RealSimPLE:

Strings

Monochord Lab Instructions

Illustrates how the vibrations of the string are affected by its mechanical properties and how it is excited

RealSimPLE lives on the web:

For high school: in Swedish and English http://www.speech.kth.se/realsimple

For college and university, in English: http://ccrma.stanford.edu/realsimple

Questions about RealSimPLE can be e-mailed to nelsonapollolee@gmail.com or to hellmer@kth.se .

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Kungliga Tekniska Högskolan; School of Computer Science and Communication; Department of Speech, Music and Hearing. www.speech.kth.se

ROYAL INSTITUTE OF TECHNOLOGY

Stanford University, California, USA - Department of Music, Center for Computer Research in Music and Acoustics (CCRMA). http://ccrma.stanford.edu

House of Science, KTH Albanova, www.houseofscience.se

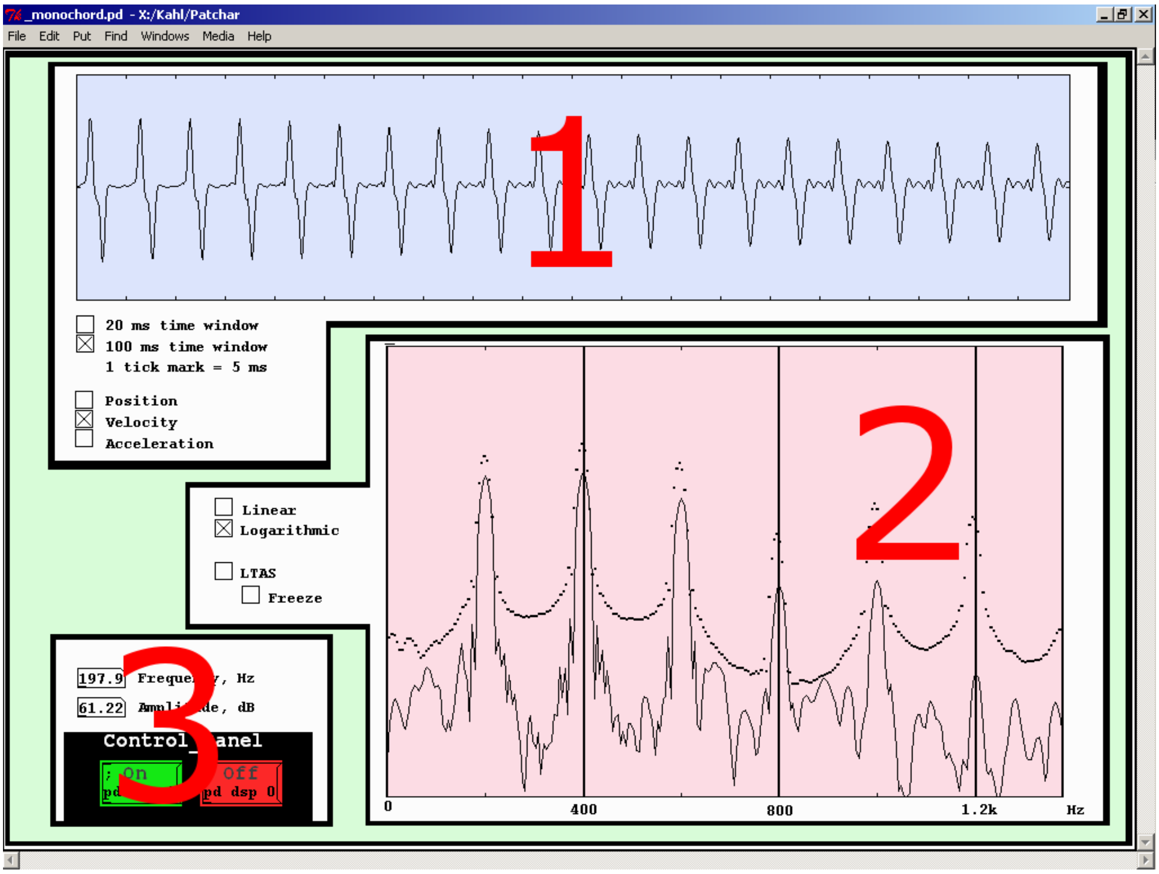
Table of Contents

Introduction

The Monochord laboratory is designed for use with the RealSimPLE monochord and a software model (patch) that runs under PureData (Pd). For monochord assembly instructions and Pd installation instructions please see the RealSimPLE website.

Run the program `Pd.exe` (PureData) and choose: `File -> Open`...

Choose the file `monochord.pd` and click `Open`.



The Monochord.pd patch.

1: Oscilloscope. The time window can be set to either 20 or 100 ms and to show the string's position, velocity or acceleration in the magnetic field. When the string is excited the first 20 or 100 ms of the string's position, velocity or acceleration will be shown here.

