Using Wavelet Based Analysis and Resynthesis to Uncover the Past

Jonathan Berger
Associate Professor
CSMT, Yale University
jberger@alice.music.yale.edu

Charles Nichols
Research Associate
CSMT, Yale University
cnichols@alice.music.yale.edu

Abstract

In 1889 Johannes Brahms recorded a segment of the first of his Ungarische Tänzen in an arrangement for solo piano. This paper describes the analysis and reconstruction of this recording and examines the implications of this work as a contribution to the understanding of performance practices in the late nineteenth century.

1 Background

On December 2 1889, Theo Wangemann, a representative of Thomas Edison recorded Johannes Brahms introducing himself and performing two segments of music at the piano. Brahms played a segment (mm 13 - 72) of a solo arrangement of his own Ungarischen Tänz No. 1, and a segment of a paraphrase of Strauss' Libelle.

Our analysis of the Brahms cylinder began as a test for an ongoing research project in which wavelet packets are used to separate signal from noise. (This method is described in [Berger, Coifman and Goldberg, 1994a] in this volume and detailed in [Berger, Coifman and Goldberg, 1994b).

In the course of our tests we realized that Brahms was altering large segments of the music. Since these departures from the score were not recognizeable prior to our denoising efforts we felt obliged to transcribe our findings. In addition to actual alterations of the music Brahms made liberal use of rubato and added protracted fermatti. We tried to generalize the temporal data we gathered into performance attributes in order to determine how consistent Brahms was in his performance to the musical context and structural features of the work.

Our method of denoising and reconstruction of a signal involves the following process:

The musical segment is digitized and the signal is expanded in each of a library of orthonormal bases. The basis giving rise to the least cost (using the Shanon entropy as a cost function) is chosen, the coefficients are ordered by magnitude, and a number of the leading terms is kept as the coherent part based upon the threshold cost of the remaining terms. The residual terms constitute noise. The noise signal is recursively expanded producing more and more detail. The coherent results are then recombined. We were thus able to eliminate a significant amount of masking noise and focus on the piano sound.

A scorefile or MIDI file transcription of the analysis using timing data extracted from the reconstruction process was then produced.

2. Data Analysis

The reconstructed sound file allowed us to measure and compare various temporal aspects of the performance. Since the dance uses a small set of rhythmic units we first subdivided the data by rhythmic types. The most recurrent of these types is the [♩ . ♪] measure unit. There are sixteen occurrences of this rhythm. These units occur in four consequent six measure phrases each divided by a terminating measure in which a half note is accompanied by arpeggiation.

The second section of the dance is characterized by two four measure phrases of sequential upper neighbor note motion in three [♪♪♪] note groups separated by a [♪ ♩ ♪] measure unit. This section is cadenced

by a two measure sixteenth note sequence of descending conjunct tetrachords followed by a sixteenth note ascending scale passage terminated by [♪ 𝅘𝅥𝅯𝅘𝅥𝅯 ♩]. The score repeats the last phrase with the neighbor note embellishment replaced by octave skips and a sextuplet arpeggio replacing the sixteenth note sequence.

For reasons that are not immediately obvious Brahms commenced his recording of the Ungarischen Tanze segment on the consequent of the first phrase thus starting on a V_9 harmony.

Brahms begins his performance at measure 13, which continues the six measure phrase structure that commences the work.

The second section of the piece is sub-phrased into four measure groups preserving the twelve measure phrase structure (4+4+4) rather than (6+6). Although the recording ends at this point, the score follows with a transition of one (4+4+4) phrase followed by one (6+6) phrase which leads into a recapitulation of the opening section.

A detailed analysis of the performance of each of the rhythmic types of the work follows:

1. [♩. ♪] measure groups:

While the overall durations of the three phrase groups do not differ radically the internal lengths and proportions of each measure unit is remarkably flexible.

Although in the score the [♩. ♪] pattern continues in measures 25--36, Brahms alters this group considerably in his performance completely subverting the [♩. ♪] units.

By scaling the proportions of the [♩. ♪] measures to one the general tendency towards underdotting becomes apparent. The eighth note is extended by almost a factor of two in three of the sixteen measures. Brahms substantially overdots only in the second measure unit. This rather surprising feature of the performance runs contrary to our expectations based on the persistent and intuitive tendency for performers to extend the longer duration at the expense of the shorter rhythmic value.

2. [𝅘𝅥𝅯𝅘𝅥𝅯𝅘𝅥𝅯] rhythmic units:

The middle section of the work is comprised largely of three sixteenth note elaborative figures characterized by an upper neighbor in the center of each figure. We were able to detect the structural line that was being elaborated. However due in part to the proximity in frequency of the structural notes and their elaborating neighbors we were unsuccessful in our attempts to detect and separate the elaborations.

3. [♪ ♩ ♪] rhythmic units:

The most exaggerated temporal fluctuations occur in [♪ ♩ ♪] measures that are terminators of the four bar phrase groups in measures 49--68.

Although the second and third occurrences of these measures are distorted (possibly by media deformity) the first and last instances of this type place a long caesura on the inner quarter note. These measures become significantly extended with overall durations of 1.033" (m. 52) and 1.146" (m. 68) in contrast to the average duration of 806 ms per measure.

The amphibrach [♪ ♩ ♪] permeates both Hungarian speech and dance patterns. Exaggeration of the internal quarter note is a feature of numerous dances in Eastern Europe.

