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D2b - Instrument Essay
Commerical Music Producer
(Online Blended)

**FluteHarmonix - a reflective
essay**

3739 Words

Introduction to the Instrument

My virtual instrument FluteHarmonix is an atmospheric and creative instrument based on the natural harmonic series of a western concert flute (referred to as a flute for the remainder of this paper). I decided early on in the process of planning that I wanted to sample the flute, as it is something I am familiar with being both an experienced flute player and having sampled flutes before - if to a less thorough degree to this project! My options for building a sample based instrument were fairly limited to either Kontakt or HISE, and I chose HISE due, primarily, to the fact it was free and open source. There is also an excellent tutorial on MusicHackspace.com which I referenced heavily in the building of the instrument, as well as a very active community forum which I also took advantage of with lots of specific questions. The software seems to have near limitless capability to do fascinating sample manipulation, limited only by my utter inexperience with scripting!

FluteHarmonix increases the number of harmonic layers triggered in the sound based on the velocity of the keystroke, with a higher velocity triggering more harmonic layers to be played at once. This is layered with two additional synthesisers: a waveform generator synthesiser which is subtly added to fill the sound out and also modulates to mix more triangle wave into the sine wave as velocity is increased, and a much louder sine wave generator which the user can manipulate the octave and saturation intensity. The sine wave helps to add bass and depth to the sound. Both of the synthesisers can be switched off by the user through the GUI. When the modulation wheel is moved up saturation is added (i.e adding harmonics) to the sine wave and emphasising the 'roughness' of the sound. Alongside this the pitch of the harmonics present in the sound shifts up or down to and then beyond their equal temperament pitch to create a denser and more interesting sound with more out of tune partials clashing with the saturation from the sine wave.

The pitch bend wheel controls the frequency of an emulation of a Moog Low Pass Filter, which is essentially a steep LP filter with a resonance bump. The filter creates a really interesting effect because as the top end is rolled off it

emphasises the synthesisers in the mix and the flutes start to disappear, where as increasing the frequency of the filter brings in a lot of the 'air' sound of the flutes creating a more gritty sound.

There is also a simple reverb that can be controlled by the user to adjust the wet/dry balance as well as the room size.

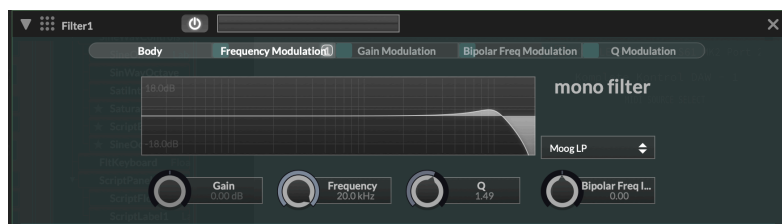


Figure 1 - Moog LP Filter in the instrument

Flute Harmonics and Acoustics

The flute is an acoustic ‘open pipe’, which means it is open on both ends with the air at both ends of the tube at atmospheric pressure.¹ When all of keys are closed on a flute and the instrument is blown a standing wave is generated that has a wavelength twice as long as the length of the flute, shown in figure 2². The bold line represents the air pressure in the flute with the pressure being highest in the middle of the tube, and the thinner line is the displacement of air i.e. the sound wave. The fundamental frequency of a flute in most cases is middle C or C4. When using the same fingering a flute player can produce other notes in the harmonic series, that is notes where the frequency is an exact multiple of the fundamental, by increasing the speed of the air within the tube. These wave forms are shown in figure 3³, with the pitches produced shown in figure 4⁴. Notes marked 8f upwards are incredibly difficult to produce, so are not included In FluteHarmonix. Note that the 7th harmonic is marked as a quarter sharp, it falls in-between an A and a Bb.

