22

Case Studies

Learning by Doing.

22.1 Schumann's *Träumerei*: The First Performance Experiment with RUBATO®

Our first longer performance was constructed in 1995 with Robert Schumann's famous *Träumerei*, the seventh *Kinderszene* in his collection op.15. It was an experiment conducted in the context of a performance conference at the KTH, where different approaches to performance were compared [82], and from where we take the following presentation. The performance was played on a MIDI Boesendorfer Imperial grand piano at the School of Music in Karlsruhe. This piece was chosen because we have the detailed analysis of agogics as measured by Bruno Repp from 28 famous performances [111] by, among others, Marta Argerich, Vladimir Horowitz, and Alfred Cortot.

For this experiment, we made a rhythmical analysis by the MetroRubette and a motivic analysis by the MeloRubette. The HarmoRubette was not implemented in those days.

The rhythmical analysis is shown in figure 22.1. The parameters for these weights are minimal admitted local meter lengths = 2 and profile = 2. We see from top to bottom the weights $metroWeight_{LH}, metroWeight_{RH}$, and $metroWeight_{BH}$ for the left hand, the right hand, and for both hands, respectively. We recognize the markedly different profiles of these three weights, a phenomenon already observed in our previous discussion of the composition's rhythmical analysis in section 16.1.

For our performance, we have these weighted combinations of metrical weights for the left- and right-hand shaping:

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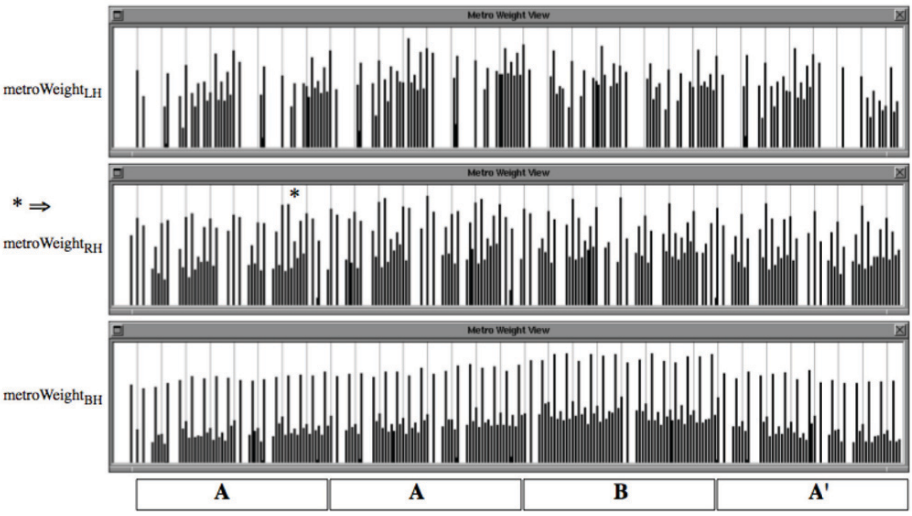

Fig. 22.1. The metrical weights $metroWeight_{LH}, metroWeight_{RH}, metroWeight_{BH}$ for the left hand, the right hand, and for both hands, respectively, with minimal local meter length = 2 and profile = 2 for Schumann's *Träumerei*. The star marks the harmonically important point where the secondary dominant appears.

$$metroComWeight_{LH} = 100\%metroWeight_{LH} + 10\%metroWeight_{BH}, \text{ and}$$
$$metroComWeight_{RH} = 100\%metroWeight_{RH} + 10\%metroWeight_{BH}.$$

which is a strong account on the original-handed contributions, plus a small account on the combined rhythmical structure. As already discussed in chapter 16, these discrete weights are always interpolated by cubic splines. In figure 22.2, we see the splines for the weights

$$metroComWeight_{LH}, metroComWeight_{RH}$$

and their difference. We have also chosen the high and low limits of these spline weights to be 1.2 and 0.9, respectively.

The melodic analysis used here was done using the so-called *elastic* paradigm of motivic similarity. This one looks at the slopes of the lines connecting successive notes and the relative Euclidean lengths of these connections, so it is a very geometrical paradigm. Comparison among motives would use similarity of that elastic data. The similarity limit ϵ discussed in section 16.2 was chosen to be $\epsilon = 0.2$. We also decided not to compare inversion or retrograde or retrograde-inversion of such motives, but only the given motives. We also chose a small window of motives, namely only motives of two, three, and four notes each and having their note onsets between one-half measure length. This yields 1574 two-note, 1465 three-note, and 71 four-note motives. At that time, the selection of significantly more motives would have exceeded the calculation power of a NeXT computer. The graphical representaton of

