Synth Challenge 2019 – Report

1. Compulsory composition

For this category I have chosen to synthesize Waterloo by Benny Andersson & Björn Ulvaeus.

1.1. Piano

To create piano sound I used an additive synthesis approach. I chose the amplitudes based on analyzing piano sounds from [1]. The signal is filtered through a series of lowpass filters to better imitate fading of amplitudes of higher order harmonics for higher fundamental frequencies as well as the attenuation caused by the wooden body. Envelope is a decaying exponential with a short linear attack and release to suppress clicks in sound.

1.2. Bass guitar

My reference for the bass guitar was [2]. I used additive synthesis with frequency and amplitude modulation. I made different harmonics to decay with a different time constant. Both the modulation index and amplitude modulation index also decay in time to distinguish between the attack and sustain phases. Envelope is a decaying exponential function with short linear attack and release to suppress clicks in sound.

1.3. Guitar

For the guitar sound I decided to go with “palm muted” guitar from [3]. I used additive synthesis with frequency modulation and exponential decay envelope with short linear attack and release to suppress major clicks. I added a tiny bit of extra band-pass filtered noise to make it rawer.

1.4. Alto saxophone

First I analyzed [4] and then tried to reconstruct it with additive synthesis. Each harmonic is frequency modulated with a modulation ratio of 1/6. The final sound has an ADSR envelope with exponential release phase overlapping defined duration to make for a better reverberation effect.

1.5. Trumpet

To make a trumpet sound I used frequency modulation with modulation index equal to 5 and modulation ratio (fundamental to modulating frequency ratio) equal to 1. Amplitude envelope is a standard ADSR model and is also used to shape the modulation index.

1.6. Vocals

This sound was the most difficult one and is probably the worst performing among the sounds I created. I used additive synthesis, i.e. 20 harmonics with the same amplitude and filtered them through a custom made filter imitating three formants of the vowel “a” as in “hot”, i.e. F1=830 Hz, F2=1170 Hz, F3=2400 Hz.

2. Compulsory scale

For this task I used a D-dur scale starting at D2 (73.416 Hz) and going up to D5 (587.328 Hz). The instruments take turns in the following order:

1. Bass guitar
2. Guitar
3. Piano
4. Trumpet (takes turns with saxophone)
5. Alto saxophone (takes turns with trumpet)
6. Piano
7. Vocal
8. Piano

3. Custom composition – Bear thriller (stereo headphones)

My custom composition is a story of a man (hunter) walking through a forest in autumn, while suddenly he meets an angry bear. Being scarred, the man fires two shots from his shotgun at the bear resulting only in irritating the bear more. He then starts running away from the bear, exiting the leafy area and continuing running on a dirt road.

I've tried to analyze real sounds by viewing the waveform spectrometer and power spectral density (PSD) of each sound. To synthesize similar sounds I've tried to achieve high similarity in PSDs and spectrometers of both real and synthesized sounds.

As a final step I tried to make this story more believable by making the sounds stereo, putting them in space by HRTF (head-related transfer function) filtering [10], [11]. In fact, this was done by filtering the signal in time using a HRIR (head-related impulse response).

Therefore, it is highly recommended if not necessary to use stereo headphones when listening to this composition.

3.1. Bear

To create bear sounds I used mainly filtering synthesis with time-variant filters, for which is used formula from [5] as a framework that I improved. Excitation signal is composed of frequency and amplitude modulated square waves with additional white noise. Pitch, envelope, filter frequencies and filter widths change in time with a custom made function. To make the sound more trembling and mighty, the resulting sound is a weighted sum of HRTF-filtered (0.9) and unfiltered sound (0.1).

Reference/inspiration signal – [6]

3.2. Footsteps on leaves

This sound is a combination of filtered white noise, representing rustling, and granular synthesis, representing cracking sound of leaves. Grains contain pulses of random amplitude. The final sound is a weighted sum of these two with a Chebyshev window envelope. Footsteps are spatialized at -30 degrees of elevation.

Reference/inspiration signal – [7]

3.3. Footsteps on dirt

These footsteps were created by filtering white noise through a custom made filter and applying an exponential envelope. The final sound is a weighted sum of spatialized and unspatialized sounds.

Reference/inspiration signal – [8]

3.4. Bear footsteps

Similar to footsteps on dirt, these are created by filtering white noise through a custom made filter and then through a lowpass butterworth filter with an exponential envelope. The footsteps are grouped into quartets to imitate the bear's movement.

3.5. Shotgun

Shotgun sound was created using two sets of filters. First, white noise is filtered through a second order butterworth lowpass filter, which changes its cut-off frequency in time, making high frequencies decay much faster than the low ones. Afterwards, the signal is filtered through a custom made filter and multiplied by an amplitude modulated (sine modulated) exponential function to imitate a better "boom echo" expression. To support this feeling, the resulting sound is a weighted sum of HRTF-filtered (0.2) and unfiltered sound (0.8).

Reference/inspiration signal – [9]

4. Reference

[1] http://sami.fel.cvut.cz/syn/

[2] https://freewavesamples.com/sample-type/bass/electric, "E-Mu Proteus FX Thunder C1"

[3] https://freewavesamples.com/sample-type/guitar/electric, "Korg M3R Rock Mutes C3"

[4] https://freewavesamples.com/instrument/alto-sax, "Kawai K5000W AltoSax C4"

[5] https://www.mathworks.com/matlabcentral/answers/9900-use-filter-constants-to-hard-code-filter, answer from Jan Simon, added 20th June 2011, edited 26th October 2014

[6] https://www.freesoundeffects.com/free-sounds/bears-10017/20/tot_sold/20/2/, "bear roar" sound sample

[7] https://audiojungle.net/search/footsteps%20in%20the%20forest, "Footsteps In The Forest" by applehillstudios in Human Sounds – preview

[8] https://www.premiumbeat.com/blog/40-free-footstep-foley-sound-effects/, 40+ footstep sound effects, "Dirt_Jogging" sound sample

[9] http://soundbible.com/1960-Shotgun-Old-School.html, "Shotgun Old School" sound sample

[10] SOFA API for Matlab and Octave by Acoustics Research Institute, Austrian Academy of Sciences, Vienna, Piotr Majdak, available at: https://sourceforge.net/projects/sofacoustics/, and at: https://github.com/sofacoustics/API_MO,

[11] https://www.sofaconventions.org/data/database/ari/, "hrtf b_nh165.sofa" – HRTF (HRIR) function