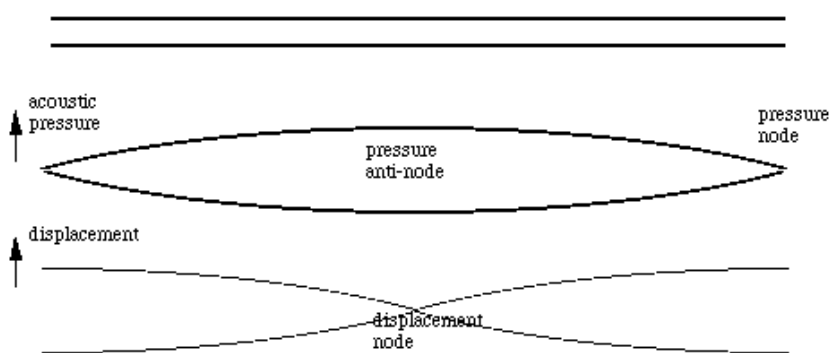


Figure 2 - fundamental frequency of a flute

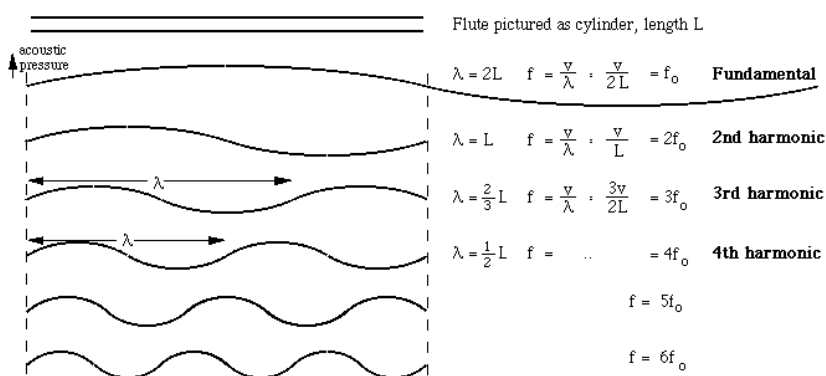


Figure 3 - harmonic waveforms of a flute from C4



Figure 4 - harmonic pitches of a flute from C4

¹ Wolfe, J. (n.d.). *Open vs Closed pipes (Flutes vs Clarinets)*. [online] newt.phys.unsw.edu.au. Available at: <https://newt.phys.unsw.edu.au/jw/flutes.v.clarinets.html> [Accessed 20 Jun. 2023].

² Wolfe, J. (n.d.). *Flute acoustics: an introduction*. [online] newt.phys.unsw.edu.au. Available at: <https://newt.phys.unsw.edu.au/jw/fluteacoustics.html#harmonics> [Accessed 20 Jun. 2023].

³ ibid

⁴ ibid

This discrepancy in tuning is what made me so interested in creating an instrument based not he natural harmonics in the first place.

Note Name	Frequency in Equal Temperament (Hz)	Flute Harmonic Frequency (Hz)	Difference
C4	261.63	261.63	0
C5	523.25	523.26	+0.01
G5	783.99	784.89	+0.9
C6	1046.50	1046.52	+0.02
E6	1318.51	1308.15	-10.36
G6	1567.98	1569.78	+1.8
Bb6	1864.66	1831.41	-33.25
C7	2093.00	2093.04	+0.04

Figure 5 - pitch discrepancies between Equal Temperament and flute harmonics

Figure 5 demonstrates the theoretical pitch for each note in the harmonic series based on Equal Temperament. Equal Temperament is a divisional system where an octave is divided into 12 steps of 100 cents, with an octave therefore doubling the pitch.⁵ However, since Equal Temperament is based on the frequency of A4 (440hz), and our harmonic series on the flute is baed on C4 (261hz) this results in the discrepancies shown in the table above, particularly around E6 and Bb6.

