

# Back to the future

## The digitisation of reproducing piano rolls as a rendering of the past

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### Introduction

In recent years, early recordings have become increasingly significant sources of evidence within various fields of musical research. This is, at least in part, because acoustic recordings, reproducing piano rolls, and early electrical recordings preserve performance styles that have, in many cases, disappeared from contemporary performance practice. That such early recordings are now in vogue testifies to the valuable role that they play within contemporary music research, particularly with regard to musicological interest in performance studies. Their rise to prominence, however, is partially a consequence of accessibility. The original recordings are difficult to encounter first-hand, since the technologies involved are not only scarce but many have deteriorated in the period since their construction. The digital age of sound recording has, however, allowed for a degree of unprecedented accessibility; digitised versions of early recordings have been published on countless CDs and DVDs, and a host of digital files may now be streamed from sound libraries and websites around the world. Digitisations are therefore invaluable, since they allow access to recordings in ways that would otherwise be impractical or impossible.

This article considers digitisations as form of evidence. It takes stock of what digitisations have to offer, considers what kind of research sources they might be, and assesses the ramifications for any form of music research that is based on this kind of evidence. In order to achieve this, the article focuses upon digitisations of reproducing piano rolls; these are invaluable sources of evidence that illuminate stylistic conventions of piano playing common during the late nineteenth and early twentieth centuries, testifying to changing fashions in performance practice, whilst demonstrating an evolution of performing styles over time. The article starts by identifying some of the many variables involved in the original production of such rolls. It goes on to address some of the ways in which digitisations may be produced from piano rolls, highlighting key variables that ultimately differentiate digitisations of the same roll. Observing the range and scale of these variables, it is suggested that digitisations are far from neutral copies or mere reproductions of the original. Rather, they have a substantial impact upon the many ways in which we encounter and experience the original. To demonstrate this point, a

case study examines nine digitised versions of the same reproducing piano roll: Frédéric Chopin's Nocturne Op. 27 No.2 performed by Theodor Leschetizky and recorded using a Welte-Mignon reproducing piano system. This roll was recorded in February 1906 in Leipzig, Germany, and has since become an extremely popular example of pianism from the time, largely on account of the legendary status bestowed upon Leschetizky, as both pianist and pedagogue. As a result of this popularity, the original roll has been digitised in numerous different ways, and these allow for a range of comparisons to be drawn. Using a range of visualisation tools to examine the differences between these nine digitisations, a surprising degree of diversity becomes apparent; despite being drawn from the same roll, the nine digitisations display conspicuous differences in recording format and quality, clarity, dynamics, pitch, duration, timbre and spectral balance.

Findings from the case study highlight some of the manifold factors that need to be considered and addressed by anyone hoping to use digitisations as a source of evidence. Taken as a whole, therefore, this article is intended as a guide to aid those using digitisations within their research. As with all research sources, sonic evidence cannot be relied upon without recourse to additional, supplementary, information. In this particular case, one must pay attention to the various ways in which digitisations stamp their own impression upon the original. It is paramount that we understand this impression, so that early recordings, which allow the research to go back to the past, remain invaluable sources of evidence long into the future.

## The Welte-Mignon reproducing piano rolls

The Welte-Mignon reproducing piano system was premiered in 1904 by Edwin Welte (1875–1957) and Karl Bockisch (1874–1952). This system preserved, with a high degree of accuracy, the pitch, rhythm, tempo and phrasing of a given performance, including the use of pedals and dynamic nuances (Hall, 2001, p. 6). After the recording process, the roll that was produced could be played back on a specially designed reproducing piano, which has a built-in pneumatic mechanism made by Welte-Mignon, or with the use of a *Vorsetzer*; a device that 'sits' in front of a piano, as implied by the German name, and presses the keys with felt-covered leavers powered by a pneumatic mechanism that covers the keyboard.

The reproducing piano used to make the recording had an in-built mechanism that marked performance information on a paper roll as the pianist pressed the keys. Although there were certain differences between the various reproducing piano companies, most produced marks with a pencil or stylus to represent notes, tempo, rhythm, the speed of hammers and pedalling (Bescoby-Chambers, 1964, p. 15). After a given performance, holes would be cut into the marked paper roll. A pneumatic mechanism would then follow

these holes, as a form of instruction, to reproduce an instance of the original performance. Thus, although sound was not captured, the piano roll was able to reproduce performances on demand and, as such, constitutes a form of early recording.

