

The dynamics of dynamics: A model of musical expression

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In this paper, Todd presents a computational model of musical dynamics and demonstrates how this model could serve as the basis for a method of performance analysis.

The basic foundation of Todd's model lies in the observation that musical phrase structure is often expressed through a *crescendo/decrescendo* shaping. In order to model the functional form of this dynamic shaping, Todd makes two assumptions: 1. that musical dynamics are coupled to tempo (ie: the faster the louder, the slower the softer), and 2. that tempo change can be successfully modeled by the equations that govern physical movement. To support the underlying assumptions of his model, Todd cites studies by Gabrielsson (1987), Shaffer (1981), and notes that in this paper he is extending some of his own earlier models of expressive tempo variation. In addition to the two assumptions made above, he proposes that the structural importance of the given phrase affects the particular *crescendo/decrescendo* shaping chosen.

Todd begins by choosing a functional form for tempo variation within a single phrase. He connects tempo variation with the elementary mechanics of physical movement by equating metrical distance with spatial distance and tempo with velocity. Metrical distance is simply defined as temporal distance between two events in terms of the metrical unit or underlying beat of the piece. Tempo variation is then modeled as being equal to the velocity of a particle of mass m in a V-shaped potential well of length L . Todd couples musical dynamics with tempo by relating intensity with velocity through the equation $I = Kv^2$ where K is a constant. He does not provide much motivation for choosing this coupling other than that there are many physical systems in which intensity is proportional to the square of velocity.

There are essentially three parameters one can vary: the depth of the well, U , the location of the minimum, ∂ , and the x-coordinate, X . Musically, these correspond to the maximum intensity of the *crescendo*, the location of the transition from *crescendo* to *decrescendo*, and the location within the *crescendo/decrescendo* structure, respectively. In order to couple the structural importance, S , to the potential function, Todd proposes that each of the three parameters listed above be a linear function of S . By varying these linear functions, one is able to control how S affects the shape of the potential well. Todd suggests that two strategies seem to be used in performance: 1. S affects only U and therefore the maximum intensity of the *crescendo*, and 2. S affects only ∂ and therefore the temporal location of the maximum while keeping the magnitude of the maximum constant. Finally, Todd notes that the model can be applied to different levels in the hierarchy of structure, from global variation of a piece to the variation within a phrase. The final model is simply the superposition of these various structural components.

In its implementation, the various parameters of the model are estimated from actual performance data. The model is then used to synthesize a performance which is then compared to the original data using regression analysis. This cycle is repeated until the variance accounted for by the regression equals the variance accounted for by a repeat performance. When applied to a performance of Chopin, the model fit the actual performance data with $R^2 = 74\%$. It is implied that the synthesized performance sounded natural.

The paper presents a compelling idea for the modeling of musical dynamics and expression. I believe the strengths of the model lie in its relative simplicity and the control it affords the researcher in quantitatively varying the parameters of the *crescendo/decrescendo* shaping. Todd speculates that the success of the model could have several possible neurophysiological interpretations, one of which postulates that the organs of the inner ear –

which are sensitive to gravity, linear and rotational acceleration – may also be sensitive to vibrational phenomena, thus explaining the connection between perception of musical expression and physical motion. However, I would be wary of drawing any hard conclusions from this study, because postulating a link between musical expression and physical movement is merely speculation: the aural acceptability of the model does not prove the uniqueness of the underlying theory that generated the model. If Todd had used some other complex mathematical theory to derive the same relationship between intensity and tempo, would we then postulate a deep connection between that theory and musical expression? To strengthen the case for a coupling of musical expression and physical motion, further research must be done to expand the connection beyond the fact that expression based on physical motion sounds right.