JOURNAL OF Music RESEARCH ONLINE

A JOURNAL OF MUSICAUSTRALIA

Seeing Carlos Kleiber's Vocalised Intentions through the Pitch-Dynamics Motion Microscope

GERALD MOSHAMMER

Mahidol University International College
999 Phutthamonthon 4 Road
Salaya, Nakhonpathom
Thailand 73170

gerald.moshammer@gmail.com

JMRO
www.jmro.org.au

www.musicaustralia.org.au

Introduction

Music moves — in itself and us, performers and listeners alike. In contemporary music research, however, motion appears a secondary notion, hardly addressed directly and considered merely a metaphorical phenomenon (see the discussions in Clarke 2001, Budd 2003, Scruton 2004, Zangwill 2010). Indeed, it appears that if ecological validity is taken seriously, musical motion can only be addressed as a derivative, mainly generated through expressive timing (Repp 1989, 1995, Todd 1995, Honing 2005), mirrored in bodily movement such as performance gestures (Gritten and King 2006, 2011, Schutz 2008, Platz and Kopiez 2012), and possibly corresponding to global features such as tension (Farbood 2012). Curiously, expressive fine-tuning and motional sourcing are rather abandoned phenomena in current scholarship on musical emotions, although on its own the motion of a single sound object is able to express animacy (Nielsen, Vuust and Wallentin 2015) and an isolated tone can allude to basic types of human locomotion through dynamic shaping (Friberg, Sundberg and Frydén 2000). Juslin (2013), for instance, integrates his highly differentiated account of emotional responses to music, the so-called BRECVEM model, into a finalising category called aesthetic judgement, which also implicitly underlines the model's inclusiveness, yet without addressing musical motion *per se*.

In this article, I provide evidence for a novel and autonomous acoustic basis of musical motion and its expressive idiosyncrasies. By means of what I call the Pitch-Dynamics Motion Microscope (PDMM), animation software created in order to facilitate my argument, I address the expressive vocalising of musical intentions, i.e. the occurrence of continuous pitch trajectories in tandem with dynamic shaping. The resulting motion blueprints do not only provide evidence that intrinsic musical movement is irreducible to solely temporal parameters. Furthermore, the modelling presented hints at an isolated role for discrete tonality in the aesthetic functioning of genuine melodic movement that research on that topic does not address.

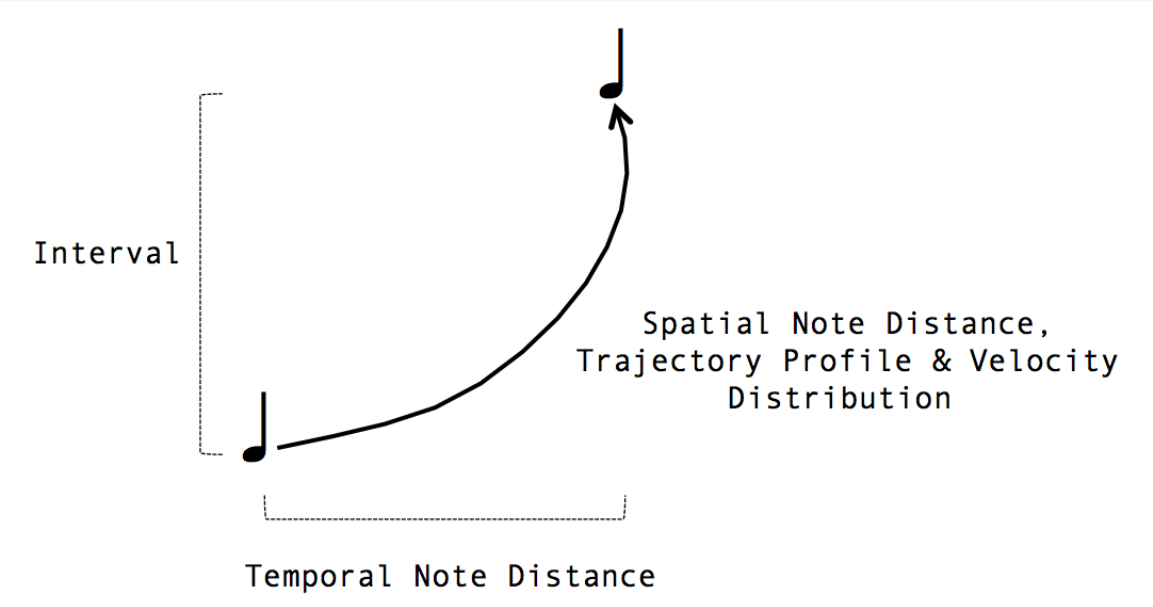
The introduction of PDMM is motivated by a paradoxical hypothesis that underpins the idea of abstract score animation in Moshammer (2012). There, I suggested that, when music's pulse slows, its motion could still accelerate. To posit that musical motion is not a function of solely temporal parameters shifts constitutive power to contours of

pitch, dynamics and timbre in the determination of sonic movement. Note that this is the main challenge of a theory of musical motion: to show or precisely outline how a particular stretch of music is supposed to move. Yet, what makes this task aesthetically fruitful equally creates an obstacle. Pitch transition and articulation that are not legato make music intrinsically discrete, while motion is essentially continuous. In a straightforward mapping of musical motion onto Euclidean space, for instance, spatial note distance appears to be a free-standing variable that is not acoustic. Subsequently, from the perspective of visual simulation, musical motion involves spatial intentionality concerning continuous trajectory profiles that bridge the gap between two subsequent notes, as well as velocity distribution along such paths (see Fig. 1). The bigger the temporal gap between two notes in a motion sequence or the longer the note values involved, the more space opens up for motion interpretation. In fast passages that demand expressive timing, say Chopin's idiosyncratic, ornate embellishments, motion imaging is more directly bound to acoustic input. PDMM, however, is not primarily designed to visually simulate such scenarios and would need further development to yield useful demonstrations of more complex motion formations. It rather should serve as a visual lens through which one can see brief acoustic simulations in a continuous pitch space that reinterprets and enriches melodic elements of discrete tonality. The acoustic formulation of motion trajectories is especially characteristic in the vocalising of aesthetic intentions during musical practice, notably instrumental teaching and rehearsing. In my view, vocalised sketches of performance intentions provide the most striking empirical evidence for a variable expressive space between discrete tones in informed music performance and perception, whose synaesthetic motion properties are otherwise difficult to grasp. Thus, PDMM's main purpose is to objectify a usually unseen and inaccessible continuous space of musical expressivity.

