radian

VST by xoxos

Introduction

Circular membranes have been reluctant to join the assortment of acoustic forms easily translated to procedural synthesis. We have asked nicely.

I have reexamined the issue many times. Recently I improved the computational efficiency of a mass-spring modeling algorithm and realised that, by dropping a multiply, it was now reasonably efficient enough to use as a bank of sine oscillators. While the rendering of spectra by partials is technically additive synthesis, the reactive mass-spring algorithm (also known as the harmonic oscillator) has further advantages in modeling.

Radian VST avails a combination of precedent synthesis and dsp methods to present an improved solution for emulative percussion synthesis. It is certainly an intermediary stage between the practical considerations of contemporary synthesis environments and the idealised computational solutions one expects to predominate in the future.

There are some things that are good about this model:

- Flexible rendering of up to 256 partials at frequencies pertinent to the ideal 2D circular membrane
- Modulation entirely driven by performance of velocity and striking position, unlike samples
- Membrane coupled with rim and air (Helmholtz resonator)

There are also some areas that are short of the ideal:

- No multidimensionality in modal synthesis (eg. rim and air couple membrane at same juncture)
- No interaction between membrane and striker
- Simplified translation of striking position to amplitudes of partials
- Rim and other components too simple for effectively modeling many instruments

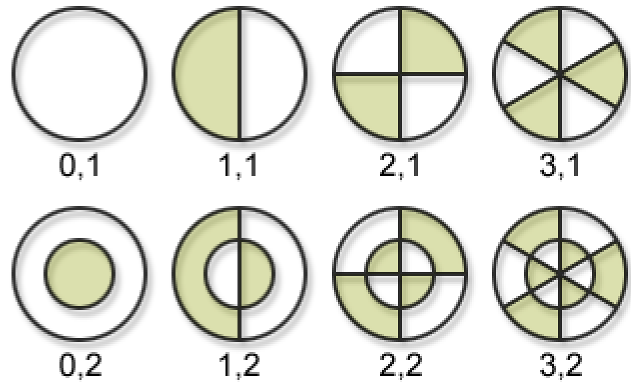
The model is an interactive structure comprised of the membrane, rim, and airspace common to many types of drums. It is advised that processing eg. equalisation be used to augment the perceptual setting of Radian in use.

Multiple Instances

If your host or system crashes during use or render when using more than one instance, copy the .dll file several times and rename the files radian1.dll, radian2.dll and so on.

The Ideal 2-D Circular Membrane

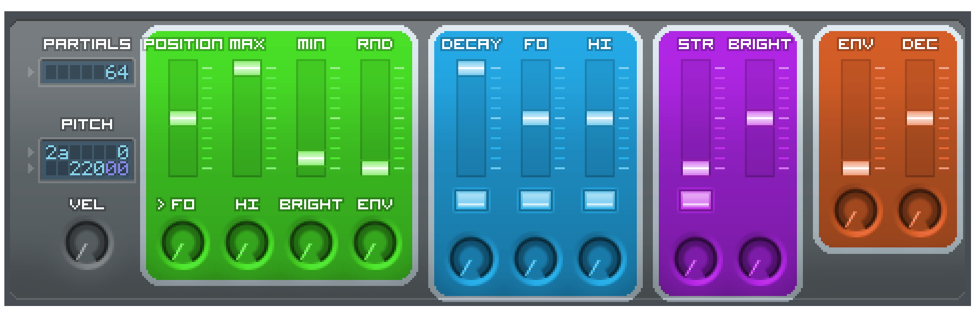
The vibrational modes of a circular membrane are discerned by diametric and radial divisions. In the 0,1 mode the entire membrane oscillates up and down. In each subsequent mode of vibration, the shaded areas oscillate against the unshaded areas. The solid lines dividing the membrane are nodes which remain static. Typically, many modes of vibration are supported simultaneously.



The location of excitation applied to the membrane indicates which modes are present in the timbre, for instance, striking the membrane precisely in the center would excite all of the 0,n or radial modes. Any mode with a node passing through the center would not be excited.

An extensive amount of online material illustrates vibrational modes in membranes and other objects, eg. high speed camera videos on youtube, simulations (such as http://www.falstad.com/circosc), and videos and images of Chladni plate experiments, so the topic is only briefly mentioned here. The more regions the membrane is divided into by a given vibrational mode, the higher the frequency in relation to the fundamental, or the 0,1 mode.

Most real drums differ to some degree from the ideal, notably the tabla, which is weighted in the center of the head to modify the harmonic ratio of the partials.



Membrane Model

Radian uses a bank of 4 to 256 sine oscillators to render the partials of the membrane. When the note is triggered, the modes with the highest volume are selected. A large amount of calculations are performed when Radian is triggered in a new location or different pitch, which will probably create a discernible increase in the cpu load if notes are triggered very rapidly (eg. at 128ths).

The translation of striking position to partials uses a Fourier process which is not exact but is feasible and efficient.