The concluding four measure phrase which Brahms records (mm 69--72) poses interesting problems in transcription. In order to facilitate a closing cadence Brahms shifts the scansion of the phrase from the feminine to a complete masculine cadence:

This is achieved by shifting the metric weight to the second beat of measure 69 and preserving this scansion until the close of the segment.

4. arpeggios and scalar runs:

Terminating each phrase unit of the Dance is either a sixteenth note arpeggiation or a sixteenth note scalar run. In general Brahms performs these measures far more strictly than any of the other rhythmic types in the recording.

The most noticeable feature of the performance of these units is the augmentation of the second beat of measure

24. This change effectively creates an added beat such that the duple rhythm [♪♪♪♪] is played [♩♩♪♪]. Although the eighth note arpeggio is perceptible, the prominent notes in our reconstruction are:

Detection of arpeggios and groups of notes with short durations proved problematic at this stage of our research. We hope to improve the resolution of this data in future work.

3. Improvisation in Brahms' Performance

Improvised segments are of two types, prominent melodic insertion within the phrase structure of the original score, and alteration of the phrase structure in order to facilitate closure at a non-terminal point of the piece.

Of the latter, the most prominent is the augmentation of the cadence of measures 71--72 which facilitated closure with a masculine ending.

Of the former type the most prominent change is a distortion of the metric layout of the second phrase that Brahms plays, measures 25--36. The resulting line bears a rather prominent and independent melodic character. Although we have yet to isolate the accompaniment and all the internal detail of this phrase we have arrived at the following transcription of these measures:

The shift of weight from the first to second beat in Brahms' performance is consistent with the composer's predilection for metric ambiguity.

4. Media Deformities and Temporal Alterations

We attempted to search out periodic temporal distortion patterns that could have resulted from warping or machine imbalance.

In order to factor physical media irregularities into our performance analysis the following steps were taken:

1. systematically plot the onset times of various recurrent rhythmic motives,
2. compare the proportions derived from the rhythmic onset times between similar sections of the piece,
3. find patterns of recurrent proportions derived from the rhythmic onset times as they relate to the dimensions of the recording medium and the possible physical deterioration of the wax cylinder, and finally
4. compare steps 2 and 3, deciding which patterns more strongly suggest musically logical rubato and which resemble recurrent or even cyclic physical distortion of the wax cylinder.

5. Summary

Aside from the musicological and theoretical relevance of the performance data we believe that our work is a first step towards the development of robust tools for analysis, reconstruction and resynthesis of historical musical recordings. We have succeeded in exposing a significant amount of data which until now was either misinterpreted or deemed inaccessible. In so doing we believe that, however modest, this work is a contribution to studies on performance practice in the nineteenth century. It is also of interest in that we provide a glimpse of a composer of enormous stature taking leave of the score in his own performance. We plan to continue our efforts with the Brahms cylinder as well as perform similar analyses of recordings of Debussy and Grieg performing their own works.

The reconstruction method was far less successful then we hoped at clarifying the inner voices of the work. The basic premise of our analytical system is that data, once identified to be salient, can be separated from the whole. The reconstruction process can preserve both the extracted data as well as the residue. As our analysis tools become refined, we hope to return to the residue data and, in multiple passes, extract more detail.

Features of Hungarian music became an integral part of his musical style. Brahms performed Hungarian gypsy music on concert tours with the violinist Remenyi earlier in his career. Originally composed between 1852 and 1864 the four-hand set of twenty dances was transcribed by Brahms for two hands in 1872 and for orchestra in 1874. A violin and piano arrangement was prepared by Joachim. In addition to the

Hungarian dances Brahms wrote the Variations on a Hungarian Song (op. 21 no. 1) in 1857 and the 11 Zigeunerlieder op. 103 in 1887. The Piano Quartet, op. 25 (1861) features a Rondo alla zingarese and a set of gypsy poems in translation that comprise four of the op. 112 quartets (1891).

The Hungarian Dances were enormously popular during Brahms' lifetime. Whether or not this had bearing on Brahms' choice of the first dance for the recording is open to conjecture.

One issue that we are curious about is the radical differences between our analysis of the Brahms and that of [Kowar, et al 1983].

We hope to continue to refine our methods of analysis, reconstruction and transcription and to work towards further automating the process.

By applying orthogonal trigonometric and wavelet based analysis techniques we were able to map enough meaningful musical data for us to challenge this long held view. Our initial success in charting and transcribing the performance suggests that further work in this direction may yield much information in the way of performance practice.

6. Acknowledgements

Professor Ronald Coifman of the Applied Mathematics Department at Yale University has been at the forefront of research and development of wavelet based analysis and reconstruction methods. Our research is entirely based upon his insights.

In addition to his key role in the development of the denoising process Maxim Goldberg has had the patience of a saint in helping us to understand the mathematics involved in our work.

This research was funded in part by the Wavelet Research Group at Yale University.

References

[Berger, Goldberg and Nichols, 1994a] Berger, Jonathan, R Coifman and M Goldberg, "A Method of Denoising and Reconstructing Audio Signals" , Proceedings of the ICMC, 1994.

[Berger, Goldberg and Nichols, 1994b] Berger, Jonathan, M Goldberg and R Coifman, "Removing Noise form Music Using Local Trigonometric Bases and Wavelet Packets" , Journal of the Audio Engineering Society, forthcoming.

[Kowar, et al, 1983] Kowar, Helmut, Franz Lechleitner and Dietrich Schiller, "Zur Wiederherausgabe des einzigen Tondokuments von Johannes Brahms durch das Phonogrammarchiv", in Schallarchiv, 14 December, 1983.