One could argue that gestural analysis of bodily movement, say by conductors or instrumentalists, is ecologically the most valid method to pick up the suggested spatial intentionality of musical motion. Such an approach, however, is problematic on many fronts (see Moshammer 2012). In the context of the present paper, let me particularly highlight that not only rhythm (see Repp and Penel 2004) but also motion should be considered more definite and differentiated in hearing than in vision, which would provide evidence against bodily movement being the main basis of how one conceives motion in music. This thesis, however, needs some scrutiny. Rhythm is a discrete phenomenon based on temporal structure, which, for the human perceptual apparatus, sound is able to represent more precisely than light. Since musical motion is a continuous phenomenon that crucially plays out between notes, actual physical movement of performers and listeners indeed constitutes a telling source for the understanding of music's expressivity. Note that visual information can influence music perception, which, for instance, the so-called Schutz-Lipscomb illusion stipulates in relation to note duration (see Schutz and Kubovy 2009 for a discussion). It is evident that music may correspond to performance gestures as well as, more broadly, diverse forms of locomotion and ecological movement. Yet, as PDMM aims to demonstrate, musical imagination as to motion must be considered autonomous due to its accuracy and unmatched potential to produce minimalistic yet meaningful expressive distinctions through sonic movement.

In Moshammer (2012), I discuss music animation as a form of analog simulation, similar to that which can be found in the natural sciences. The merits of continuous visual trajectories in abstract score animation are, with reference to discrete pitch contours, evident. One simply has to be able to generate and differentiate concrete pathways of continuous movement in order to make the notion of musical motion meaningful. There is, however, no algorithmic solution in sight that, with at least some degree of versatility, could transform, say, MIDI data into meaningful visual motion trajectories. Hands-on animation of musical movement, in contrast, is not only time-consuming but also rather speculative without genuine empirical rooting. While this paper offers a method that counters these shortcomings, one might question whether it is actually necessary to implicate animation when acoustic data alone can prove that musicians involve continuous pitch contours in their vocalising of performance intentions. If only the legitimatisation of musical motion as a valid notion for theories of expressivity was at stake, this would indeed be a valid objection. In order to find out, however, exactly what motion contributes to the aesthetic functioning of music, its visual simulation provides a powerful medium through the creation of an observable moving entity. Since, at present, there is simply no satisfying theoretical model of musical motion, the immediacy of an analog moving image appears to me necessary for the researcher in order to form a proper hypothesis about music's expressive movement. Only such an approach, I believe, will convince sceptics that it is indeed aesthetically relevant to ask whether a particular musical sequence moves as an agent or rather as a passive object under the regime of kinematics. Further, a versatile visual interface for musical motion would certainly be useful in music pedagogy as well as allowing for innovative experimental designs in cognitive science and music psychology.

Figure 1. Spatial distance and velocity distribution as autonomous parameters in the shaping of musical motion



In order to demonstrate PDMM's subtle level of motion analysis, this introductory paper is based on four simple tonal sequences: firstly, a couple of tones that change mainly in timbre, and secondly, two vocalisations that the legendary conductor, Carlos Kleiber, employed during rehearsal work. I shall analyse and discuss these samples after a brief description of PDMM's technical *modus operandi*.

How PDMM Works and What it Does

PDMM extracts fundamental frequency from sound files through a probabilistic version of the YIN algorithm (see Mauch and Dixon 2014). More specifically, it utilises *Sonic Visualiser's* 'pYin Smoothed Pitch Track' plug-in (see www.sonicvisualiser.org), which generates fundamental frequency at sample points that are approximately 5.8 milliseconds apart. Further, PDMM builds upon the *scipy.io.wavefile.read* function that allows for a mapping of continuous sound pressure values to integer values (see www.scipy.org). The current version of PDMM does not calculate the quadratic mean of the amplitude data imported through *scipy.io* for each frequency value identified by pYin. Rather, all amplitude data, ignoring signs, are averaged and assigned to the respective frequency entries. This simplified procedure ultimately generates a satisfying visual approximation to the acoustic profile. Note that PDMM is an audio-visual animation tool that focuses on frequency trajectories and their timing. In relation to the brief motion trajectories PDMM displays, dynamic change is important merely as a relative direction indicator (moving forward as opposed to moving backwards, for instance). The degrees to which different algorithmic models of amplitude affect the audio-visual animation of dynamics remains an interesting question. The current paper, however, does not consider this area in any detail.

PDMM allows its user to choose diverse degrees of Gaussian smoothing of the raw data. The result of this process is displayed in two overlapping graphs, with the raw data in red and the smoothed trajectory in blue. For both the frequency and amplitude graphs the x-axis signifies the number of sample data points, as gathered by the pYin algorithm. Concerning these sample points, the y-axes display fundamental frequency and amplitude magnitudes respectively. The targeted data trajectory is finally converted into JavaScript Object Notation (JSON) for the purpose of animated visualisation which is facilitated by GreenSock (see www.greensock.com).

PDMM's basic symbol is a circle, the vertical positioning of which follows the fundamental frequency, while its radius alters according to amplitude. Throughout, PDMM visualisations follow linear scaling, which PDMM automatically calculates in relation to pitch distribution in proportion to screen space, whereas the circle's initial measurement as to amplitude can be selected. Linear scaling, in contrast to logarithmic scaling, is adopted because the analysed sound samples are all playing out within the rather narrow interval of a ninth. PDMM

uses five circles that form a line ordered from right to left that moves up and down according to frequency. The circle on the right displays the current time window and those further left the previous ones. Such a procedure has the advantage of giving the movement a body.

PDMM enables instant animations that are isomorphic to the acoustic microstructure of the analysed sound objects, which goes significantly further than expressive modelling in a mere tempo-loudness space as proposed by Langner and Goebl (2003). There are obvious constraints: PDMM cannot incorporate the specificity of timbre and only addresses this parameter indirectly (see the following section). Furthermore, the software is restricted to monophonic tonal sequences and has merit only in the analysis of legato passages. As demonstrated in Moshammer (2012), articulation that is not legato, particularly a staccato, can portray motion forms such as jumps and dives, which PDMM is unable to generate. To the best of my knowledge, however, there is no algorithm-based music visualiser that goes beyond discrete pitch structure, which is usually derived from MIDI data. PDMM, by contrast, has the novel ability to capture the vibrancy of natural voices and continuous pitch instruments.

The Motional Drama of a Single Tone

In order to introduce PDMM, this section analyses two singular tones that fluctuate around 439 Hertz with marginally changing amplitude profiles and abrupt changes in timbre.

Sound Sample 1. A single noisy tone that fluctuates around 439 Hertz and changes dynamically within a small range, yet alters its timbre.

Sound Sample 2. A single organ tone that fluctuates around 439 Hertz and changes dynamically within a small range, and yet alters its timbre.

