FIRST STEPS TOWARDS MODELLING EXPRESSIVE TIMING IN GERMAN LATE ROMANTIC ORGAN MUSIC

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ABSTRACT

The present study introduces a mathematical model for the symmetric phrasing scheme of German musicologist Hugo Riemann (1849–1919). The model is used to create an artificially expressive timing pattern in Max Reger's (1873–1916) organ *Prelude* op. 135a/1 and is evaluated analytically against professional human interpretation.

1. INTRODUCTION

Quantitative research of expressive timing in musical performance on keyboard instruments has so far largely focused on the piano [1] and the harpsichord [2], whereas very little attention has been paid to the pipe organ. Few empirical studies on expressive organ performance have been published in recent decades [3-4], but they merely aim attention at J. S. Bach's work and early music, that is why the observations made are stylistically inapplicable within the late Romantic framework. This research was initiated, therefore, to create a specific model of expressive timing for the organ performance according to distinct properties of the instrument, as well as indispensable attributes of the German late Romantic style.

2. MODEL DESCRIPTION

The fundamental Riemannian theory is brought into play for this task. The starting point for the model is Riemann's motivic scheme, which shows how the short 3-notes or 2-notes initial motives–"*the smallest possible musical units of stand-alone expressive importance*"–form larger groups in the symmetric hierarchical order [5] (see Figure 1).

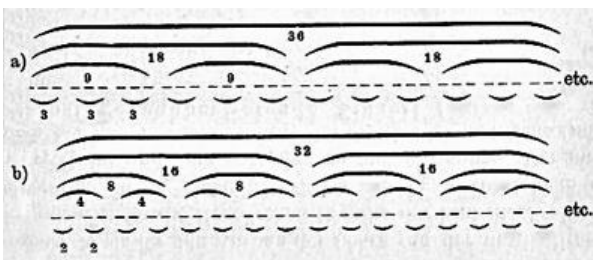

Figure 1. Riemann's motivic scheme [5].

In order to create a mathematical model of this scheme, Riemann's phrasing arcs on each level are simulated as positive semi-ellipses:

$$y_{ij} = \left(\sqrt{1-\left(x-\frac{h_{ij}}{a_{ij}}\right)^2}\right) * b_{ij} + T, \qquad (1)$$

where i denotes the number of the level; j, sequence number of the ellipse on the i^{th} level; a_{ij}, the long axe of an ellipse, corresponding to the Riemannian motivic length; h_{ij}, x-coordinate of the ellipse's center, corresponding to the middle point of each motive; T, starting metronomic tempo value (constant); b_{ij}, the short axe of the ellipse, proportional to T:

$$b_{ij} = e_{ij} * T \qquad (2)$$

The parameter e is defined as *temporal elasticity:* it shows the maximum of the model tempo deviation against the metronomic tempo for each level. If $e = e_0$ is the temporal elasticity for the global arch over the whole piece ($a_{ij} = a_0$ $= 0.5*(length\ of\ the\ piece)$), then, in the symmetric case, temporal elasticities on subsequent levels are related to the e_0 in the following way:

$$e_{ij} = e_i = 1.5 * e_0/N_{i,} \qquad (3)$$

where N_i is an overall quantity of ellipses on the i^{th} level. However, in real performance practice, the absolute symmetry is rarely kept, and some irregularities may be possible. In the more general case, temporal elasticities take values:

$$e_{ij} = k_{ij} * e_0/N_{i,} \qquad (4)$$

where the weights coefficients k_{ij} may differ both within the specific level and over all levels. Thus, the main goal of this research becomes finding parameters e_0 and e_{ij} that, on the one hand, would preserve the Riemannian idea of the built-in motivic symmetry, and on the other hand, would approximate the real performance data and therefore might be used in computer simulation of expressive timing.

3. ANALYTICAL EVALUATION OF THE SIMPLE SYMMETRIC MODEL

The model was evaluated analytically on the Max Reger's *Choral Prelude* op. 135a/1. It is a textbook example of the Riemannian scheme with the time signature of 4/4 (Figure 1, b): eight bars long, clear cadences in bars number 2, 4, 6, 8. The performance data was collected as the MIDI recording of the professional organist interpretation at the Casavant organ at The Church of Saint Andrew and Saint Paul in Montreal (Canada). Temporal information was extracted through the manual beat-mapping process in

Logic Pro X and exported to *Matlab* for further processing. The local tempo at the sixteenth-note level was calculated with *Matlab* MIDI Toolbox as:

$$T_{(n)} = 60 * \frac{b_{onset(n+1)} - b_{onset(n)}}{t_{onset(n+1)} - t_{onset(n)}}, \qquad (5)$$

where b_{onset} and t_{onset} are the onset time of note n in the score (in beats) and in the recording (in seconds), respectively. If there was no event at the sixteenth-note level, the local tempo value was interpolated and set to the local tempo of the preceding note (n-1).