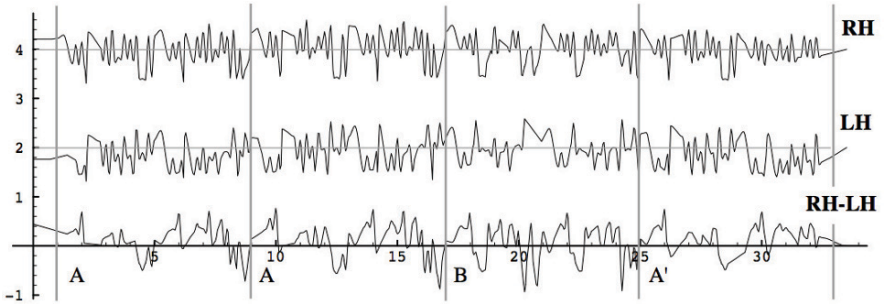

Fig. 22.2. Splines for the weights $metroComWeight_{LH}, metroComWeight_{RH}$ and their difference.

this weight is shown in figure 22.3. Since we also applied the melodic weight to shaping agogics, we needed a boiled-down version of the melodic weight, which is a function of onset only. This function just adds all note weights of notes with given onset.

The melodic weight and the inverted (!) spline of the boiled-down motivic weight is shown in figure 22.3. We have chosen the *inverted* spline between high and low limits, 1.2 and 0.9, because for some operators it was reasonable to have low influence for high melodic weights. For example, agogics should go down for high motivic weight. It is interesting to see the performance field

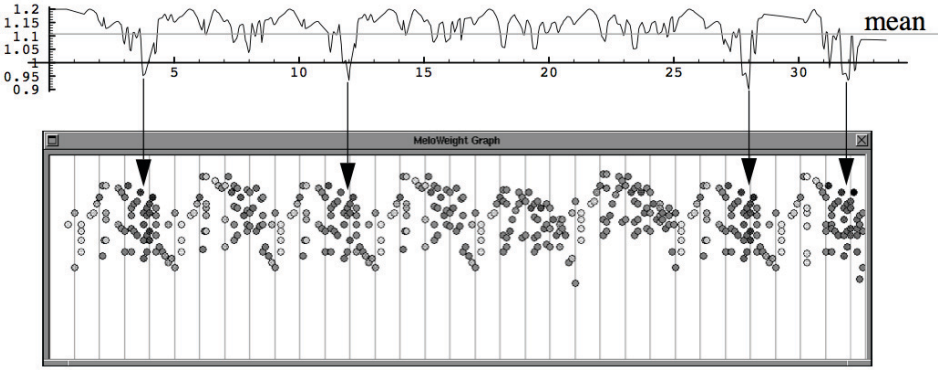

Fig. 22.3. The motivic weight *meloWeight* for both hands (bottom) shows a markedly high weight at the end of the piece, in the repeated ascending motif $g - a - b_\flat - d$, as an important melodic instance. Above, we see the inverted boiled-down motivic weight spline.

of articulation being constructed by the tempo operator, as is shown in figure 22.4.

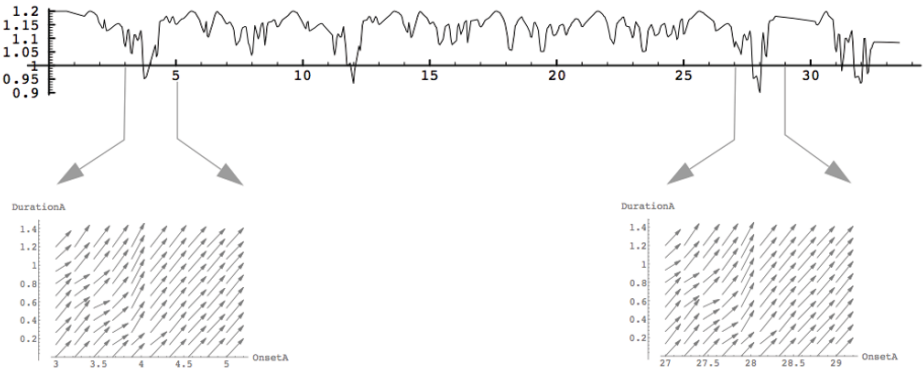

Fig. 22.4. The articulation fields generated by the tempo operator by use of the inverted bolied-down melodic weight.

Besides these analytical weights, we have created also primavista weights for agogics, dynamics right hand, and dynamics left hand. This is shown in figure 22.5.

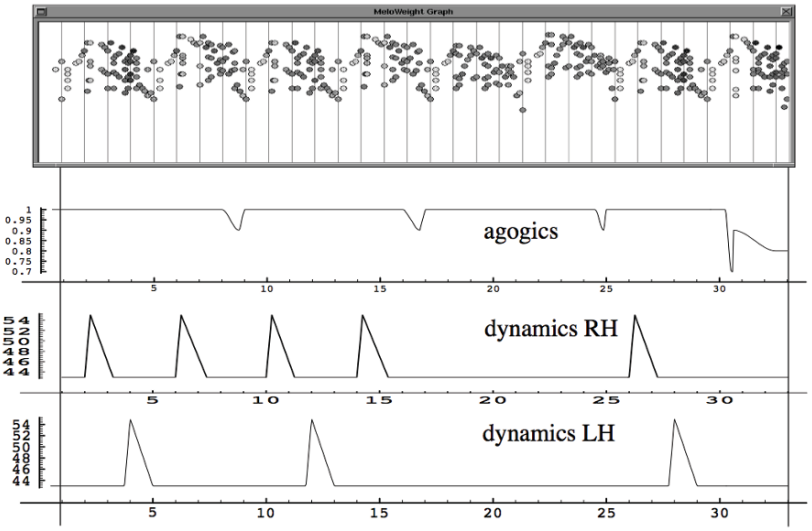

Fig. 22.5. The three primavista weights.

