Audio Technology Purr data Synthesis Assignment

A description and analysis of two contrasting synthesisers, coded in Purr data (Pd), and their historical context.

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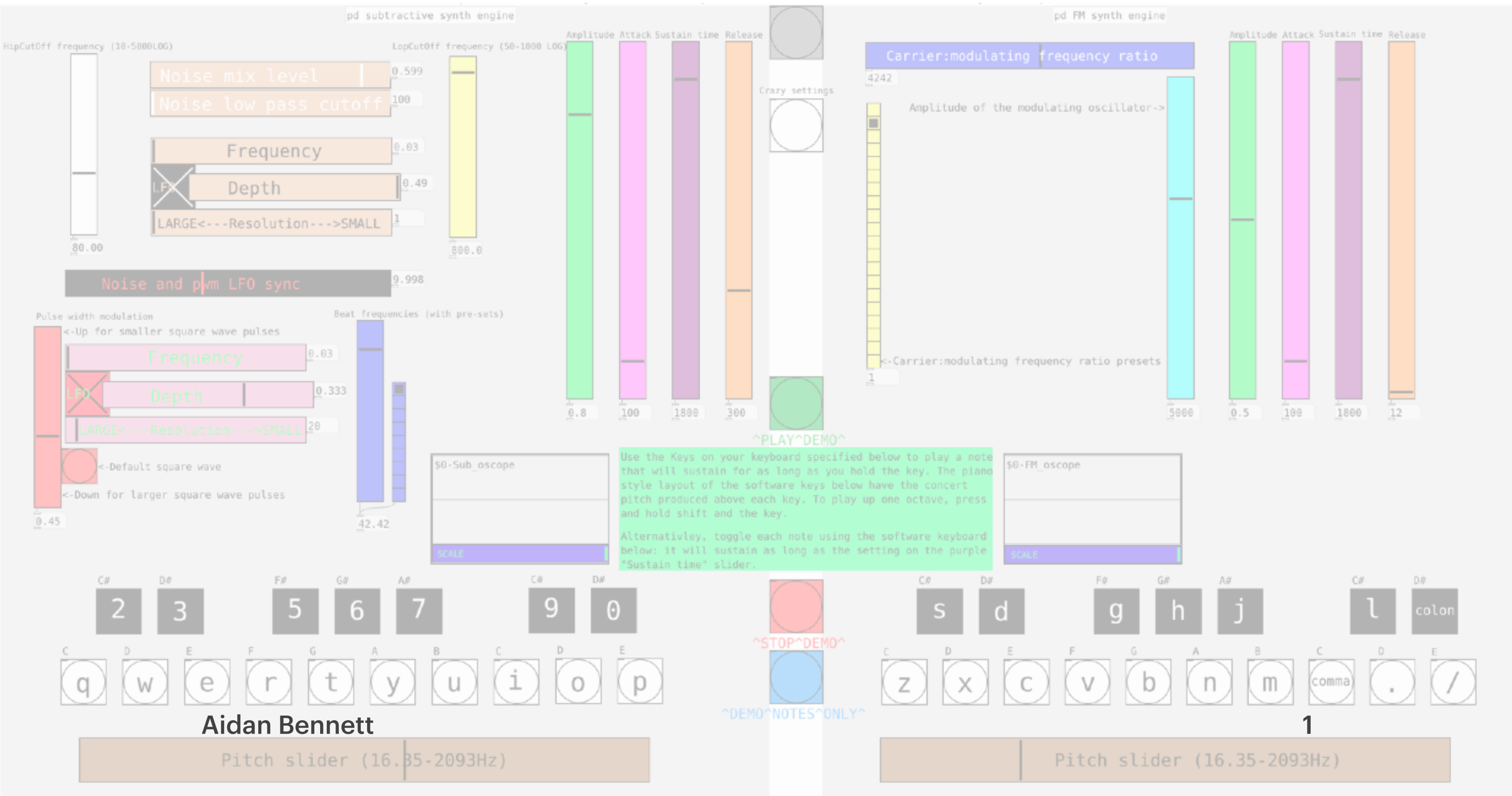


Abstract

This report starts with historical context for audio synthesis as a whole, then insight into the theory behind the two synthesis methods. This lays the groundwork for a design summary including the motivations and inspirations for the design, an overview of the engines that drive each synthesiser, how the graphical user interface (GUI) controls this, and how the sequencer is used to trigger the audio demos. The final section is a critical evaluation of this design, including the quality of the sound produced when the user is controlling it, as well as the audio demo.

1. Historical Context of Audio Synthesis

The end of the Second World War heralded a new focus on the arts; new studios were set up around the world so that individuals could experiment with new ways of synthesising sounds [10].

