REALTIME ANALYSIS OF DYNAMIC SHAPING

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Introduction

Compared to research on timing, the field of musical dynamics is a neglected parameter in performance research. For example, despite a focus on musical rhythm, timing and performance, the latest edition of Deutsch's (1999) survey over a whole discipline, *The psychology of music* does not even contain a sub-chapter on dynamics. Other research literature is widely distributed. We cannot say whether this situation is due to a lack of interest but would rather assume that it is due to a lack of adequate research methods, which prevents a deeper understanding of the nature of dynamics. To sum up we can formulate some important research topics:

- Although the history of performance practice shows the increasingly important role of dynamic shaping for conveying expression in music, we know only very little about the relationship between musical form and musical dynamics. Based on musical experience we can say that e.g. a Bruckner-Symphony is unimaginable without the form-generating force of dynamics.

- The relationship between timing and dynamics and its importance for musical perception is unclear: they either exist in a hierarchical relationship (e.g. with a dominance of timing over

dynamics), or are of equal importance. In the first case we could assume that dynamics have only a small effect on a global level and a greater effect on a more local level – this contradicts musical experience; in the second case the problem of redundancy is evoked: why should we take care of a second expressive parameter (dynamics), if expression is already mediated by the domain of timing?

- Which methods of analysis of dynamics and of obvious presentation of results are available? This question concerns the field of performance analysis as well as that of educational application. Only a highly obvious and easy manageable analysis of dynamics will be accepted by the majority of instrumental teachers. This means a special need for realtime methods of analysis and presentation.

Some answers to the above mentioned questions can be found in the literature: as one of the founding authors, Riemann (1884) published a treatise on musical phrasing which concentrated exclusively on the role of dynamics and rubato. His simple assumption was that dynamics and rubato are coupled, and that the development of an eight bar long musical phrase is shaped simultaneously by a crescendo and an accelerando until the climax of the phrase. This more global perspective of dynamics seems to be more plausible. Huron's (1991; 1992) perception theory of "ramp archetypes" fits well into this perspective. Huron (1991) calculated a mean length of 4.3 bars for crescendi and of 5.8 bars for decrescendi using a sample of 537 works or movements of 14 composers with a total of 85476 bars. The same idea of a simple coupling of the two parameters can be found in Todd's (1990) model of musical expression: "the faster the louder, the slower the softer" (p. 3540). We don't believe in such a simple, rule-based relationship of parameters and assume that this perspective meets only a part of musical reality. This approach allows only a very limited view. However, as Friberg (1991) tried to show, it is possible to generate decent synthesized performances by use of such a rule-based system.

We would like to try a different approach: referring to the "Theory of oscillating systems" (TOS) by Langner (1999) we hypothesize that the timing and dynamics of a performance are shaped on multiple levels, including local *and* global layers. Local layers concern the dynamic shaping for example from note to note or from measure to measure; global layers on the other hand are connected to the relationship of dynamics between larger sections or subsections of a piece of

music. (Such multi-level structure can also be found in other domains of performance; for the analysis of timing see Langner & Kopiez 1995). An adequate method of performance analysis should preserve the full information contained in the performance data (without any reduction), and as Langner (1999, pp. 153-155; 1997) demonstrated, this multi-dimensional character of dynamic shaping is in strong concordance with musical perception and experience.

If possible, analysis of dynamics should be done in realtime. Our demonstration uses recently developed software, and shows by use of graphical output in the form of so-called "Dynagrams" some possibilities for application.

Method

The procedure will now be described, based on the assumption that the piece of music to be analysed is available as complete audio file. Following that is an outline of the modifications made when the analysis 'works through' the music step by step in realtime.

(a) Non-realtime procedure

The starting point for the procedure is the digitized audio signal. From this (step 1) the loudness curve of the piece is calculated – this means that at regular intervals in the piece a loudness value is allocated in *Sone* units. For this purpose a particular computer programme was used which was developed by Bernhard Feiten & Markus Spitzer (Technological University of Berlin) on commission from the Hochschule für Musik und Theater Hannover (see also Langner, Kopiez & Feiten 1998, pp. 18–20). This programme is based on Zwicker's 'Model of loudness' (Zwicker & Fastl 1990, pp. 197–214), which guarantees close proximity to the perceived loudness, and produces superior quality to the simple use of decibel values.

