Vibrato as a means for Sonification of Athletes Heartrate Data
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ABSTRACT
Vibrato is an audio effect that uses time delay modulation technique. As opposed to the prior uses of this audio effect, the aim of this project is to develop a system by using the effect of Vibrato, which gauges fitness levels in athletes by sonifying their heartbeats/minutes data. Heartrates in athletes vary due to their fitness levels and there are tools like smartwatches that measure them however there is lack of fitness tools that can promptly measure and produce a direct outcome that can provoke them promptly towards higher goals. This project investigates how vibrato can be used as an effect to enhance this proposed system’s effectiveness in pushing athletes further towards their goals.

1. INTRODUCTION
In this project the main object is to devise a system that can translate a set of heartrate data into sounds through user input. The system will be built upon a widely used audio effect in the musical world, called Vibrato. The choice of vibrato as an effect and a system generator is due to its parametric relevance to our dataset, which will be discussed further in the paper.

Vibrato is an audio effect which by periodical variation of delay in time will yield a periodical pitch variation (Zölzer, 2011). Vibrato is an effect that needs a delay line and low frequency oscillator as parameters to push the delay time parameter (Zölzer, 2011). This effect is based on the principles of the doppler effect (this is the natural aspect of pitch rising when the source comes closer and the pitch drops when it goes away (Hanrahan, C. 2012)). The typical parameters are 5 to 10 milliseconds average delay time and 5 to 14 Hz rate of low-frequency oscillator. However, in this project we are using the data from the Heartrate as the width of the delay and manipulating it to adjust between 5 to 15 milliseconds. This is because of the reason that the variance in the pitch will be affected by the variance in the time. Thus, giving us the tool for gauging our desired outcome. A basic diagram that shows the generation of vibrato with its key elements is given below.

Figure 1: Taken from DESC9115 Lecture Slides
Considering musical instruments, in the field of guitar effects, tremolo and vibrato has been used interchangeably, however, writers have now coined the term True Vibrato to represent Pitch Vibrato which makes it distinguishable from other forms of effects (Manor, E. 2019). It is strange that in human singing voices, girl’s voices develop small amounts of vibrato while they grow older from their childhood onwards, although after the age of 20 the extent of vibrato becomes a matter of artistic choice (Fletcher, N. H. 2001). Some artists do maintain as small vibrato as they can until their later years and that favours composers like Purcell and much of folk music (Fletcher, N. H. 2001). The use of vibrato in music especially in string instruments and human voice has been recorded and researched quite extensively. This is an effect used to add warmth to a note in music (“Vibrato” 2017) but the extent of research of its use for practical purposes, for instance, the analysis of variation in fitness levels is lacking as opposed to vibrato’s own analysis for musical and pitch analytical purposes. Many techniques are being used to analyse vibrato in music some of which are; Time Domain Analysis, Fourier and Fast Fourier Analysis, Galerkin Analysis and Sonagraph Analysis (Fletcher, N. H. 2001). These techniques are informative, some more than the others, although there is research lacking in using Vibrato effect as a tool for sonification and audification to gain information about another phenomenon.

1.1 Sonification

The significance of this project is to use parameters of time delay modulation and produce a system that generates pitch variation due to the variation in data fed into the system. The process of using audio to understand a phenomenon which has wide ranging, and diverse data is called sonification. Sonification as a tool has been used to hear critical data that is otherwise inefficient to read through visualization e.g; sonification of electroencephalogram (EEG) data would render deviations in electrical activity in the brain easier to read (“Experiments in Sonification of EEG,” n.d.). There are several other projects that use Matlab as a tool for computation and generation of sounds using audio functions. Sonification of Formant Synthesis (Data Sonification Using Formant (Lee, K., n.d.) and Sonifying seismic data (Kilb D. et al., n.d.) are some of the projects that provide an inspiration for this endeavour.

1.2 Development of the System

In this project we are aiming to sonify heartbeat data from athletes using vibrato functions created in Matlab by Zölzer (2011) in DAFx book. The system is based on using Vibrato effect as a sonifying machine. The system will be user operated with user-inputs. The one-dimensional dataset will be used as one of the parameters in the system to modulate pitch in the audio in the system which gives us an output that yields information. The pitch variation in the audio generated by the system due to the diversity of values in data will give us information on the fitness levels of the athletes.

A simple script that gets user inputs will be appropriated and modified from the project on Vibrato by Manor E. (2019). The system works by getting inputs of number of poles, instrument, width and depth from the user and uses it to produce sound and then stores it. This will be discussed further in the next section. The figure below describes a simple vibrato system.
2. LAB WORK

The system uses the basic concept of Vibrato by using the function of vibrato by Zölzer (2011). The script implements the use of audio signals and passing them through the delay line and filters to apply vibrato. The modulation of the time delay is based on a simple delay modulation that consists of two parameters, width and the depth. The width can also be defined as the concentration or strength of the system which makes the pitch variation differ from the original pitch, measured in milliseconds (O’Brien D. 2014). Depth can be understood as the speed of the frequency that creates the effect.

The system will take audio recordings of two audio files and supply it as input in the system. The audio files are of two musical instruments, Violin and Viola, which are very appropriate for the Vibrato effect. The user inputs the instrument choice and then depth, width (the heart rate data) and number of poles in the system as numbers to feed the system. Then the system uses the LPC coefficients of the instrument and filters it to get a residual signal. The system then acquires the LPC coefficients of the vowel sounds (see code files) and then applies cross-synthesis between the original signal and the residual signal. An all-zero filter is used here. Since the system will be taking the heart rate data (width) as the width parameter through an excel file there are numerous data values. The system will have to use the data iteratively on the audio signal. Finally, it generates an audio signal with vibrato applied on it. The system results do yield differences with different data inputs. A simple diagram shows the flow of the system below.
2.1 Application in Matlab

The Vibrato effect is created through an all-pass interpolated fractional delay line to get fractional segment of delay length, this fractional line is fed by input arguments (O’Brien D. 2014). A pitch variation is created due to a low-frequency oscillator. This code will be using linear interpolation algorithms to implement the effect by Zölzer (2011). This can be represented in a mathematical equation as:

$$y(n) = x(n-\lfloor M+1 \rfloor)\text{frac}+x(n-M)(1-\text{frac})$$

The linear interpolation represented in matlab code is represented as:

$$y(n,1) = \text{Delayline}(i+1)\text{frac}\text{+Delay line}(i)*(1-\text{frac});$$

2.2 Vibrato for Practical Purposes not Musical

Vibrato can reveal information for the analysis of phenomenon other than music. The current sound systems are mostly related to music creation, but a lot can be achieved through using software like Matlab to engage in problems beyond musical effects. Vibrato and its characteristic of pitch variation can be used to devise equipment that may solve problems.
3. DISCUSSION & CONCLUSION

The choice of Vibrato effect for sonification of heartrate data was problematic since vibrato itself is a modulation based on time and an audio effect. The fluctuations of pitch and the variations in the data can be seemingly difficult to appropriate to produce an informative output. This exercise did produce a result that is consistent with data and a step towards the creation of a machine that can provide information and gauge fitness levels of athletes through listening to the output of the system. However, much work needs to be done to create a system that uses diverse data to produce sounds for information and problem detection that relies on pitch variation.
4. REFERENCES


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