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Michele Della Ventura, *editor*

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Michele Della Ventura
Editor

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Preface

This volume of proceedings from the conference provides an opportunity for readers to engage with a selection of refereed papers that were presented during the International Conference on New Music Concepts, Inspired Education and New Computer Science Generation. The reader will sample here reports of research on topics ranging from a diverse set of disciplines, including mathematical models in music, computer science, learning and conceptual change; teaching strategies, e-learning and innovative learning, neuroscience, engineering and machine learning.

This conference intended to provide a platform for those researchers in music, education, computer science and educational technology to share experiences of effectively applying cutting-edge technologies to learning and to further spark brightening prospects. It is hoped that the findings of each work presented at the conference have enlightened relevant researchers or education practitioners to create more effective learning environments.
This year we received 57 papers from 19 countries worldwide. After a rigorous review process, 24 paper were accepted for presentation or poster display at the conference, yelling an acceptance rate of 42%. All the submissions were reviewed on the basis of their significance, novelty, technical quality, and practical impact.

The Conferece featured three keynote speakers: Prof. **Giuditta Alessandrini** (Università degli Studi Roma TRE, Italy), Prof. **Renee Timmers** (The University of Sheffield, UK) and Prof. **Axel Roebel** (IRCAM Paris, France).
I would like to thank the Organizing Committee for their efforts and time spent to ensure the success of the conference. I would also like to express my gratitude to the program Committee members for their timely and helpful reviews. Last but not least, I would like to thank all the authors for they contribution in maintaining a high-quality conference and I hope in your continued support in playing a significant role in the Innovative Technologies and Learning community in the future.

March 2020

Michele Della Ventura

Conference Chair

Michele Della Ventura, Accademia Musicale Studio Musica, Treviso, Italy

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A Multidimensional Model of Music Tension

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Abstract. Tension is a high-level concept to describe the instability of music. In this article, we propose a multidimensional method to quantitatively model music tension of symbolic music in a comprehensive way. Multiple factors including melodic, harmonic, dynamics and timbral are collaborated to calculate the value of music tension. The effectiveness is examined by comparing the model's computational results with the measures of the examiners' music tension of three selected pieces of classical piano music. This examination shows that the computational result of our model is close to the experimented result of the listeners. We finally compare our model to the model of "Tension Ribbons", in which there're three methods to estimate tonal tension of symbolic music.

Keywords. music tension, multidimensional model, symbolic music, music perception

1 Introduction

It is argued by Aristonxenus (364-304 B.C.E.) that music can be understood by investigating both the musician and listener. A number of music theorists have stated that music perception is highly determined by the tension-relaxation relations of music [1-3]. Tension is one of the critical concepts of music perception. The ebb and flow of music tension is strongly correlated to a listener's experience of emotional response [4]. There is no universal agreement on the definition of music tension. Tension can be expressed as "instability" while relaxation can be considered "stability". Tension and relaxation are even correlated to "consonance and dissonance" [5].

"Increasing tension can be described as a feeling of rising intensity or impending climax, while decreasing tension can be described as a feeling of relaxation or resolution [6]." It is regarded that music is multidimensional [7]. Music tension as a psychological concept can be affected by a number of auditory and musical features including melodic expectation, harmony, dynamics and loudness [6-12].

In prior studies, different music features have been tried to model music tension. Music tension plays an important role in the emotional aspects of music perception [2], [13-17]. Quantitative studies in psychological domain are interested in the listeners' experience in the process of music listening. Empirical approaches have been used to demonstrated the relationship between the emotional responses of a group of listeners and their ratings to music tension [18, 19].

In respect of low-level music parameters, various auditory and music features are considered having contributions to listeners' music tension. Dynamics, also defined as loudness change, is one of the most important features related to music tension since it has influences on the expressiveness of music [11], [20-23]. Harmony is also a critical music feature in western tonal music. Considerable literature indicates that harmony is highly correlated to music tension [7-10], [12], [25]. Lerdahl's work which computed tonal tension with the idea of chord distance calculation has been widely applied to obtain a harmonic tension in several studies [26-28]. The melodic feature has strong contribution to music tension as well. Theorists of western classic music usually define tonal change to model the melodic expectation of music listeners. Expectation of melody as a music perception concept is often linked to the derivation of music tension [29-33]. A quantitative model is even proposed to model music tension with the computational result of melody expectation. On timbral elements, a few prior studies have looked at characteristics such roughness as well as brightness and their effect on music tension [34-36]. In Farbood's study [37], roughness, inharmonicity and spectral flatness have a strong relationship with a listener's experience of music tension. This study also implicates the potential of these parameters to model music tension in a linear combination approach.

