Using Wavelet Based Analysis and Resynthesis to Uncover the Past

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Abstract

In 1889 Johannes Brahms recorded a segment of the first of his Ungarische Tänze 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 Tänze 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 recognizable 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 fermat.

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:

1. 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 Shannon entropy or 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 recomposed. 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 $\{\downarrow, \downarrow\}$ 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 $\{\uparrow, \downarrow\}$ note groups separated by a $\{\uparrow\}$ measure unit. This section is cadenced.

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by a two measure sixteenth note sequence of
descending conjunct sixteenths followed by
a sixteenth note ascending scale passage
terminated by \( \boxed{\text{J \boxed{J}} \boxed{J}} \). 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 Ungar-Chen Tanzeg segment on the
consequent of the first phrase thus starting
on a \( V_0 \) 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 \((4+4+4+4)\) rather than \((6+6)\). Although the recording
ends at this point, the score follows with a
transition of one \((4+4+4+4)\) 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. \( \boxed{\text{J \boxed{J} \boxed{J}}} \) 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 \( \boxed{\text{J \boxed{J} \boxed{J}}} \) pattern
continues in measures 25–36, Brahms alters
this group considerably in his performance
completely subverting the \( \boxed{\text{J \boxed{J}}} \) units.

By scaling the proportions of the \( \boxed{\text{J \boxed{J}}} \) 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. \( \boxed{\text{J \boxed{J} \boxed{J}}} \) 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. \( \boxed{\text{J \boxed{J} \boxed{J}}} \) rhythmic units:

The most exaggerated temporal fluctuations
occur in \( \boxed{\text{J \boxed{J}}} \) measures that are terminals
of the four bar phrase groups in measures
49–68.

Although the second and third occurrences
of these measures are distorted (possibly by
media deformation) 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 \( \boxed{\text{J \boxed{J}}} \) 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 problem 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 \( \frac{2}{3} \) is played \( \frac{3}{4} \). 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 Bralzn’s 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. systemically 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 turca and a set of gypsy poems in transcription 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 hai 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