The oscillators employ a mass-spring algorithm which, similarly to a resonant filter, produces a sinusoid with an exponential amplitude decay - perfect for modeling partials in percussion. In addition to computational efficiency, this algorithm allows for interactivity with other elements, which can cause the oscillation to change in pitch and duration. Limiting performance for all cases would strongly increase the computational load, so combinations of very extreme settings may crash in some environments (this is due to out of range pow calculations).

The number of partials selected affects the cpu load of the patch. The lowest frequency partials are given priority, so that high partial count also correlates with brighter, more realistic patches. If a patch is used in a mix, it may only need a small number of partials.

The pitch setting is applied to the frequency of the fundamental, or 0,1 mode of the membrane. The fundamental is

Membrane Model (continued)

the lowest frequency associated with the membrane, however the air tone, produced by the resonant cavity, generally produces the lowest frequency. Like the partials parameter, pitch is adjusted by dragging the LCD graphic up or down. Perhaps less obvious is that this graphic is divided into two adjustment regions: the top row adjusts the semitone and the lower row adjusts cents, though the top row graphic contains both semitone and cents readouts and the lower graphic displays freqency in hertz.

The **position** slider indicates the striking position from the edge to the center of the membrane. Pitch bend is routed to this parameter, though you may wish to assign another MIDI controller using your host. This slider is accoutred with maximum and minimum settings to cap the range of the parameter in performance. The maximum cap prevents the membrane from being struck exactly in the center, which would produce an unnatural, synthetic tone with no diametric modes.

Lower position settings will also trigger the rim as well as the membrane. The lower cap can be used to select a preferred tonality as successively higher, thinner diametric modes are excited near the rim. Note that the lowest setting, indicating the theoretical edge of the membrane, produces no sound if the rim is not used.

All performance features of Radian are recallable. It will produce the same signal if given the same performance data, with two exceptions: a randomising feature can be applied to striking position so that mechanically generated sequences sound more vital, and an internal voice pickup feature, which prevents notes that interrupt previous notes from producing a sharp DC offset, so that the attack of a note may differ very slightly based on the timbre it is interrupting.

Striking position is also used to drive modulation to four other parameters. Modulation to all four parameters increases towards the edge. Overall decay is increased internally as part of the model. These four parameters: decrease the decay of the fundamental towards the edge, increase the decay of higher partials towards the edge, increase the brightness (or amplitude) of higher partials towards the edge, and reduce the height of the pitch envelope towards the edge.

The next group of sliders detail the amplitude **decay** of the membrane. The first slider is overall, or global decay rate. A toggle button underneath the slider options for a longer range (0-10s or 0-50s). The decay rate will change based upon coupling settings.

The second slider **F0** affects the decay rate of the fundamental, which varies based on the design of the drum. This mode usually transduces energy into sound very efficiently, producing a loud, rapidly decaying tone. The button options the slider to increase the decay, though this option is less pertinent to emulation of acoustic drums.

The third slider **HI** controls the decay of higher partials as a function of their ratio to the fundamental: the higher the pitch, the faster the decay. Higher settings are appropriate for heavier skins, like congas. The button does not change the orientation of the slider but adds a negative constant to the slider value.

The knobs under each slider here and afterwards on the gui trim **velocity** to each parameter. Velocity is applied as best suits the parameter, eg. either expanding the modulation around the parameter setting as for global decay, or, more frequently, using the parameter as a floor or ceiling setting. Hopefully these relations will seem straightforward and appropriate in use.

The **str** or **stretch** slider increases (or decreases, when the toggle button is selected) the ratio between partial frequencies. I can not offer empiric information about what factors in form may contribute to the spectral distribution of frequencies. I associate stretched partials with more rigid, dispersive material. In use, the reduction of ratios has sounded more natural to me in most cases, especially as this produces a denser timbre.

The **bright** parameter increases or decreases the amplitude of ascending partials. In the central position, each partial's gain is the inverse of its ratio, similar to the harmonic series constituting a sawtooth wave. If a partial has a 10 to 1 ratio to the fundamental, it's amplitude would be 1/10th of the fundamentals.

Larger drums especially exhibit a drop in pitch which most sources attribute to imperfect fastening of the membrane. An exponential **pitch envelope** is used to simulate this. While in kick drums and toms this pitch drop can be over several semitones, the slider is linearly calibrated to a maximum of 1 octave to the fundamental. Velocity can be used to increase the height of the pitch envelope beyond this. This pitch contour has an increasingly greater effect on the lower partials.

Amp Envelope

The amp envelope has a slightly different functionality from a conventional amplifier section: the attack stage applies only to the membrane and is used to soften the attack of the membrane so that the striker timbre can be discerned. When patching the striker, it is useful to set this at the highest setting. Alternatively, the attack of the membrane alone may prove percussive enough for the patch as it is initialised with a dc offset.

