

Lab Report 2

Musical Applications of the Modulation Signal for Modulation-Based Effects (Tremolo and Vibrato)

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Introduction

Digital Synthesis of Modulation-Based effects is an area of study that is regularly revisited and improved. The ability to apply a vibrato or tremolo effect that sounds natural is extremely difficult due to a number of factors. The main difficulty is being able to apply a modulation signal that makes the vibrato (frequency modulated) or tremolo (amplitude modulated) effect seem natural, and not like it was created by the process of digital synthesis. This modulation signal is the central part of the creation of a vibrato or tremolo effect, as will be explained in this paper. For people to creatively use digitally synthesised vibrato or tremolo effects, the modulation signal needs to be designed to sound as natural as possible.

Tremolo and Vibrato Effect

The Tremolo Effect works by applying a modulation signal to an input signal (Shown in Figure 1). The modulation signal is created as a function of the frequency of the tremolo signal (referred to as the Modulation Rate), as well as the maximum amount of attenuation

created by the modulation signal, known as the 'Depth' of the Tremolo. The Modulating signal operates as a multiplier between 0 and 1 to create the amplitude modulation between 0 and 1. The equation for sample n can be seen in Figure 2.

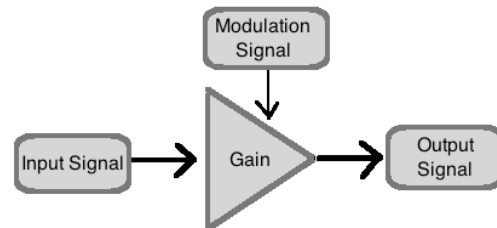


Figure 1 – Signal Flow of Amplitude Modulating Tremolo Effect

$$m[n] = (1 - A) + D \frac{1 + \cos x \left(\frac{2\pi f n}{f_s} \right)}{2}$$

Figure 2 – Equation of Modulation Signal in Amplitude Modulating Tremolo Effect for sample n

A Vibrato effect utilises a modulation signal to drive the delay time within the delay line. By changing the time of the delay, the effect creates a modulation in pitch over time. The modulating signal, unlike the modulating signal for the tremolo effect, operates between -1 and 1 so the pitch fluctuates above and below the target pitch. This would be instead of fluctuating between the target pitch and a higher pitch, which would happen when the modulating wave for an amplitude modulating effect was used for a frequency modulating effect. This imitates the musical technique, Vibrato. The use of the modulation signal can be visualised using the

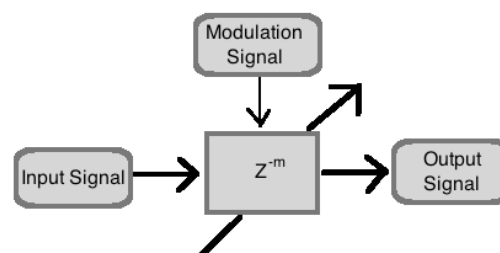


Figure 3 – Signal Flow of Frequency Modulating Vibrato Effect

diagram in Figure 3. The equation for the frequency modulating effect's modulation signal can be seen in below.

$$m(n) = \sin(M \times \pi \times n)$$

Where M is the modulation frequency and n is the sample being affected.

Because of the multiple delay lines within a digitally synthesised vibrato effect, the phase of each of the delay lines need to be fixed. To do this, each delay line is passed through an all-pass interpolation process. In Matlab this interpolation line looks like this:

```
y(n,1)=(Delayline(i+1)+(1-frac)*Delayline(i)-(1-frac)*ya_alt);
```

Where `Delayline` is the memory allocation for delay, `i` is the rounded integers of delay, `frac` is a function of the vibrato delay, width and modulation, and `ya_alt` is used for reference as 0.

The Problem

The issue that arises with the creation of a modulation signal is whether or not it sounds natural, and not synthetic or "robotic". Honing believes the problem can be attributed to knowing, or not knowing, how the modulation signal should behave when "it is used for a longer note, or, equivalently, when the note is stretched" (Honing, 1995).

The problem partly lies within the inability of the large majority performers to perform vibrato or tremolo with the precision of a sinusoidal wave. This leads to the

'robotic' tone of voice, and is easily distinguishable by the human ear. Literature from as early as 1964 (Harvey, Maclean, 1964) has shown that the modulation rate is already known. It is the translation of this knowledge to practical digital synthesis that is proving the problem.

As well as this, the selection of the parameters depth and modulation rate that are not beneficial and can even be detrimental to the tone of the sound being affected have also been proven to affect the perception of a musical sound (Martins et al. 2006).

To fully understand how to replicate vibrato or tremolo at a high order, these problems need to be fully understood

Evidence

Martins & Atsushi (Martins, Atsushi, 2006) discussed the rate and depth of a vibrato effect that was perceived to be either not contributing to the sound, or too strong to be musically useful. Figure 4 shows the results of their experiment, where the area between the green and red line provides a useful mix of depth and modulation rate.

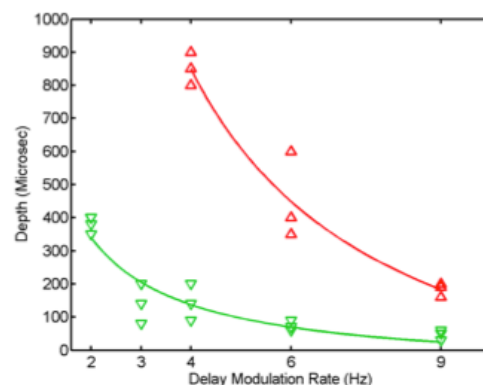


Figure 4 - Results of Martins & Atsushi (Martins & Atsushi, 2006)

These presented results show that the choice of depth and modulation rate can affect how humans perceive digitally synthesised vibrato in a musical sense. The research does leave room for more study to be done, as these results may have only been relevant to the stimuli used within the tests.