The literature of modeling music tension in an integrated way is rare. Farbood [6] designs a temporal model to calculate music tension which takes into account a number of musical factors. However, these timbral elements are quantitatively calculated in this model. Our contribution is that we devise a multidimensional model that includes not only melodic expectation, dynamics and harmony but also the timbral factor. This is the first multidimensional model of symbolic music tension that have considered timbre as a computational element.

Firstly, we propose our linear combination model of melodic, dynamic, harmonic along with timbral elements in this article. Secondly, we have applied an examination to estimate the weights of the model. Finally, we have designed an experiment of continuous-tension task to examined that how various weights in the model affects the fitness of the computational results to the measure tension values of the 106 participants.

2 Approach

Music is multidimensional. Farbood's thesis [38] suggests that a new tension model is plausible to defined by integrating multiple independent music parameters. Our innovative model performs a linear combination on these features to obtain a multidimensional model of music tension.

The complete model is formulated by the weighted sum of four parameters. Denote each parameter with variable t and a subscription of the corresponding parameter. For instance, melodic expectation factor of tension is denoted as t_{ME}. The weights that are applied as the parameter of linear function of the formula is signed as with v with the corresponding subscription. The model is defined as:

$$T = v_{ME}t_{ME} + v_{HA}t_{HA} + v_{DY}t_{DY} + v_{TIM}t_{TIM}$$

where t_{ME}, t_{HA}, t_{DY} and t_{TIM} represent tension of melodic expectation, harmony, dynamics and timbral elements while v_{ME}, v_{HA}, v_{DY} and v_{TIM} represent the weights respectively.

Melodic Expectation

The melodic tension is derived by Margulis' model of melodic expectation [15] which extends the I-R model. The extension is the attempt to derive not only intervallic(local) expectation but also schematic(global)expectation. For this purpose, Lerdahl's tonal pitch space which can express tonal characteristic as well as intervallic characteristic is taken into account. The formula to define the expectation of tension is:

$$t_{ME} = (smp) + d$$

where s, m, p and d represent stability, mobility, proximity and direction separately. Stability is the rating of the note in the current key and chord context. In the situation of chord root, chord third & fifth, chord diatonic and chord chromatic, the corresponding stability ratings are 6, 5, 4 and 2. Mobility describes the relationship of the current note with the previous note. The mobility rating equals 2/3 if the current note repeats the previous note. In other cases, the mobility rating equals 1. The proximity represents the intervallic relation between the current note and the previous note. TABLE I shows the correspondences of proximity rating and the pitch distance in semitones:

TABLE I: CORRESPONDENCES OF PROXIMITY RATING AND THE PITCH DISTANCE IN SEMITONES.

Pitch Distance in Semitones	Proximity Rating
1	36
2	32
3	25
4	20
5	16
6	12
7	9

8	6
9	4
10	2
11	1
12	0.25
13	0.02
>14	0.01

The direction rating is a description of the relationship between the current note and the previous two notes. TABLE II shows the relationship between the direction rating and the interval size in semitones.

TABLE II: CORRESPONDENCES OF DIRECTION RATING AND THE INTERVAL SIZE IN SEMITONES.

Interval size in Semitones	Direction Rating
0	6
1	20
2	12
3	6
4	0
5	6
6	12
7	25
8	36
9	52
>=10	75

Harmonic Tension

The harmonic aspect of the model is derived from Lerdahl's work on tonal tension [39]. The harmonic tension formula is established by the distance between two adjacent chords.

$$t_{HA} = i + j + k$$

where i is the number of steps on the cycle of fifths and j is the number of moves on diatonic fifth circle. k is the number of distinguishing pitch classes in the basic space of a chord compared to those in the basic space of another chord.