Applications of theory in the VST

Whilst conventionally we strive to avoid notes sounding ‘out of tune’ in modern production, I decided I wanted to exploit these discrepancies to create a more unique and atmospheric sound for my instrument. To that end I avoided any pitch correction of the samples at the recording and mapping stage, leaving them at the pitches I ‘heard’ them at when recording, and, as described above, I mapped the modulation wheel to adjust the pitches by less than half a semitone. For all of the harmonics except E6 I had the modulation wheel push the notes sharp with the effect becoming more pronounced as the pitch of the harmonic gets higher. For E6 I decided that the modulation wheel should actually pull the note flat by up to around 300 Cents. I did this because in Just Temperament, the divisional system where the scale is based on the naturally occurring harmonics (i.e. the closest divisional system for the natural harmonics of the flute) the major third (E in this case) would sound ‘flat’ anyway. It is worth noting that our ears naturally tend to hear Just Tempered chords more ‘in tune’ that those of Equal Temperament, and singers in a choir will

⁵ Encyclopedia Britannica. (n.d.). *equal temperament* | *Definition & Facts*. [online] Available at: <https://www.britannica.com/art/equal-temperament> [Accessed 20 Jun. 2023].

naturally lean towards Just Temperament⁶. Unfortunately due to Just Temperament dividing octaves based on ratios of the harmonic root note, it doesn't work for tuning keyboard instruments and other polyphonic instruments due to the tuning requirements of a C major chord being very different to those of an F major chord for example.

Creating an instrument that made use of these additional harmonics was an obvious choice for me, especially when you consider that the flute creates this layering effect naturally, albeit with a more subtle result. The sound of a flute when played at soft dynamic is closer to a pure sine wave than when playing loudly⁷ when the harmonic spectrum becomes much more apparent. This is demonstrated by Figure 6 where you can see that the volume of the fundamental frequency around 260hz barely changes between the two volume levels, however it is the upper harmonics that become considerably louder and create the richer, louder sound. My virtual instrument simply exaggerates the naturally occurring phenomenon of the upper harmonics becoming increasingly audible at higher dynamic levels.

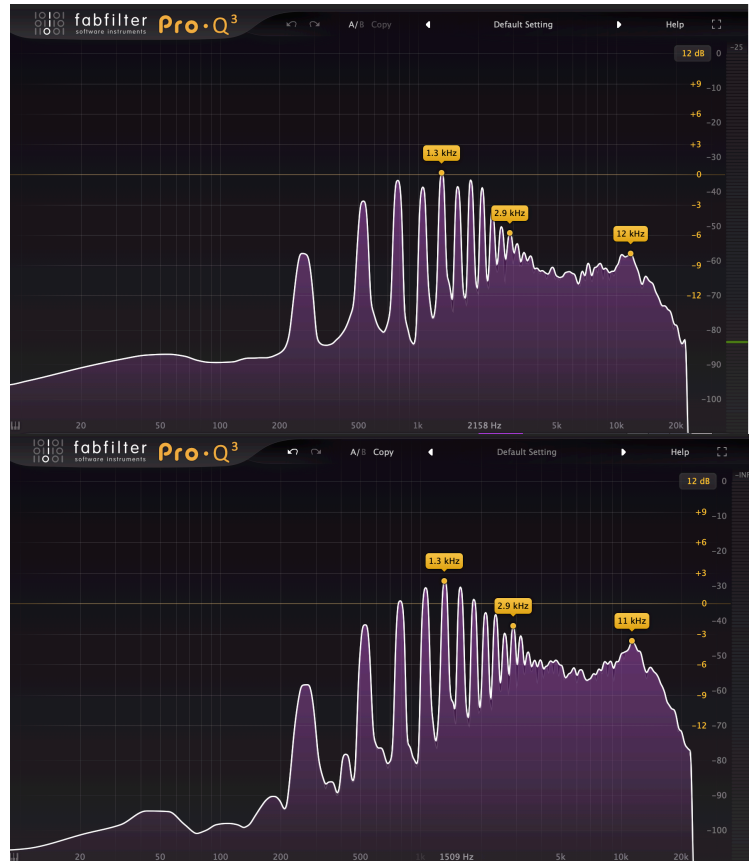


Figure 6 - Spectral analysis of C4 played mf (top) and f (bottom)

