SYNTH CHALLENGE 2021

Synthesis report

Part no. 1: Synthesis of the Mission impossible theme

I have chosen the "MISSION.MID" file for this part of the challenge. This file consists of following instruments (13 melodic instruments and 25 percussions):

MIDI Channel	MIDI instrument ID	Instrument	Synthesis type
2	74	Flute	Additive + FM
3	39	Synth Bass 1	Additive
4	40	Synth Bass 2	Simple wavegen
5	56	Orchestral Hit	Pitch shifting
7	126	Helicopter	Additive + Subtractive
8	89	New Age Pad	Additive
9	49	String Ensemble 1	Formants + tremolo + chorus
10	17	Hammond Organ	Additive + FM
10	26	Acoustic steel guitar	Karplus-Strong algorithm
10	36	Bass Drum 1	Subtractive + Additive
	37	Side Stick	Subtractive
	38	Snare Drum 1	Subtractive + Additive
	39	Hand Clap	Subtractive + "chorus "
	41	Low Tom 2	FM + Additive
	42	Closed Hi-Hat	Subtractive
	43	Low Tom 1	FM + Additive
	44	Pedal Hi-Hat	Subtractive
	45	Mid Tom 2	FM + Additive
	46	Open Hi-Hat	Subtractive + Additive
	47	Mid Tom 1	FM + Additive
	48	High Tom 2	FM + Additive
	49	Crash Cymbal 1	Additive
	51	Ride Cymbal 1	Additive
	52	Chinese Cymbal	Additive + Subtractive
	54	Tambourine	Formants + Additive
	55	Splash Cymbal	Additive + Subtractive
	57	Crash Cymbal 2	Additive + Subtractive
	61	Low bongo	FM + Additive
	62	Mute High Conga	FM + Additive
	63	Open High Conga	FM + Additive
	69	Cabasa	Subtractive
	74	Long Guiro	Repeating LPC pattern
	75	Claves	Additive + Subtractive
	81	Open Triangle	Additive

11	33	Acoustic bass	Karplus-Strong algorithm
12	62	Brass section	Formants + tremolo + chorus
13	123	Seashore	Formant synthesis
14	96	Sweep pad	Additive + tremolo + FM

The **flute** was created by simple additive synthesis. The amplitudes for harmonic frequencies are defined in vector. For more realistic sound, the synthesis is enhanced with vibrato effect, which is created using FM modulation.

For both **Synth Bass** instruments it was necessary to mimic the typical "more-harmonics" effect on the beginnings of each note. For this reason, they are both created using sawtooth wave. For even stronger harmonics effect in **Synth Bass 1**, I've created some harmonic pulse, which is added on the beginning of each note.

Creating an **Orchestra Hit** with just plain synthesis would be extremely time-consuming. For this reason, I've chosen to use just simple pitch-shifting algorithm (phase vocoder with resample) to which a downloaded [1] audio is fed.

The **Helicopter** was created with more components to bring more realistic sound to the track. There is a noise-impulses component which mimics the "chop" sound of the rotor (subtractive synthesis). The engines burst is created with the same algorithm with just higher frequency. Rotor tone – the "whiz"– is created by FM-modulated sawtooth. In the end there are some formants to mimic the monotone sounds and noise to hide the imperfections of the synthesis :-). In the end, the helicopter was not synthesized as pitch-controlled instrument, because the effect was harsh to hear.

When I tried to listen to **New Age Pad** on a synthesizer I have realized there is a sort-of "ding" sound on the beginning of each tone. In my script this ding is created by simple additive synthesis. The rest of the tone is created by FM-modulated sawtooth wave. A reverb effect is added to bring more "padness ". The **Sweep pad** is synthesized very similar way.

String Ensemble 1 is created by my chorus() function. This function creates sound by filtrating a pulses or sawtooth wave (like in this case) by formant filters and then performing a tremolo effect. Moreover, this function creates multiple tones with slightly different frequencies and slightly different starting time coordinates which mimics real chorus. For more booming sound the chorus() function is called twice – with the *freq* frequency and with *freq/2* frequency (to add cello). These two tones are then added together. **Brass section** is created nearly the same way. Instead of sawtooth wave, the formants filters (with different parameters) are fed with pulses. The envelope has shorter rise and fall times.

After studying the **Hammond organ** functioning principle on the internet [2] I've created very simple additive-synthesis script which simulates the output of the instrument by given parameters. I've even added a *drawbars* vector which simulates the real drawbars on the **organ**.