Using this data, we have then constructed a simple stemma as shown in figure 22.6. It splits left from right hand, then applies primavista shaping, then the physical operator (called brute operator at that time) to dynamics—using the splined weights from

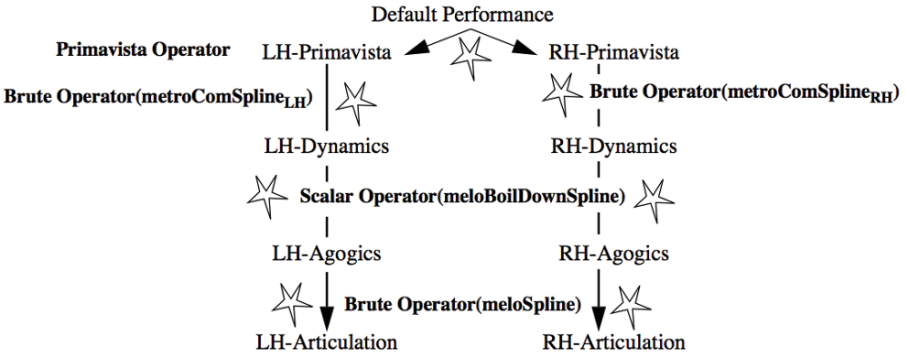

Fig. 22.6. The stemma of our performance of *Träumerei*.

$$metroComWeight_{LH}, metroComWeight_{RH}$$

then the tempo operator (called scalar operator at that time) with inverted boiled down-melodic weight, then again the physical operator for articulation—this time using the melodic weight, not the inverted boiled-down version, to the single notes' durations.

What is the relationship between the described RUBATO® performance and the well-known performances by famous artists? This question turns out to have an remarkable answer. To deal with the empirical data, we refer to the Repp's paper [111]. Repp has measured the tempo curves by the measurement of the IOI (intertone onset intervals, which is a discrete measure for 1/tempo). He than applied a statistical factor analysis to the first eight measures of the 28 performances and got four significant factors. Three of these factors turned out to be represented by high loading for a group of artists. The first factor is that shared by a large number of artists, among them Alfred Brendel. The second factor is led by Horowitz, and Repp therefore calls it the "Horowitz factor." The third factor is called the "Cortot factor" for analogous reasons.

We have analyzed the three timing patterns corresponding to the three important factors. It turns out that the situation for the Horowitz factor is in remarkable coincidence with the agogics obtained by the RUBATO® calculation, i.e. by the agogics deformation via the tempo operator from the boiled-down melodic weight. We are comparing the tempo curve of the Horowitz situation as it reads when the discrete data are completed to a cubic spline (the same method was used for the melodic weight spline), see figure 22.7. The upper curve is that of the RUBATO® agogics, then comes that of a prototypical Horowitz timing, and the third one is the product of the derivatives of the two agogics. It is negative if the slopes of the two candidates are contrarious. This shows that the fitting quality of the two curves is extremely good. This fact can also be seen by visual inspection. To say more about the rare discrepancies, we would have to go back to these recordings on one side, and do harmonic analysis on the other. But it is clear that the agogics of the

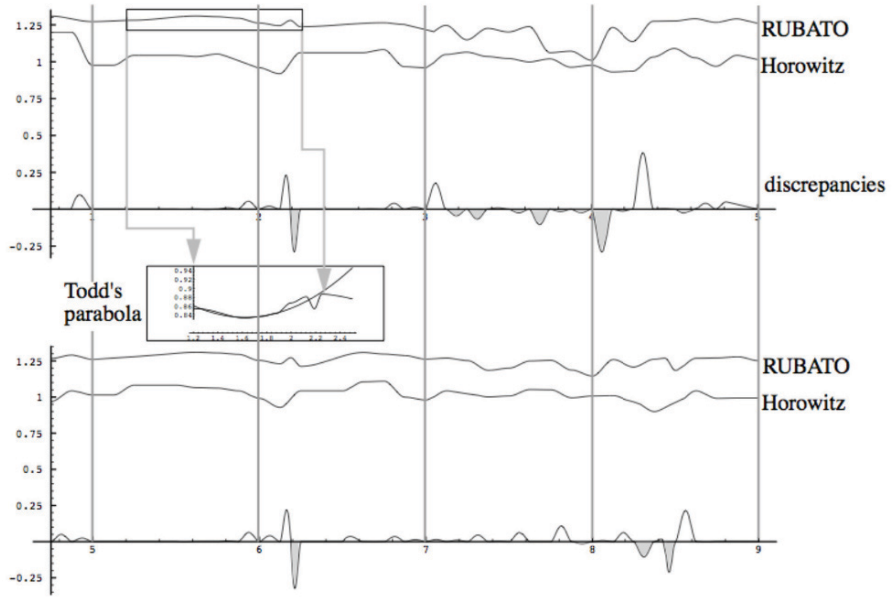

Fig. 22.7. Comparison of the RUBATO® tempo curve and the Horowitz curve measured by Repp.