Whilst FluteHarmonix is inherently polyphonic, with several notes being sounded on one keypress, the instrument was not initially designed to be used polyphonically, largely due to the unintended artefacts that start to appear if played truly polyphonically. Firstly the waveforms from the waveform generators start to interfere with each other creating acoustic 'beating' and distortion effects. Mainly though it is due to the limited range of the harmonic series in the flute. Considering that the pitch Bb6 is sounding at a max velocity C4 keystroke, moving up the keyboard with the same relative mapped pitches quickly results in incredibly high tones being generated which if nothing else is unpleasant. There are also several high quality chromatic flute sampled instruments available on the market today which do polyphonic playing exceptionally well and I didn't feel the need to compete with that functionality. That being said, in the piece of

⁶ Suits, B.H. (1998). *Scales: Just vs Equal Temperament*. [online] pages.mtu.edu. Available at: <https://pages.mtu.edu/~suits/scales.html> [Accessed 22 Jun. 2023].

⁷ Wolfe, J. (n.d.). *Flute acoustics: an introduction*. [online] newt.phys.unsw.edu.au. Available at: <https://newt.phys.unsw.edu.au/jw/fluteacoustics.html#harmonics> [Accessed 20 Jun. 2023].

music I created with FluteHarmonix which is featured in my video presentation, I actually ended up using the instrument polyphonically an awful lot! However when doing so I tended to only use one key that actually had mapped flute samples at a time, with the other pitches being played purely on the synthesisers. I found that sticking to the higher pitches with the synthesised sound complimented the harmonics of the flute well without interfering too much, and that the occasional 'accidental' switch between the synthesised tone and the flute sample created an organic and interesting sound world.

On the flute it is only possible to get a true harmonic series with more than 5 partials above the fundamental from the notes C4, C#4, D4, D#4 and E4. Above that the harmonic series become increasingly limited due to the top partials becoming too high to actually sound. For that reason I have only mapped my initial samples from C4 to E4, leaving the rest of the keyboard empty except for the individual samples of each harmonic (e.g. C5, G5 etc).

For these reasons the main use I see for the instrument is in 'mono' playing where one key is manipulated at a time through the mod wheel and the 'pitch bend' filter to create dramatic and atmospheric effects, as opposed to as a truly polyphonic keyboard or melodic instrument.

Limitations and Future Improvements

The main limitations of this project were time and experience with HISE. If I had more time the greatest improvement I could make sonically to the instrument is to actually sample the harmonics and fundamentals of C#4-E4 rather than relying on mapping and re-pitching the original C4 samples. This would make the harmonics much more realistic sounding, as well as making the pitch discrepancies fit more closely with the Just Temperament I discussed earlier rather than being direct transpositions of the C harmonics. This additional sampling would also open the door to more chordal playing possibilities as more of the upper notes on the keyboard would be naturally filled with the original samples.

In addition to this I would love to extend the overall range of the instrument by sampling additional flutes. I would initially sample an alto flute in G, which would extend the natural harmonics and fundamentals all the way down to G3. The alto flute has a distinct timbre as well, which would create more variation within the instrument. There is also the opportunity there to mix harmonics from the alto flute in with the concert flute stacks to create more tonal variety and dissonance where the same notes come from different harmonic series. For example, when sampling the harmonic series of A3 on the alto flute, you would end up with C6 as the 4th partial. This could be blended with the C6 from the 3rd partial of the concert flute samples to create a unique blend and sound. This would also create more microtonal dissonance as those two samples would not be the exact same pitch due to being different degrees of the scale.

The same process could be applied to the piccolo starting from D5. Whilst the harmonic range of the piccolo is limited compared to the flute due to the partials getting too high, it would greatly increase the overall range of the instrument as well as adding another unique timbre to the mix as the alto flute does.

Once these additional instruments were added I could create an interface that would allow the user to custom mix the balance of the different instruments, as well as solo them out or mute them entirely. There would also be an option to set the sine wave generator to a solo mode so that the user could build up polyphonic chords in one instance of the VST without the sine wave also layering up and disrupting the sound.

