BNAM 2018
Baltic-Nordic Acoustics Meeting
15-18 April 2018
Harpa, Reykjavík, Iceland

Piano Music Performance Analyses; Technologies and Examples.

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Timing, accentuations and specific piano performance data are studied by various analyses on several recorded versions of the same excerpt from Symphonic Etudes op.13 by R. Schumann. The professional pianist performed the piece with several different timbral intentions, in this paper reduced to only “SOFT” and “BRIGHT”.

The main topic is to compare two different methodologies; analysing the phrasing by digital signal processing (looking for musical information in the acoustical signal) vs. establish reasonably mechanical performance events (analysing registered piano key actions according to the MIDI specification). The two methods may be more complementary than competing.

Keywords: Music performance analyses; Musicology; Digital music signal processing; Music Information Retrieval; MIDI analyses

1 Introduction

All instruments can produce a range of different timbres and sound qualities depending on playing style, intentional variations and performance control. It is highly relevant for a musician knowing about these innate properties of the instrument, as well as appropriate technical skills in order to change the musical expression.

In this paper, piano timbre, defined by timing and dynamical variations, is studied by performing various analyses on several recorded versions of the same piano piece. The DSP analyses included properties of temporal features, envelope amplitudes of signals, spectral centroids, roll off frequencies, spectra and histogram envelopes, low-energy ratios and temporal development of energy together with average RMS energy for each signal in the attempt to distinguish these two timbre expressions from each other with quantitative measures.

The presented examples will focus on possibilities/similarities/differences between digital signal processing versus MIDI recording analyses.

This work is part of an ongoing study of music performology, here as a research cooperation between internationally established music and technology research laboratories, Acoustical Research Centre, NTNU, Trondheim, and ESMAE/Politécnico do Porto, as an attempt to define important reliable and significant quantitative measures describing qualitative timbre expression.

2 Data acquisition

Simultaneously recorded sound and MIDI information is the bases of this study. A professional musician performed the piano piece with three different timbral intentions of his own choice, in this paper reduced to only “SOFT” and

“BRIGHT”, in two separate recording sessions in a professional music studio at the Casa da Musica, Porto, and the latter session with a suggested enhanced timbral expression. These 4 versions are later on named as “SOFT”, “moreSOFT”, “BRIGHT” and “moreBRIGHT”.

Both sound and MIDI signals where recorded direct-to-disk using a Yamaha Disklavier Grand GC1.

The total data base comprises 6 stereo recordings of the Schumann etude performed in 3 different “moods”, 1 hour of scientific discussion between the performer and the project management, and more than 50000 lines of MIDI commands.

3 Methodologies

Moffat et.al. [1] have discussed several digital signal processing toolboxes for music feature extraction evaluation: Aubio, Essentia, jAudio, Librosa, LibXtract, Marsyas, Meyda, MIR Toolbox, Timbre Toolbox and YAAFE.

For the present project two different methods of music performance analyses have been partly discussed and compared: Digital signal processing (MIR Toolbox) and event recording (MIDI).

3.1 MIR (Music Information Retrieval)

Parametric music information extraction using the matlab based MIRToolbox is thoroughly explained in [2]. Figure 2 shows part of the analysing structure.

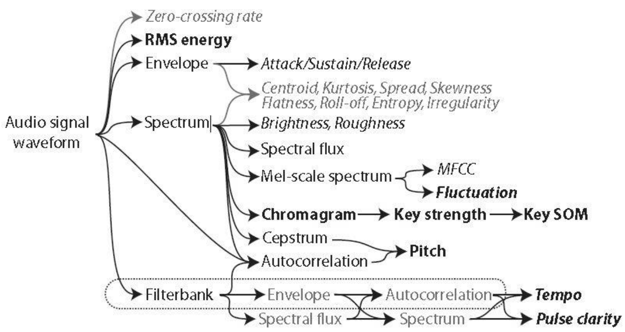

Figure 1: Structure of the music information retrieval process. (From [2])

This DSP analyses include properties of temporal features, envelope amplitudes of signals, spectral centroids, roll off frequencies, spectra and histogram envelopes, low-energy ratios, and temporal development of energy together with average RMS energy mainly to distinguish the two timbre expressions “SOFT” and “BRIGHT” from each other with quantitative measures. In addition the analyses include a new developed parameter, an inter-measure time interval (IMI) similar to the well-known inter-onset interval (IOI). The IMI may be considered as a low-pass filtered IOI.