Acoustic Steel Guitar is synthesized with simple Karplus-Strong algorithm. For consistency the initial state is defined by saved vector of numbers. To bring in the "steeliness" of real guitar – high inner sampling frequency is set. **Acoustic Bass** is created with Karplus-Strong algorithm as well. Only the parameters are slightly changed.

Seashore is synthesized by algorithm borrowed from [3]. It uses formant filters which are changing in time together with amplitude envelope. The result is than multiplied numerous times to fill in the requested duration. The inner coefficients are changed, so this is not a direct copy of [3] algorithm. Similarly to the helicopter sound, this sound is not pitch-controlled, so the same pitch is played always.

For **percussion instruments** I've created just few algorithms which are slightly changed for each type of percussion.

Side stick, **Closed Hi-Hat**, **Pedal Hi-Hat** and **Cabasa** are synthesized the simplest way – by filtrating noise and then weighting it by an envelope.

Bass drum, **Snare drum**, **Chinese Cymbal**, **Splash Cymbal** and **Claves** are synthesized by adding together multiple filtrated noises – each with different pitch and bandwidth. Some additional effects occur individually – such as various envelopes or wideband pulse added to the beginning of each note.

Open Hi-Hat, **Crash Cymbal 1**, **Ride Cymbal 1**, **Crash Cymbal 2** are synthesized similarly to the previous ones but with added harmonic component (sawtooth wave).

More complex sounds such as those produced by **Low Tom 2**, **Low Tom 1**, **Mid Tom 2**, **Mid Tom 1**, **High Tom 2**, **Low bongo**, **Mute High Conga**, **Open High Conga** are mimicked by FM synthesis. There are usually 3 generated waveforms. The first one modulates the second one and the result modulates the third one. This idea came from [4]. These waveforms are often sawtooth waves with different parameters or sine waves. Each one having an specific envelope and frequency. Wideband impulse is added to the beginning of each note as the waveforms themselves do not mimic this impulse well. Noise and frequency decay is added according to taste.

My solution of **Hand clap** synthesizing was inspired by this video [5]. The principle is simple. Numerous noises weighted by envelopes with different timing are added together and filtrated.

Tambourine like sound is produced by sum of 2 components which were analysed by hearing to records of real tambourines. The first component is obtained by filtrating white noise by formant filters. This component brings the harmonic pulse to the beginning of the tone. The second component is high pitched noise with slower decay.

Long guiro's 1 impulse sound was extracted from [6]. This impulse is then repeated by LPC numerous times. The period of repetition is partially random to restrict "buzz" sound.

Finally, the **Open triangle** sound is created simply by additive synthesis. The coefficients were obtained from numerous sources – experimentally.

Part no. 2: Synthesis of 3 octaves of major scale

Simple MIDI file was created which plays 3 octaves of C-major scale on every created instrument. Some octaves are played lower or higher – depending on the type of instrument.

The instruments play the scale in this order:

1. Flute
2. Synth Bass 1
3. Synth Bass 2
4. Orchestra Hit
5. New Age Pad
6. String Ensemble
7. Hammond Organ
8. Acoustic Steel Guitar
9. Acoustic Bass
10. Brass Section
11. Sweep Pad
12. All percussions
13. Helicopter
14. Sea shore

Part no. 3: Synthesis of crash on level crossing

As the year goes by we can see the enormous number of accidents that happens on the railroad level crossings, mainly because of the car driver's thoughtlessness. So I've tried to synthesize the sound of the crash. The sound of the crossing's signalling system is created by additive synthesis. The analyzed model was classic Czech AŽD97 system [7] installed on many Czech level crossings. The steam locomotive sound is created by modified **Helicopter** script. Today – of course – it would be more appropriate to synthesize electric or diesel locomotive, but that's my subjective choice. The sound of car is downloaded from here [8] and simply played. The crash sound is created by modified **Bass Drum** script. At the end of the synthesis, the typical Czech funeral music is played on the synthesized **Brass Section**.

Sources:

[1] https://freewavesamples.com/korg-n1r-stereo-hit

[2] https://www.soundonsound.com/techniques/synthesizing-tonewheel-organs-part-1

[3] SYN subject on FEL CTU in Prague

[4] https://www.youtube.com/watch?v=JQVLw7o0Qd0

[5] https://www.youtube.com/watch?v=lG1h28gv1HU

[6] https://freewavesamples.com/korg-n1r-long-guiro

[7] https://www.youtube.com/watch?v=BW8afStFjdU&t=8s

[8] https://freewavesamples.com/race-car