Music Synthesizer

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1 The Philosophy

Music synthesis and composition has definitions which vary over the musical fraternity throughout the world. The ambiguity of the definition is what drives the generation of new music through the ancients to the modern era. Composition refers to the manipulation of tone, note , pitch and timbre. In the most common definition it consists of two things:
1) ordering and disposing of two sounds such that their playing in succession is pleasant(Melody.
2) Rendering the disposition of two sounds played together pleasant (Harmony).

Note: Sounds refer to notes of fixed frequency in the above context. The above synopsis describes the philosophy behind the synthesis of music from tones and notes.

2 Music Instruments

The way music instruments work is manipulating the notes to be played as their variation in the frequency and the time domain : the spectral and the temporal envelopes respectively. These define the timbre of the notes and hence the music being played on the instrument. The temporal envelope of each instrument being different is what renders the instrument unique : the ADSR. The timbre also depends on the environmental factors i.e the convolution reverberation.

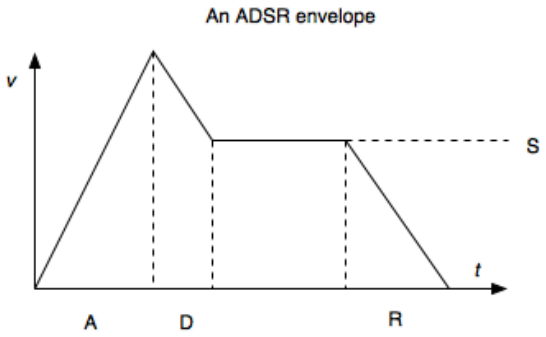
Theme for the generation of music used by us:

1. Define the notes of fixed frequency
2. Appropriate ADSR is chosen.
3. Method of chord progression has been used to combine the notes of fixed frequency with the same weights which might not be true in general.
4. Using the ADSR and chord progression the chosen song is played.
5. Convolution reverberation is applied to show the effect of environment on the timbre and sound quality.

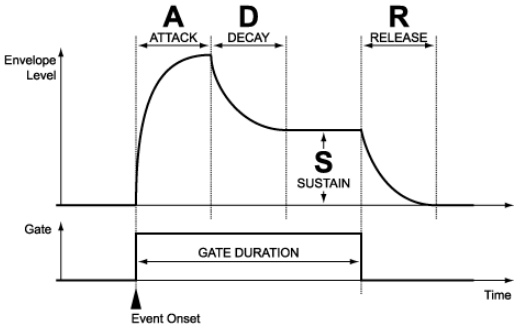
3 ADSR envelope

3.1 What is ADSR?

1. ADSR stands for Attack Decay Sustain Release. These are the parameters that govern the time domain envelope of a note played by an instrument.
2. Attack, Decay and Release are specified as temporal parameters while Sustain is a level parameter.



(a) ADSR Linear



(b) ADSR exponential

3. Attack is the duration in which the note intensity goes from zero to it's maximum.
4. During decay, the intensity falls from the maximum level to the sustain level.
5. Intensity is maintained at the sustain level. The duration of sustain is not fixed and depends on how long the note is played by the player of the instrument.
6. After this, the intensity falls from Sustain level to zero during the Release phase. Various instruments have different temporal envelopes which can be described in terms of ADSR parameters.

3.2 Various interpolations used for ADSR envelop

Following functional forms were used for attack, delay and release periods (M is the maximum level and T is the note duration)

- Attack

$$linear \quad y(t) = M\frac{t}{A}$$

$$Exponential \quad y(t) = M(1 - e^{\frac{-t}{\tau}}) \quad \tau = \frac{A}{5}$$

- Decay

$$linear \quad y(t) = M - \frac{M - S}{D}(t - A)$$

$$Exponential \quad C_1 + C_2 e^{\frac{-t}{\tau}} \quad \tau = \frac{D}{5}$$

- Release : From sustain level to zero

$$linear \quad y(t) = S - \frac{S}{R}(t - (T - R))$$

$$Exponential \quad C_1 + C_2 e^{\frac{-t}{\tau}} \quad \tau = \frac{R}{5}$$

4 ADSR of Instruments

4.1 ADSR of Piano

1. Attack used is linear and with a large slope. This is due to the fact that when a key is pressed the max level is reached quickly
2. If key is pressed for a long duration the piano has some sustain after which there is exponential decay (Release).[3]