3.2 MIDI (Musical Instrument Digital Interface)

With a well-controlled and calibrated MIDI implementation we may extract detailed information from the event recording system (MIDI), such as:

- Time stamp
- Key number (pitch)
- Key number chord rank
- Key velocity
- Sustain pedal (MIDI con 64)
- Soft pedal (MIDI con 67)

The temporal precision is defined by the computer controlled time-stamp. Concerning the sound recording we may establish the time information with a resolution down to approximately 10-15 ms but with a higher uncertainty compared to the MIDI info. Analyzing drum beats the precision may be down to some few ms.

Single tone pitches may be calculated from the sound spectrum but the definition of chords or simultaneously pressed keys are harder to define whereas the MIDI information directly includes Key number and pitch rank (ranking pressed keys as the MIDI data protocol defines a serial data stream).

4 Analysis Examples and Discussion

The tone parameters have to include a definition of the behaviour of the tone amplitude depending on the performing intention. Referring to a piano tone the ADSR (Attack, Decay, Sustain, Release) is reduced to attack time, maximum amplitude and specifications of the sustained tone depending of both key release and pedalling. In this case an event recording system produces relatively correct timing numbers even if *attack* is defined when the piano key is pressed 1 mm down (or when the key hammer shaft is passing the two speed measuring light diodes) which may be some milliseconds ahead of the sounding tone.

4.1 DSP and MIDI possibilities.

Timing.

- Using DSP the definition of tone on-set has to be specifically defined (between positive transient 3 dB above noise floor and -3 dB below maximum amplitude?)
- MIDI time stamp is precisely defining key action.

Single pitch.

- Pitch estimation of single tones may be handled by dynamic filtering and frequency analyses procedures.
- MIDI pitch is defined by library look-up: Key number.

Chord pitch.

- Pitch estimation of simultaneously struck strings is not straight forward; can be solved with a combination of library look-up and frequency partials analysis.
- As MIDI is a serial data protocol all pitches are defined by the equivalent pressed keys, with at least 1 ms time distance.

Amplitude.

- RMS and peak values are acceptable measures for single events but may be imprecise for rapid passages with multiple keys.
- MIDI key velocity is dependent on a sufficiently correct transformation from internal key hammer velocity to an amplitude measure.

Timbre.

- Spectral centroid, harmonic contents and fundamental frequency measures may give a certain definition of timbre.
- MIDI has no direct timbre measure but may be defined/calculated by a combination of key numbers and key velocity.

Pedalling.

- DSP based pedalling analyses have just recently been a research topic with some success. Liang et.al. [3] states "The current method is able to detect the pedalling techniques for single notes in the middle range of the piano. .. more sophisticated approaches should be developed and applied in order to solve pedalling detection in the context of polyphonic piano music." (Oct., 2017)
- MIDI detects both the sustain pedal (MIDI controller 64) and the soft pedal (MIDI controller 67).

4.2 Analysis examples

The BNAM Conference presentation will include a lot of both MIDI and MIR analysis examples, where only some few are presented here.

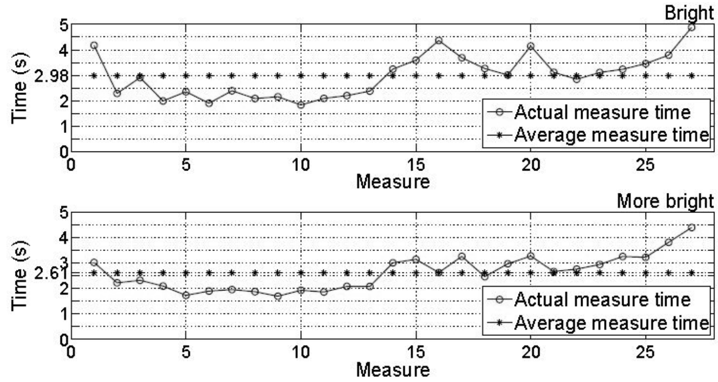

Figure 2: Inter-measure intervals (IMI)

Fluctuation in timing for the “BRIGHT” and “moreBRIGHT” recording shows small but significant differences.