Figure 2. Frequency and amplitude data for Sound Sample 1 without smoothing

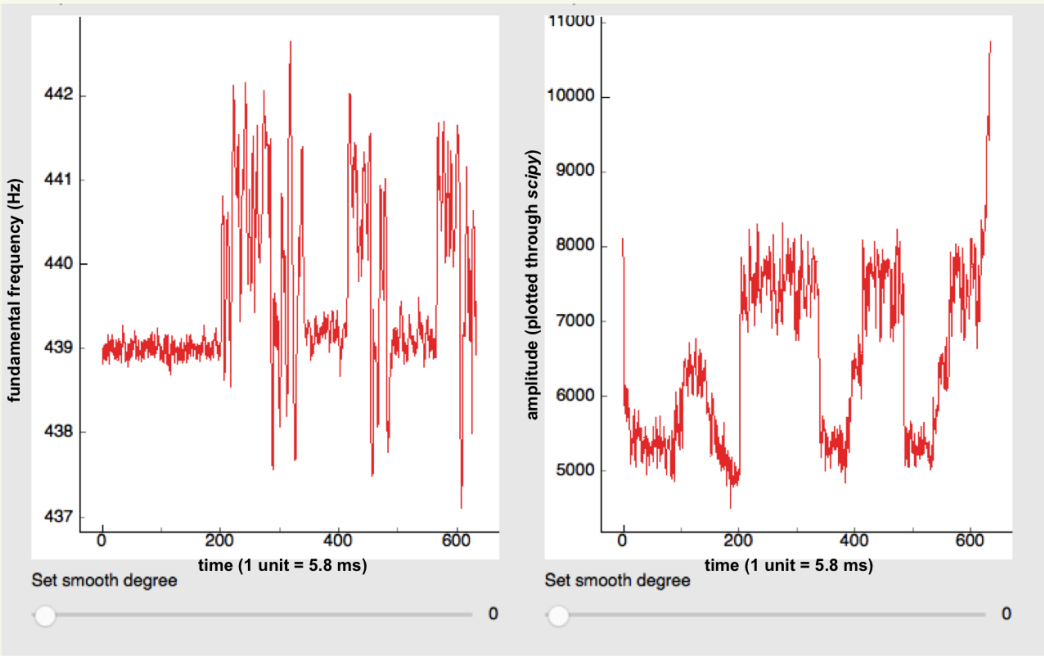


Figure 3. Frequency and amplitude data for Sound Sample 1 with a high degree of smoothing of the former

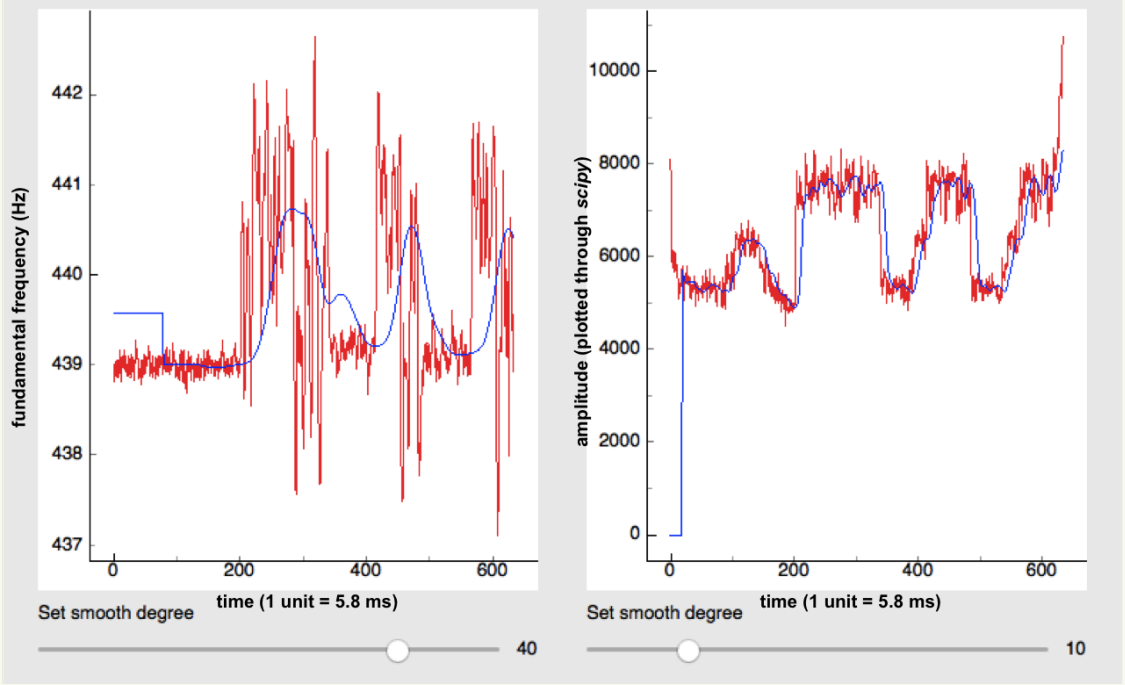


Figure 4. Frequency and amplitude data for Sound Sample 2 with a high degree of smoothing

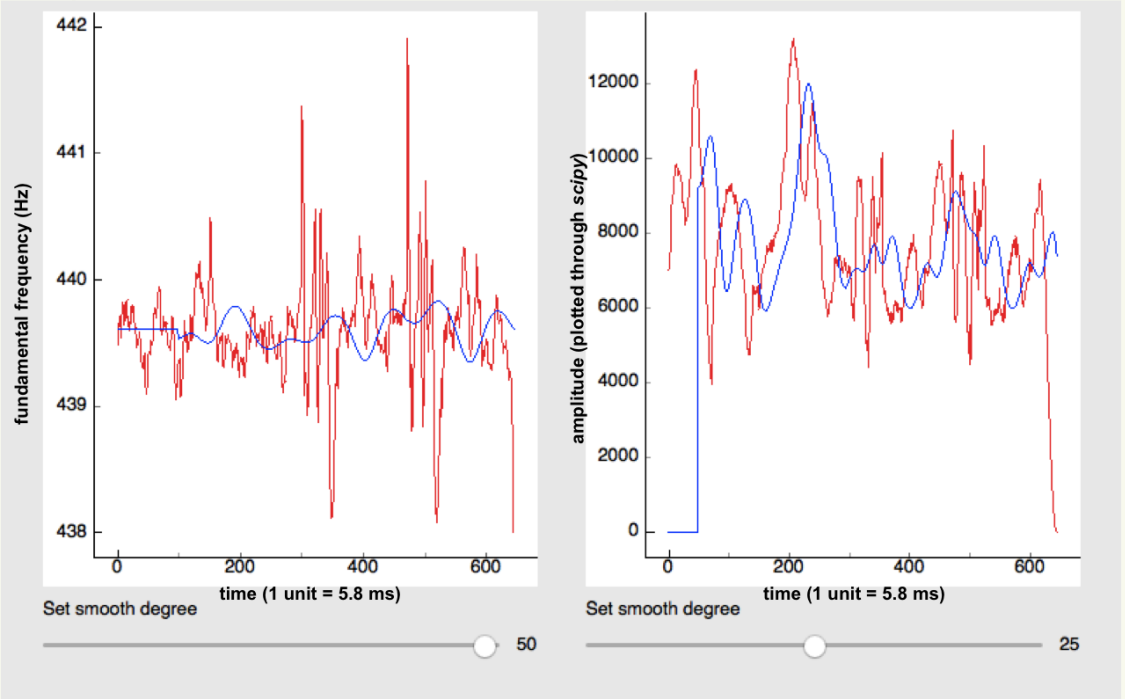


Table 1. Descriptions of PDMM Animations A–D (see Moving Image 1), based on Sound Samples 1 and 2