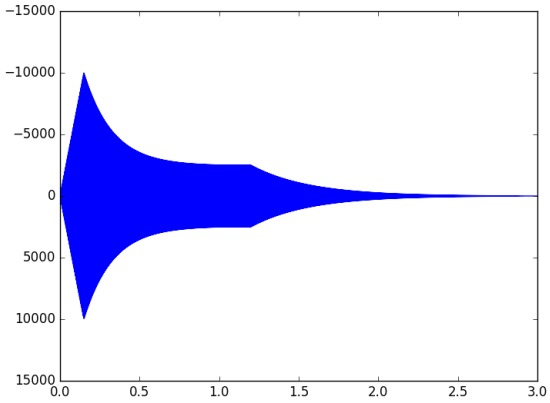


Figure 2: ADSR for C (523.25Hz) played on Piano

4.2 ADSR of Violin

1. Till the player keeps stroking the violin with the bow the amplitude is sustained. So there is a long sustain.
2. When the player stops the release is instantaneous as the string is damped due to the hair of the bow.

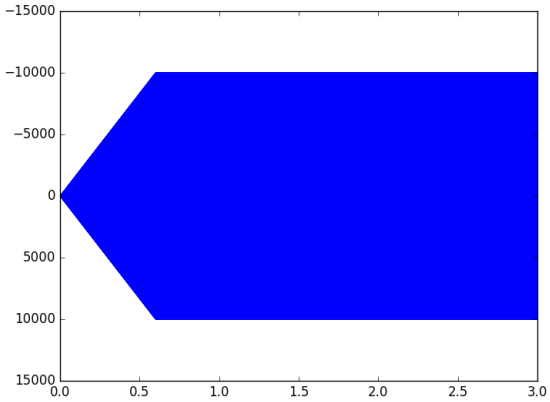


Figure 3: ADSR for C (523.25Hz) on Violin

4.3 ADSR of Guitar

1. Attack is almost instantaneous.
2. There can be no sustain for guitar because the player can't hold a note.
3. For guitar a superposition of harmonics up to 4th harmonic is taken with decreasing amplitudes.

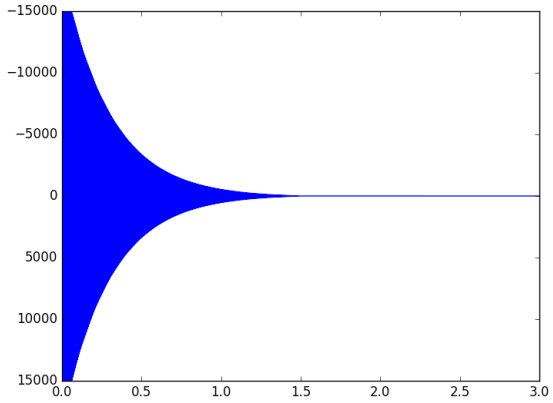


Figure 4: ADSR for Harmonics of G played on Guitar

4.4 ADSR of Flute

1. The attack and release is smooth with respect to the other instruments.
2. The sustain is long as it and in general it depends on the player how much he want to extend the note.

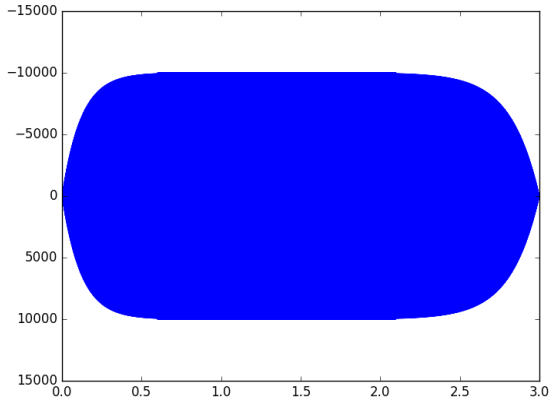
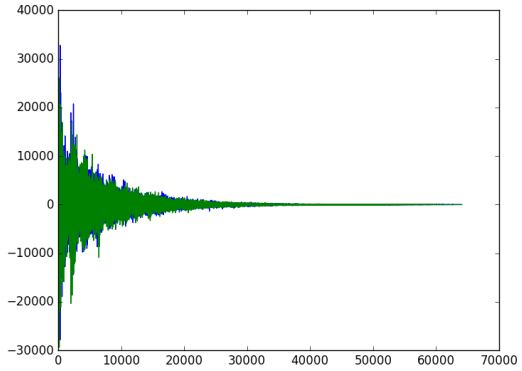