Certain details of the recording process remain a mystery; Welte-Mignon methods were a well-guarded secret and, after the Welte factory was bombed in 1944, crucial evidence of the recording processes was lost forever. For this reason, there is ongoing disagreement about certain aspects of the recording process (Peres Da Costa, 2012, pp. 10–11). There are several testimonies, including one by Richard Simonton (1915–1979) who met Welte-inventors in 1948 in Freiburg, Germany. Simonton, published on five 12-inch vinyl records by Columbia Masterworks Record (ML 4291–95), left valuable documentation about this visit and recording process (Peres Da Costa, 2001, p. 11). Despite this, however, several authors find his testimony lacking important details and questionable in certain key areas (Van Riper, 2012, pp. 2–3). There are several theories describing how the system recorded dynamics (Edwin Welte claimed that dynamics were registered automatically during the recording; Hall, 2001, p. 7) and even the speed of the keys (even though this is clearly registered on the roll). There are various accounts of the recording technologies, and most of them conflicting.

Rolls were sometimes edited post-recording; note positions (pitch) could be altered, along with dynamics and pedalling. In this way, it was possible to correct wrong notes on rolls; the method of correction simply involved covering the 'wrong' hole before punching a new hole in the 'correct' place. Despite this, Welte-Mignon rolls do not appear to have been edited very often. Peres Da Costa suggests that the early Welte recordings were most likely edited very little, if at all, in line with company policy; proof of this lies in the fact that the company did not always edit out the wrong notes, preferring to leave them in to preserve the performance as captured. In any case, many aspects of the recording (such as rhythm and dislocation between melody and accompaniment) could not be easily changed; it would be almost impossible, for example, to line up the holes in the paper with minor and, more importantly, irregular delays, as are often found in these kinds of recording (Peres Da Costa, 2012, p. 29).

This section served to briefly explain the nature of piano rolls and the processes involved in playback. It was noted that piano rolls may preserve a combination of information registered during recording alongside additional information edited afterwards. There is some debate as to how this was achieved and at which point in the process. Since this article focuses on digitisations of piano rolls, this debate is largely incidental; the act of digitisation takes place once the roll has been finalised, regardless of when the information was registered during the recording process. Accordingly, we shall now consider such an act, drawing attention to the many variables involved in digitisation.

## The playback and digitisation of the reproducing piano rolls

At first, the digitisation of reproducing piano rolls may seem like a relatively straightforward process, given that the roll may be played on an appropriate instrument, and simply recorded in a digital format. On closer inspection, however, this process proves complicated; multiple factors exert a potentially significant influence upon what is ultimately captured. In this section, we briefly survey such factors, starting with the instrument that may be chosen for playback.

When a finished roll is played back, using either the specially designed reproducing piano or a *Vorsetzer*, the quality of the instrument becomes paramount;<sup>1</sup> the overall sound of the piano roll recordings will always depend on the quality of the instrument on which they are performed (Peres Da Costa, 2012, p. 27; Philip, 2004, pp. 31–34). In ideal circumstances, therefore, the roll would be played on the same instrument used during the recording. In most cases, however, this is not possible.<sup>2</sup> Not only are these instruments widely displaced, and therefore often inaccessible. Many have fallen into disrepair; a decline in popularity after 1930 meant that many of these mechanical instruments were rarely maintained, reducing the quality of their reproduction of the original performance, particularly in terms of voicing and the overall balance of the keyboard. Thus, even if one managed to locate the original instrument, there is no guarantee that the roll would sound as it once did. Maintenance of player pianos is a technically demanding job, and has become much more complicated with the passage of time; parts wear and tear, the soundboard deteriorates with time, as do the hammers, dampers and action parts. The reproducing roll system is equally complicated; one has to maintain the pouch, lifter, valve area, as well as valve travel and bleed size and percentage, and spring rates, to name but a few. As a direct consequence, rolls are often played on different instruments from those used in recording. The significance of this cannot be underestimated; as with all pianos, the touch, attack, tone, balance, voicing, dynamics, pedalling, is instrument-specific and will consequently impact upon what is heard when the roll is played back.

Given what has been said above, the best-case scenario for producing a digital version of a piano roll would be one in which the original instrument is available, and in perfect working order. In this case, one may proceed by simply playing the roll whilst recording

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1 Early twentieth-century pianos tended to have much lighter action than their contemporary counterparts, and this becomes particularly significant when using a *Vorsetzer* on a modern instrument since it is likely to produce quite a different result than that originally captured.

2 The author is very grateful to one of the anonymous peer reviewers for noting that there are some, albeit rare, instances in which piano rolls were played back and recorded with microphones under the supervision of Welte and Böckisch. These include the rolls made by Simonton in 1948. These recordings are of particular interest, since they were clearly approved by the inventors of the system and it would be interesting to compare the supervised recordings with digitisations made since. Unfortunately, Leschetizky's piano roll was not recorded in this way and, as a result, we have no supervised digitisation to enter into the discussion.