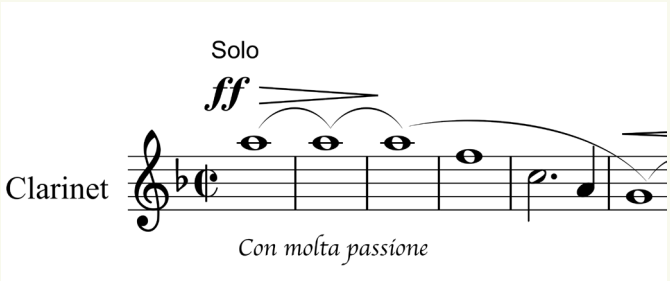
Figure	Animation	Acoustic Source	Audiovisual Smoothing		Animation Characteristics
			Frequency	Amplitude	
2	A	Sound Sample 1	None	None	High degree of audio-visual fluctuation which is mainly based on spectrum and envelope changes.
3	B		High	Low	Emergence of a trajectory through smoothing of the detailed frequency data. This example already highlights two of PDMM's main features: first, through continuous and directed analog visualisation the tone turns into an energised contour with non-linear velocity distribution; second, the tone's motion formation is not only visible in isolation, but its movement appears zoomed-in and is subsequently perceivable in its microstructure.
4	C	Sound Sample 2	None and High in comparison (split screen)	None and Medium in comparison (split screen)	This animation exemplifies the aforementioned contrast between fluctuation pattern (black background in split screen animation) and directed trajectory (white background) through raw data smoothing in direct comparison. Here Sound Sample 2 exhibits an even richer motion microstructure than Sound Sample 1.
3 and 4	D		High	Low and Medium (split screen)	Although the sound samples from this section follow similar patterns of timbre change, their differences in rhythm and accentuation lead to substantially heterogeneous motion formations, highlighted by the contrast between the original trajectory for Sound Sample 2 (white background in split screen animation) with the mismatched trajectory taken from Sound Sample 1 (Fig. 3, black background).

Figures. 1, 2 and 3 display respective frequency and dynamic progressions of the sound samples used in this section, forming the basis for the correlated animations A–D, which are presented in Moving Image 1. For the creation of a defined motion path, Gaussian smoothing is applied, the degree and result of which is shown in the respective figures. Animation details and major motion characteristics of the chosen modes of analysis are described in Table 1.

Moving Image 1. Animations A–D based on Sound Samples 1 and 2 (see Table 1 for details).

Moving Image 2. Animations E–H based on Sound Samples 3 and 4 (see Table 2 for details).

Figure 5. Score excerpt from the Overture to *Der Freischütz,* bars 66–71



Two Vocalisations by Carlos Kleiber

Carlos Kleiber rehearsed Carl Maria von Weber's Overture to *Der Freischütz* and Johann Strauss' Overture to *Die Fledermaus* with the *Radio-Sinfonieorchester Stuttgart* in 1970. Like other conductors, instrumentalists and music instructors, Kleiber uses his voice to simulate his musical intentions for the orchestra. Such sketches of musical intention are fruitful targets for the analysis of motion and expressivity in music. In what follows, I apply PDMM to two passages: firstly, bars 66–71 from the Overture to *Der Freischütz.*

In the course of my analysis, this example is compared to a slightly modified version of Kleiber's original (see Table 2 for details). Here, a part of the source file was cut out in the sound editing program, *Audacity* (www.audacityteam.org), in order to generate a more abrupt transition from the first to the second note in Fig. 5. The second passage under scrutiny in this section concerns bars 102–3 from the Overture to *Die Fledermaus.* Sound Sample 5 at reduced speed, which was created using *Audacity's* 'change tempo' function, is also used. Figures 6–10 provide an overview as to the acoustic features of the analysed sound samples, which are explained in Table 2 and sequentially animated in the Moving Image 2 and Moving Image 3.

Sound Sample 3. Carlos Kleiber's vocalisation of the clarinet part from the overture to Der Freischütz, bars 66-71.

Sound Sample 4. Modified Sound Sample 3, with deletion of the frequency continuum between the first two notes.

Sound Sample 5. Carlos Kleiber's vocalisation of the oboe part from the Overture to *Die Fledermaus,* bars 102–3.

Sound Sample 6. Sound Sample 5 reduced to 20% its original speed.

Moving Image 3. Animations I and J, based on Sound Samples 5 and 6 (see Table 2 for details).

Figure 6. Score excerpt from the Overture to *Die Fledermaus,* bars 102–3

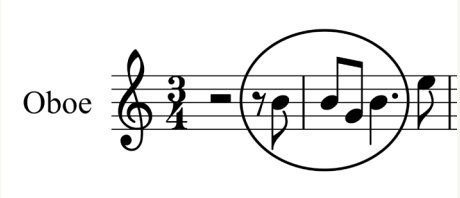


Figure 7. Frequency and amplitude data for Sound Sample 3 with no smoothing and focus on the significant pitch continuum

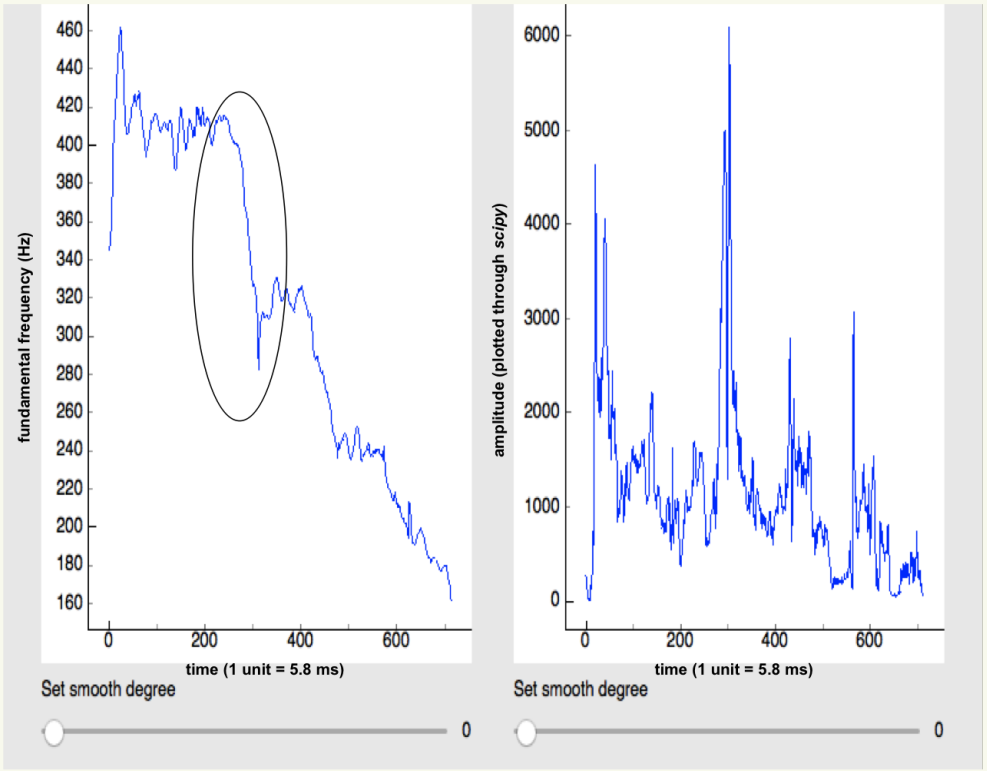


Figure 8. Frequency and amplitude data for Sound Sample 3 with a modest degree of smoothing

