Computational analysis of guitar vibrato for extended guitar techniques

Ben Trovato
Institute for Clarity in Documentation
1932 Wallamaloo Lane
Wallamaloo, New Zealand
trovato@corporation.com

ABSTRACT

1. INTRODUCTION

Electric guitar offers several ways of shaping and articulating sound: techniques such as vibrato, slide, bending, tapping modify the dynamics and the timbral characteristics of a note. The guitarist's "touch" is considered to be very personal, and the style of a guitar player largely depends on how they articulate notes. Guitar articulations are correlated to hand motion.

Recent advancements in sensing technologies have brought attention to the embodied dimensions of musical practice, and several studies have employed computational methods for analysis of embodied knowledge of specific instrumental techniques [5, 7, 8]. At the same time, designers of Interactive Music Systems are using real-time body sensing to integrate embodied perspectives in their digital performance systems [3, 10]. In this context, mapping sensor data to synthesis parameters is a non trivial task, which is affected by aesthetic choices as well as by technical and perceptive constraints [6, 9].

My project has the objective of informing sensor mapping strategies with a computational analysis of embodied data and audio of a specific musical technique: guitar vibrato. The purpose of my project is to track hand movement of a guitar player to develop an interface for electronically-extended guitar techniques. The interface combines sound features and hand motion data to detect the kind of guitar vibrato from real-time hand movements and exposes mapping parameters for dynamic sound shaping.

2. BACKGROUND

2.1 Embodiment and musical gestures

2.2 Interactive Music Systems

2.3 Computational studies of instrumental techniques

3. SYSTEM DESIGN

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3.1 Data Collection

Collecting a dataset of guitar vibrato techinques mapped to the related hand movements using motion capture. For each note on the guitar, four instances will be recorded: no vibrato, vertical vibrato, horizontal vibrato and circular vibrato. For each of these, multiple recordings will be realized with different vibrato intensity. The hand movements will be recorded using the AX6 6-axis logging accelerometer and gyroscope. At the same time, audio from the guitar will be recorded using a digital audio interface. The data recording process will be repeated multiple times in order to identify the position of the sensor on the hands which guarantees the cleanest data.

3.2 Data Preprocessing

Segmentation and feature extraction Are there differences in spectral shape descriptors between the different kinds of vibrato?

3.2.1 *Segmentation*

The data from audio and sensors will be aligned and each note will be segmented using transient detection. Spectral audio descriptors will be computed from each instance: loudness (dB), true-peak descriptor (dB), loudness (linear "RMS"), spectral centroid (Hz), spectral spread (Hz), spectral flatness (dB), and 6 Mfcc descriptors. The most significant features contributing to distinguishing the different kinds of vibrato will be identified using feature importance and autocorrelation coefficients.

3.2.2 *Feature extraction and analysis*

As pointed out in [2], [1] and [4], vibrato is identified in the oscillation of the central frequency f0. Since we want to understand the differences between the different kinds of vibrato from a sonic point of view, our hypothesis is that different types of vibrato affect the note in different ways, changing not only the central frequency but also acting on the different harmonics in different ways. To demonstrate this, we extract the pitch estimates and the amplitude envelopes of the lowest five harmonics separately. By plotting them, we notice that vertical, horizontal and circular vibrato affect pitch and envelope of the harmonics in different ways. For example, horizontal vibrato keeps the higher harmonics for longer, while in circular vibrato the higher harmonics are cut earlier.

To extract these features, we go through this process:

1. Identify the central frequency f0 using the pYIN algorithm []

2. Calculate the harmonics

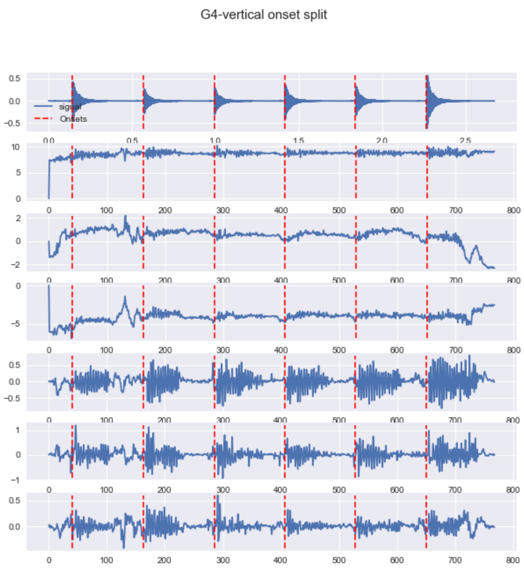

Figure 1: Segmentation of sound and sensor data.