using some form of digital media. Once again, however, this process is far from straightforward, involving a great many variables that are far from neutral. Crucially, the process of recording requires numerous choices on the part of the producer or recording engineer; pianos, a notoriously difficult instrument to record, may be approached in many different ways that will profoundly affect the digitisation. For example, there is initially the choice of an appropriate microphone; although there are various specialised piano microphones on the market, engineers rarely agree on which is the most appropriate, often discussing differences relatively to the characteristics of specific pianos. Since different microphones emphasise or deemphasise different aspects of the frequency spectrum, they have the potential to change the tonal balance of the piano. Beyond this, there is a question of placement. For example, one may wish to place a microphone close to the resonant box of the piano, in order to capture more of the direct sound emitted from the instrument. In doing so, however, one captures something very different from what any audience might hear at a performance or concert, in which high frequencies occurring when the hammer strikes the string are invariably pronounced. Clearly, then, this is often a question of taste, since there are no determinate rules about where to place a microphone on a piano. There is also a question of balance; a microphone played close to one part of the piano will not necessarily capture frequencies produced across the instrument, and this is particularly significant when dealing with the relative size of the player piano. Moving microphones further away from the instrument, however, produces the opposite effect; the acoustics of the room becomes more significant, with frequencies being absorbed, diffused and refracted within the recording space. In this case, direct sound is replaced by indirect sound lacking the specificity and clarity of the closer microphone, but capturing a more familiar concert-style setting where the piano is heard relative to a listening position.

There are multiple additional choices that must be made. For example, a recording engineer may capture the piano in mono, stereo or, as now common, with multiple stereo pairs of microphones. Furthermore, the room acoustic needs to be considered; different recording spaces will ultimately determine what might be captured once the piano roll is running, altering the frequency content picked up by the microphones, and changing the dynamic levels so carefully controlled by the pianist. Beyond these, there are questions of format, image balance, mixing, mastering, and many associated technical questions that someone, recording engineer or other, must address in order to produce a digitisation. These factors cannot be dismissed or ignored; just as aspects of a pianist's pianism are radically dependent upon the aural, haptic and kinaesthetic feedback received during the act of performance, so too is our ability to appreciate the digitisation radically dependent upon choices made during the recording; microphones placed at a distance in a

highly reverberant room will, for example, likely remove just about any trace of nuance and technique captured by the roll, whereas a close microphone in a dry space may well render loud and brash a performance that was initially soft and delicate.

An alternative means of reproducing the piano rolls serves to transfer the analogue data (essentially, what has been punched into the roll) into digital data. This has been achieved in multiple ways. For example, Mike Szczys used optical sensors to transform the roll data into digital data (putting infrared LED on one side of the roll, and 88 light sensors on the other side, and read the data from the sensors), using fibre optic cable to align the holes.<sup>3</sup> Warren Trachman digitises with optical scanning of rolls, before converting the scanned, graphic image to MIDI data. Following this, he converts the data to an electronic roll, which can be played on any standard playback system.<sup>4</sup> Gustavo Colmenares, René Escalante, Juan F. Sans and Rina Surós suggest mathematical and computational analysis of the rolls, through using RollToMidi application after the roll has been scanned (Colmenares et al., 2011, pp. 58–75). The use of digital scanning technologies in order to preserve rolls is being developed at Stanford University in their well-known Player Piano Project.<sup>5</sup> At the other end of the scale, music enthusiasts are developing new ways of preserving piano rolls. For example, volunteers from the International Association of Mechanical Music Preservationists (IAMMP) have numerous approaches, with shared findings and music files.<sup>6</sup> Ultimately, methods for the digitisation of rolls are so diverse that one even finds MIDI files, derived from rolls, being run on a wristwatch.<sup>7</sup>

Assuming that these devices are accurate in their rendering of the digital information (and there is no reason to assume that they are not), one might reasonably prefer these realisations to those discussed previously. There is, however, a question as to how the MIDI information is to be used. If used entirely within the digital domain, MIDI can only be used to trigger samples or, alternatively, synthetic versions of a piano. This potentially limits their value; whatever their merits of samples and synthesis, one cannot reasonably downplay the significance of replacing the sound of an actual piano with that of synthetic instrument, since the latter is not capable of replicating the exact character of the former. At the time of writing, it is impossible to imagine a synthetic instrument ever being in a position to reasonably challenge an acoustic instrument in terms of fidelity. An alternative option would be to use MIDI as a way of instructing a MIDI-controlled player piano, thus combining the accuracy of MIDI information with an acoustic instrument.

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3 For more information, see: <https://quelab.net/172/player-piano-roll-reader-project-part-2>

4 For more information, see: <http://www.trachtman.org/rollscans/scanningbackground.htm>

5 For more information, see: <http://library.stanford.edu/blogs/stanford-libraries-blog/2017/04/piano-roll-scanner-update>

6 For more information, see: <http://www.iammp.org>

7 For more information, see: <http://www.qrsmusic.com>

In doing this, however, one is immediately back to where this section started; a MIDI-controlled piano (necessarily a relatively new instrument) is invariably different from the instrument used to make the roll in the first place. Furthermore, this new piano would also need to be recorded for a digitisation to be made. In short, MIDI is no more neutral, in terms of producing a digitisation, than other methods.

