Modal Synthesis

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(also Music)

Views of Sound: Time Domain

Sound is produced/modeled by physics, described by quantities of

- Force — force = mass * acceleration
- Position — x(t) — actually < x(t), y(t), z(t) >
- Velocity — Rate of change of position — dx/dt
- Acceleration — Rate of change of velocity — dv/dt

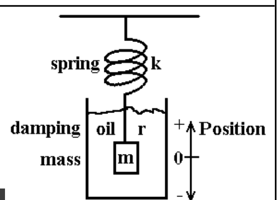
Examples: ***Mass+Spring+Damper***
Wave Equation

Mass/Spring/Damper

F = ma = - ky - rv - mg

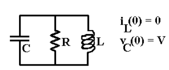
F = ma = - ky - rv

(if gravity negligible)



$$\frac{d^2y}{dt^2}+\frac{r}{m}\frac{dy}{dt}+\frac{k}{m}y=0$$

$$D^2+Dr/m+k/m=0$$

()

2nd Order Linear Diff Eq. Solution

1) Underdamped:

$y(t) = Y_0\, e^{-t/\tau} \cos(\omega t)$

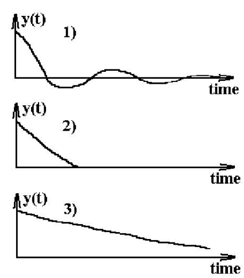
*exp. * oscillation*

2) Critically damped:

fast exponential decay

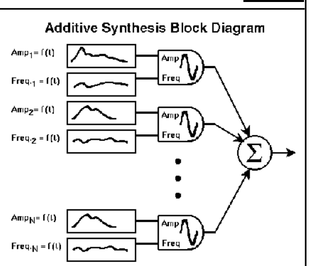
3) Overdamped:

slow exponential decay



Additive Synthesis

Control the amplitude and frequency of a set of oscillators



The sinusoidal model:

$$s(t)=\sum_{r=1}^{R}A_r(t)\cos[\theta_r(t)]$$

R : number of sinewave components,
$A_r(t)$: instantaneous amplitude,
$\theta_r(t)$: instantaneous phase

Modal Synthesis

Systems with resonances
(eigenmodes of vibration)

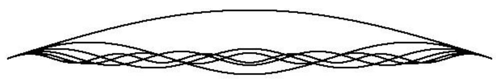
Bars, plates, tubes, rooms, etc.

Practical and efficient, if few modes

Essentially a subtractive model in that there is some excitation and some filters to shape it.

Modal Synthesis: Strings

Strings are pinned at both ends

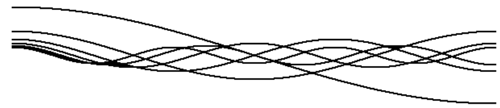


Generally harmonic relationship

Stiffness can cause minor stretching of harmonic frequencies

Modal Synthesis: Bars

Modes of Bars: Free at each end

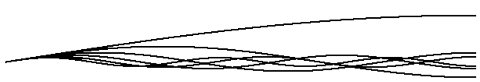


These would be harmonic, but stiffness of rigid bars stretches frequencies.

Modes: 1.0, 2.765, 5.404, 8.933

Modal Synthesis: Tubes

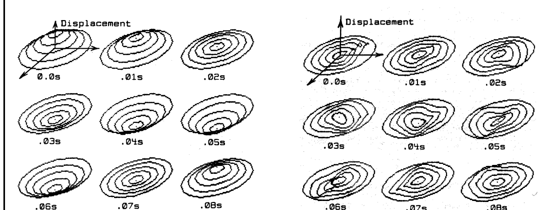
Open or closed at each end, same as strings and bars, but harmonic because speed of sound is constant with frequency



Open + Closed:odd multiples of fundamental (quarter wavelength)

Modal Synthesis: Plates, Drums

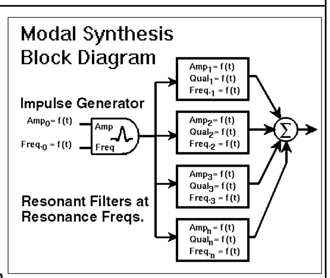
Modes of Plates: inharmonic (round = Bessel)



Center strike **Edge strike**

Modal Synthesis: Block Diagram

- Impulse generator excites filters
- Residue can be used for excitation
- Filters shape spectrum, model eigenmodes
- Filter parameters can be time-varying



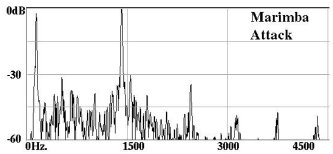
Modal: Residual Excitation

Linear source/filter decomposition

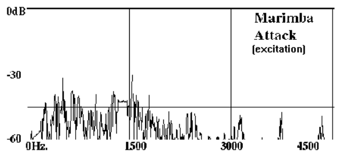
- "Parametric sampling"
  - *–Drive filter with source and get back identity*
  - *–Can modify the parameters in interesting ways*

Residual Extraction, Example

Original struck bar



After modal subtraction



Modal Synthesis

Strengths:

- Generic, flexible, cheap if only a few modes
- Great for modeling struck objects of metal, glass, wood

Weaknesses:

- No spatial sampling
- No (meaningful) phase delay
- Hard to interact directly and continuously (rubbing, damping, etc).

References: Sinusoidal Models

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