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Expert pianists' expressive timing consistency: a case study of the Gluck-Sgambati Melody played by Rachmaninoff

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Background

Performances of Western art music are generally based on the composer's score, but each performance is unique. At the expert level, the main source of variation is the performer's musical expressivity, i.e., expressive deviations from the score.

While no two human performances can be identical, certain renowned artists, such as composer-pianist Sergei Rachmaninoff (1873-1943), are said to have been remarkably consistent. As quantitative data are scarce despite some prior work[1], we present a case study of a piece he recorded on piano roll in January 1925, then as an acoustic recording four months later in May 1925.

The music is Sgambati's 1878 piano solo transcription of "Melody", originally from Gluck's opera Orfeo ed Eurydice (1774). This relatively slow piece was chosen because, compared with classical renditions of the original, Rachmaninoff's interpretations are idiosyncratically expressive with ample tempo rubato.

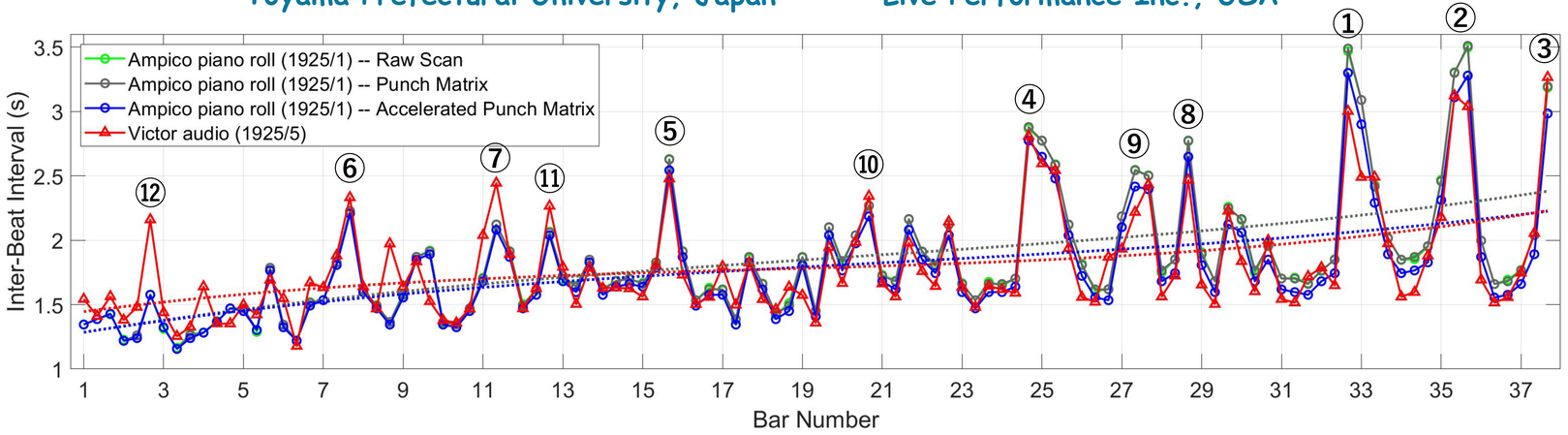
Music Data

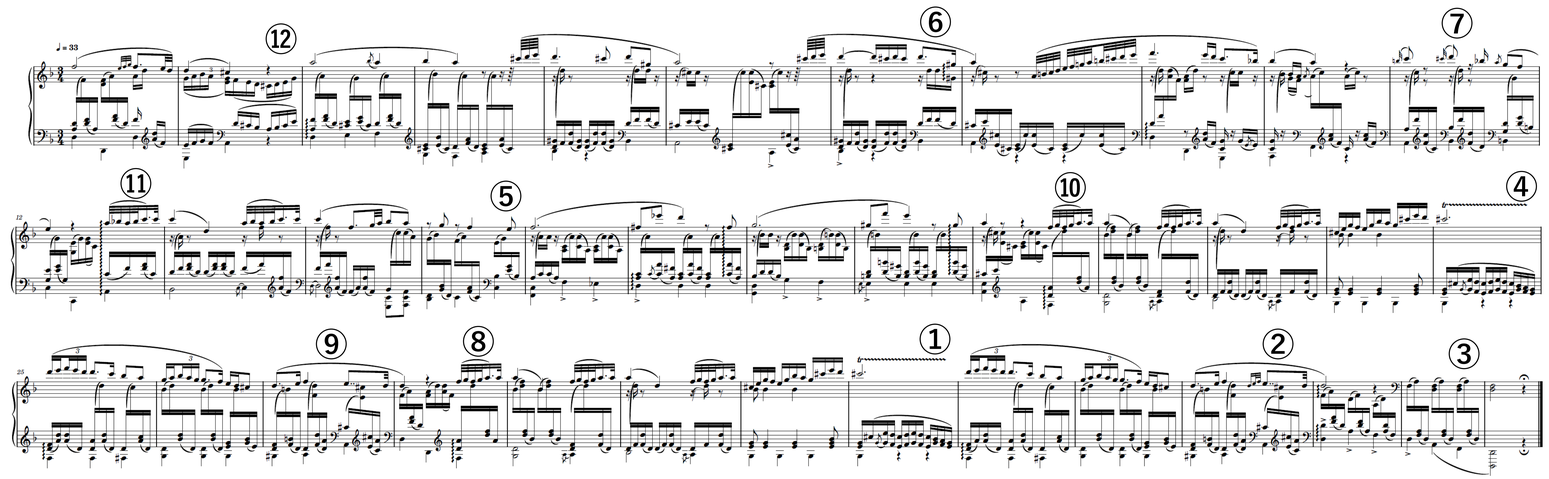
The acoustic recording was taken from a commercial CD (2005 Sony BMG, RCA label), originally recorded in 1925 by Victor.