Although briefly introduced, there are clearly many variables that coalesce within the process of digitisation; the many decisions made by the recording engineer, or producer, may have a potentially profound effect on our ability to hear a given piano roll as it sounded upon capture. Whilst MIDI realisations would serve to remove some of these recording decisions, they are also far from neutral, offering either more of the same, or the option to synthetically render the playing. Rather than leaving the discussion at this stage, however, we shall now introduce a case study in which nine separate digitisations of the same piano roll are discussed. As we shall discover, the digitisations differ in surprising and substantial ways, despite their shared origins. These differences spring from the many variables outlined above, but it is striking to observe the extent of such differences in respect to a given roll.

## The case study

This case study considers nine digitisations of Leschetizky's piano roll of Chopin's Nocturne Op. 27 No. 2. The original roll was recorded on 18th February 1906 by Welte-Mignon in Leipzig. Included are:

- Archiphon,<sup>8</sup> made on the Steinway-Welte piano which belonged to Edwin Welte, restored and furnished with electric speed control (according to Werner Unger, the director of Archiphon company, this guarantees the exact tempo reproduction). Two files were downloaded both from Amazon and iTunes in order to assess whether there are any differences between the two.
- Opal, made in 1988. Opal digitisations are widely praised for their quality. This particular file was purchased electronically and specific information about the piano and the method for the digitisation could not be sourced.<sup>9</sup>
- Two radio broadcasts were used, one from Stitcher Radio and one from Sveriges Radio (Swedish Radio). Private testimonies from those involved into the production of these digitisations suggest that both were done with a modern Steinway grand piano and the use of *Vorsetzer*. However, the author was unable to confirm this fact.

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<sup>8</sup> *The closest approach to 19th century piano interpretation*, 1992 [CD] Archiphon 106.

<sup>9</sup> *Pupils of Leschetizky*, 1988 [CD]. OPAL 9839.

- A private recording made by Denis Hall using a well-maintained original Steinway-Welte in excellent condition.
- Two YouTube digitisations: YouTube has become a popular tool for accessing early recordings and therefore plays a significant role in the ways that digitisations are accessed and used. Furthermore, both YouTube digitisations are played on different instruments: one on Bechstein-Welte and one on Steinway-Welte.
- Tacet, again using the *Vorsetzer*, but on a Steinway D model, while Hans-W. Schmitz adjusted the Welte-Mignon system.<sup>10</sup>

Taken as a whole, these digitisations include: professional recordings released on commercial CDs; amateur recordings which are unreleased; online digitisations available for streaming; various different pianos used for playback (some with a built-in mechanism and others with the *Vorsetzer*). As such, these digitisations represent a range of different ways in which a researcher might gain access to the Leschetizky roll if he or she wants to use this within a research project. We shall now consider the similarities and differences between these various digitisations, in six different stages, in order to demonstrate the degree of variability that emerges when piano rolls are rendered in a digital form.

### Stage 1: format

The various digitisations of the Leschetizky roll were collected, and their digitisation format was determined. This enables one to see whether there are any significant differences in quality between them, particularly in terms of sample rate in Hertz (Hz) (which can tell us how many times the piano roll was sampled per section, and this determines the eventual frequency range and the likely clarity of the recording), bit depth (the larger the bit depth, the larger the dynamic range), whether the recording is mono or stereo (since stereo recordings capture a much more sophisticated spatial image) and file type (there are numerous different possibilities in terms of encoding digital data, and some of these use compression). Here follow the various recordings with their format information:

#### *Format of digitisation*

- Leschetizky Archiphon (Amazon): 44,100Hz, 16 Bit, stereo, WAV
- Leschetizky Archiphon (iTunes): 44,100Hz, 16 Bit, stereo, MP3
- Leschetizky Bechstein-Welte (YouTube): 44,100Hz, 16 Bit, stereo, WAV
- Leschetizky Steinway-Welte (YouTube): 44,100Hz, 16 Bit, stereo, WAV
- Leschetizky Denis Hall: 44,100Hz, 16 Bit, stereo, MP3
- Leschetizky Sveriges Radio: 44,100Hz, 16 Bit, stereo, WAV

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<sup>10</sup> *The Welte Mignon Mystery*, vol. XIII. *Theodor Leschetizky, today playing his 1906 interpretations. Works by Leschetizky, Chopin, Mozart and Heller*, 2009 [CD] Tacet 177.



