Master’s Thesis Proposal

Virtual Slide Guitar – A Digital Wave Guide Approach

David G. Smith

11/04/2022

Introduction/Motivation

One of the more unique and interesting methods of playing guitar is an approach referred to as “slide guitar”. This consists of using a rigid object, most frequently a tube made of metal or glass, to control the length of the string, instead of the traditional fretting approach. The slide acts as another method of string termination and influences the vibration of the string by creating a new load impedance in between the nut and the bridge on the length of the string. This allows unique articulations and pitch inflections to be generated as the player is no-longer constrained to the pitches provided by the fret-locations. Additionally, the interaction of the slide’s surface with that of the string adds a new timbral component related to the slide’s velocity. In the case of wound strings, this adds two new components. The first is a time-varying harmonic component due to the interaction of the slide with the spatially periodic pattern of windings on the string’s surface (inherent in a wound string’s construction). The second component is due to the stimulation of the string’s longitudinal modes as the slide introduces disturbances in this direction when it impacts the ridges of the windings. Given that the slide does not provide sufficient force to change the length of the string from the perspective of the longitudinal modes, the modal frequencies are static, regardless of the motion of the slide.

This method hasn’t been explored nearly as much from a synthesis standpoint as compared the plucked-string approaches of guitar playing. Part of the motivation comes from the fact the topic is less explored territory. Additionally, the author has long been a guitar player and slide guitar enthusiast, so understanding the physical mechanisms at play in slide articulation (as well as guitar playing in general) are of keen interest to him in general. As an aspiring luthier, this knowledge and the measurement methods/techniques developed over the course of this project could be applied in future attempts at guitar construction.

Previous Work

Sound synthesis of a vibrating string has long been of interest to researchers as illustrated by the work of Karplus-Strong (Karplus, 1983) and Jaffee-Smith (Jaffe, 1983). The loop filter has also provided fertile ground to extend the timbre from that of a plucked string to the electric guitar in general, including feedback and distortion (Sullivan, 1990). However, very little work exists which specifically focuses on the slide guitar. The first published journal article regarding it came out of a group of Finnish researchers in 2008 (Pakarinen, Jyri, et al., 2008). This material also appeared in several other places such as NIME, but the most complete collection of all the work is a master’s thesis by Tapio Puputti published in 2010 (Puputti, 2010). All the work published in the other journals, is a subset of what appears within his thesis. Additionally, this set of papers involves a substantial component related to the gestural control of the synthesizer using a pre-existing Virtual Air Guitar system. Accordingly, the sound synthesis aspect is only half the focus, and the approach taken is a DWG model based on other work from the Helsinki University of Technology.

The same group of researchers has done prior work which was incorporated into DWG model for slide guitar. A paper of theirs from 2007 focuses on the interaction noises of fingers with wound strings (Pakarinen, J., et al., 2007). This work heavily informs the model of slide/string surface interaction and

translates into a parametric model dependent on the slide and string properties. The same paper influenced a synthesis model of the Chinese guqin (Penttinen, Henri, et al., 2007). One of the distinguishing characteristics of the guqin is that it is a fret-less plucked instrument which uses wound strings. Correspondingly, the friction model developed for the VSG model is heavily influenced by the guqin's which was heavily influenced by the work focusing strictly on the finger-string interactions.

Recent work has also attempted to extend the DWG model or use a finite-difference approach. Gianpaolo Evangelista has a history of modeling player/instrument interaction aspects of guitar playing. These have focused just on frets and strings (Evangelista, 2011) as well as the different touch and collision sounds involved in guitar playing in general (Evangelista, 2010). More recently, he has extended the work done by the Finnish research group and produced a more physically informed slide model (Evangelista, 2012). The most recent approach however is a finite difference model produced by researchers at Queen's University which explicitly models the string forces on both the left and right hands and produces quality results (Bhanuprakash, Abhiram, et al., 2020).

