# xoxos Pling4 VST

This VST expounds upon the previous releases in the Pling (an abbreviation of "plucked string") series to produce a flexible and cpu-sensible instrument suitable for a wide range of emulative applications. This document intends to explain the history and function of the synthesis technique as a comprehensive introduction to physical modeling or all VST users.

HISTORY

The Karplus-Strong algorithm was introduced in Computer Music Journal in 1983. The plucked string was emulated by feeding a pick impulse generated by a short burst of white noise into a tuned delay line with a simple first order lowpass filter in the delay path. The delay line was analogue to the travel of the vibration along the string and the lowpass filter modeled the high frequency losses present in the acoustic string.
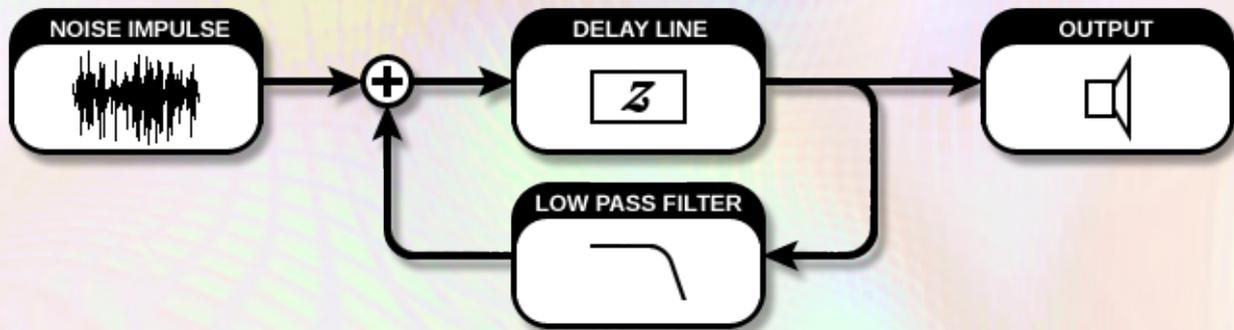
Stanford's Julius O. Smith championed the continued development of the Karplus-Strong algorithm as digital waveguide synthesis, using digital delays and filtering to model acoustic vibration. Smith remains a major proponent of physical modeling synthesis due to his policy of documentation. Smith describes a number of improvements to the Karplus-Strong algorithm which are used here. These include allpass filtering to model string stiffness, and orthogonal coupling, or using separate delay paths (or waveguides) to model horizontal and vertical vibration in the string.

There are many methods that can be used to model or otherwise synthesize physical acoustics. The improved Karplus-Strong technique remains an efficient and configurable method of generating plucked string sounds. The string model used for Pling4 is my implementation of canonical waveguide synthesis. The design of the picking impulse is less derivative.

Pling4 is a spartan form of this synthesis technique. There are no augmentations for sympathetic string or body resonances, pickups, or human performance. These are left to the informed and informing artist to implement around this essential engine.

MODEL

I.   The String

The string model, being primarily described above, is probably the easiest part to understand initially.

The delay lines used to model string transmission use hermite interpolation, which, being an upgrade from the linear interpolation used for previous Pling builds, have good retention of high frequencies as well as of low frequencies. Gain, or feedback, in these delay lines is fractionally close to 1.0 in order to produce the expected sustain.

I a.   Damping

Two filters are included in the delay loop. The first is a first order lowpass filter. This filter is used to model the sum of energy losses present in the string in one computation, and collectively emulates losses from material, imperfectly terminated strings, palm muting et c. Tracking is applied so that higher filter cutoff values can be used for higher pitches.

Damping (continued)

The phase response of this filter acts to slightly lengthen the delay loop (depending on the frequency), increasing with lower cutoff values. This has the effect of lowering the pitch of the "string" as the cutoff is lowered. Occasionally this is desirable, most of the time it is not. A button next to the damping parameter options for the delay length to be recalculated to consider the lowpass phase response so that changing the damping does not alter the pitch.