RUBATO® performance—though it has a very simple stemma—is in the line of one of the most profiled styles as described by Repp.

Let us also notice that the parabolic accelerando in measures 1 to 2 discussed by Repp in the light of Todd's hypothesis [137] is not in contradiction with the RUBATO® agogics in this location. From a mathematical point of view, it is by no means clear that a parabolic accelerando is the only reasonable solution. This issue has to be settled in the light of a systematic inverse performance theory, but see chapter 24.

22.2 Schumann's *Kuriose Geschichte*: The First Analytically Complete Performance Experiment with RUBATO®

A still more realistic second example of a stemma is shown in figure 22.8, the very first *extensive* experiment in Rubato-driven performance we did in 1996 on the MIDI Boesendorfer Imperial grand at the School of Music in Karlsruhe. The deadpan version (without any performative shaping of the score data) can be heard in example ♫ 21; the final performance is documented in ♫ 22.

Let us look at this historical example of a stemma: the stemma for the composition *Kuriose Geschichte*, the second *Kinderszene* in Robert Schumann's synonymous collection op.15. This stemma was constructed for the

NEXTSTEP RUBATO® by the author, Oliver Zahorka, and Joachim Stange-Elbe. It took us three days to realize the whole setup and performance. The performance of the piece is documented on ♫ 22, and in a broadcast of the Austrian TV [34]. Although the stemma is quite primitive, the shaping results were satisfactory and taught us a lot about the empirical aspects of computer-assisted performance research. In particular, we learned that it can be very difficult for humans to listen dozens of times to successive and only slightly altered versions of a performance. At the end of a day of such work, one cannot tell anymore what matters and what is really different or just imagination, even for three independent listeners!

Although each single refinement layer is controlled by one and the same operator (horizontal arrow), each daughter had to be performed as an isolated instance, since no grouping methods were implemented. The construction of this stemma first follows the splitting of right (RH) and left hands (LH), then, after the shaping of primavista dynamics and agogics, global agogics is constructed on these two LH and RH symbolic kernels. The splitting for operators $\Omega_5, \Omega_6, \Omega_7$ regards a small number of measures that have to undergo a more differentiated rubato. The final shaping regards fine "tuning" of dynamics and articulation in all leaves.

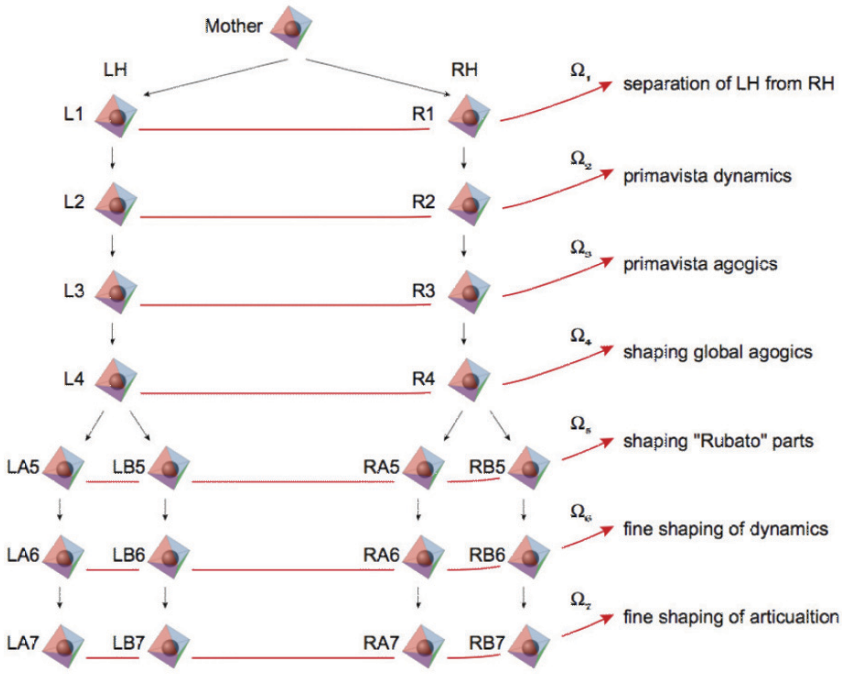

Fig. 22.8. The stemma of the first RUBATO®-driven performance construction of Schumann's *Kuriose Geschichte* in 1996.