1.(1) Early Studios and Projects

One early such studio belonged to *Pierre Schaeffer* at French National Radio where he experimented with magnetic tape to produce "sound collages" of real world sources. In 1949/1950, he produced "*Symphonie pour un homme seul*" which used modified tape voice recordings; this composition style was eventually termed "*musique concrète*" [11]. Contrastly, a group of engineers and composers at *West German Radio* in *Köln* were using oscillators and noise generators to synthesise music by electronic means alone; this was eventually termed "*Elektronische Musik" [12]*. The *"Monochord",* which was available in the *Köln* studios in the 1950s, is considered an early progenitor of modern synthesisers; despite its ability to play live, it was often ignored in favour of other techniques due to its limited control of sound [13].

In 1956, the Radio Corporation of America (RCA) housed the first synthesiser which allowed intricate control of sound by composers [14]. However, this room sized instrument was unsuitable for live performances of its contemporary Rock and Pop music [15].

1) Bob Moog sitting with his "Minimoog" synthesiser [32]

1.(2) Transistors and the Digital Revolution

Transistor circuits in the late 1950s revolutionised the use of synthesisers in live performance; designs were generally smaller, like *Robert Moog's* first transistor based synthesiser produced in 1966, which had an early use in film soundtracks such *Stanley Kubrick's "A Clockwork Orange" (1971)* [16].

The advent of digital computing also streamlined live music synthesis: "In 1957 Max Mathews produced the world's first computer program (MUSIC I) which could synthesise sound" [17]. However, use of such programs was often impractical for performance as there was no live feedback for the musician [18].

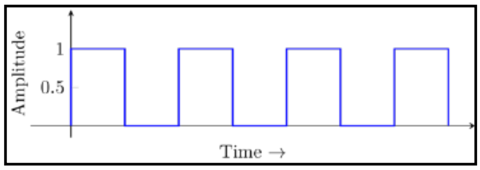
As the technology improved, for instance with the introduction of the "*MIDI"* protocol in the early 1980s [22], the music scene adopted it's use: "From 1980–82 there was a flourishing use of synthesisers in pop groups, very much at the expense of the electric guitar" [21].

Purr data is one such piece of digital technology who's foundations lie in these innovations throughout history.

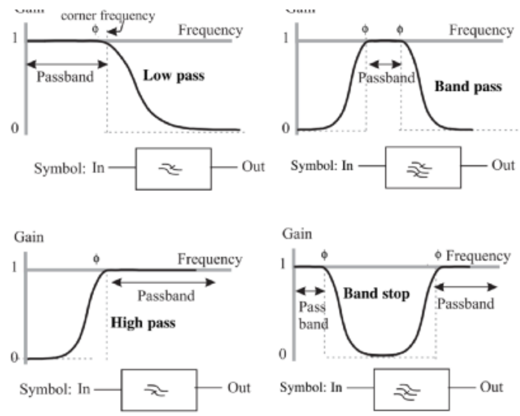
2. Theory of the Synthesis Methods in the Purr data patch

2.(1) Subtractive Synthesis

2) The variation of amplitude over time for a square wave [26]



3) The four major types of audio filter [24]



Subtractive synthesis uses filters to shape the harmonic content of starting input wave: filters are components “which [amplify] or [attenuate] certain frequencies in relation to others” [24]. An oscillator outputs a wave with a rich harmonic content as a starting point; waveforms such as the square wave shown in figure two are composed of a fundamental frequency, which is perceived as the pitch, and other harmonics which form the timbre of the sound produced. This is additive synthesis [25]. The starting wave is passed through filters which attenuate frequencies of harmonics: figure three shows a low pass filter which lets in lower frequencies for a “muffled” sound, a high pass filter which lets in high frequencies for a “bright/tinny” sound, a band pass filter which only lets in a certain band of frequencies, and a band stop filter which attenuates a band of frequencies resulting in a “thin” sound. They each have cutoff frequencies, labelled with ϕ in figure 3, above or below which frequencies will start to ramp off. Another feature of filters is their resonance: the degree to which frequencies at the cutoff frequency are amplified adding to the “dramatic quality” of the sound [33].

2.(2) Frequency Modulation (FM) Synthesis

For FM synthesis, one oscillator produces a sine wave whose frequency is modulated by the amplitude of another sine wave; these waveforms are known as the “carrier” and “modulator” respectively. When the frequency and amplitude of the modulator is low enough, this is perceived as a “vibrato” effect. However, at much higher frequencies and amplitudes of the modulator signal, more extreme timbres are produced due to sidebands in the signal; the perceived pitch is not constant unless the ratio between the carrier and modulation frequencies are kept constant [28].