The average measure duration for the “BRIGHT” and “moreBRIGHT” is 2.98 s and 2.61 s, respectively, reaffirm that the “moreBRIGHT” intention leads to performing faster, with less deviation from the average value. This can be interpreted as less room for rubato.

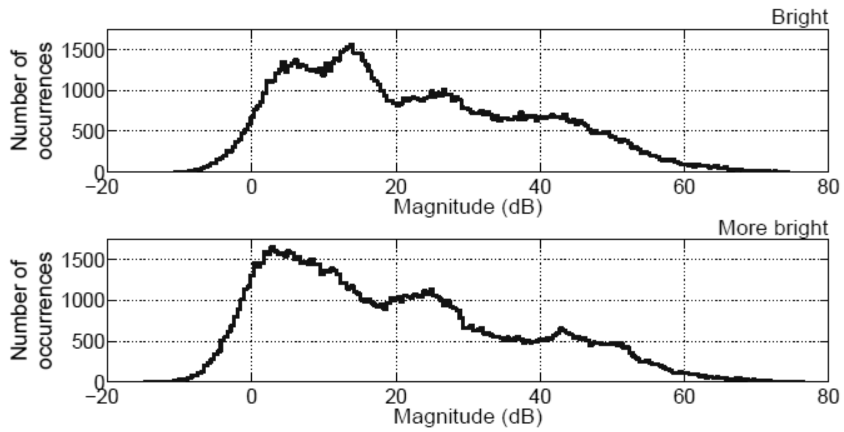

Figure 3: Histogram envelope calculated from magnitude (dB) spectrum

As an alternative to over-all spectra, the magnitude distribution is presented. The histograms show distinct peaks but overall a relatively even distribution. The majority of occurrences seem to be centred at about the same magnitude range, indicating a rather similar dynamic level of the recording.

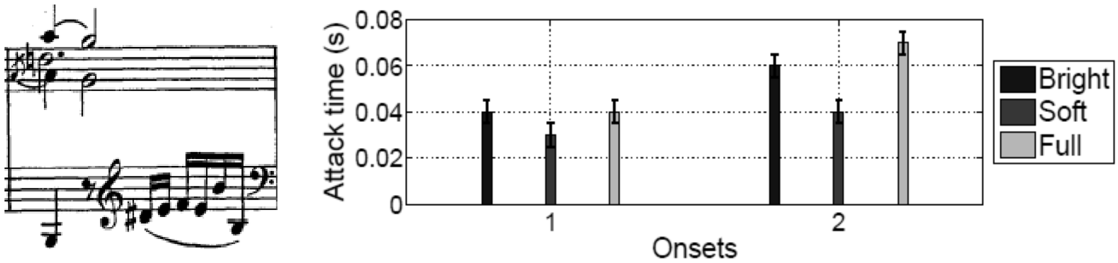

Figure 4: Bar 22, attack time.

Figure 4 shows the attack time for the first two onsets of measure 22 (to the left), the first onset seems to be played with the same attack time in all recordings. Attack times for the second onset are notably longer. This may be due to an unclear placement of the attack start in the MIRToolbox.