22.3 Joachim Stange Elbe's Performance of Johann Sebastian Bach's *Kunst der Fuge*

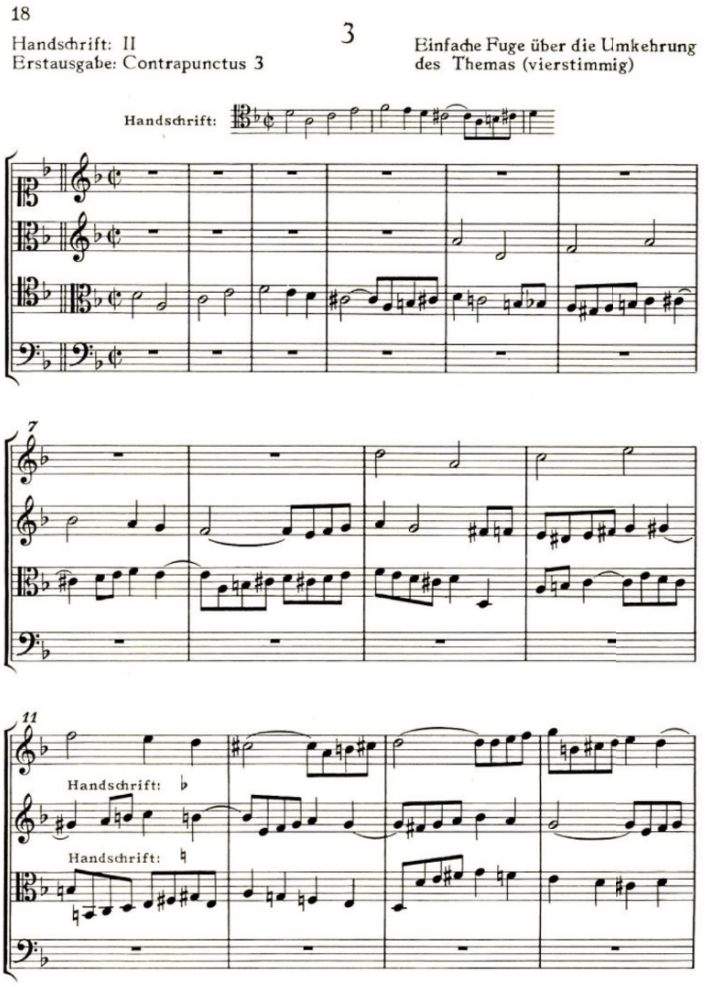

Fig. 22.9. First page of Bach's *Kunst der Fuge*.

Joachim Stange-Elbe has investigated Bach's *Kunst der Fuge* (figure 22.9) in detail and created very convincing performances thereof with RUBATO®. The deadpan version of its *contrapunctus III* is documented in example ♫ 23, while the final performance can be heard on example ♫ 24. We however do not include this work as a further example of performance construction in a technical sense, rather we focus on the problem of analytical performance as

such. What is the relation of analytial weights, operators, and the aesthetics of performance?

So, let us first look at the premises used by Stange-Elbe.

This experiment is fully accounted in [130], here, we give a concise presentation. The version of RUBATO® used in this experiment is the one compiled for OPENSTEP/Intel. The *contrapunctus III* in Bach's *Kunst der Fuge* has these characteristics: It is a four-voice composition, comprises 72 measures, has time signature 4/4, and has tonality *D*-minor. The main theme of *Kunst der Fuge* is only used in its inversion and appears the first time in a rhythmically dotted and syncopated variant; the fugue starts with the theme in its comes shape and contains three complete developments (measures 1-19, 23-47, and 51-67).

We give an account of the rhythmical and melodic analyses, whereas the harmonic analysis has not been done. Stange-Elbe decided that Hugo Riemann's theory, which is implemented in the HarmoRubette, is not suited for Bach's harmonies. He argues that when using the Riemann theory, which was developed from the Viennnes classics, the specific harmonic structures of a contrapuntal maze, where harmony does not result from progression of fundamental chords but from the linearly composed voices, can be captured only in an incomplete way.

22.3.1 Rhythmical Analysis

For the rhythmical analysis of the *contrapunctus III*, the calculations were made for each single voice, including the sum of the voice weights, and for the union of all voices. The settings of the weight parameters are these: metrical profile is 2, quantization is 1/16, distributor value (the weight factor for weighted sums of weights) is 1. Since the metrical profile of all voices should be viewed under the same valuation, the distributor value was set to a common neutral value; the value 2 for the metrical profile resulted from several trials of analyses and yields a balanced distribution of the weight profile.

The value for minimal length of local meters was successively decremented starting from the length of the largest local meter and descending until value 2, where the smallest cells are caught in their signification for the metrical overall image.

22.3.2 Motif Analysis

For the calculation of motivic weights, each single voice of the *contrapunctus III* was analyzed separately. Stange-Elbe refrained from a motivic analysis of the union of all voices because by the contrapuntal structure of the single and autonomous voices within the polyphonic setting, a motivic setup across the voices seemed rather unlikely and therefore was omitted.

The settings for the motivic analysis were chosen as follows: Symmetry group: counterpoint, which means that motives also were compared to inversion, retrograde, and retrograde-inversion of other motives; the similarity paradigm was chosen equal to that in our discussion of Schumann's *Träumerei*, namely elastic; the tolerance number was set to $\epsilon = 0.2$. By the choice of the counterpoint symmetry group, the theme forms *recta* and *inversa*, as well as their (possibly appearing) retrogrades, were considered as being of equal weight. The neighborhood value has been chosen as based upon analytical experiments during the development period of RUBATO®.