- Leschetizky Stitcher Radio: 44,100Hz, 16 Bit, stereo, WAV
- Leschetizky Tacet: 44,100Hz, 16 Bit, stereo, WAV
- Leschetizky Opal: 44,100Hz, 16 Bit, stereo, MP3

As we can see, there appears to be very little difference between the various recordings. They are all at the same sample rate, all at the same bit depth, and all appear to be in stereo. This implies that they are all, roughly, at the same level of digital quality. The only significant difference is that six of the recordings are in WAV format, whilst the other three are MP3; the former does not involve any form of compression, whereas the latter does, implying that the quality might have been reduced; we shall return to this later on in the case study.

### Stage 2: amplitude

After determining the various formats for the digitisations, the second stage involved a method for determining the average amplitudes for the various recordings. This enables one to determine how much of the available dynamic range the various recordings fill. More importantly, it enables one to assess whether there are any differences between the left and right sides of the stereo image; one would expect to find differences if the recording was made with a stereo pair of microphones. If the amplitude is identical, or almost identical, in both channels, then it is reasonable to assume that the recording is actually mono. There is no easy way of determining the overall amplitudes. As such, the root mean square (RMS) power average was calculated (as an average) for both left and right channels of each recording. RMS is a statistical measurement of the magnitude of a varying quantity, in this case a waveform, applied to voltage or current. In this context, RMS power is the measure of continuous power that an amplifier or loudspeaker can output with 0db being the maximum and a negative reading being below this threshold. In other words, the higher the reading, the louder the average audio power in the digitised recording.

*RMS (root mean square) power average for entire recording*

- Leschetizky Stitcher Radio: -24.88db (left channel); -25.65db (right channel)
- Leschetizky Archiphon (Amazon): -27.55db (left channel); -26.65db (right channel)
- Leschetizky Archiphon (iTunes): -27.64db (left channel); -26.73db (right channel)
- Leschetizky Bechstein-Welte (YouTube): -25.73db (left channel); -28.36db (right channel)
- Leschetizky Steinway-Welte (YouTube): -27.58db (left channel); -26.67db (right channel)
- Leschetizky Denis Hall: -32.41db (left channel); -30.41db (right channel)
- Leschetizky Sveriges Radio: -22.90db (left channel); -23.34db (right channel)
- Leschetizky Tacet: -27.78db (left channel); -29.99db (right channel)
- Leschetizky Opal: -24.58db (left channel); -24.40db (right channel)

As we can see, the various digitisations range from -22db through to -29db. In the context of pianism, a 7db difference is reasonably substantial (particularly given that the decibel scale is logarithmic). We do not know, of course, whether this is due to different levels of the recorded roll, or to do with the way in which the various rolls were recorded or even altered post-recording. Either way, there are clearly dynamic differences between the digitisations. More importantly, it is interesting to note that the two Archiphon digitisations, from iTunes and Amazon, present a high degree of similarity; these slight differences are most likely due to the fact that one is WAV and the other compressed MP3. It would appear, therefore, that these are actually the same digitisation.

### Stage 3: duration

The duration (in minutes, seconds and milliseconds) was calculated for each of the nine digitisations. This reading was taken from the start of the very first note, to the start of the very last note; the final note is sustained for varying degrees, partly because some of the recordings have been manually faded out.

#### *Durations of digitisations*

- Leschetizky Stitcher Radio: 6'11"540ms
- Leschetizky Archiphon (Amazon): 6'03"520ms
- Leschetizky Archiphon (iTunes): 6'03"572ms
- Leschetizky Bechstein-Welte (Youtube): 6'04"820ms
- Leschetizky Denis Hall: 6'21"884ms
- Leschetizky Sveriges Radio: 6'11"542ms
- Leschetizky Steinway-Welte (Youtube): 6'03"543ms
- Leschetizky Tacet: 6'19"248ms
- Leschetizky Opal: 5'14"472ms

As we can see, the durations of these digitisations vary, with most of them between 6'02" and 6'21". This, in itself, is quite surprising given that they are all drawn from the same roll. This implies that the roll is being played at different speeds on different mechanisms, and thus we cannot guarantee that we are hearing the speed at which Leschetizky originally performed the piece on any of the given digital versions. This is a particularly significant fact, given that so much research is conducted into time and timings with regard to early recordings and yet we cannot conclude, from this information, which speed Leschetizky chose. The Opal digitisation is wildly, and surprisingly, different. Despite being drawn from the same piano roll, it is a mere 5'14" which, considering the slowest at 6'21" means that there is a 1'07" difference between them. This might be due to an editing error or decision, but the author was unable to identify any musical information omitted

from the digitisation. Whatever the reason, the resulting measurements of Leschetizky's tempo in, say, beats per minute (BPM), would be significantly skewed (relative to any other chosen digitisation) if the only source of evidence used was the Opal digitisation. In two cases, the durations are almost identical. The Stitcher and Sveriges Radio recordings are just 2 milliseconds different, and this may be put down to the small margin of error that occurs when making a reading of this kind. Furthermore, the Amazon and iTunes digitisations are also practically identical in term of their duration and, given what was discovered about their amplitudes, we might now assume that they are, in fact, the same digitisation. From this point onwards, therefore, the Sveriges Radio and iTunes digitisations will be removed from the discussion.

