TOWARD A RULE-BASED MODEL FOR VIOLIN VIBRATO

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Abstract

Vibrato is one of the most important expressive parameters that players can control when rendering a piece of music. The simulation of vibrato, in systems for automatic music performance, is still an open problem. A mere regular periodic modulation of pitch generally yields unsatisfactory results, sounding both unnatural and mechanical. An appropriate control of vibrato rate and vibrato extent is a major requirement of a successful vibrato model. The goal of the present work was to develop a generative, rule-based model for expressive violin vibrato. Measurements of vibrato as performed by professional violinists were used for this purpose. The model generates vibrato rate and extent envelopes, which are used to control a sampled violin synthesizer.

1 Introduction

As an expressive means, vibrato plays an important role in conveying the musical interpretation to the listener. In recent research note-by-note relations between averaged vibrato rate and extent and structural aspects, such as phrasing, melodic charge and metrical stress were reported [1] [2]. This suggests that the performer varies vibrato rate and extent in a certain structured way.

This indicates the problem of vibrato generation in artificial performances. A regular modulation of pitch yields uninteresting or even irritating results. Variation of vibrato seems to be of crucial importance, but should be applied in a musically meaningful way. Because of the continuous character of vibrato, vibrato rate and extent should not only be controlled from note to note – also within note variations play an important role.

The goal of the present work was to develop a generative model for violin vibrato, which included both between and within-note properties of vibrato rate and extent. For this purpose, real violin performances were analyzed in order to design basic envelope shapes and to develop a set of generative rules. In developing the rules and envelopes we strived for simplicity, both to reduce the computational complexity and to allow for a clear overview of the model.

The model could be used to provide vibrato control envelopes for a violin synthesizer. Thus, the model could contribute to more natural sounding artificial violin performance, because appropriate control of the synthesizer can be as important as the digital instrument itself [3].

2 Data analysis

We analyzed performances of Schubert's Ave Maria by four violinists (2 professionals, 2 advanced students) used in an earlier study [2]. The recordings were made in the lab, with a microphone placed on the violin. To make the recording situation as natural as possible, the violinists were accompanied by piano. Ave Maria was selected because the character of the piece requires an expressive use of vibrato, especially on the long notes. F0 signals were extracted using an auto-correlation method. Vibrato rate and extent envelopes were obtained from these F0 signals. Sound level profiles were obtained by low-pass filtering the squared sound waves [2].

The extent envelopes could be subdivided in four parts: a non-vibrato part (delay), vibrato rise (attack), full vibrato (sustain) and vibrato decay (release). During the sustain part, vibrato extent was found to be relatively constant. However, in some instances vibrato extent was found to increase or decrease slowly during the whole note. The attack and release parts were generally found to be small time intervals of 350 and 300 ms respectively. The points, marking the separate parts, were labeled in time when it was possible to identify them clearly. These time labels were used to analyze within-note timing of vibrato. It was found that notes, shorter than 350 ms (about two vibrato cycles at 6 Hz) were mostly played without vibrato. In long notes the beginning of vibrato was generally delayed. The delay was found to increase with note length, up to 600 ms in notes longer than 1.5 s.

Vibrato rate was found to be relatively constant within notes. However, vibrato rate generally increased at note endings. This is in agreement with earlier findings by Prame [4], who reported a vibrato rate increase of 15% in the last 2-5 vibrato cycles in singing performance.

For the sound level profiles, typical shapes were observed for short notes and long notes with vibrato delay. Short, separately bowed notes generally exhibited a rapidly increasing sound level. In long notes, the sound level tended to increase during the beginning of the note until the vibrato start. This clearly indicated a coupling between sound level and extent envelopes.

Between-note relations between vibrato extent and sound level were also investigated. For this purpose the mean vibrato extent and sound level were calculated for the sustain part of a selection of long notes. Short notes were not taken in consideration, because of the absence of a sustain part. Linear fits of vibrato extent versus sound level were significant for each performance and the correlation coefficient *R* varied from 0.60 to 0.80.

3 The vibrato model

The vibrato model was developed within Director Musices, a rule-based system for generating expressive artificial music performances [5]. Director Musices applies transformations on timing, articulation and dynamics interpreting an annotated score. The user can select the rules to be applied and influence the size of their effect by changing the input parameters. Director Musices includes a set of hierarchical phrasing rules, which generate phrase arches in timing as well as in sound level.