As to the values for motif limits, compromises with the calculation power had to be made. By making the span[1] equal to 0.625 and setting the cardinalities of motives from 2 to 7, motives within a span of a half note plus a quaver were captured; this corresponds exactly to the duration of the theme where the transition of the virtual theme to the interludes must be recognized. With the results of the metrical analysis, some regularities in the microstructures can be read at first sight; herein we find in particular the onsets of the theme within a particular development.

While further considering these weights, the overly long pauses in the soprano, tenor, and bass voices attract attention. Further, in the length proportion of the single weight representations, the succession of onsets of the single voices (tenor-alto-soprano-bass) is reflected. Moreover, a significantly lower motivic profile at the beginning and after the longer pauses of the respective weights can be observed—due to preceding pauses, this is the case of exposed thematic onsets.

For the weight values, a neat exposition of the inverted gestalt of the original theme is observed, bearing nearly identical weights at the beginning of every motivic weight. Here even the differences of comes and dux forms are visible, since the weights of the tenor (first appearance) and soprano (third appearance) differ slightly by the different initial interval of the theme (descending fourth in the comes and descending fifth in the dux form) from the weights of the alto (second appearance) and bass (fourth appearance).

Other clearly visible onsets of the theme in inverted shape are recognized after the long pauses in the soprano (eighth appearance), bass (ninth appearance), and tenor (twelfth appearance). Characteristically, the inverted shape always appears after pauses.

At first sight, these observations may seem to be tautological. However, if these weights are viewed with respect to their sense and purpose and their force to shape performance, then the transition from a quantitative to a qualitative information content becomes evident. Thus the different onsets of themes can be shaped by these weights in one and the same way; if these weights are used—in inverted form—for the dynamic shaping, then the thematic onsets can be stressed with plasticity.

[1] This is the maximal admitted distance between first and last onset of a motif.

22.3.3 Target-driven vs. Experimental Stemma Constructions

Before the stemmatic construction for *contrapunctus III* is discussed, some general remarks regarding the various performance strategies are necessary. In the course of the single performance parcours, two different approaches resulted that would turn the given analytical weights into expressivity: the *target-driven* and the *experimental* strategies.

The target-driven strategy has its roots in the knowledge about existing performances; it is stamped by a preliminary experience of how the piece should sound and has been performed. With this procedure, the weights are used in a way that targets a predefined performance. One—just to name a pithy example—was oriented towards Glenn Gould's Bach interpretation; the corresponding weights were selected according to these targets to obtain particular effects. In this procedure, however, the intrinsic structural meaning of analytical weights was ignored! Stamped by the knowledge and the expectation of the existing performances, this strategy did not allow one to judge and categorize those performance constructions that did not suffice for the music-esthetic exigencies.

The other approach, the experimental strategy, moves the analytical weight to the center in order to investigate how this weight could 'sound', and which analytical insight it could convey in the listening. With this procedure, which views the main performing agent entirely within the weight, one has to free oneself completely from horizons of expectation for any particular performance target. The working process on such performances, the acquaintance of experience with the most different weights, and the playing with their effects taught us in the course of many experiments that this strategy would give rise to much more interesting performance aspects. Here we also have the freedom to admit extremal positions that disclose more about the inherent musical structure and as 'daring ingredients' may evoke lively musical expression.

Moreover, the experimental approach to single performance aspects, which starts from curiosity about the sonic realization of analytical weights, conveys a deeper insight into to score's musical structure. This path has its take-off in a "sonic analysis," or else in "the sonic analytical structure" and aims at a "musically reasonable performance." It is centered around the researcher's curiosity for a sounding and interpretational realization of analytical weights and for "the never heard," and it is paralleled by a liberation from expectational presets. Moreover, this strategy tries to apply as few weights as possible in order to couple the clearest possible analytical statements with the resulting performance.

22.3.4 Performance Setup

The performance of *contrapunctus III* took place in three parcours. The first one was entirely devoted to a target-driven strategy centered around the shaping with a single weight in order to sound the potential of a single weight. The

global application of weights and the usage of a single weight showed its limits. For example, the global application of weights failed in the different grades between the contributions of the four voices. Especially with the motivic weights of the tenor and bass voices, different weight profiles become visible that cannot be eliminated even by suitable deformations. These differing profiles of weights result from the compositional structure. As this one splits into a number of parts—developments and interludes, groupings by harmonic closes and semi-closes—the division of the voices according to such compositional criteria is legitimized. Within these parts, the selected weights can be applied with different intensities and thus equalize the disparate shapings.

The subsequent parcours switched to an experimental strategy, which yielded much more successful and conclusive results. Nonetheless, all these approaches contributed results that influenced the final result in a significant way.

Generally speaking, the procedure in all these parcours first focused on isolated single aspects of performance (articulation, dynamics, agogics) and then were put together for the final parcours. For the complete description of all these steps, see [130].