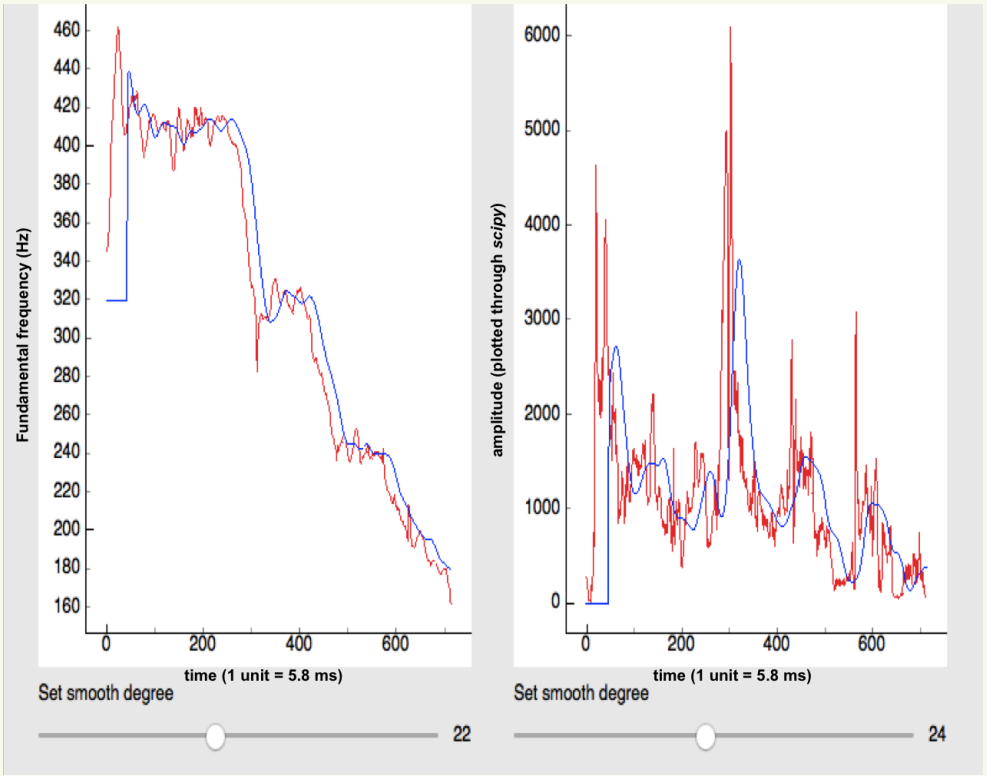


Figure 9. Frequency and amplitude data for Sound Sample 4 with a modest degree of smoothing and a focus on the frequency switch between the first two notes which is cleaner than that in Fig. 6

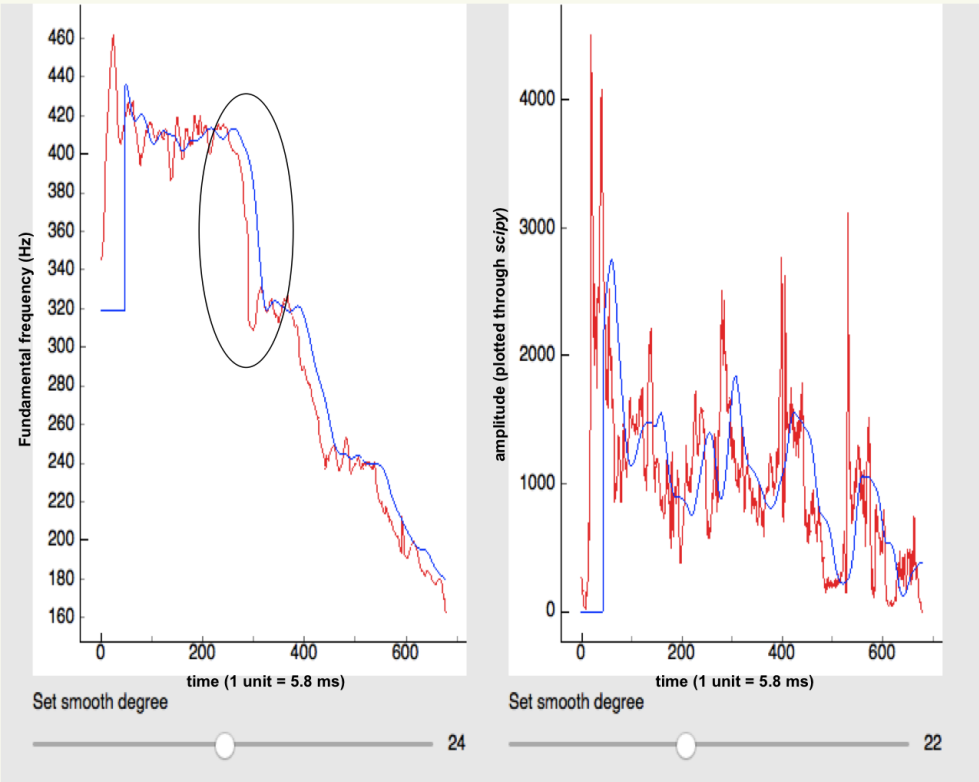


Figure 10. Frequency and amplitude data for Sound Sample 5 with a modest degree of smoothing