Sandler & Xue (2008) recognise the need for amplitude variations, as well as frequency variations in vibrato. This is due to the naturally occurring change in loudness that occurs when an instrument plays music with vibrato. The paper discusses the variations that occur, and points out that the frequency modulation within vibrato is not perfectly sinusoidal as can be seen in Figure 5.

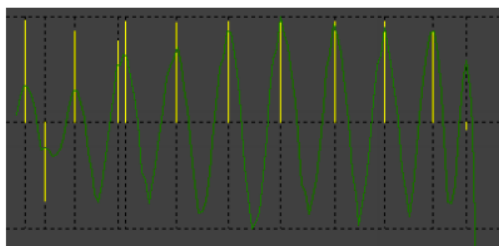


Figure 5 – Measured Vibrato of the human voice (Sandler & Xue, 2008)

Sandler & Xue note that within the vibrato of the human voice, there is actually a second modulation that occurs. This can be seen in Figure 6, where the sinusoidal wave modulates slowly up and down by the distance indicated by the red bracket.

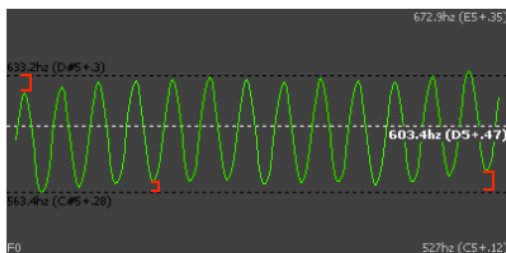


Figure 6 – Measured Vibrato showing amplitude modulation (Sandler & Xue, 2008)

Sandler & Xue also provide examples of Honing’s “Vibrato problem” (See Figure 7). That being that often vibrato is not uniform across the length of a note. This non-uniformity is characterised by the stretching of the vibrato-modulating signal, thereby stretching the modulating rate of the vibrato.

More evidence of complications in creating the modulating signal of a vibrato effect is discussed in Maher’s 2008 paper “Control of Synthesised Vibrato during Portamento Musical Pitch Transitions”. Maher discusses how digitally synthesised vibrato, when applied to a human voice that is performing a legato pitch transition. Figure 7 displays what a digitally synthesised vibrato that does not consider the Portamento transition would appear like. While Figure 8 shows how the vibrato naturally occurs on the human voice when performing a Portamento transition.

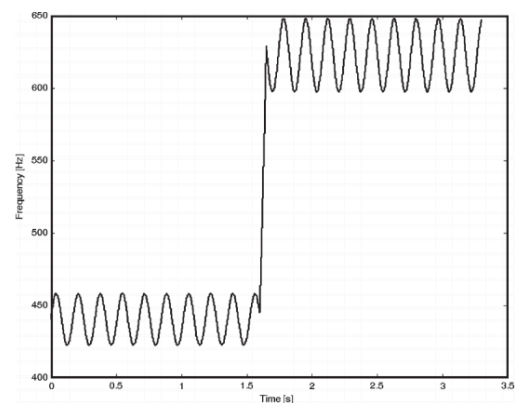


Figure 7 – Synthesised Vibrato not accounting for Portamento transition (Maher, 2008)

Maher determined that a digitally synthesised vibrato’s failure to sound like a naturally produced vibrato was due to its lack of a smooth transition between pitches.

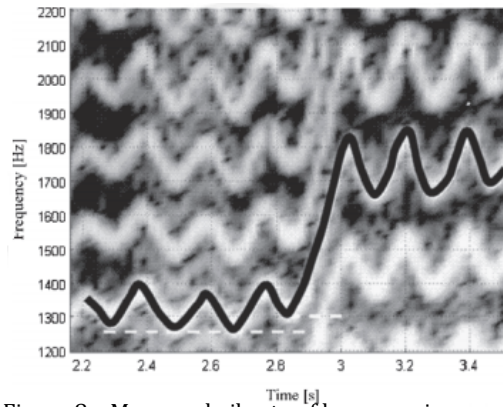


Figure 8 – Measured vibrato of human voice performing Portamento transition (Sandler & Xue, 2008)

Solutions

The papers by Honing (1995), Sandler & Xue (2008), and Maher (2008) all provide solutions and systems that can address the problem they present. However, these solutions are not easily accessible to the people who will creatively use the vibrato effect in their creation of music. Honing, as an example, notes in his Conclusion that while his two solutions given do solve the “Vibrato Problem”, they do not account for other factors that are needed for the construction of a representational system for music.

Companies such as Waves and Digidesign have created RTAS (Real-Time AudioSuite) and VST (Virtual Studio Technology) Vibrato plugins for use in Digital Audio Workstations, however these products are much more complex than the simple implementation, wherein these problems exist. The technology required for the necessary solutions presented by Honing (1995), Sandler & Xue (2008) and Maher (2008) is beyond the technology available for this simple implementation within a program such as Matlab.

Simpler solutions could include a basic inclusion of amplitude

modulation as well as frequency modulation as noted by Sandler et al. (2008). The “stretching” of the frequency modulation effect’s modulation signal discussed by Honing could be replicated within the Matlab environment, however may be significantly more difficult for implementation over phrases with multiple notes or expressions.

Conclusion

The problems associated with the simple implementation of a digitally synthesised vibrato effect can be solved. However, the process of pre-analysis, the specification of what instrument the vibrato needs to be replicated on, as well as the system that needs to be designed, are too complex for their design to be implemented in a program such as Matlab.

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