The model tempo curve Y involving the global arch and 4 subsequent levels was created in *Matlab* as:

$$Y = Y_0 + \sum_{i=1}^{4}\sum_{j=1}^{N_i}\left(\sqrt{1-\left(x-\frac{h_{ij}}{a_{ij}}\right)^2}\right) * e_{ij} * T \qquad (6)$$

with the following global set-up: starting tempo of the performance data $T=27$ *bpm;* total number of sixteenth notes in the piece $S_{16}=128$; total number of note onsets $n_{chuncks}=S_{16}+1=129$; Y_0, global arch obtained from the equation (1) with center $h_0 = S_{16}/2 = 64$ and long axe $a_0 = S_{16}/2 = 64$. For the subsequent levels, the quantities of ellipses N_i on the i^{th} level are N_1=2, N_2=4, N_3=8, N_4=16. The center of the j^{th} ellipse on the i^{th} level is defined as $h_{ij} = m_k * h_0 / N_i$, where $m_k = (2*k+1),\ k \in \mathbb{Z},\ 0 \le k \le N_i - 1$, and $a_{ij} = h_0 / N_i$ denotes the long axe of the j^{th} ellipse on the i^{th} level.

An example symmetrical model curve (normalized to the mean tempo value of human performance data) with temporal elasticity values $e_0 = 0.5$ and $e_{ij} = 1.5 * e_0/N_i$ is shown in Figure 2:

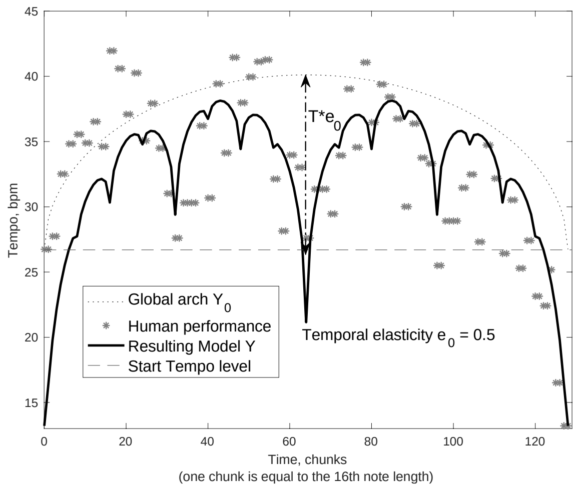

Figure 2 Mathematical model for M. Reger's op. 135a/1

The performed regression of this simple symmetric model with fixed elasticity values against the human performance data gave $R^2=0.43$ ($p<0.001$). It can be notionally compared, for example, with the results in [6], where the highest R^2 obtained for timing from the somewhat similar symmetric model was $R^2=0.299$.

4. IMPROVED SYMMETRIC MODEL

The built-in *Matlab* Nelder-Mead simplex algorithm was used to evaluate the generic model with the varying values of e_{ij}. Temporal elasticities for the model curve Y from (6) were represented as $e_{ij} = k_{ij} * e_0/N_i$, and the coefficients k_{ij} together with the global value e_0 were set as parameters to optimize for the `fminsearch` function so to minimize the distance between Y and the performance data. The obtained optimized curve Y provided a highly significant $R^2=0.816$ ($p<0.001$), which might compete with the values of the variance accounted for by a repeat human performance.

5. DISCUSSION

Despite the high value of R^2, the parameters obtained through the optimization process cannot be directly used for the simulation because they contain information about both relevant (performer's expressive intent) and irrelevant (e.g., related to the technical issues) tempo deviations. However, matching the most prominent trends in the obtained weights distribution to the music score details allowed to create a quite reliable model. For example, introducing the levels' inequality (setting levels 2 and 4 more elastic than levels 1 and 3) and boosting the temporal elasticity of the first ellipse at the second level resulted in the coefficient of determination $R^2=0.63$ ($p<0.001$). Planned research include collecting more data by analyzing the model on different short late Romantic organ pieces so to approach the automated weighting in the improved model, as well as evaluating model performance through the listening tests.

6. CONCLUSION

For the first time, the mathematical model of the Riemannian motivic scheme was created and evaluated analytically on organ music. The model has a two-fold application: it can be used in performance analysis, as well as in computer simulation of expressive timing.

7. ACKNOWLEDGEMENT

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