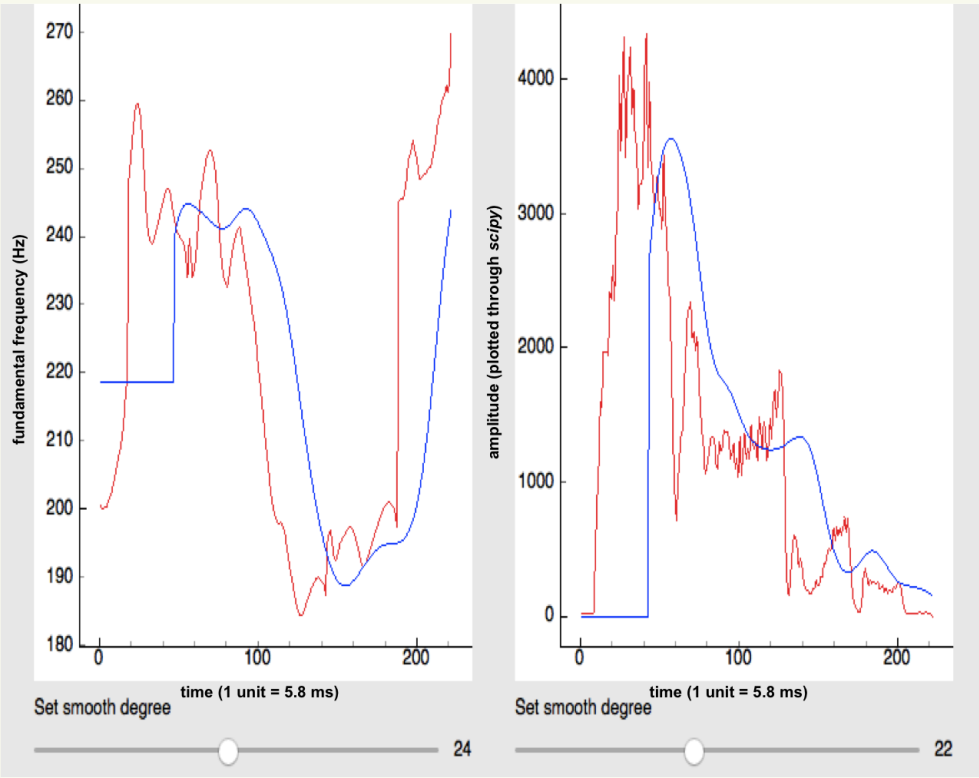


Figure 11. Frequency and amplitude data for Sound Sample 6 with a modest degree of smoothing

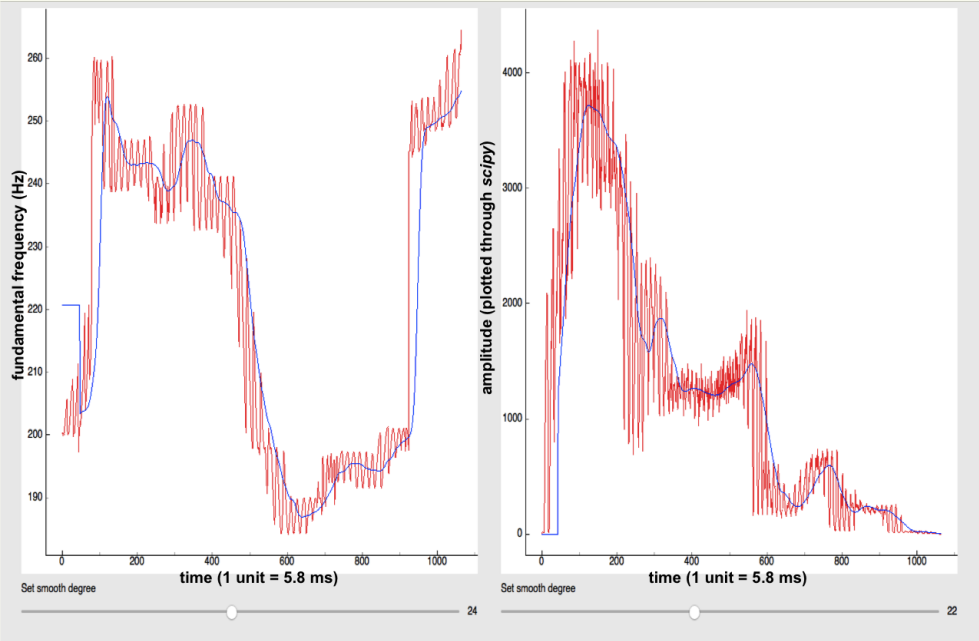
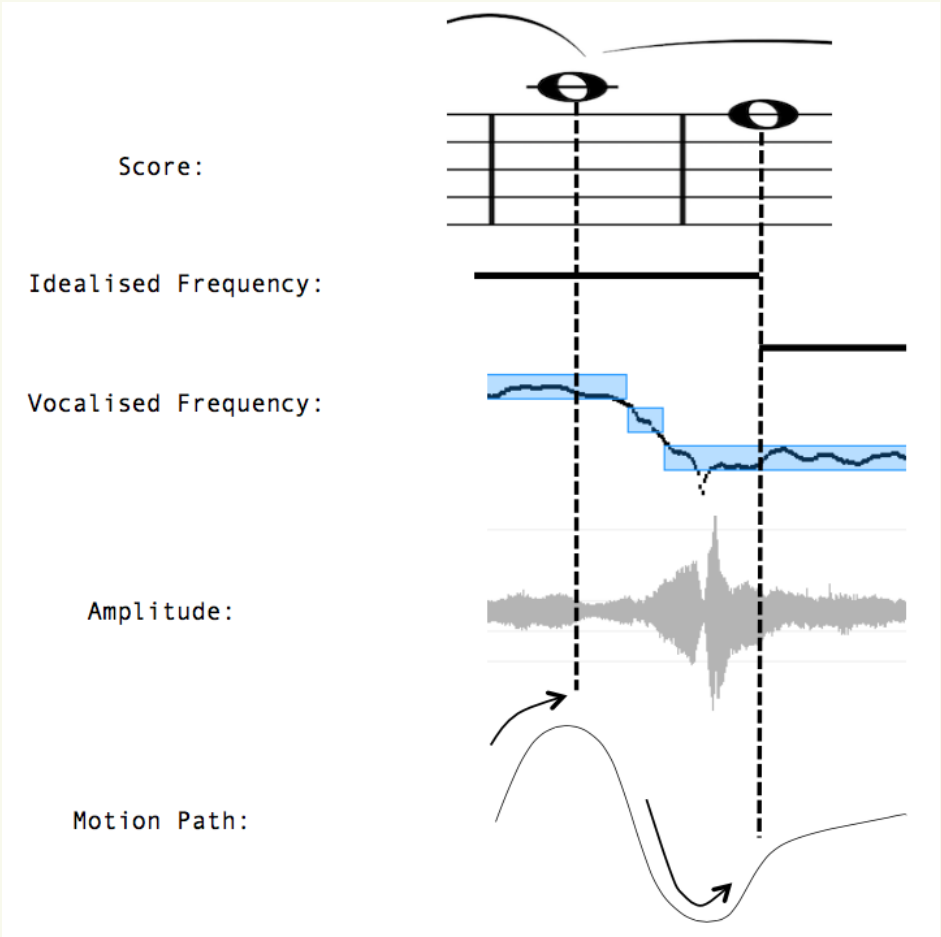


Figure 12. Idiosyncratic frequency and amplitude data in Kleiber's vocalised bridge between the first and second note of Sound Sample 3 (from *Der Freischütz)* and a possible corresponding motional trajectory



Discussion

Figure 12 highlights that, in his *Freischütz* vocalisation of the legato between the A and the F (see Fig. 5), Kleiber employs rich continuity in pitch as a carrier for dynamic shaping. Similarly, Animation I indicates Kleiber's frequency lift in order to emphasise and put tension on the first beat of bar 103 in the oboe part from the Overture to *Die Fledermaus*. Although such instances of continuous shaping won't surprise anyone who has actually modelled a motif or melody with their own voice for instructional purposes, musicological scholarship does not seem to acknowledge this idiosyncrasy. Note that it is impossible for a clarinet or oboe that is played without glissando to copy Kleiber's vocalisation of the respective target passages. Strictly spoken, a legato between two distinct notes should be visualised as a pair of spatially disconnected events, where the second starts when the first stops. Yet, if it is assumed that a legato phrase can be perceived as continuous motion in the sense of Kleiber's vocalisations, then possible 'motion bridges' connecting separate notes are rather puzzling.