#### Stage 4: pitch

Removing the files that are deemed identical, pitches have been determined for the first note in each of the digitisations. This enables one to assess the extent to which pitches differ across the set. The pitch was difficult to calculate, since some of the recordings have a poor balance across the frequency spectrum. As such, the loudest frequency component was identified, and this was calculated as a pitch equivalent. In some cases, the loudest frequency seemed to be misleading; a substantial bass response, or a poor balance in the frequencies, caused the loudest frequency to be below the audible range of the piano. In each of these cases, a synthetic tone was generated to see whether this matched the pitch of the piano note. In cases where there was an obvious mismatch, the second loudest frequency component was captured and the test repeated. In the cases presented below, the loudest is given in brackets, since this seemed to be the most plausible in terms of pitch. Below we can see the various frequencies in Hertz (Hz) and the closest, approximate pitch.

- Leschetizky Stitcher Radio: 280Hz approx. C#
- Leschetizky Archiphon (Amazon): 345Hz approx. F (second loudest 218Hz approx. A)
- Leschetizky Bechstein-Welte (YouTube): 86 Hz approx. E (second 237Hz approx. Bb)
- Leschetizky Denis Hall: 70Hz approx. C# (second loudest 238Hz approx. Bb)
- Leschetizky Steinway-Welte (YouTube): 345Hz approx. F (second loudest 848Hz F)
- Leschetizky Tacet: 129hz (approx. C)
- Leschetizky Opal: 129hz (approx. C)

As we can see from the above, only the Tacet and Opal recordings are identical in terms of the loudest frequency (although Bechstein-Welte and Denis Hall are so close that they might as well be called identical). Despite this, there is a note range including C#, C, Bb and A. The reading of the Steinway-Welte YouTube is most likely incorrect; an aural check by the author suggests that this is actually more closely related to C. Although these differences might not seem immediately striking, they are highly significant in the context of pitch; the piece is effectively transposed across the various different recordings. This is, most likely, due to the pitch of the piano that was used in the making of the digitisation, which may again be connected to the use of old grand pianos, which have a tendency to be tuned at a lower pitch. Added to the differences in duration, this implies that digitisations are equally vulnerable when one attempts to say anything concrete about the pitch within the context of research. Thus, we have effectively thrown both time and pitch into question.

### Stage 5: spectral visualisations

Stage five involved the same first notes cut from the start of each digitisation (the only instances of the single voice in the nocturne). Each note was analysed using a spectral visualisation tool to produce a series of graphs. Each graph enables one to see the frequency range along the horizontal axis, and amplitude along the vertical axis. Both sides of the stereo image are represented, with the left channel in light blue and the right channel in dark blue. These graphs show a jagged overview of the spectral content of the first note, from which one can observe the spectral balance and the clarity of the tone of the note. In many respects, this is the closest that the reader may come to appreciating the sonic differences between the various digitisations, albeit in a visual representation of sound.

Image 1. Leschetizky *Stitcher* Radio.

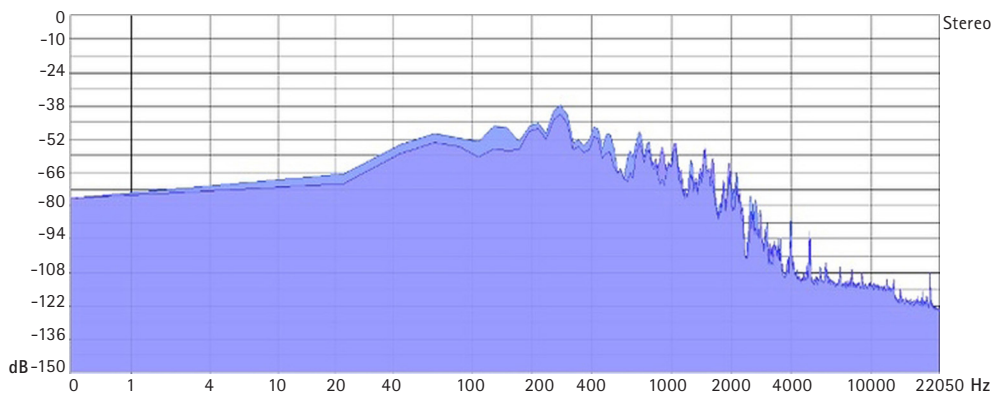


Image 2. Leschetizky Archiphon (Amazon).