The vibrato model calculates vibrato rate and extent in two consequent steps. First, an overall value for vibrato rate and extent is calculated for each note (note-value). Second, envelope shapes are made for each vibrato note. The overall note values are calculated by a set of rules, which modify a given standard value for vibrato rate and extent. Preprogrammed standard values for vibrato rate and extent are 6 Hz and 20 cent respectively.

In the vibrato model the *note-value* for vibrato extent depends directly on sound level. Thus, the phrasing arches, calculated for sound level, also apply to vibrato extent. Furthermore, rules were formulated for the dependence of vibrato rate and extent on melodic charge, as reported in another study [1]. In this study it was shown that both vibrato rate and extent increased with melodic charge in violin performance. The *vibrato rate envelope* consists of a constant part, followed by a tail in which the rate increases (Fig. 1 a). In the model, the increase is set to 15% over the 3 final vibrato cycles.

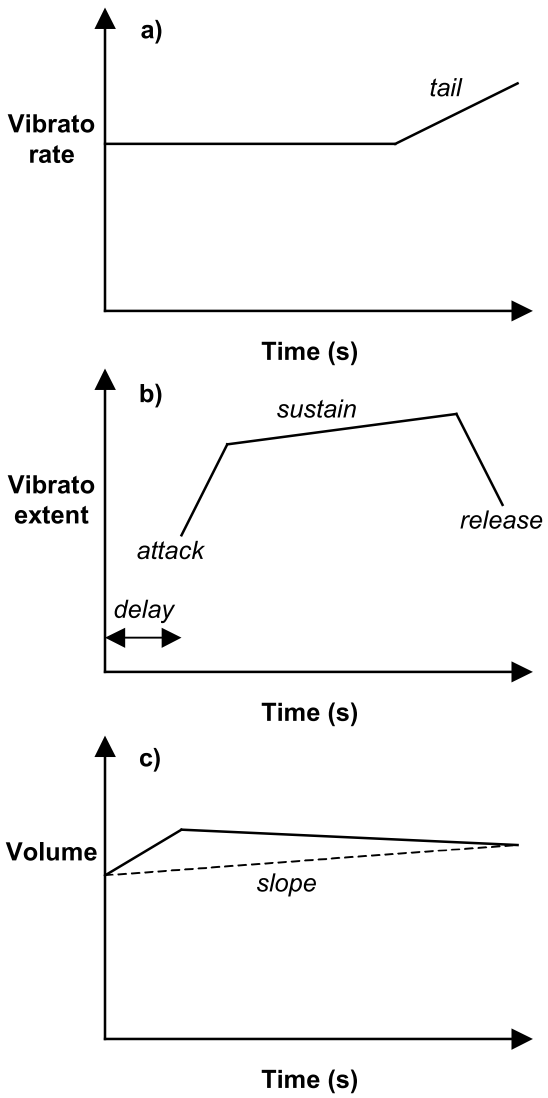

Figure 1: Basic envelope shapes in the model for vibrato rate (a), vibrato extent (b) and sound level (c).

The *vibrato extent envelope* (Fig. 1 b) is composed of a delay, attack, sustain and release part. The attack and delay parts have fixed durations of 350 ms and 300 ms respectively. The vibrato attack and release parts start and end respectively at 2/3 of the extent of the sustain part. When vibrato is absent, the extent is set to zero. The center of the sustain part is equal to the note-value for vibrato extent and the slope is coupled to the sound level envelope.

Sound level envelopes are composed of two shapes, a slope and an additional shape (Fig. 1 c). Sound level slopes are calculated for each note by interpolation of note-by-note sound level, obtained by the phrasing rules in Director Musices. The additional shapes can be subdivided in two types, one for short notes and the other for long notes with vibrato delay. For short notes, the additional shape is characterized by a sharp