This loudness curve (step 2) was then subjected to multiple 'smoothing out' processes of varied strength. This 'smoothing out' was achieved through the inclusion, when measuring at a particular point of time, of not only the loudness value at exactly this point but also the surrounding values, thus creating a mean measurement. This 'surround' of the point is also termed the 'window' for calculation. The wider the calculation window, the stronger the smoothing out effect. If one were to take in an extreme case the length of the entire piece of music on a window, there would be only one

mean value for the whole piece, and the smoothing out would therefore be at its maximum. In contrast, a very narrow window would produce a smoothing out very similar to the original loudness curve. There are many interim steps between these extremes. Concrete graphic examples are to be found in Langner (1997). A strong 'smoothing out' of the loudness curve only represents differences (that is deviation from a horizontal line) when the appropriate wide-ranging dynamic shaping exists; precisely these varied strength smoothing out cases allow multi-layer analysis as mentioned in the introduction. Our procedure uses a wide spectrum of various window sizes. The exact range can be selected within the programme. A frequently applied setting contains 37 different 'windows', sized between 0.25 and 128 seconds (in logarithmic steps).

Finally (step 3) the gradients in every smoothing out curve are calculated at each point in time. The procedure is similar to that of the first derivative in mathematics and physics; here though the gradients according to each separate window size for each smoothing out curve were calculated. The effect is that the strongly smoothed out curves (which generally show much weaker fluctuation) can obtain just as steep gradients as the more weakly smoothed out. There is a sense of 'equal treatment' under the contrasting smoothing realignments.

Following from this change to gradients, the analytical perspective changes from focusing upon loudness to focusing upon loudness changes – that is from loud/soft to crescendo/decrescendo. (This change in perspective stood the test of previous analyses; the final decision as to whether loudness or loudness changes are actually represented has not yet been reached).

The output (step 4) is produced in graph form showing the gradients referred to, in a so-called "Dynagram" (see fig. 1 and fig. 2). The time axis shows the horizontal axis; the window size is represented on the vertical axis. Red colouring signifies crescendo (the more intense the red the stronger the crescendo); green colouring then shows decrescendo (the more intense the green, the stronger the decrescendo).

(b) Realtime procedure

During the realtime version, the audio signal is recorded through a microphone link to the computer. The procedure described above is carried out in the same way. In order to create the Dynagram it must be considered that in calculating the smoothing out, a certain surrounding area of a point in

time has constantly to be included. One must almost "look into the future" – for the weaker smoothing out to a lesser extent, for the stronger one to a greater extent. (Such "looking into the future" can be considered with retrospective re-interpretation of what is heard and is from this point of view plausible). As far as the procedure is concerned, the following is relevant: the Dynagram can only be calculated retrospectively – with inconsequential delay for the small window sizes, but with considerable delay for the large window sizes. The data points of a realtime Dynagram thus appear on the screen not in vertical axis form, but approximately as a diagonal line.

