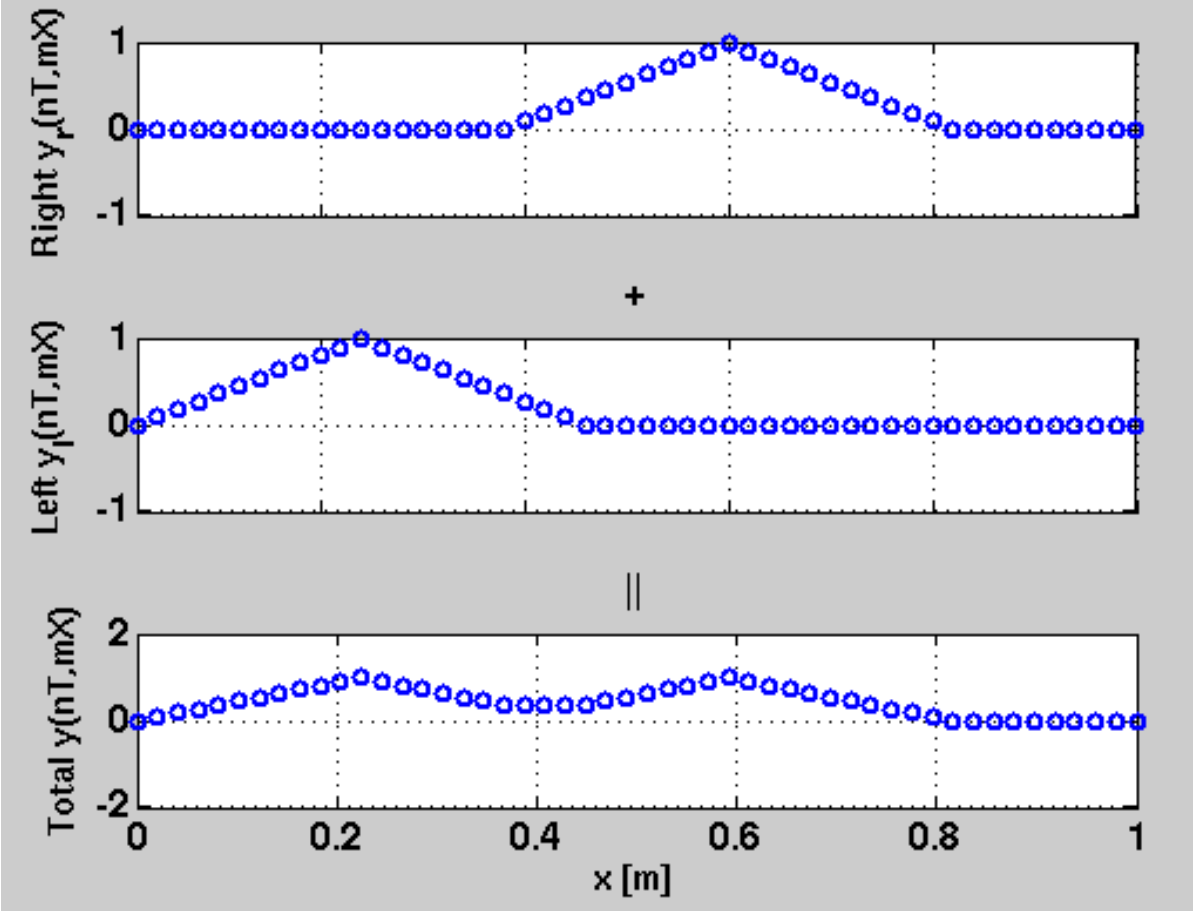


Animations of Sampled Traveling Waves



- New animations can be automatically generated simply using different initial conditions.

Animations of Sampled Traveling Waves



- New animations can be automatically generated simply using different initial conditions.
- Developers can quickly mass produce many animations.

Mass Producing Animations With MATLAB

1. Create each figure and write it to disk as a PNG.

Mass Producing Animations With MATLAB

1. Create each figure and write it to disk as a PNG.
2. Convert the PNG files to GIF using `convert` in UNIX.

Mass Producing Animations With MATLAB

1. Create each figure and write it to disk as a PNG.
2. Convert the PNG files to GIF using `convert` in UNIX.
3. Create a GIF animation using the free program `gifsicle` for UNIX.