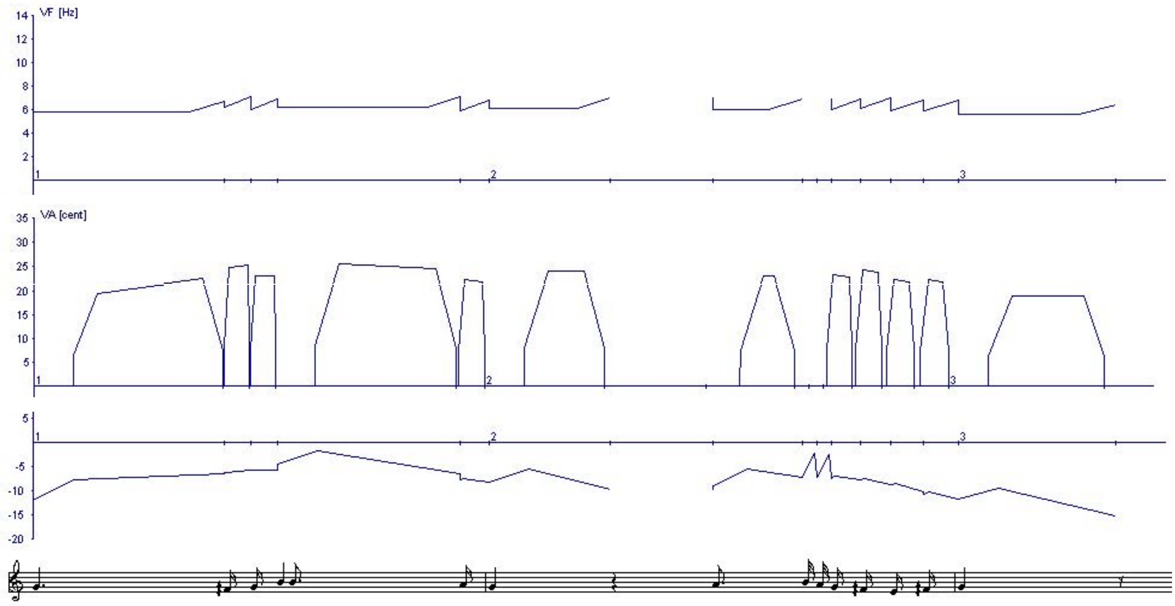

Figure 2: Vibrato rate, extent and sound level envelopes generated by DM for Schubert's Ave Maria.

increasing sound level. For long notes, the additional shape consists of two parts: the first increasing until vibrato starts and the second decreasing until the note end. The total sound level envelope is constructed by superposition of these two shapes.

4 Implementation and results

To listen to the vibrato model, a sample-based violin synthesizer was constructed in Reactor, a commercial program for the design of digital and analogue instruments [6]. For this purpose a set of steady violin tones of two seconds each was recorded. Long tones in the synthesizer are produced by looping, crossfading the beginning and the end of the loop to avoid clicks. A spectral shape filter, coupled to the sound level, was included to vary the spectral slope with dynamics. A low frequency oscillator (LFO), producing a sine wave, was used to modulate the pitch in the synthesizer. The LFO's frequency and amplitude input were controlled via MIDI by the vibrato rate and extent envelopes, generated by Director Musices. In order to make a simple approximation of spectral modulations due to vibrato, a second spectral shape filter was coupled to the output of the LFO.

As an example, a performance of Schubert's Ave Maria was rendered. The envelopes, generated by Director Musices, are shown in Fig. 2. In an informal evaluation, the model's performance was compared to a version without vibrato and a version with a constant vibrato of 6 Hz and 20 cent, which can be considered as baselines for the achievement of model. Furthermore, the measured envelopes of a real performance were used for a re-synthesized version, in order to compare the model to a real performance, without being confused by the difference in sound. The model led to a more satisfactory performance than both baseline performances, but sounded still a little mechanical, compared to the re-synthesized version.

Via the user interface in Director Musices, the user can change the standard values for vibrato rate and extent, as well as the parameters, governing the size of the effect of the individual rules. Thus, the system is flexible enough to account for different musical styles and personal preferences. On the other hand the model could lead to new insights in an analysis-by-synthesis approach, by fitting the parameters to performances.

5 Conclusions

We have developed a generative rule-based model for violin vibrato. The envelope shapes for vibrato rate and extent are abstracted from real performances, and consist of a limited number of linear parts. Note-by-note values for vibrato rate and extent are varied according to phrasing and melodic charge.

Relations have been found between vibrato extent and sound level. Note-by-note values of vibrato extent and sound level were positively correlated for long notes in the analyzed performances. On the within-note level, sound level tended to increase until vibrato started. These observations were included in the model.

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