I intended and tried to include a switch for polyphonic and solo/mono as found in synthesisers, along with a control for the glide between notes when in solo mode, and in fact found a script on the HISE forum that promised to do just that with all the relevant controls. However I don't have the skill required to successfully implement scripting within HISE, so couldn't complete this feature. There is also a bug present in my instrument where the first time the pitch bend wheel is moved whilst note is sound results in an enormous pop/bang sound which is incredibly unpleasant. I did not have the time or skill to resolve this bug so resorted to writing a warning about it on the GUI, which is obviously not ideal. With more time I could learn the relevant scripting and HISE skills to in order to implement these features and resolve the existing bugs.

It would be nice to have more control over the reverb from the UI, specifically being able to EQ the reverb on its own as well as being able to select which elements of the instrument go through the reverb i.e. being able to remove the synthesisers from the reverb whilst still having the flutes in the mix. At present everything goes through which can result in a muddy sound especially when the room is set to large and there's a lot of saturation.

There are also times where using the instrument as a stand alone application is useful as it adds a lot more versatility to the software, however presently that is quite impractical due to the inability to select an audio output for the VST meaning all of the audio by default comes out of the built in speakers with no other option.

Interface

Having little to no graphic design expertise I prioritised simplicity in all aspects of my GUI. I spent some time researching existing flute VSTs and found that a lot of the interfaces that incorporated an image of the instrument or ensemble to look a bit tacky and overly dated as shown in Figure 7.

Out of the interfaces I found the only examples that looked great and modern whilst including an image obviously required a lot of design work to look good, such as in Figure 8 which includes a

modern interface, a good looking image with shadow and lighting work and a satisfying colour palette.

Knowing that I lacked the design and HISE skills to end up with something as polished as Figure 8 I opted for no images and ultimate simplicity. The US Governments guidelines for GUI design prioritise keeping the interface simple, consistency and common elements, purposeful layout, and ensuring that the GUI communicates what is happening in the system.⁸ To that end I focused on a simple and high contrast colour scheme, with a grey to black gradient background and white text. I selected a clear font (Source Code Pro) and used it consistently throughout, placing the vast majority of the text inside interface panels coloured slightly darker than the background for extra contrast. I also utilised these panels to create a 'purposeful layout', creating sections of the interface for each element of the instrument - a section for reverb, one for the filter, one for the waveform generator and one for the sine wave generator. These panels have clearly marked and consistent on/off switches, as well as unique parameters with consistent controls and labelling. The filter panel not only includes an on/off switch, but also a graphical representation of what the filter is actually doing, to the end of ensuring the GUI is communicating with the user. There is also a MIDI input panel for this reason, which includes an activity light so the user can be



Figure 7 - tacky/dated looking GUIs



Figure 8 - a great modern interface



Figure 9 - My GUI for FluteHarmonix

⁸ usability.gov (2019). *User Interface Design Basics* | Usability.gov. [online] Usability.gov. Available at: <https://www.usability.gov/what-and-why/user-interface-design.html> [Accessed 25 Jun. 2023].

sure that MIDI data is being received by the instrument. I also included a keyboard at the bottom of the interface which allows the instrument to be played without a MIDI source as well as seeing which notes are being played in real time.

I took a good deal of inspiration in this area from the developers of Valhalla reverbs - particularly the interface for ValhallaRoom. Its interface is completely two-dimensional and has no images and yet is extremely popular with professionals and amateurs due to its ease of use and fantastic functionality. It also has such a clean and modern design that it still looks legitimate and 'expensive' despite not having any 3D rendered elements.