The Ampico piano roll (64921) was first digitized with a pneumatic scanner and image processing to locate all perforations. These **Raw Scan** data were then corrected[2] for skew and scatter errors caused by imperfections of the perforator, paper, and scanner. The result was a **Reconstructed Punch Matrix** with all note onsets & offsets aligned on a 2D grid with fixed distances between rows (along roll length) and between notes (along roll width). As the presence or absence of paper acceleration could not be definitively determined, both the original and a uniformly accelerated version[3] were prepared and analyzed.

Beat Labelling & IBI profiles

Beat labelling was performed manually at the level of quarter notes (three beats per bar). Potential ambiguities were avoided by using the same beat onset notes in both recordings.





For the acoustic recording, the time instants of all 112 beats were marked manually with the aid of a zoomed-in waveform display and repeated listening to the corresponding short intervals.

For the piano roll data (Raw Scan, Punch Matrix and accelerated Punch Matrix), all 112 beats were marked manually with the aid of a zoomed-in piano-roll display.

The Raw Scan beats (in cm along the roll) were converted to time (s) according to "Tempo 80" marked on the roll: 8.0 feet/min = 4.064 cm/s.

The Punch Matrix beats (in row number) were converted to time (s) by additionally using the row pitch: 356.9 rows/foot, i.e., 47.59 rows/s.

The performance timing profiles shown in the figure above were obtained by calculating the difference between every adjacent pair of beat instants, i.e., the Inter-Beat Intervals (IBIs). IBI is effectively the inverse of local tempo.

Results & Discussion

First, the figure above shows that the IBI profiles derived from the Raw Scan (green) and non-accelerated Punch Matrix (grey) are almost indistinguishable (r = 0.9998, MAE = 6.7 ms). This confirms our expectation that the punch matrix reconstruction corrected the scanned perforations on the order of only a few ms, leaving beat-level timing (e.g., rubato) essentially unaffected.

Also as expected, the effect of paper acceleration gradually increases along roll length, from almost no effect at the start, to a maximum reduction in IBI of 0.21 s at the last beat (grey vs blue).

Taking the Punch Matrix IBI profiles (grey & blue) to represent the piano roll performance, we next compare them with the Audio IBI profile (red). Although the recordings were made at different studios, on different pianos, and four months apart, the IBI profiles are remarkably similar.

The **mean tempi** indicate consistency, with the audio performance lying between the two piano roll data.

Accelerated Piano Roll:	33.7 BPM
Audio:	33.3 BPM
Non-accelerated Piano Roll:	32.5 BPM

The profile shapes are also quite similar. Pearson correlations and mean absolute differences relative to the audio, show the accelerated roll IBIs are marginally closer.

Accel. roll: r = 0.93, MAD = 121 ms

Non-accel. roll: r = 0.92, MAD = 143 ms

Long-term Tempo curves

The red, grey and blue dotted lines show the respective Cubic curves of best fit. They confirm that in comparison with the audio, the piano roll begins a little faster (shorter IBIs especially in the first 3 bars), and ends a little slower (longer IBIs especially in bars 25-36), with the accelerated roll matching closer to the audio in the latter half. The 3 curves share a similar overall shape: concave down in the first part and concave up in the latter half.

Rubato-induced beat prolongations

At a finer level of comparison, each Cubic curve was subtracted from its IBI profile and the 12 most prominent peaks identified. These beats of greatest prolongation are labelled in both the figure and the score. Prolongations ① and ④ occur at the end of two long trills and the start of their following melodic phrases (bars 32-33 and 24-25). Prolongations ② and ③ occur in the final bars near the end of closing phrases. Prolongations ⑧, ⑩, and ⑪ occur at the 3 first instances of the repeated groups of expressive demisemiquaver (32nd) notes. Prolongations occur most commonly (but not exclusively) at the 3rd beat of a bar.

Conclusions

Quantitative comparison of inter-beat intervals of two recordings separated by four months, confirmed that expert piano virtuoso Rachmaninoff executed this piece with uncanny consistency. Remarkable similarities were found in overall mean tempi, global tempo profiles, & local beat prolongations due to rubato.

We aim to extend this case study to other pieces he recorded more than once.

References

[1] An,M. (2020) "The mathematics of rubato: Analyzing expressive timing...," *PhD dissert.*, Univ. South Carolina.

[2] Stahnke,W., "Skew, scatter, and pitch in music roll scans" *

[3] Stahnke,W., "Acceleration in music rolls" *

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