22.3.5 Construction of Third Performance Parcours

Because of these different dynamical profiles, the principle of former performance experiments—the exclusive usage of a weight and its global extension—had to be given up. In a first step, it was recommended to split the single voices at appropriate locations, and in a second step, a regress to the metrical weights already used in the first parcours and their renewed application under other viewpoints (a mixed usage together with motivic weights) seemed reasonable. The shaping of articulation from the second parcours would be conserved.

In a preliminary step, a division of the single voices had to be executed. To this end, one had to find structurally legitimate points from the musical context, such as articulation by harmonic incisions or thematic groupings for developments and interludes.

The first division of all four voices took place in measure 39, legitimated by a harmonic close to the major parallel of the minor dominant (C-major); at the same time this is viewed as a possible ending of the second (however incomplete) development and a beginning of a four-measure interlude.

In order to equalize the dynamical unbalances relating to the interludes from measure 19 and 46, a further division of the two halves of the fugue was necessary. A division of the first half was recommended in measure 19, having a close of the first development (exposition of fugue) and its half close on the dominant (A-major).

Because of the too-strong dynamic sink of the three-voice interlude from measure 46/47, the division of the second half had to take place no later than at this point. This division was legitimized by the half close on the minor

dominant (*A*-minor) beginning in measure 46 on the one hand, and the simultaneous ending of the second (then complete) development according to the three-part construction of the fugue.

For the subsequent performance shaping, consider figure 22.10. Besides the already known preparatory steps—horizontal division into single voices (Level 3) and equalizing of loudness (Level 4)—two performance steps for the later shaping of global agogics were inserted (Levels 5 and 6). This trick is applied because agogics needs long calculation time on the global level of single voices and should be calculated after the stemmatically subsequent shaping articulation and dynamics. The vertical division of the single voices is applied in the previously described steps (Level 7 and 8). For the subsequent shaping of articulation and dynamics, each voice had to receive its separate and individual performance shaping for the four sections. This enabled us to apply different parameter values for the intensity effects, one per used weight.

For the shaping of articulation, the three already elaborated performance steps were inherited.

As is seen in the stemma (figure 22.10), the shaping of dynamics was realized in three consecutive steps. Here, besides the known motivic weights, two additional metrical weights were applied. For the first step (Level 10), we applied the metrical weight from the union of all voices with minimal length of local meters equal to 2, in inverted form, and without deformation.

Upon this stemma, the second step (Level 11) applied the metrical weights with value 5 for minimal length of local meters for each individual voice in inverted form and also without deformation. For the concluding shaping of dynamics, the already known motivic weights were applied to give the thematic onsets a plastic relief.

The result of this performance communicates a relatively balanced dynamics, spread over the whole contrapunctus; the thematic onsets gain a profile, which can also be confirmed in the slight crescendo that leads to the beginning of the third development after the three-voiced interlude (from measure 46/47).

Bringing together the dynamic and the already elaborated articulatory aspects, the result can be stated as a complementary shaping of both performance aspects, which on top of that reveals a musical sense in the elaboration of thematic onsets and the three-voiced passages of the interludes.

For the shaping of agogics, the said levels 5 and 6 of our stemma were reserved. Stange-Elbe did two different subsequent performance parcours with two different metrical weights: the sum of all voice weights (minimal length of local meters: 2) and the weight of the voice union (minimal length of local meters: 91 (!)).

22.3.6 Final Discussion

In the course of the performance experiments, two different approaches and performance strategies crystallized. Stange-Elbe tried to give the score's text an immanent shaping by means of two approaches:

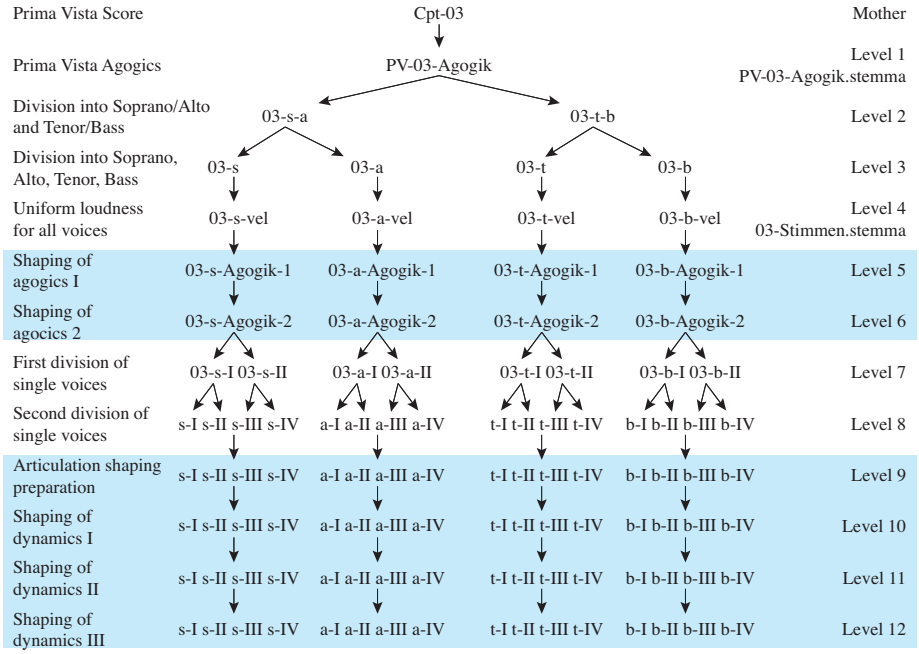

Fig. 22.10. The stemma of the third parcours.