Dynamics Tension

Granot's work [24] indicates that loudness change has a strong relation with the effect on music tension. Moreover, Vines' work suggests that the difference of loudness has direct link to the music tension. In our model, we build our dynamics aspect of tension with the loudness change divided by a magnitude of 128 where the loudness is obtained by the velocity of the given midi file. The formula is:

$$t_{DY} = \frac{\Delta l}{128}$$

Timbral Tension

Farbood's study shows that timbre elements including roughness, inharmonicity as well as spectral flatness are positive correlated to music tension. The computation method of roughness is the implementation of the widely used approach suggested by Sethares [40]. Firstly, the peaks of the spectrum are calculated. Then, the dissonance among spectral peaks are determined and averaged. Roughness is denoted as R in our model. Inharmonicity is an audio feature that defines the degree that partial tones are offset from the fundamental frequency.

$$I = \frac{2}{f_0} \times \frac{\sum_{n=1}^{N} |f_n - nf_0|(A_t^n)^2}{\sum_{n=1}^{N}(A_t^n)^2}$$

Spectral flatness is a measure of the similarity of a signal to white noise.

$$SFM = \frac{(\prod_{k=1}^{k} a[k])^{1/K}}{\frac{1}{K}\sum_{k=1}^{k} a[k]}$$

In Vines and Granot's study [4], [24], music tension is highly related to differential quantity. Based on this idea, the model of timbral aspect is build up as:

$$t_{TIM} = \frac{\Delta R}{max(R)} + \frac{\Delta I}{max(I)} + \frac{\Delta SFM}{max(SFM)}$$

Weights Determination

Even though each factor of music tension can be calculated explicitly, the weights of the linear combination remains unknown. An experiment has been designed to estimate the weights of the equations. One of the approaches is that: Firstly, to invite a group of participants to measure the music tension of their listening experience. Secondly, we implement a measurement for the participants of the music tension in each dimension [9]. In this way, the Euclidian distance of the points of two measurements will be applied to compute the weights of the music tension model.

Concretely, 106 participants (55 males and 51 females) were invited to listen to a music clip chosen from the first movement of Beethoven's Symphony No.1. The ages of the participants were ranged from 21 years old to 44 years old. All of the participants were non-musicians.

Fig. 1. Part of the score of Beethoven's Symphony No.1.

Prior studies of music tension measurement can be classified into two categories: continuous-tension task [11], [39], [41-43] as well as stop-tension task [24], [39], [43]. The stop-tension task is a discrete test for a participant to rate for the tension in each time step. This kind of task can normally result in relatively precise measurement. On the other hand, although the continuous-tension task is not that precise, it usually generates much denser results. Since our purpose is to find out the similarity of the model's computational tension curve and the participants' measured tension curve, we choose continuous-tension task as our method.

All of the participants were asked to do the test in the recording studio. Only one participant was tested in each round. In the examination process, the musical example was played twice. Each participant was asked to push or pull a slider on the MIDI keyboard as the controller that express the tension degree. The more the slider was moved, the higher the tension value was.

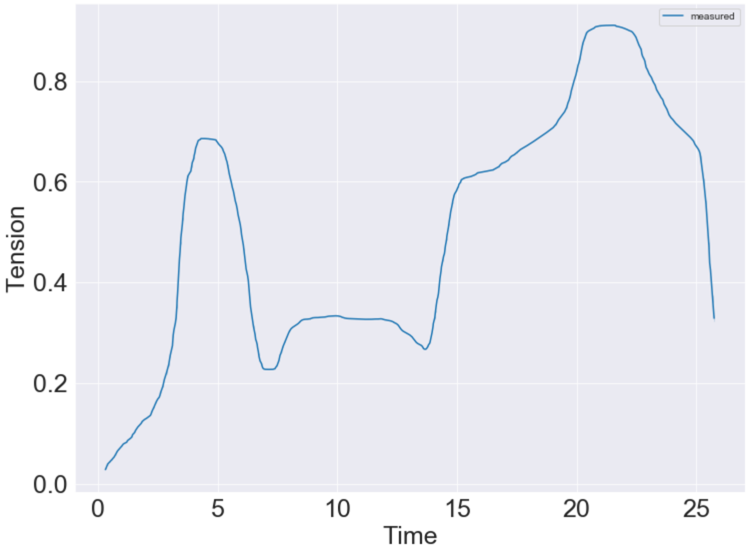


Fig. 2. Average of measured tension values of the 106 participants.