Mass Producing Animations With MATLAB

1. Create each figure and write it to disk as a PNG.
2. Convert the PNG files to GIF using `convert` in UNIX.
3. Create a GIF animation using the free program `gifsicle` for UNIX.

Shell script for creating `new-animation.gif` from the PNG files in the `images` directory:

makeanimation

```
#!/bin/csh -f

foreach d ( images/* )
    echo "Converting" $d "to" $d.gif
    convert -compress LZW $d $d.gif
end

gifsicle --loop --delay=36 --optimize=2 images/*.gif > ../new-animation.gif
```

Outline

Stanford Website

- The laboratory sessions and related information are all freely available online.

[1] http://ccrma.stanford.edu/realsimple

Stanford Website

- The laboratory sessions and related information are all freely available online.
- We are releasing the website materials under the Creative Commons License, allowing anyone to freely use and continue developing the materials further.

[1] http://ccrma.stanford.edu/realsimple

Stanford Website

- The laboratory sessions and related information are all freely available online.
- We are releasing the website materials under the Creative Commons License, allowing anyone to freely use and continue developing the materials further.
- The Stanford RealSimPLE website[1] includes rollover “pop-up” definitions for many technical terms.

[1] http://ccrma.stanford.edu/realsimple

Stanford Website

- The laboratory sessions and related information are all freely available online.
- We are releasing the website materials under the Creative Commons License, allowing anyone to freely use and continue developing the materials further.
- The Stanford RealSimPLE website[1] includes rollover "pop-up" definitions for many technical terms.
  - These pop-ups allow website visitors to easily dig deeper down through the tree of prerequisite terms, thereby filling in any knowledge gaps they may have.

[1] http://ccrma.stanford.edu/realsimple

Stanford Website

- The laboratory sessions and related information are all freely available online.
- We are releasing the website materials under the Creative Commons License, allowing anyone to freely use and continue developing the materials further.
- The Stanford RealSimPLE website[1] includes rollover "pop-up" definitions for many technical terms.
  - These pop-ups allow website visitors to easily dig deeper down through the tree of prerequisite terms, thereby filling in any knowledge gaps they may have.
  - A motivated student anywhere in the world with a basic math and physics background can obtain advanced graduate-level knowledge from the website in a self-paced, demand-driven manner.