- what is the sound of the analytical structure?
- can the sounding analytical structure yield a musically reasonable performance?

and two contrary performance strategies:

- the target-driven strategy,
- the experimental strategy.

In contrast to objective analytical approaches, when studying performance, subjective ingredients cannot be completely eliminated. They are present in their feedback with the performance result, while weights and intensity parameters in the WeightWatcher are determined, but they play a fairly reduced role.

From the first performance experiments, which have not been discussed in detail here, until the complete performance as described above, Stange-Elbe has known situations which demonstrated several problematic issues: It was not easy to eliminate the impression of an existing performance—in our case by Glenn Gould, say—and to stick strictly to what is written in the score; the performed version of the piece automatically resonates as a comparison while doing the performance work. This was the situation where Stange-Elbe started

these experiments with the ambitious task of approaching an artistical and aesthetical performance as far as possible.

Therefore, the *target-driven* strategy was to a certain degree determined by the comparison with traditional human performances. Under these conditions, weights were applied and results were judged. This turned the tradition into an obstruction: It positioned the expected performance in the foreground and the shaping weight in the background.

Only the consequent questioning of the analytical structure and the systematic liberation from traditional performance expectations led to a performance strategy that positioned the analytical weights in the center of the investigation. This *experimental* strategy was coined by an as-unbiased-as-possible sounding realization of analytical structures, centered around the question of how a weight, when applied to a particular performance aspect, would sound. Within this procedure, it was possible to insert 'unheard' results, to admit purposed over-subscriptions in the sense of the 'still more clear,' whereas the question of whether an interpreter would play in this way turned out to be completely irrelevant.

From this point of departure, how a determined analytical structure would sound, the experimental approach to shaping a musically reasonable performance was sought. This qualitative determination of what is a "musically reasonable" performance is inevitably a subjective one which as such decides the subsequent steps toward the final performance. Much like the interpreter who puts up for discussion his provisionally final version while performing in concert—where in the last analysis it is more his personality than the musical performance which is judged—in computer-assisted performance, the subject who works with the performance workstation RUBATO® presents his results as a provisionally final contribution to the ongoing discussion.

When judging all these performances, one has to take into account that only metrical and motivic weights were applied and the effects of harmonic passages were not included in the shaping of performance (except of the motivations for the not-machine-made subdivisions from global to more local applications of weights in the third parcours). Furthermore, a certain economy in the choice of weights and their application was applied. In this sense, Stange-Elbe first had to check out which weights would involve what type of shaping consequences, and how the change of intensity parameters would influence the musical expressivity. It was only after this preliminary work that a systematic application of the weights and a partially purposed work with their intensity parameters became possible.

The portability of the presently described performance technique must be deduced from the compositional structure (a fugue in general and the thematic structure of the *Kunst der Fuge* in particular) as well as from the instrumental context. *In nuce* it can be said that such systematic statements are still premature. Many more analyses and performances would be necessary, but these can only be realized as soon as RUBATO® has become a common tool of musicology. Then the question can be asked whether general recipes can

be stated that are valid beyond the limits of single compositions, or whether performance is rather bound to each individual composition.

The problem of historical context is undoubtedly a difficult one in view of systematic approaches. Should one use different analytical weights as a function of the historical situation (*Kunst der Fuge* requiring different weights/operators than *Träumerei*)? Or should one just use different operators with given weights? Could it be that at certain historical moments, the strong stress on weights' expressivity is more accepted than at other moments, where the interpretation is set more inside the listener's imagination?

Whatever is true for the transformation of the analytical structure in a scientific work targeting an artistically valid aesthetic performance, one should not forget about the elimination of (and nonetheless omnipresent) emotional and gestural aspects. The realization of a sonification of analytical structures during the interaction with the computer always bears a degree of emotionality, a phenomenon that should be taken into account as a kind of "uncertainty relation."

The judgment of the performance results took place in the same line as the judgment of a human performance, and the work with RUBATO® was also proposed as a provisionally final contribution to the work's discussion.

While describing the performance results, stress was put on a scientific analytic performance. The feedback to the analysis has a particular significance in that the conclusive character of a performance possibly could yield an analytical criterium. This implies an absolutely serious attitude toward analysis and no disclosure from emergent new aspects and innovative analytical ways of hearing.

Therefore, Stange-Elbe refrains from a discussion of subjects such as "prejudices against results which are produced by a machine", or "performance and the soul of music versus soulless performance machines". Instead, Stange-Elbe favors representations of procedures and performance strategies, the exemplary demonstration of connections between analyzed structures, performed results, and the attempt at a generalization of these insights in the form of a performance grammar in its dependency on the instrumental conditions.