The values extracted from the MIDI slider were scaled from (0, 128) to (0, 1) and calculated the mean value to derive the continuous tension curve. The measured music tension values of each time step of the music piece are shown in Fig. 2.

For measuring the influence of each music factor to the music tension, we took the other 4 examinations by modifying the score of the first movement of Beethoven's Symphony No.1. To measure the melodic part (Fig. 3.), the melodic of the multi-voice Symphony was extracted as a piece of monody music. For the harmonic part (Fig. 4.), we extracted the chord of the score and keeping the original voicing but omitted the rhythmic components. For testing the influence of the dynamic, we kept the rhythmic element of the music only. The orchestration part was tested by changing all notes into the notes named "A4" and keeping the original orchestration.

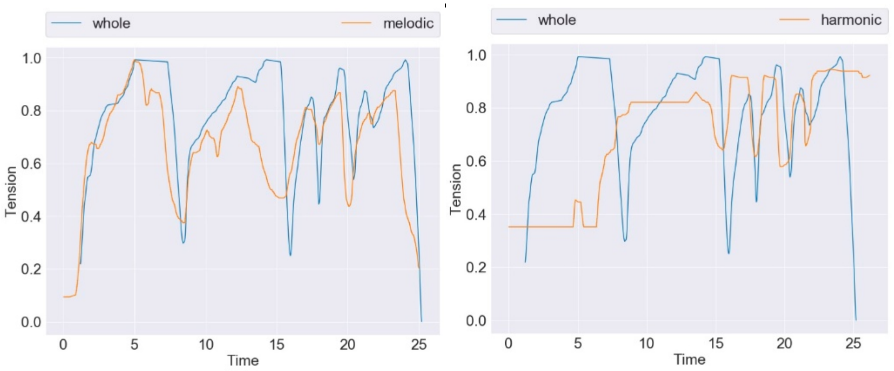
With the process, the continued music tension values of each factors of the test music piece would be derived (Fig. 5.). For computing the Euclidean distance between the music tension values of the multidimensional model and the music tension values of the single-factor model, a sampling operation were applied to obtain discrete points. For each continued measurement, 125 points were sampled for the computation of the Euclidean distances between the multidimensional model and the model of one of the melodic, harmonic, dynamic and timbral factors. The resulted distances were 4.603, 7.938, 5.778, 7.684 for melodic, harmonic, dynamic and timbral separately. With a normalization process, the weights for each component are shown in Table. III.

TABLE III: WEIGHT FOR EACH FACTOR.

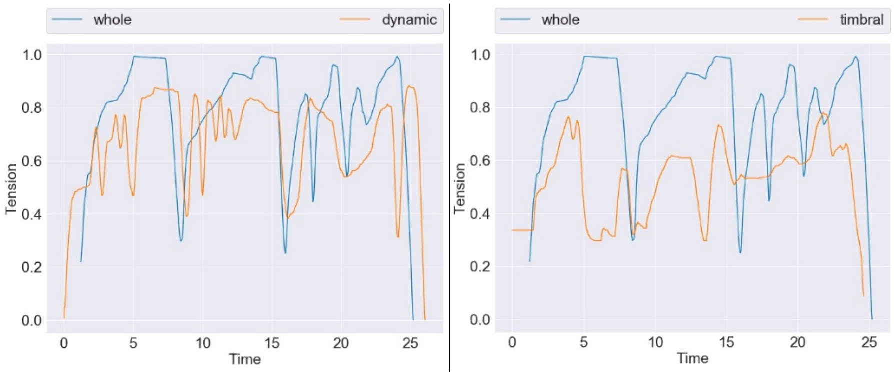
Weight for	Weight value
Melodic	0.177
Harmonic	0.305
Dynamic	0.222
Timbral	0.296

Fig. 3. Example of score to examine the influence of melodic factor.