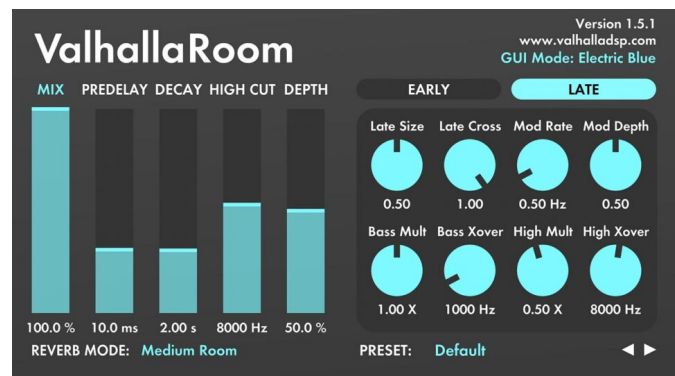


Figure 10 - ValhallaRoom

If I had more time and HISE skills there are several improvements I would like to make to the interface. Firstly I would have liked to have kept the keyboard as it is, but shaded out the least useful parts of the keyboard to highlight where the interest of the instrument is (C4-E4 and the various partials above that). This would decrease the risk of a user picking up the instrument for the first time and not playing the right range of the keyboard to find what the instrument can really offer. I have tried to address this in the text I have included on the interface, but this is obviously not a perfect solution! I would have liked to have included an audio out selector to match the MIDI source selector. This would allow the VST to be used as a standalone application much more easily, as at the moment it only seems to play sound through the built in outputs of my computer. I'm sure that this is possible within HISE but I couldn't figure it out in the time I had with the skills I have!

Potential Applications

Whilst FluteHarmonix might not have much of a place in commercial pop music, it certainly has several applications within the cinematic, experimental and ambient spheres. It could certainly find a home in soundtracks for contemporary television and film, being a product along the same lines as Spitfire Audio's British Drama Toolkit which also features playing styles mapped to velocity: "Ensembles are mapped across the full length of the keyboard, and the playing styles are tied to velocity – from whispered textures through to bold solos. British Drama Toolkit understands that the difference between playing softly and loudly isn't just volume – it is also about character and emotion."⁹

⁹ www.spitfireaudio.com. (n.d.). *British Drama Toolkit* — Spitfire Audio. [online] Available at: <https://www.spitfireaudio.com/british-drama-toolkit#whats-included> [Accessed 29 Jun. 2023].

As it is not a fully featured instrument, in that it is not fully chromatic, I don't think it would do astonishingly well commercially, but could absolutely be used as a free give away in order to gather customer information such as emails for a newsletter. Many VST and sample library companies do this, with Spitfire Audio offering its free LABS instruments, which often also have interesting but limited use, and Native Instruments recently giving away Irish Harp for free as a 'summer gift'. I can easily imagine a similar LABS instrument to this, offering something totally unique sounding in a relatively compact package.

Conclusion

In conclusion, the development of FluteHarmonix, a virtual instrument based on the natural harmonic series of a concert flute, has been a rewarding and educational experience. The instrument utilises sampling, synthesis, and modulation techniques to create a unique and atmospheric sound.

Throughout the project, the use of HISE, a free and open-source software, proved to be a valuable choice due to its capabilities and active community support. The instrument incorporates multiple layers of harmonics triggered by the velocity of the keystrokes, along with waveform and sine wave generators to add depth and richness to the sound. The modulation wheel controls the frequency of a Moog Low Pass Filter, allowing for a wide range of sound manipulation. A simple reverb is also included to adjust the wet/dry balance and room size.

The instrument takes advantage of the natural characteristics of the flute, where the upper harmonics become more audible at higher dynamic levels. By embracing the pitch discrepancies in the harmonic series, the instrument creates a unique and atmospheric sound that exploits the natural tendencies of the flute.

While the instrument is primarily designed for monophonic playing, it can be used polyphonically with careful consideration to avoid unwanted artefacts and high-pitched tones. Future improvements could involve sampling additional flutes, such as the alto flute and piccolo, to expand the range and timbre of the instrument. The inclusion of more control options, such as EQ for the reverb and individual instrument blending, would also enhance the instrument's versatility.

The graphical user interface (GUI) of FluteHarmonix prioritises simplicity and functionality, following design principles of simplicity, consistency, purposeful layout, and effective communication. Although lacking in graphic design expertise, the GUI provides clear controls and informative elements to facilitate ease of use.

Overall, FluteHarmonix demonstrates the possibilities of blending traditional acoustic instruments with digital technology to create unique and expressive sounds. The project highlights the

potential for further exploration and improvement, offering a foundation for future developments in virtual instrument design and sound manipulation.