Firstly, one could not just correct Kleiber's intonation and project his dynamic shaping into the notes as they stand. For instance, with reference to Fig. 12, playing the A cleanly, yet with the same dynamic hump as in Kleiber's actual continuous pitch trajectory, would create a motional effect on the A itself, but not in the transition from the A to the F.

Secondly, if one can indeed 'hear' Kleiber's motion image within the interval of a major third that is neatly intonated and played legato, then any realistic perception of note duration in such contexts is fundamentally challenged. As indicated in Fig. 12 in terms of idealised frequency, the clarinet, for instance, has to play the A until the F starts in order to allow legato perception. Subsequently, perceiving this connection as motion similar to that given in Kleiber's vocalised frequency would have to result in the perceptual shortening of the A's actual acoustic duration and, probably, also an acoustically unrealistic delay of the F's beginning.

Thirdly, as Sound Sample 4 and the respective animation sector G demonstrate, the original acoustic motion seems still present, at least to a certain degree, when Kleiber's 'frequency valley' is cut out from his imaging of the concerned clarinet passage from *Der Freischütz*. The perceived difference between the two versions (Sound Samples 3 and 4) could subsequently be seen as less significant than what animation H is suggesting. However, the difficult *gestalt* theoretical question here is whether Sound Sample 3 is actually only an exaggeration of Sound Sample 4, or whether the latter, particularly through the still prevalent accentuation of the F in this sequence, has enough acoustic resources in order to produce an audible impression of the motion image that actually only the former clearly marks.

Fourthly, musical motion, being closely linked to the phenomena of tension and release, can establish subjective, active gestures in contrast to kinematic, passive movement, as noted with regard to Animation J in Table 2 (see Moshammer 2012 for a more detailed discussion). The suggested motion form in Fig. 12, for instance, interprets Kleiber's vocalisation as pushing and holding up the A ('potential energy'), before being released into a natural fall ('kinetic energy') that leads to a slight upward motion towards the F. A similar scenario seems to play out with regard to the analysed *Fledermaus* passage. Here the motion trajectory is not added into the space between two notes, but more directly shaped by the turn B–G–B (see the score excerpt in Fig. 5 and the corresponding Animation I), where the B preceding the G is storing potential energy, before being released. However, as Animation J particularly instantiates, Kleiber counters gravity at this point for the sake of motional expressivity. What seems to matter in such cases is not the motion type alone, but its particular aesthetic implementation. According to Kleiber's verbal instructions, the *Freischütz* passage should express desperation (note Kleiber's onomatopoeic imitation of a scream with the initial A), while the *Fledermaus* motif is supposed to indicate a kind of hyperbolic whispering. This suggests a close link between the individuation of musical emotions and motional fine-tuning and is another indicator that any straightforward algorithmic motion modelling based on discrete data in relation to isolated musical parameters should be deemed aesthetically unfaithful.

In contrast to a rather immediate impact of timbre on motion and rhythm perception, as portrayed in the section entitled 'The Motional Drama of a Single Tone', melodic characteristics must be considered highly mediated (i.e. culturally acquainted) contributors to the precise motional imaging of music, such as in differentiations between pastoral, satiric, comedic, heroic, elegiac, and tragic character

Table 2. Descriptions of PDMM Animations E-J (see the Moving Image 2 and Moving Image 3), based on Sound Samples 3, 4 and 5

Figure	Example	Acoustic Source	Audiovisual Smoothing		Animation Characteristics
			Frequency	Amplitude	
7	E	Carlos Kleiber's Freischütz sample (Sound Sample 3).	None	None	The animation in slow motion (25%, without sound) demonstrates Kleiber's musical imaging through the resulting continuously valued and dynamically fluctuating frequency trajectory, particularly between the first two notes.
8	F		High	High	The smoothed animated version turns Kleiber's energetic turn between the first and second note into an eruptive jump.
9	G	Sound Sample 3 with deleted 'frequency valley' (Sound Sample 4)	Modest	Modest	Having cut out Kleiber's frequency valley between the first two notes, the animation plays out as a rather balanced progression downwards, although there is still urgency and acceleration between the first two notes visible.
(8 and 9 animated in split screen)	H	(The two preceding sources.)	Example F and G in split screen		The comparison between the previous two acoustic sources (Fig. 7, the original and Fig. 9, modified) clearly demonstrates Kleiber's vivid acceleration in his original connection of the first two notes in the passage concerned.
10	I	Carlos Kleiber's Fledermaus sample (Sound Sample 5).	Modest	Modest	The most significant feature in this animation is the emphasis on and holding of the first note in bar 103 (second B), which is followed by a fall to the G that subsequently bounces back to the third B in this sequence.
11	J	Carlos Kleiber's Fledermaus sample, reduced to a speed of 20%.	Modest	Modest	This slow motion animation shows that Kleiber employs a frequency lift in order to emphasise the passage's second note (the first beat of bar 103). More importantly, in this slowed down analog visual simulation one can immediately sense, even when the sound is muted, that, in gliding down to the motif's valley, Kleiber is not adhering to the kinematics of ecological physics. On the contrary, he 'counters gravity' in order to create idiosyncratic expression. This specific feature is not so clear in the original. Speed reduction is subsequently an additional tool that provides aesthetic insights in the application of PDMM.

types (see Hatten 2004). This makes the intentionality of musical motion significantly different from the sensation of a steady beat, which is a physiologically well-understood phenomenon that is interpreted by the basal ganglia (Grahn 2009, Phillips-Silver, Aktipis and Bryant 2010), or the rather straightforward perception of rhythm and accentuation. As demonstrated above, PDMM generates an autonomous channel to the motional expressivity of sound that an analysis of the aforementioned phenomena cannot fully encapsulate.

Conclusion

Locating musical motions is a delicate affair. It is indeed the human voice that most appropriately shapes particular sonic movements through its flexibility in the modulation of frequency, dynamics and timbre. Yet the actual functioning of discrete pitch structures in most music, vocal as well as instrumental, makes it counter-intuitive to stipulate musical motion's dependency on continuous trajectories in frequency. Indeed, continuous motion streams and discrete melodic characteristics seem to be separable phenomena that are interdependent at a merely semiotic level. This simply means that, in order to formulate a clear idea about the expressive and motional shaping of a motif or melody, one has to inject it with cultural meaning, which, at least in the tradition of classical music, rests substantially on the aesthetic individuation and characterisation of pitch, rhythmic and harmonic structure. What makes communication of meaningful continuous motion with discrete tones possible remains unclear. Bodily movement and gestures, however, appear too imprecise as sources for musical intentions with respect to sonic motion. This article has introduced PDMM animations and supported the idea of analysing vocalised musical intentions of professional musicians in order to come as close as possible to what musical motion is really intended to be. One should not ask whether motion applies only metaphorically to music, but rather, whether motion should actually be considered essentially spatial.