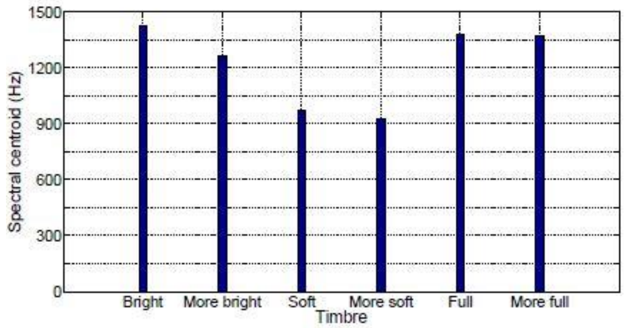

Figure 5: Spectral centroids (Hz) for all six piano recordings.

Centroids of all six recordings are plotted in Figure 6. Centroids were found for the whole recordings. Soft timbre recordings resulted in spectral centroids within the interval 900 Hz - 1 kHz, and these were significantly lower values compared to bright and full timbres, as a lower dynamic level and a softer attack on the piano keys will result in fewer resonated overtones and thus less high frequency components.

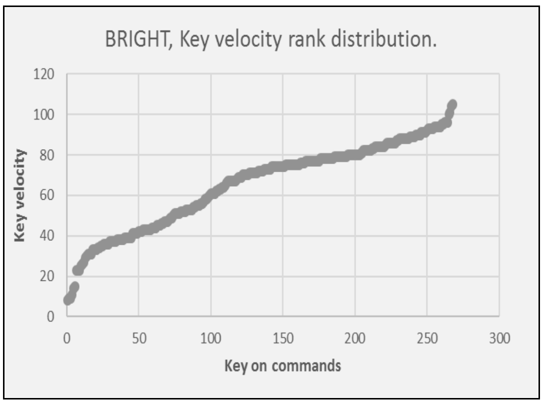

Figure 6: Distribution of Key Velocity for the recording "BRIGHT".

The distribution of MIDI key velocities may reveal information related the previous figure on spectral centroids and other amplitude or intensity measures.

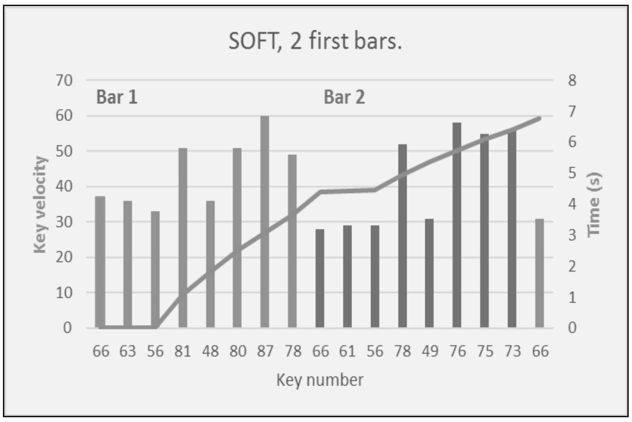

Figure 7: Key velocities and timing, two first bars, "SOFT".

The graph (right) shows Key Velocity (left vertical axis) for all the tone onsets (horizontal axis) referring to the music notation (left). The solid line indicates timing (right vertical axis). The horizontal parts of the time line show (almost) simultaneous onset for the three tone chord on beat one in both bars. The accompaniment with left hand tones (Key number 66 and below) have a softer onset (Key velocity below 40) compared to the melodic tones. The time line inclination indicates a slower first bar compared to the second one.

5 Concluding remarks

This paper concerns different methods for doing music performance analyses and give some examples based on both DSP and MIDI. As long as the MIDI mechanical and software system is controlled, calibrated and reliable, data is easy to obtain and the analyses may be easy to perform. However, in the long run it seems that DSP solutions can be preferred, as a lot of instruments and orchestra do not have a MIDI implementation. Concerning “simple” MIDI implemented instruments, like the piano, we still may consider DSP and MIDI analysis systems as complementary.

6 Acknowledgement

This project is part of the ongoing Music Performology Program at the Acoustical Research Centre (ARC), University of Science and Technology (NTNU), Trondheim, Norway. The MIR presented results are from the M.Sc. Thesis by Lerstad [4], which is considered as a milestone in the research program, since the start in 1990 [5]. Comprehensive discussions with colleagues have been highly appreciated.

References

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