Results

Figures 1 and 2 show the Dynagram of both a professional and a non-professional performance of Erik Satie's *Gymnopédie No.1*. The generally more intense loudness pattern from the professional pianist is noticeable. Particularly remarkable is also the greater intensity in the larger window area; the shading in this area reveals correspondence of loudness organization to formal structure. The composition namely is made of two identical parts, each of which again consists of two almost equal sized sections.
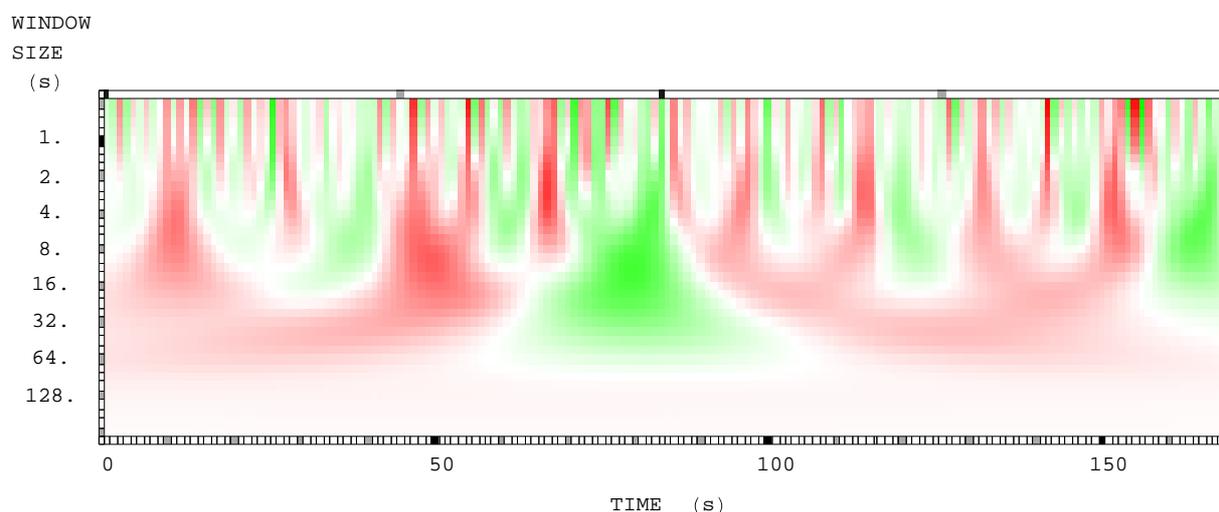

Fig. 1: Dynagram of a professional performance of Erik Satie's *Gymnopédie No.1*. The different colours have the following meaning: intense red = strong crescendo, pale red = weak crescendo, white = constant loudness, pale green = weak decrescendo, intense green = strong decrescendo. The dynamic shaping reflects clearly the formal structure of the composition (the formal breaks are marked in the upper horizontal frame).
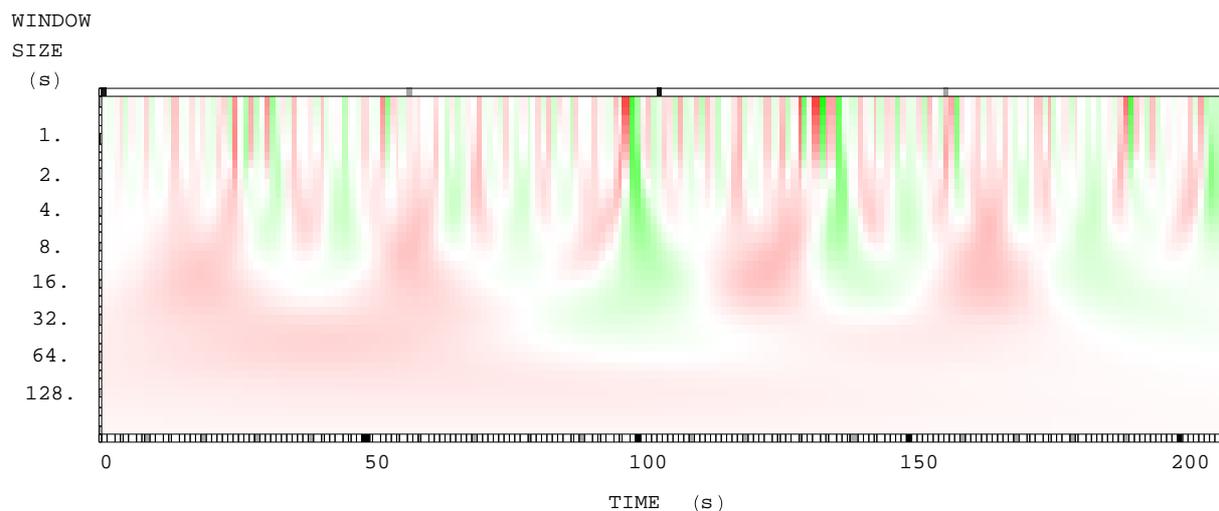
Fig. 2: Dynagram of a non-professional performance of Erik Satie's *Gymnopédie No.1*. The dynamic shaping is not as strong as in the professional performance and reflects the formal structure of the composition less clearly.