2: Spectroscope. Displays the movements of the string as a function of frequency. Its Y-axis (amplitude) can be set to linear or logarithmic. The toggle button LTAS (Long Time Average Spectrum) displays and average spectrum in which it is easier to see the amplitude of individual resonances, the Freeze button holds the LTAS spectum until it is deselected.

3: Control panel. On and Off buttons are used to start and stop the model. Here is also information on amplitude and fundamental frequency of the string.

The patch is designed for a string tuned to approximately 200 Hz.

The String

The main acoustical properties of a vibrating string is ϱ mass per unit length, [kg/m], tension T [N], and length l [m].

Measuring the string tension

At its midpoint, pull the taut string from its rest position with a weight or with a dynamometer, and measure how far from the rest position the midpoint has moved. Compute the string tension.

$$T = \frac{F}{4} \cdot \frac{l}{h}$$

Parameter	Symbol	Unit	Your result
pulling force	*F*	N	
string length	*L*	m	
midpoint displacement	*H*	m	

Answer

string tension	*T*	N	

Pulse Propagation

Striking the string will excite two pulses that propagate in opposite directions along the string. The propagation velocity of each pulse is set by the string tension (*T*), and mass per unit length (*ϱ, rho*). Each pulse will travel a round trip: (1) it starts from the strike point to the first support, (2) it is reflected along the whole string to the opposite support, (3) it is reflected again, and returns to the strike point. The round trip completes one period of the string's oscillation.

1. Measure the period time for the pulse propagation from the strike point via the two reflections and back. Compute the propagation velocity of the pulse using the oscilloscope in the patch monochord.pd.

$$c = \frac{2l}{t}$$

Parameter	Symbol	Unit	Your result
string length	*l*	m	
period time	*t*	s	

Answer

propagation velocity	*c*	m/s	

2. Weigh a copy of the string and compute its mass per meter. If you do not have access to a scale you can use the approximate value 2.5 g/m. Compute the propagation velocity from its known relation to the string's mass per meter and tension. Does the result match the observed velocity? If not, why might that be?

$$c = \sqrt{\frac{T}{\rho}}$$

Parameter	Symbol	Unit	Your result
string tension	T	N	
mass per unit legnth	ρ	kg/m	

Answer

propagation velocity	c	m/s	

3. The fundamental frequency f is the inverse of the period time t, that is $1/t$. The distance covered by the pulse during one period equals the wavelength of the fundamental frequency of the string. There is a basic relation between frequency, wavelength and propagation velocity. What is this relation?

Now, calculate the wavelength of the string's fundamental frequency!

Parameter	Symbol	Unit	Your result
propagations velocity	c	m/s	
frequency	f	Hz	

Answer

wavelength	λ	m	

Resonances of the String

If the string is excited by a single frequency signal that equals its fundamental frequency, the string will vibrate in phase with this frequency. At the center of the string it vibrates maximally, this is called an *anti-node*. The string does not vibrate much in its end points since its mount is almost perfectly rigid, these are called *nodes*. In other words; the boundary conditions for the taut string are that there must be vibration nodes at the string's ends. Still, the boundary conditions can be met for more than just one frequency!

4. Look at the spectroscope in the monochord patch and pluck the string so that you can see its spectrum. The resonances of the string are shown as sharp peaks. What is the relationship between the frequencies of these resonances and the fundamental frequency of the taut string?:

$$f_n = n * f_1 \text{ , } n = 1,2,3\ldots$$

Which is the frequency of the n:th resonance?

Parameter	**Symbol**	**Unit**	**Your result**
fundamental frequency	f_1	Hz	

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the n:th string resonance	f_n	Hz	

Without a theoretical derivation, it seems plausible that several half wavelengths along the string gives resonances when this complies with the boundary condition: no vibration at the string ends. Thus a resonance can have several nodes and anti-nodes at a specific resonance frequency. The vibrations of a given resonance can not be excited or measured in a node.

5. Strike the string at its midpoint, at one third of its length and at one quarter of its length. Register positions of maximum and minimum vibrations for each strike. Explain how the spectrum is affected and why.

6. At which positions are the nodes and anti-nodes located on the string, for the lowest five resonances? Which are the resonance frequencies?

Striking the string using a harder or softer material will also affect the spectrum. By just listening to the string, it is possible to tell whether it was struck with a hard or soft material.

7. Strike the string at one eighth of its length using a small wooden pen or pencil (hard material) and then with a piano hammer or an eraser or some such (soft) attached to the pencil. What features makes it possible separate the two sounds?

8. Strike the string just as in task 7 and this time look at the resonance frequencies. Are the frequencies the same?

Now, look at the the signal of the string in the time domain instead of the frequency domain.

9. Strike the string at its midpoint, at one third of its length and at one quarter of its length. Does the signal appear to be different? Explain.

10. Strike the string at one eighth of its length using a pen or pencil (hard material) and then with a piano hammer or an eraser or some such (soft) attached to the pencil. How is the signal affected?

FAQ