3. Filter the signal to the harmonics
4. For each harmonic find the pitch and the amplitude envelope using YIN [] and RMS []
5. Normalize to make it independent from pitch

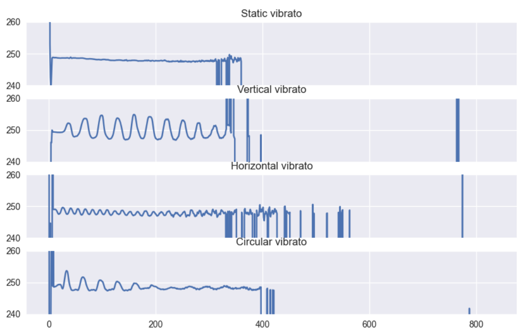

Figure 2: Comparison of the spectrograms of different kinds of vibrato.

3.3 Machine learning

A machine learning model will be trained to classify the kind of vibrato from the sensor data in the 4 classes: no vibrato, vertical vibrato, horizontal vibrato or circular vibrato. A regression model will be trained to infer the descriptors corresponding to hand movements.

3.3.1 Vibrato type classification

Sensors –> Vibrato class (static, vertical, horizontal, circular) Sensors+Audio –> Vibrato class (static, vertical, horizontal, circular)

3.3.2 Spectral centroid regression

Sequence modeling

Sensors –> Regression of harmonics and amplitude of the lowest five harmonics

3.4 Interactive Music System

Real-time mapping strategies for vibrato-aware guitar effects will be explored using a Pure Data interface and real-time hand motion capture and the trained models (eg. vibrato-dependent reverb, distortion, sustain, delay. . .).

3.4.1 Vibrato-aware distortion

3.4.2 Vibrato transfer

Vibrato on a synth note through physical modeling driven from sensor data. PD vibrato

4. RESULTS

5. CONCLUSIONS

Computational analysis of embodied technique allows to focus on nuance in the development of interactive music systems. However it is necessary to study the technique specifically taking into account the specificity of the instrument.

6. REFERENCES

[1] Y.-P. Chen, L. Su, and Y.-H. Yang. ELECTRIC GUITAR PLAYING TECHNIQUE DETECTION IN REAL-WORLD RECORDINGS BASED ON F0 SEQUENCE PATTERN RECOGNITION. 2015.

[2] H. Jarvelainen. Perception-based control of vibrato parameters in string instrument synthesis.

[3] A. R. Jensenius and C. Erdem. Gestures in ensemble performance. In *Together in Music*, pages 109–118. Oxford University Press, Nov. 2021.

[4] Y. Nishikawa and T. Matsumura. Proficiency Estimation Method in Vibrato: A Special Technique of an Electric Guitar. In *2021 6th International Conference on Intelligent Informatics and Biomedical Sciences (ICIIBMS)*, pages 20–21, Oita, Japan, Nov. 2021. IEEE.

[5] E. Seye and A. Mashino. The corporeality of sound and movement in performance. *World of Music*, 9:25–45, 01 2021.

[6] L. Strauss and M. Yee-King. Extensible Embodied Knowledge: Bridging Performance Practice and Intelligent Performance System Design. 2023.

[7] S. Tanaka. *The notion of embodied knowledge*, pages 149–157. 01 2011.

[8] D. van der Schyff, A. Schiavio, A. Walton, V. Velardo, and A. Chemero. Musical creativity and the embodied mind: Exploring the possibilities of 4e cognition and dynamical systems theory. 1:1–18, 09 2018.

[9] D. Van Nort, M. M. Wanderley, and P. Depalle. Mapping Control Structures for Sound Synthesis: Functional and Topological Perspectives. *Computer Music Journal*, 38(3):6–22, Sept. 2014.

[10] F. G. Visi and A. Tanaka. Interactive Machine Learning of Musical Gesture. In E. R. Miranda, editor, *Handbook of Artificial Intelligence for Music*, pages 771–798. Springer International Publishing, Cham, 2021.