REFERENCES

1. Budd, M. 2003. 'Musical Movement and Aesthetic Metaphors'. *The British Journal of Aesthetics*. 43 (3): 209–23.
2. Clarke, E. 2001. 'Meaning and the Specification of Motion in Music'. *Musicae Scientiae*. 5 (2): 213–34.
3. Farbood, M.M. 2012. 'A Parametric, Temporal Model of Musical Tension'. *Music Perception.* 29 (4): 387–428.
4. Friberg, A., J. Sundberg and L. Frydén. 2000. 'Music from Motion: Sound Level Envelopes of Tones Expressing Human Locomotion'. *Journal of New Music Research*. 29 (3): 199–210.
5. Grahn, J.A. 2009. 'The Role of the Basal Ganglia in Beat Perception'. *Annals of the New York Academy of Sciences*. 1169 (1): 35–45.
6. Gritten, Anthony and E. King, eds. 2006. *Music and Gesture*. Aldershot: Ashgate.
7. _____ 2011. *New Perspectives on Music and Gestures*. Aldershot: Ashgate.
8. Hatten, R.S. 2004. *Musical Meaning in Beethoven: Markedness, Correlation, and Interpretation*. Bloomington: Indiana University Press.
9. Honing, H. 2005. 'Is There a Perception-Based Alternative to Kinematic Models of *Tempo Rubato*?' *Music Perception*. 2 (1): 79–85.
10. Juslin, P.N. 2013. 'From Everyday Emotions to Aesthetic Emotions: Towards a Unified Theory of Musical Emotions'. *Physics of Life Reviews*. 10 (3): 235–66.
11. Langner, J. and W. Goebl. 2003. 'Visualizing Expressive Performance in Tempo-Loudness Space'. *Computer Music Journal*. 27 (4): 69–83.
12. Mauch, M. and S. Dixon. 2014. 'pYIN: A Fundamental Frequency Estimator using Probabilistic Threshold Distributions'. *Acoustics, Speech and Signal Processing*. In Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2014). 659–63.
13. Moshammer, G. 2012. 'Contour, Motion and Gesture in Abstract Score Animation: A First Approach'. *Journal of Music Research Online*. 3.
14. Nielsen, R. H., P. Vuust and M. Wallentin. 2015. 'Perception of Animacy from the Motion of a Single Sound Object'. *Perception*. 44 (2): 183–97.
15. Phillips-Silver, J., C.A. Aktipis and G.A. Bryant. 2010. 'The Ecology of Entrainment: Foundations of Coordinated Rhythmic Movement. *Music Perception*. 28 (1): 3.
16. Platz, F. and R. Kopiez. 2012. 'When the Eye Listens: A Meta-analysis of How Audio-visual Presentation Enhances the Appreciation of Music Performance'. *Music Perception*. 30 (1), 71–83.
17. Repp, B.H. 1989. 'Expressive Microstructure in Music: A Preliminary Perceptual Assessment of Four Composers' ''Pulses'''. *Music Perception*. 6(3): 243–74.

18. _____. 1995. ‘Expressive Timing in Schumann’s Träumerei: An Analysis of Performances by Graduate Student Pianists’. *Journal of the Acoustical Society of America*. 9 (2): 2,413–27.
19. Repp, B.H. and A. Penel. 2004. ‘Rhythmic Movement is Attracted More Strongly to Auditory than to Visual Rhythms’. *Psychological Research*. 68: 252–70.
20. Schutz, M. 2008. ‘Seeing Music? What Musicians Need to Know about Vision’. *Empirical Musicology Review*. 3 (3): 83–108.
21. Schutz, M. and M. Kubovy. 2009. ‘Deconstructing a Musical Delusion: Point-light Representations Capture Salient Properties of Impact Motions’. *Canadian Acoustics*. 37 (1): 23–6.
22. Scruton, Roger. 2004. ‘Musical Movement: A Reply to Budd’. *British Journal of Aesthetics*. 44 (2): 184–7.
23. Todd, N.P.M. 1995. ‘The Kinematics of Musical Expression’. *The Journal of the Acoustical Society of America*. 97(3): 1,940–9.
24. Zangwill, N. 2010. ‘Scruton’s Musical Experiences’. *Philosophy*. 85 (1): 91–104.

ABSTRACT

The notion of musical motion is scrutinised by means of novel animation software, called Pitch-Dynamics Motion Microscope (PDMM), which is rooted in the so-called pYIN algorithm. Musicians’ exemplary vocalisations of musical intentions are identified as fruitful targets for the analysis of expressive continuity that emerges from discrete tonal sequences. In this study two of legendary conductor Carlos Kleiber’s vocalised passages, taken from the overtures to *Der Freischütz*, and *Die Fledermaus,* are analysed. While music visualisation software that enables pitch correspondence is usually bound to MIDI data, PDMM animations visualise actual frequency fluctuations of voices (or continuous pitch instruments). Thus, they open the door to a whole new view on intended musical motion, allowing for direct interplay between software modelling and genuine aesthetic questions about melodic shaping and its meaning. The study’s findings suggest that one cannot derive musical motion from temporal musical characteristics alone. Further, it denies the possibility of any straightforward algorithmic motion modelling based on discrete data in relation to isolated musical parameters, which implies that continuous motion streams and discrete melodic characteristics are separate phenomena. The human voice or continuous pitch instruments, however, can acoustically blur this boundary, something which particularly takes place in aesthetic instruction. Ultimately, from this brief case study, one can conclude that, while PDMM is able to establish an isomorphism between visual animation and musical movement, musical motion itself should not be considered a subsidiary notion that essentially is rooted in the concept of Euclidean space.

ACKNOWLEDGEMENTS

I would like to thank Ratthanan Nalintasnai, Robroo Somkiadcharoen, Nutchanon Anurakboonying, Thanapong Suthin and Varakorn Koschakosai (all of whom were undergraduate students in Computer Engineering at Mahidol University International College at the time this paper was written) for programming the Pitch-Dynamic Motion Microscope. An initial version of this paper received valuable comments from two anonymous JMRO reviewers.

SOUND SAMPLE CREDITS

The two vocalisations by Carlos Kleiber that this article has analysed are taken from the DVD, *Kleiber In Rehearsal and Performance* (2014), Euroarts, Berlin.

Keywords: musical motion, pYIN algorithm, music animation, vocalisation, expressivity, Carlos Kleiber

ABOUT THE AUTHOR

Gerald Moshammer is Humanities Program director at Mahidol University International College in Bangkok, Thailand. His research aims to exemplify a specific approach to digital humanities, by employing technological aids in countering reductionism in aesthetics. He holds degrees in both piano pedagogy and philosophy, and this agenda resulted in his focus on musical motion.

© Gerald Moshammer (2016)

Received by the editors 29 August 2015; accepted for publication (in revised form) 2 June 2016.