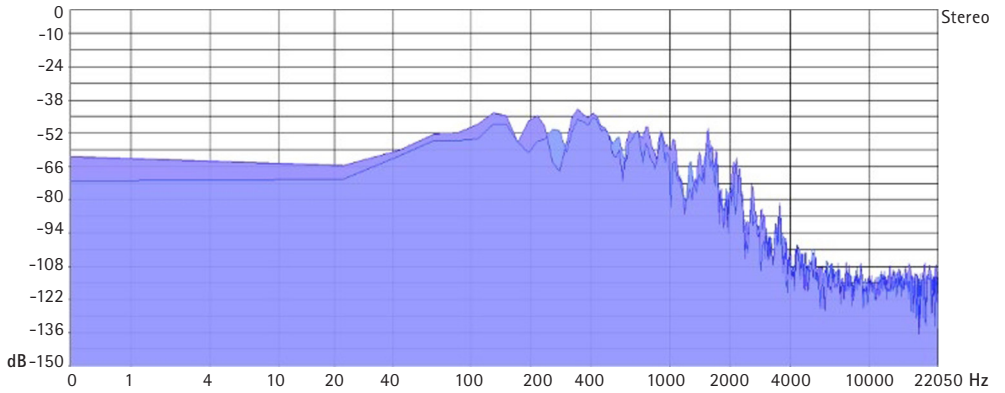


Image 3. Leschetizky Bechstein-Welte (YouTube).

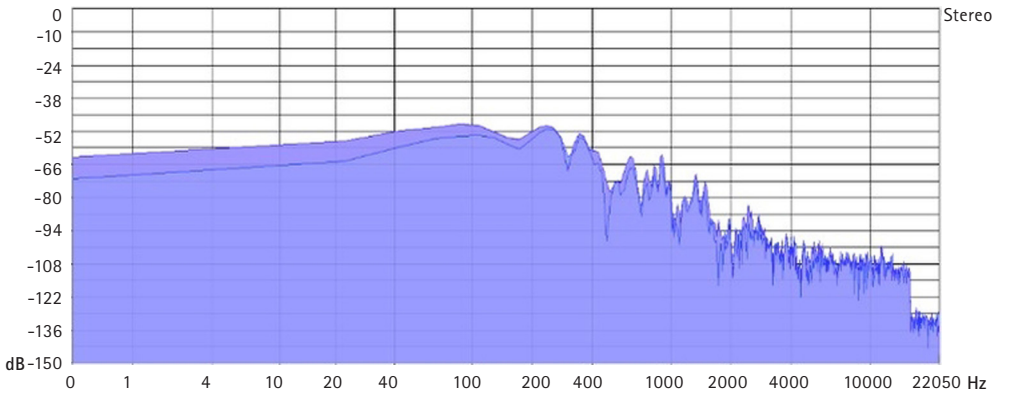


Image 4. Leschetizky Denis Hall.

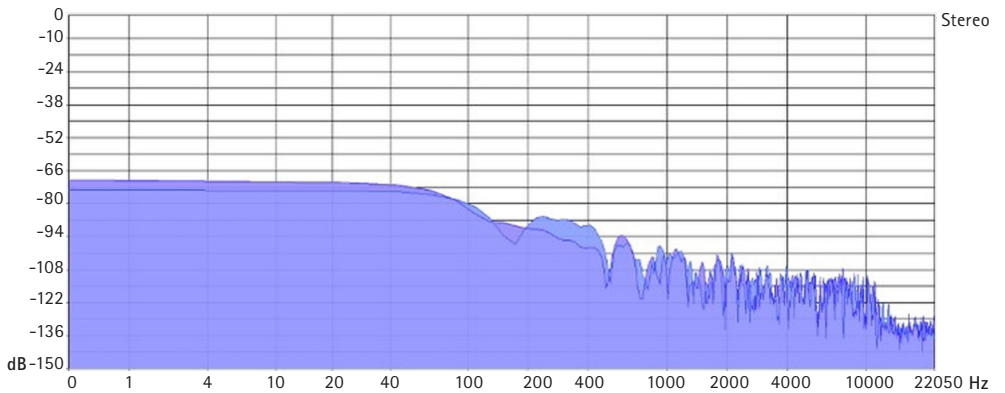


Image 5. Leschetizky Steinway-Welte (YouTube).



Image 6. Leschetizky Tacet.

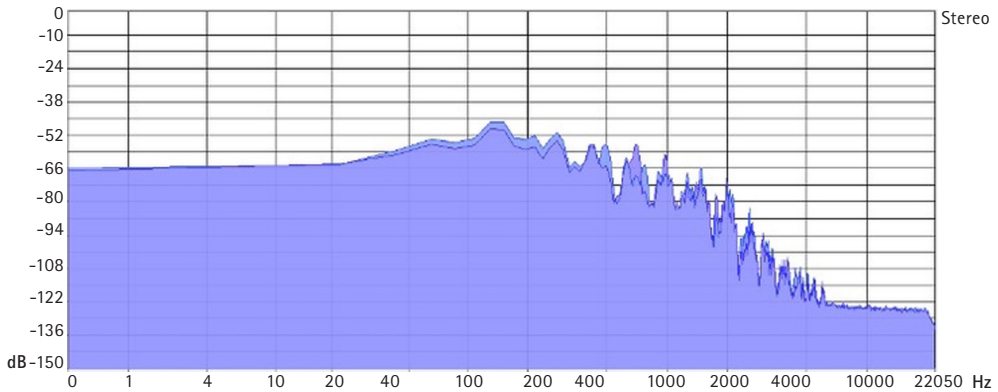


Image 7. Leschetizky Opal.