Fig. 4. Example of score to examine the influence of harmonic factor.



(a) Tension of melodic factor (b) Tension of harmonic factor



(c) Tension of dynamic factor (d) Tension of timbral factor

Fig. 5. Music tension of each musical factor.

3 Evaluation

Since the weights have been derived from the test, we would be able to calculate the multidimensional music tension for a given symbolic music piece. To evaluate our model, we would compare our model to the work that calculating tonal tension based on spiral array [25]. Three quantities of this work including cloud diameter, cloud momentum as well as tensile strain have been computed on music pieces of Wagner's Tristan Prelude (Fig. 6.), Beethoven's Sonata Op. 31 No.3. (Fig. 7.) and Beethoven's Sonata OP 81a (Fig. 8.).

In music pieces of Wagner's Tristan Prelude and Beethoven's Sonata Op. 31 No.3., the results of the cloud diameter as well as cloud momentum have a similar tendency to the results of our model (Fig. 9. & Fig. 10.). However, in music pieces of Beethoven's Sonata OP 81a, the tensile strain values are closer to the results of our model.

Fig. 6. Part of Wager’s Tristan Prelude.

Fig. 7. Part of Beethoven’s Sonata Op. 31 No.3.

Fig. 8. Part of Beethoven’s Sonata Op. 81a.

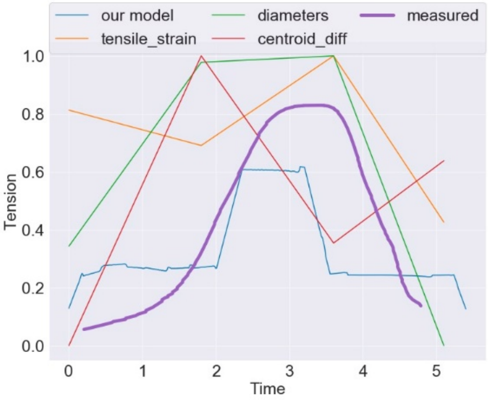


Fig. 9. Tensions of Wager's Tristan Prelude.

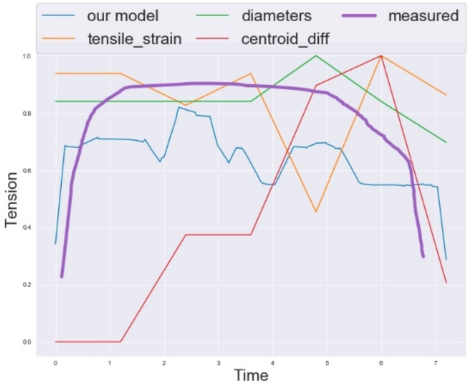


Fig. 10. Tensions of Beethoven's Sonata Op. 31 No.3.

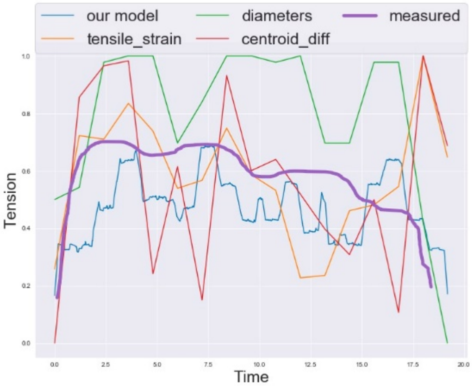


Fig. 11. Tensions of Beethoven's Sonata Op. 81a.

4 Conclusion

As a progress of the prior studies, we have innovatively proposed a multidimensional model comprising melodic, harmonic, dynamics and timbral components to calculate music tension quantitatively. From the prior studies, we have built up the model as a weighted sum model to estimate music tension. For deriving the weights of the weighted sum equation, we have taken a listening test on Beethoven's Symphony No.1 for obtaining weight for each factor. Finally, our model has been compared with the other three tonal tension methods. The comparison results show that in these three methods, the tensile strain method is closest to our modeling result when the music piece has denser notes. However, our model still better fits the results examined by 106 participants of a listening test.

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Michele Della Ventura, editor

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