I b.   Stiffness

The second filter in the delay line is an allpass filter. Allpass filters do not change the gain at any frequency but do affect the phase. This is convenient because apparently higher frequencies travel faster in solids such as metal, low frequencies being obfuscated by inconsistencies in the material. I haven't been in there to check, but applying allpass filtering effectively shortens the delay loop for higher frequencies, having the effect of spreading higher harmonics and producing a change in timbre that is reminiscent of stiffer, thicker metal vibrating things.

The allpass filter can be applied in first to fourth order. Emulation of guitar strings is usually satisfied by first or second order filtering. Tracking is also applied as shorter strings have a wider diameter in relation to their length and are thus "stiffer".

The phase response of allpass filters also necessitates recalculation of the delay length to retain correct pitch. Higher order filtering shortens the delay length as many times as there are filters applied. It is possible, especially with higher pitches, that the length of the delay will be shortened to its minimum possible length. As the delay cannot be shortened beyond this, higher notes on patches with high stiffness settings may be heard to have the wrong pitch above a certain note.

I c.   Orthogonal Coupling

Pling4 couples the horizontal and vertical waveguides at the bridge. In acoustic strings, patterns of vibration can be observed in various analyses, eg. torsional vibration, or the oscillation of the string as it twists in either direction. Vibration on the horizontal plane, considered to be parallel to the face of the instrument, generally has less loss than on the vertical plane due to increased rigidity on this axis. Because both delay lines use the same length coefficients, this method of coupling serves one purpose: to improve the modeling of dynamics.

With a single, uncoupled delay line, decay would be uniformly exponential. In acoustic instruments the contour is more complex. The orthogonal coupling allows a shorter vertical decay to be slightly coupled to a longer decay on the horizontal axis, retaining longer sustain when a shorter initial decay is appropriate. As it follows, higher coupling will generally balance the loss in the system between the two parameters, so that smaller coupling settings should be used if greater difference between decay and sustain is required.

Those of you intending to construct similar models will appreciate that this method requires twice as many delays and filters as a single waveguide model modified with a conventional envelope, although both sets use the same coefficients.

I d.   Velocity Modulation

Knobs are located under a number of sliders on the Pling4 GUI. In all instances, these apply velocity to the parameter. This is done in a number of methods. Generally, the velocity response is centered, eg. velocity 63 will produce no response, higher velocities will increase and lower velocities will decrease. Occasionally velocity is more appropriate applied otherwise, eg. for the attack of the amplifier envelope, where shorter attacks are usually more suited for higher velocity notes. And of course, very occasionally, the velocity responsivity is a uniform increase or decrease of the parameter, which should be apparent when patching :)

I e.   Tracking

Note that the GUI contains a Center parameter next to the polyphony indicator. The MIDI note indicated by this parameter acts as a transposable center, around which all tracking modulation is centered. This center is also transposed by the global octave setting, so that raising or lowering the octave parameter will shift all features of timbral performance.
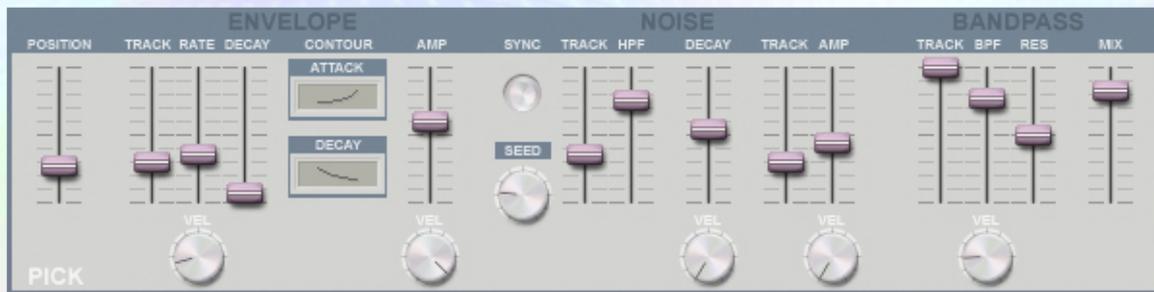
II.   The Pick

Pling4's pick model consists of three stages: a flexible attack/decay envelope, a highpass filtered noise source, and a resonant bandpass filter.