3. Design Summary of my Purr data Patch

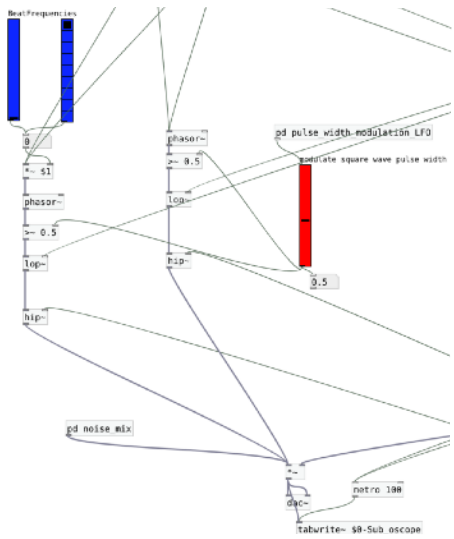
3.(1) Motivation for the Design

Subtractive synthesis was chosen because the fundamentals are very simple to produce in Pd but can easily be added to with more complex peripheral features. FM synthesis was chosen because theoretically it can produce an infinite palate of sounds meaning there is certainly a way to design a patch such that it contrasts successfully with a subtractive synthesiser [28]. The main goals with the design on the GUI were to make it colourful and neat, to make every parameter labelled, to allow the user to revert to a default setting, and to have multiple intuitive ways of triggering a note; the hardware/software key triggers are inspired by a piano keyboard layout, making it familiar to most musicians, and the pitch sliders are inspired by the ring and wire mechanism on an *Ondes Martenot* [34].

4) The ring-wire mechanism on an Ondes Martenot [34]

3.(2)The Subtractive Synth Engine

5) Main subtractive synth engine

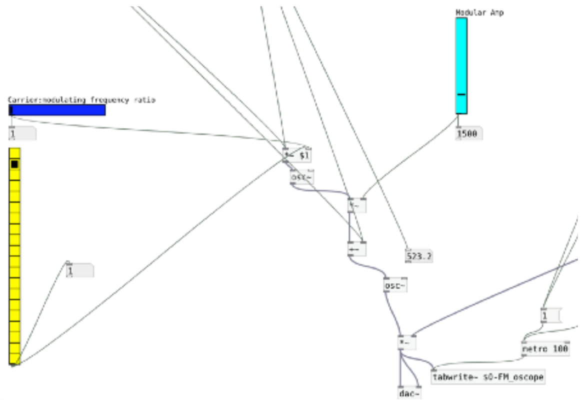


The subtractive synth engine is driven by two sawtooth wave oscillators produced by the "phasor~" object. Each is converted into a square wave by the ">~ 0.5" object which makes the amplitude remain at its minimum value until it the saw ramp reaches halfway, at which point it will jump to its maximum value; the pulse width of the square wave is modulated by the red slider, by changing the value of the ramp at which the wave jumps to it's maximum amplitude, which in turn has a low frequency oscillator (LFO) sub patch routed to it so that the pulse width can be modulated by another oscillator. Each wave is then passed through "lop~" and "hip~" objects which are the low and high pass filters respectively. The final waveforms are combined, along with any noise from the "pd noise_mix" sub patch, and sent into the left and right outputs of a "dac~" object which produces realtime audio output to external speakers or headphones. The final waveform is also sent to the oscilloscope in the GUI using the "tabwrite~" object. This provides a graphical representation of the waveform.

3.(3)The Frequency Modulation Synth Engine

Two "osc~" objects are fundamental to the FM synth: the lower most "osc~" object in figure six, the carrier oscillator, oscillates at the frequency triggered by the user interface. Its instantaneous frequency is added to that of the upper most "osc~" object, the modulation oscillator, using the "+~" object. As with the subtractive synth, the final waveform is sent to "dac~" for audio output and "tabwrite~" for graphing. The ratio of carrier frequency to modulation frequency is kept constant by feeding the carrier frequency into the topmost "*~ $1" object (figure six) which multiplies it by a float or integer, and uses the result as the modulation frequency.