The model has an intrinsic exponential amplitude decay produced by the oscillator algorithm. Unless the release stage is used to damp notes rapidly at key release, it is suggested to set a longer than normal release time so that this stage of the amplitude envelope doesn't interfere with the natural decay. The primary function of the release stage is then to stop the voice for conserving cpu. The release contour 'bows up' (an inverse exponential curve) so that it has minimal reduction of amplification in the early stages.

The amp slider includes a velocity trimmer to add responsivity, though the algorithm and its various parameters of course are already velocity sensitive.

Striker

The striker uses a simple algorithm to augment the timbre of the attack with a varying 'pop' sound. It consists of two frequency components, **F1** and **F2**. The F2 contour is driven by the F1 contour, and the striker's **bright** parameter acts like a second decay function which sets how responsive the F2 oscillator is. This is vaguely similar in concept to syncing a higher frequency oscillator, with brightness determining its amp and decay during each wavecycle of the F1 oscillator.

It is intended that F2 have a higher setting than F1, but useful timbres can result from this algorithm otherwise (the sliders have the same scale and range). Roughly, F1 can be thought of as the vibrational frequency of the length of the stick, and F2 as the frequency of the material, harder strikers having higher frequencies.

To patch the striker, it is recommended that the membrane amp attack be raised to the highest setting, and the membrane decay to be set at the shortest setting. Afterwards, lower the attack rate until the timbres seem most cohesive.

Air

The resonant air cavity is modeled effectively by a single mass-spring algorithm, commonly referenced as a Helmholtz resonator in this application. In acoustic drums, the resonator is of course usually intended to increase the volume of the drum and produce a low frequency which carries well. The air amp slider is scaled so that it can be quite loud.

The frequency of the air resonance is indicated in hertz. In many forms of drum, this is intended to reinforce the fundamental frequency of the membrane, or can perhaps be pitched an octave lower.

The membrane drives the air resonance, so that if coupling is set to zero, there is no effect. Note that both decay and coupling have ranges exceeding emulative use. Decay can usually be set quite low to produce a tone. Increasing coupling will usually shorten the decay of the membrane as the reflection damps the oscillations of the membrane. The

Air (continued)

timbre will increasingly resemble an airtight container.

Coupled oscillators displace the natural frequency of oscillation. When the frequency of the air cavity is higher than the fundamental, it will generally raise the frequency of partials above it, and lower the frequency of those below it. It is recommended to use the lowest coupling setting that produces a satisfactorily emulative timbre. With higher settings, the highest oscillator in the membrane will have an unnaturally lengthened decay in response.

Rim

Radian's rim is modeled with a bank of eight mass-springs, six of which pertain to the circumference, and two of which pertain to the depth. Like the air resonance, the rim is coupled to the membrane, though to a much lesser degree. The rim is always triggered and is loudly triggered at position settings lower than 5%. The rim will always be heard to some extent unless its decay is set at zero.

Harmonics of the radial and depth frequencies are at integer multiples (x2, x3 et c.) and the base frequency may be displayed in hertz. As a very rough guide for patching, the relation between the frequency and speed of sound in several materials may be displayed. Dimensions are given in inches and are not intended to be authoritative.

The function of the sliders does not change in response to the displayed material - lower frequencies correspond to longer dimensions and are situated at the bottom of the slider range. If you want to use this function as a rough guide to emulation, the **display** button will page through the hertz and material selections, the **R/D** button toggles whether the radius or depth figure is shown.

The rim **stretch** slider actually compresses the ratio of the partials, integer spacing is located at the top of the slider range.

The overall design of the rim model is to add a short series of harmonics that improve the model's emulative properties as a membrane. It is not complex or intensive and while a strike on the edge can produce a satisfying percussive timbre, it doesn't contain enough partials for the high frequencies usually associated with a rimshot, especially those of metal shelled drums. It may be worth layering rimshots with white noise from another synth for this application.

I have been anticipating a physically modeled drum synthesizer for a decade or so, hoping for some procedural solution that would circumvent bessel functions in some manner. Chucking a bank of oscillators at it seems inelegant. Stefan D. Bilbao has recently published a book with some very encouraging audio examples of snare drums, so I'm pleased to offer what I can for the time being.

addendum:

Radiant, a tuned version of Radian has been added by request. Radian-(Tuned) was published as a separate VST due to the necessity of a third party resource in order to process MIDI events (thank you to Peter Schoffhauzer).

Radiant removes the velocity > pitch control and replaces it with the option to send pitch tracking to the air resonance frequency and rim frequencies. Pitch tracking is centered on A2, and the membrane will be tuned on that note to whatever its original setting is. The presets for Radiant have not been adjusted from Radian. It is suggested not to play very high MIDI notes. You will also notice the previously mentioned reinforcement of the highest partial in the membrane with patches using coupling at lower notes on the keyboard.

In addition, presets have been added by Eric Morabito (TTK) and Raphael S. aka Himalaya (H). Thank you to both of these talented sound designers for lending their affinity for physical modeling synthesis to the instrument.

http://taotekid.bandcamp.com
http://www.electric-himalaya.com