Proposed Research / Methodology

A synthesis model will be developed in Matlab which supports sample-by-sample calculations of the resulting sound. The constituent components (i.e. pulse generator, loop-filter) will be made as modular as possible to allow for an exploration of different approaches to each component and their effect on the sound-synthesis system in general. Utilizing an object-oriented approach will also make it much easier to perform a characterization of each of the different components in a comprehensive manner to ensure proper functioning and understand their sonic impacts.

Additionally, physical measurements will be made recreating the original approach to capturing the longitudinal modes. Other measurements might be made in order to extend the system and the approach to understand their impact on things. This might include other parameters of the strings, such as the number of windings or linear mass density. Techniques from some of the other approaches could be experimented with, or other approaches to make it more realistic could also be explored (ie. improving the loop filter to incorporate the body effects).

Once a clearer complete synthesis model has been established, the next step would be to determine to determine the effective parameter ranges which produce musical results. After that, an attempt to characterize the best best set of synthesis parameter configurations will be made

Contributions/Summary

To summarize, a synthesis model of the slide guitar will be developed in Matlab. This model will be heavily based on the DWG model proposed by the Finnish researchers to start. Once correctness of the basic algorithm has been established, explorations will be made to see how different parametrizations/implementations of the constituent components affect the sound. Physical measurements will be made to recreate the tests done in determining the longitudinal mode frequencies. After a best model implementation and parametrization has been decided upon the parameter space will be explored to see what produces the most usable and musical results.

References

Bhanuprakash, Abhiram, et al. “A Fininte Difference Model for Articulated Slide-String Simulation.” *DAFX*, 2020, http://dafx.de/paper-archive/2020/proceedings/papers/DAFx2020_paper_68.pdf. Accessed 1 Nov. 2022.

Evangelista, Gianpaolo, and Fredrik Eckerholm. “Player–Instrument Interaction Models for Digital Waveguide Synthesis of Guitar: Touch and Collisions.” *IEEE Transactions on Audio, Speech, and Language Processing*, vol. 18, no. 4, May 2010, pp. 822–832., https://doi.org/10.1109/tasl.2009.2038822.

Evangelista, Gianpaolo. “Physical Model of the Slide Guitar: an Approach Based on Contact Forces.” Audio Engineering Society, 2012, https://www.aes.org/e-lib/. Accessed 1 Nov. 2022.

Evangelista, Gianpaolo. “Physical Model of the String-Fret Interaction.” *DAFX*, 2011, http://dafx.de/. Accessed 1 Nov. 2022.

Jaffe, David A., and Julius O. Smith. “Extensions of the Karplus-Strong Plucked-String Algorithm.” *Computer Music Journal*, vol. 7, no. 2, 1983, pp. 56–69., https://doi.org/10.2307/3680063.

Karplus, Kevin, and Alex Strong. “Digital Synthesis of Plucked-String and Drum Timbres.” *Computer Music Journal*, vol. 7, no. 2, 1983, pp. 43–55., https://doi.org/10.2307/3680062.

Pakarinen, J., et al. “Analysis of Handling Noises on Wound Strings.” *The Journal of the Acoustical Society of America*, vol. 122, no. 6, 2007, pp. EL197–EL202., https://doi.org/10.1121/1.2786607.

Pakarinen, Jyri, et al. “Virtual Slide Guitar.” *Computer Music Journal*, vol. 32, no. 3, 2008, pp. 42–54., https://doi.org/10.1162/comj.2008.32.3.42.

Penttinen, Henri, et al. “Model-Based Sound Synthesis of the Guqin.” *The Journal of the Acoustical Society of America*, vol. 120, no. 6, Jan. 2007, pp. 4052–4063., https://doi.org/10.1121/1.2360422.

Puputti, Tapio. “Real-Time Implementation of the Virtual Air Slide Guitar.” *Helsinki/Aalto University*, 2010.

Sullivan, Charles R. “Extending the Karplus-Strong Algorithm to Synthesize Electric Guitar Timbres with Distortion and Feedback.” *Computer Music Journal*, vol. 14, no. 3, 1990, pp. 26–37., https://doi.org/10.2307/3679957.