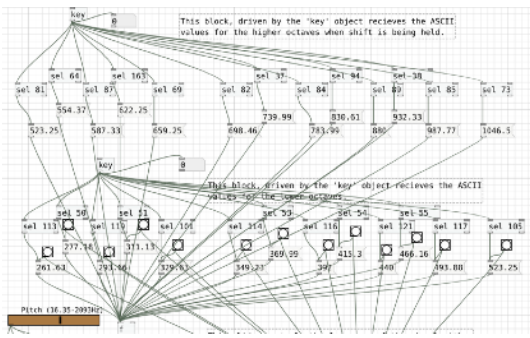
6) Main FM synth engine



3.(4)Triggering Notes

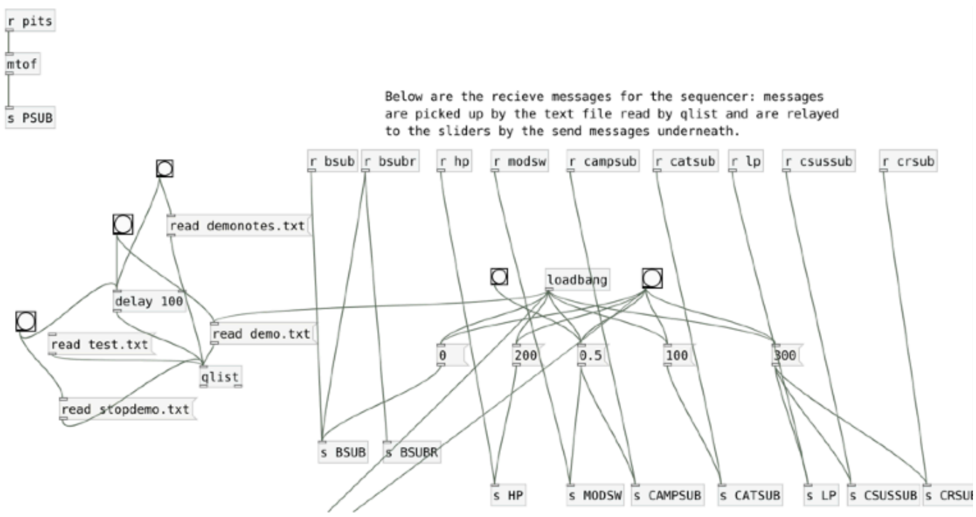
That main way for a user to trigger notes, on both synthesisers, is using a standard computer keyboard. Each "sel n" object in figure seven, where "n" represents an integer, sends a bang when the "key" object outputs said integer; the "key" object outputs the ASCII value of the hardware key just pressed. The bang from each "sel" object subsequently activates a message box with the desired frequency in hertz; this is used for the "phasor~" objects in figure five, and the "osc~" object for the carrier oscillator in figure six.

7) ASCII keyboard value to frequency converter

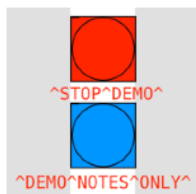


3.(5)The Sequencer and Audio Demo

8) Play demo button: This sends a message to the "qlist" object to make it in turn send the sequence of messages stored in the "demo.txt" file.



9) The sequencer: This works by receiving the messages sent by the .txt files via the "qlist" object and sending subsequent messages to the sliders, toggles, and other objects, for each synth parameter, in the main GUI. These in turn operate the internal synth engine by sending wireless messages to the sliders, toggles, and other objects there.



10) Stop demo and demo notes only buttons: These send messages to the "qlist" object but for reading the "stopdemo.txt" and "demonotes.txt" files.

4. Evaluation of the Final Design

4.(1) Usability

When users first open the synth they are confronted with a GUI that is very colourful and pleasant to look at. The presets loaded upon boot mean that sound can be produced strait away without the need to change any parameters; the explanation of how to use the hardware and software keys to produce notes facilitates this too. All the sliders are distinct from one another and clearly labelled such that someone with a basic understanding of music technology could intuitively know what they do. Every slider, set of radio buttons, and method of note activation works in the intended way. The oscilloscopes provide a great visual representation of each waveform produced.

The features that are slightly unintuitive to use are the LFOs for the noise signal and pulse width of the square wave; it is not immediately obvious that the noise mix level, and noise low pass cutoff, sliders must not be all the way to the left, as they are when the synth is first loaded, in order for the noise LFO to work.

The main demo button is very obvious, and functional, and the demo with notes only allows the user to play around with the parameters whilst the notes from the audio demo are triggered.

There are a large range of timbres that can be produced by the combination of parameters in the synth, and these contrast well for the two types of synthesis, although something that would improve the synth are some effects, such as delay and reverb, especially if these are combined with stereo panning.

A functional Attack-Decay-Sustain-Release (ADSR) envelope could not be designed, within the time frame, in a way that works alongside the hardware keys holding the sustain of each note; the attack-release envelope is enough to pleasantly shape the amplitude of each note but an ADSR would have sounded even nicer.

4.(2) Quality of the overall sound and audio demo

The overall quality of the sound is very good and there is no unwanted distortion. However, some combinations of the presets produce sounds that could be subjectively unpleasant. For instance, there are some very high frequency elements to some beat frequency and carrier to modulation frequency presets.

The audio demo effectively showcases the main timbres that can be created and has a coherent musical structure but the second half, when the noise and pulse width modulation LFOs were turned on, did not vary the LFO settings enough to fully showcase their capability.

In general, both synthesiser engines provide plenty of scope for musical creativity, with only the few possible extra features summarised in the section above.

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