[1] http://ccrma.stanford.edu/realsimple

Website Sample With Pop-Ups

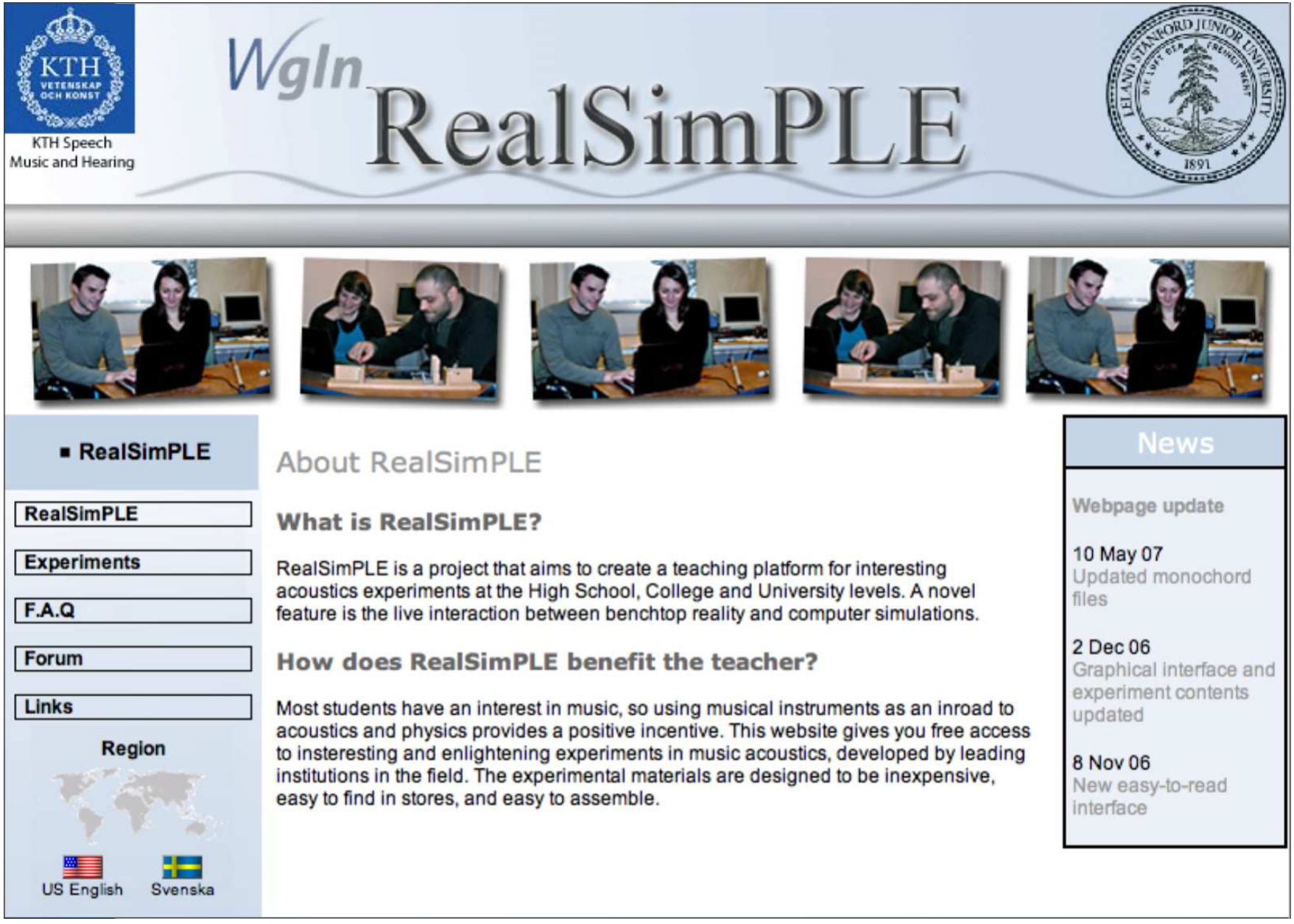
One of the most common sample rates used in audio, which is the sampling rate of compact discs (CDs), is $f_S = 44.1\,\text{kHz}$. According to the Nyquist-Shannon sampling theorem, what is the

maximum frequency that audio signals on CDs
the upper frequency limit of human hearing, whi

Derivation of the *sampling theorem* which states that any signal can be perfectly reconstructed, in principle, from uniformly spaced samples of that signal, provided that the sampling rate is higher than twice the highest frequency present in the signal — Click for http://ccrma.stanford.edu/~jos/mdft/Sampling_Theorem.html

We also need to sample the wave functions with
efficiently on a computer. We let X be the *sampling interval*, which is the distance that a traveling wave in the waveguide travels during one sampling interval. Since c measured in m/s is the wave speed in the waveguide, $X = cT$.

Swedish Website



Newsgroups

¤ Exempel på kategori	
	**Om RealSimPLE** RealSimPLE är ett projekt som syftar till att skapa intresseväckande experiment för gymnasie och högskola inom området akustik, med musikinstrument som utgångspunkt. En spännande nyhet är att den vibrerande verkligheten i strängar, pipor och stavar kombineras med datorsimuleringar av samma föremål.
	**RealSimPLE** Allmän diskussion kring RealSimPLE projektet
	**Monokordet** Diskussion kring Monokord experimentet
	**SimPLEKs Rör** Diskussion kring SimPLEKs Rör experimentet
	**Lärarrummet** Öppen diskussion för lärare
	**About RealSimPLE** RealSimPLE is a project that aims to create a teaching platform for interesting acoustics experiments at the College and University levels. A novel feature is the live interaction between benchtop reality and computer simulations.
	**General thread for english speaking visitors** A thread for discussing RealSimPLE expertiments

Outline

Evaluation At Lynbrook High School

- Nelson Lee is testing the lab assignments on juniors and seniors in high school.

Evaluation At Lynbrook High School

- Nelson Lee is testing the lab assignments on juniors and seniors in high school.
- We are planning to make additional evaluations at the House of Science in Stockholm.

Thanks

American website at Stanford University:

`http://ccrma.stanford.edu/realsimple`

Swedish website at the Royal Institute of Technology (KTH):

`http://www.speech.kth.se/realsimple`

Questions?