(To demonstrate these structural segments, the start of each section is marked in the upper horizontal frame of the Dynagram.The starting points of the two main parts are black; the less strong formal devisions are in contrast coloured grey). It is clear from the Dynagram of the professional player's version that each of the four formal sections is covered from a red-green pair in the window size area from 8 to 16 s, just as the two halves in the vicinity of 32 s. Clearly the professional pianist is capable of pointedly marking the structure of the composition through control of loudness (in other words with "arches" from crescendi and decrescendi); the non-professional meanwhile achieves this only to a smaller extent.

Further examples fitting to the procedure showed the Dynagrams to be a way of making visible in particular more extensive loudness shaping of a performance. The analysis of a recording of a movement a Bruckner Symphony (conducted by Günter Wand) for instance revealed a build-up spanning some 20 minutes from start to the final climax of the piece.

Discussion and perspectives of application

The analyses carried out up to this point give reason to believe that in the Dynagrams important attributes and qualitative characteristics can be registered. In particular the absence or presence of wide-ranging loudness shaping is clearly visualized. This can be seen in the lower part of the Dynagram, the area for larger window sizes. These characteristics of the procedure render it a useful

tool for performance research. It brings into play a new analytical tool with which the issues briefly raised in the introduction – those of the role and significance of dynamics – can be tackled in a new light. The option of carrying out the analysis in realtime, simply with a microphone and standard computer, opens up a whole new perspective for application in instrumental lessions and musicians' practice time: the Dynagram is displayed on a monitor while the pupil plays, and facilitates both pupil and teacher instant analysis of strength and weakness. The Dynagrams can be saved and printed out, and thus kept for comparison at a later date; a pupil's progress can in this way be documented. The pupil additionally has a mean to self-analysis.

Further possibilities for the analysis of music will be enabled by realtime transfer of several additional procedures. See here the contribution from Langner "Rhythm, Periodicity and Oscillation" in the accompanying volume, in which an online-compatible process encompassing rhythmical qualities is outlined. Both papers are part of a wider research project which reaches out over all areas of music, and in particular covers analytical processes for harmony and melody (Langner 1999, pp. 156–157).

References

Deutsch, D. (Ed.) (1999). *The psychology of music*. 2nd edition. New York: Academic Press.

Friberg, A. (1991). Generative rules for music performance: A formal description of a rule system. *Computer Music Journal*, 15(2), 56–71.

Huron, D. (1991). The ramp archetype: A score-based study on 14 piano composers. *Psychology of Music*, 19, 33–45.

Huron, D. (1992). The ramp archetype and the maintenance of passive auditory attention. *Music Perception*, 10(1), 83–92.

Langner, J. (1997). Multidimensional dynamic shaping. In A. Gabrielsson (Ed.), *Proceedings of the third triennial ESCOM conference*, Uppsala, Sweden, 7–12 June, 713–718.

Langner, J. (1999). *Musikalischer Rhythmus und Oszillation. Eine theoretische und empirische Erkundung*. [Musical rhythm and oscillation. A theoretical and empirical investigation]. Dissertation, Hochschule für Musik und Theater Hannover. (A printed version of this dissertation, including a comprehensive abstract in English, will be published by Peter Lang Verlag, Frankfurt/Main in 2000 or 2001).

Langner, J. & Kopiez, R. (1995). Oscillations triggered by Schumann's "Träumerei": Towards a new method of performance analysis based on a "Theory of oscillating systems" (TOS). In A. Friberg & J. Sundberg (Eds.), *Proceedings of the KTH Symposium on Grammars for music performance*, Stockholm, May 27, 45–58.

Langner, J., Kopiez, R. & Feiten, B. (1998). Perception and representation of multiple tempo hierarchies in musical performance and composition. In R. Kopiez & W. Auhagen (Eds.), *Controlling creative processes in music* (pp. 13–35). Frankfurt a.M.: P.Lang.

Riemann, H. (1884). *Musikalische Dynamik und Agogik*. [Musical dynamics and agogics]. Hamburg: Rather.

Todd, N.P. McAngus (1990). The dynamics of dynamics: A model of musical expression. *Journal of the Acoustical Society of America*, 91(6), 3540–3550.

Zwicker, E. & Fastl, H. (1990). *Psychoacoustics*. Berlin: Springer.