Figure 5: ADSR for A (440 Hz) played on Flute

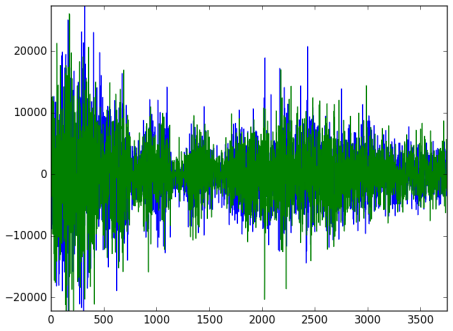
5 Convolution Reverberation

5.1 Acoustic Reverberation as a Linear Time Invariant System

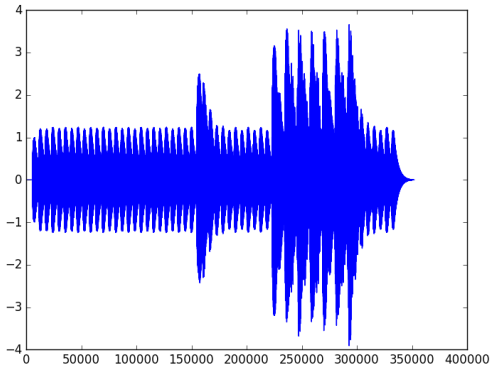
- *Linear* because the output is a linear function of the inputs applied.[5]



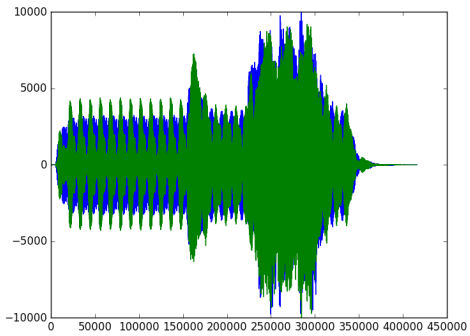
(a) Impulse Response



(b) Impulse Response (Zoomed)



(a) Temporal Output



(b) Temporal output with convolution

- *Time Invariant* because the output will be same except for the time delay if the input is applied at some later time.
- Acoustic Reverberation can be considered as a linear time invariant system as the input signal (i.e. sound) can be considered as discrete impulses moving independently, hence linear and if given that the surrounding is not changing much it can be considered as time invariant.
- *Impulse Response* is the response (or the output) of the system for a delta function input. The impulse response is recorded by placing 2 receivers at the separation of about our ears and recording the signal of a sharp input (like clap or drum).
- The output of a Linear Time Invariant System can be completely predicted by impulse response by convolving the input with the impulse response.
- Discrete Convolution of 2 function f, g defined on integers is

$$(f * g)[n] = \sum_{m=-\infty}^{\infty} f[m]g[n-m] \tag{1}$$

- Convolution adds previous input signal (i.e. sound) to the current signal with reduced amplitude (according to the impulse response) accounting for the reflection of sound from different surfaces giving the output an echo effect similar to the one in big halls.

References

[1] AudioMulch. *ADSR Timing Diagram — AudioMulch*. [Online; accessed 7-April-2017]. URL: %5Curl%7Bhttp://www.audiomulch.com/blog%7D.

[2] hackmeopen.com. *An ADSR envelope — hackmeopen*. [Online; accessed 7-April-2017]. URL: %5Curl%7Bhttp://hackmeopen.com/2011/12/synth-diy-software-for-generating-adsr-envelopes/%7D.

[3] Chris Valerie Susan. *Multi-timbral Sound Module*. 2004. URL: %5Curl%7Bhttp://web.mit.edu/6.111/www/f2004/projects/ghs_report.pdf%7D.

[4] Wikipedia. *ADSR Envelope — wikiaudio*. [Online; accessed 6-April-2017]. 2012. URL: %5Curl%7Bhttp://en.wikiaudio.org/index.php?title=ADSR_envelope&oldid=37254%7D.

[5] Wikipedia. *Convolution reverb — Wikipedia, The Free Encyclopedia*. [Online; accessed 13-April-2017]. 2016. URL: %5Curl%7Bhttps://en.wikipedia.org/w/index.php?title=Convolution_reverb&oldid=752655844%7D.