II a.   Plucking Position

The plucking position is scaled from the bridge to halfway up the length of the played string. It is a shortcoming of this build in that this parameter is not modulated by tracking: if one were playing different notes on one string without moving the plucking position, as the string is shortened for higher notes, the plucking position would "increase" relatively. Without this modulation, similar timbre is retained across the scale.

Note that, as on a real string, plucking the string in the center (highest setting) produces a square wave-like timbre, as the "duty cycle" of the string is evenly divided. Changing the plucking position is reminiscent of changing the width of a subtractive pulse wave.

II b.   Pick Envelope

The shape and length of the picking envelope can be considered to be a waveform, in that it contains the frequencies that will propogate in the string. A shorter envelope will produce higher frequencies. The rate of the envelope is set with three parameters: an overall rate parameter, a decay parameter which increases the length of the decay stage from 1 ot 8 times the length of the attack, and a tracking function. With no tracking, the same envelope, or frequency impulse, is applied to all notes. The highest tracking setting adjusts the length of the envelope in proportion to the wavelength of the note. Intermediate settings are likely to produce the most emulative timbres.

A selection of six contours are applicable to the attack and decay stages of the picking envelope generator. I find the S-curve contours more appropriate for "fingered" plucking and the linear and curved contours for emulation of plectrums. Sharper curves emphasise high frequencies, perhaps useful for emulating more rigid picks.

II c.   Noise

A separately enveloped impulse of white noise can be added to, or used instead of the picking envelope. The noise source can be synced so that each new note will generate the same segment of white noise. The seed parameter is used to generate the noise. The effect of this is that, when synced, every seed value generates an impulse with a different composition of constituent frequencies. With luck, these frequencies may be similar to the resonances of the intended acoustic form.

"Commuted waveguide synthesis" uses a body resonance impulse taken from an acoustic instrument as the picking impulse. Adding these frequencies to the picking impulse instead of using a computationally intensive resonance model is an efficient and surprisingly

Noise (continued)

effective method of acoustic emulation. Unfortunately I do not have a way of deriving these impulses, which is why the picking model is complex. Using longer decay settings will add to the impression of a resonant acoustic body in the patch by adding more shape to the impulse, or may sound unnatural.

Continous, or unsynced noise, can also be selected. This adds variation to the performance which may add interest to the patch.

Raising the highpass filter has the effect of emphasising the high frequency content of the impulse by removing samples which may cancel them as the impulse propogates in the decay loop. Tracking applied to the amplification of the noise impulse reduces gain with higher notes so that they are not unnaturally bright or loud.

II d.   Bandpass Filter

The envelope and noise impulses are summed and routed to a resonant bandpass filter. The output of this filter can be mixed with or entirely replace the dry signal.

This filter can be key tracked and modulated by key velocity. High resonance may be used to sustain at a desired frequency band which can suggest body resonances or be used to add timbral interest. A bank of several such resonant bands would produce a more convincing emulation but would become intensive to patch. As demonstrated by the banjo preset, the sustain of the single resonant filter can improve the emulative quality of a patch. A/Bing acoustic recordings or using sample analysis can assist in the patching process.

MODULATION

Two conventional LFOs and an HADSR envelope augment the architecture. Perhaps a few of these parameters need explaining:

I.   LFOs

Buttons allow the phase and rate of the LFOs to be synced. The phase is synced to position at NoteOn events so that the LFO modulation is recallable with each key press. Syncing the rate parameter locks the rate to a selection of BPM divisions.

The bias function weights the LFO in either direction, so that eg. entirely positive modulation can be applied to the destination.

II.   HADSR Envelope

The envelope includes a hold stage before the standard ADSR contour that may be useful for effects like delayed vibrato on sustained notes.

Three buttons are located beneath the Hold, Attack and Amount knobs. These buttons are all invert functions. The buttons associated with the rate parameters (Hold and Attack) invert the application of velocity, so that higher velocity shortens the rate instead of lengthens it.

When Hold is at zero, no amount of velocity modulation is applied.

Thank you for trying xoxos Pling4 plucked string synthesizer. Hopefully this information will potentiate you to approach patching by using the parameter set to mimic the action of acoustic strings and use this VST for a wide variety of timbres in your music.