Virtual Mallet instruments

The traditional sound synthesis models aim to dynamically and independently control the essential sound qualities such as pitch, timbre and loudness. The beauty of these traditional synthesis models on the one hand, the independence of pitch, timbre and loudness, on the other hand, is also a great handicap. Especially if you aim to build virtual variants of copies from real world musical instruments.

Acoustical instruments
In the case of the real mechanical-acoustical instruments, the sound qualities mentioned are always linked to each other. The real-time controlling in playing - harder to hit/blow, slower or faster bowing - therefore always influences multiple characteristics of the resulting sound output. For example, harder hitting a piano string results in a more complex vibration mode of the string. The timbre changes accordingly, the loudness also increases because the deflection of the vibration increases the amplitude. Harder blowing on a flute results in the same characteristics with a more or less slight pitch modulation because the periodicity of the vibrating air column rises.

These dynamic relationships are usually very subtle and form an essential characteristic for the sounding identity of the instrument. This coupled dynamics is particularly difficult to realize with the traditional (parametric) sound synthesis models. You have to know in advance what links that are and how they are related to each other

Physical Modeling
Why an instrument sounds as it sounds? This results from the physical system of the musical instrument and the way of playing it. The coupling between the driving force, the excitation, on the one hand and, on the other hand signal characteristics such as vibration shape, vibration excursion and periodicity, will then also be more or less present in the resulting sound of the virtual variant.

The modal model
In the modal sound model we consider a musical instrument globally, divided into two basic elements: excitator(s) and resonator(s). For example, a marimba: excitators are the mallets, the bars themselves are the resonators. Upon further consideration, these bars are then coupled to a tube resonator, which is tuned to the lowest resonant frequency of the bar resonator. Complex resonators can resonate on more than one frequency.

Harmonic and inharmonic resonators
Roughly spoken resonators can be divided in two different groups: harmonic and non-harmonic resonators. In essence, we can interpret vibrating objects such as, strings and air columns as a number of coupled mass spring systems with harmonic resonance frequencies that relate as: 1, 2, 3 .... For example, two- and three-dimensional objects such as membranes, bars and

bells produce sounds consisting of sub-frequencies in a non-harmonic relationship.

Damping

Resonators can have both large and little damping. In those with little damping, resonance frequencies with long decay times occur. The group with a high damping factor exhibits much broader resonance areas, many closely spaced frequencies, with the characteristic being short deacy times.

`MicroModal.pch2`

These synthesizer patches are based on a simplified form of modal synthesis. The simplification: an addition of resonators, combined in an additive manner, which together represent the complex resonator. The basic object, the resonator, is formed by a band pass filter with resonance. This band pass filter is actually a virtual variant of a mass spring system, of which the resonance range, the degree of damping is adjustable. Instead of attenuation, however, the parameter 'Resonance' is used here. Maximum resonance, 1, is equal to damping 0.

The excitator is formed by a noise generator object and envelope generator followed by a filter consisting of a high and low pass in series. Anyone with experience with additive synthesis will undoubtedly see similarities. In the MicroModal synth, the sine wave oscillators with accompanying envelope generators have indeed been replaced by resonators. This `MicroModal.pch2` synthesizer consists of one exciter followed by six additive resonators. Open the patches and the textpad under the Patch menu and read the clarifications on the patches.

Characteristics of idiophones

The download patches concern simple virtual variants (tube resonators have been omitted) of the following real instruments: xylophone, marimba, vibraphone and carillon bell. Four examples from the group of so-called idiophones. These are three-dimensional objects, which do not have to be put on pre-tension, and which, when excited go spontaneously into a (damped) vibration. As stated earlier, such three-dimensional objects produce multiple resonance frequencies or eigenfrequencies which are in principle non-harmonically related to each other.

Eigenfrequencies and form

The frequency ratios of these resonances (which overtones) are only determined by the shape of the object, assuming that the object has a homogeneous material structure. By means of undercutting, for example at the bottom of the bars, the shape can be changed and thus the mutual frequency ratios of the resonances can be influenced (to a certain extent). For example, in the Western mallet instruments, the three lowest resonances are harmonically tuned to each other in the following frequency ratios.

Xylophone historical: 1, 3, 6.
Marimba, Vibraphone, Xylophone modern: 1, 4, 10.

For a carillon bell, more resonances apply, the most important ones are as follows: 1, 2, 2.38, 4, 6, 8.

Material and perception

The height of the sound produced as well as the decaying time is only determined by the dimensions, the density (specific gravity) and the elasticity of the material. For example, three bars of equal dimensions, but of different material such as wood, glass and aluminum show exactly equal frequency ratios of the various eigenfrequencies.

However, the pitch they produce is different because of the differences in density. The decay times differ by the different values of the elasticity. Wood will therefore sound short, 'dry', glass will decay longer, and aluminum will have a significantly longer decay time.

The strength of the various resonance frequencies depends mainly on the size and hardness of the mallet, as well as on the hitting point on the bar. As a rule of thumb, the higher resonances are weaker than the lower one.

Rectangular bars without undercut like (ethnic) metallophones, marimba's and xylophones:

1	2.76	5.40	8.93	13.34	18.64

Depending on distinct undercut curves there are various overtone tuning possibilities (according to Ingolf Bork).

1	4	10	(standard vibraphone, marimba & xylophone)
1	3	6	(historical models of xylophones)
1	4	8	
1	4	9	
1	4	11	
1	5	10	
1	5	11	
1	5	12	
1	5	13	

eigenfrequncies proportions of a wine glass (according to Rossing):

1	1.89	3.2	4.88	6.96	9.23

Experiment with the frequency ratios (the shape of the object) and the resonance values (density and elasticity). You will notice that whatever you do it produces almost all (fantasy) sounds that nevertheless have a high acoustic quality.

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internet
About the tuning of mallet instruments:
www.lafabre.us/tuning-marimba.htm