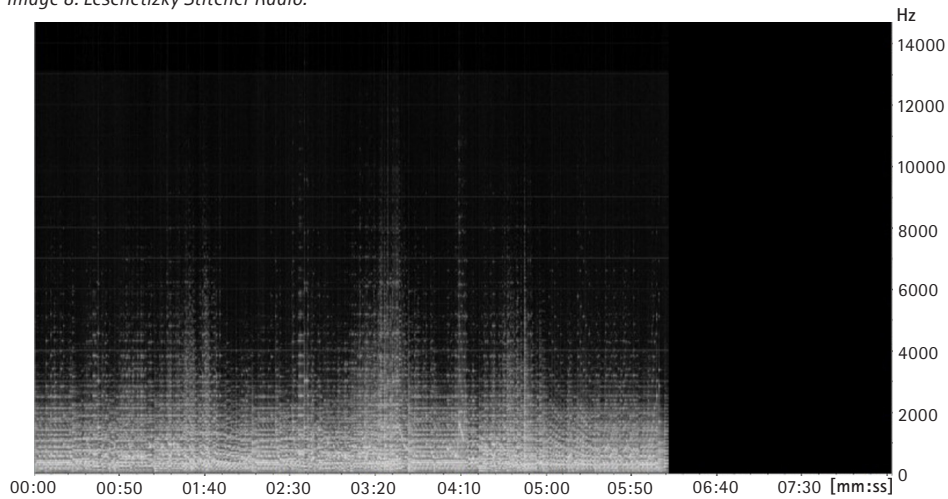
It is very difficult to summarize the content of these spectral visualisations; the images tell more than any short description could possibly hope to achieve. Even so, it is worth drawing attention to a few of the central observations that one might find interesting. The main similarity between all of the digitisations is found in the bass frequencies which, for the most part, are undifferentiated and shown from the left-hand side of the graph towards the middle. The bass is surprisingly prominent in this respect, being occasionally the loudest part of the spectrum; the Denis Hall digitisation is particularly notable in this respect, since the lower end of the spectrum is significantly more prominent than middle and higher frequencies. In all other cases, one finds a swell in the middle of the image; this is the most prominent frequency of the respective notes and usually the loudest spectral part (as explained in stage 4). The jagged spikes that follow roll off gradually towards the top end of the spectrum; this is common to all of the recordings. However, these spikes are differently placed, owing to the different note values, and more numerous in some recordings than others.

One would expect to find a fundamental frequency with subsequent harmonics and overtones represented in such a graph; a single piano note will always contain a range of frequencies with the fundamental loudest and the harmonics rolling off. What is surprising in these digitisations, however, is the extent to which the number of these spikes differ. The Opal digitisation, for example, has relatively few, implying that this piano produces relatively little noise; the tone and timbre will be fairly clear. Furthermore, there is clearly an ordered relationship between these various spikes, as one would expect to find with harmonics. The Tacet digitisation has a similarly clear relationship between the various spikes, although they are significantly more numerous. It is reasonable to suggest that the timbre of this particular instrument is therefore substantially richer. The Amazon digitisation is further along this scale; in this case, the spikes are so numerous that this is likely to be a noisy piano with a cluttered timbre. It is, perhaps, likely to be out of tune, given the lack of any clear relations between its harmonics. The final point to observe relates to the higher frequencies, identified towards the right hand side of the graph. These typically roll off gradually, but in the Bechstein-Welte and Steinway-Welte recordings there is a sharp drop-off at the extreme end. This might be due to the pianos that have been used, which have clarity at the very top end of the spectrum. More likely, this is something that has been tweaked post recording, perhaps by an engineer, or it is a consequence of the format of transmission. MP3s, for example, often reduce clarity in the upper frequencies.

### Stage 6: spectrograph visualisations

The frequency differences implied by the above graphs can be seen much more clearly in the following spectrographs (Images 8-14). Rather than merely considering the first note, the spectrographs consider the whole performance, charting the passage of time along the horizontal axis, the frequency distribution along the vertical axis, and the amplitude at a given frequency shown according to the brightness of the image at a given moment. In effect, one can see the entire performance represented in these images and, interestingly, the graininess of the image is created by the individual notes.

*Image 8. Leschetizky Stitcher Radio.*



*Image 9. Leschetizky Archiphon Amazon.*

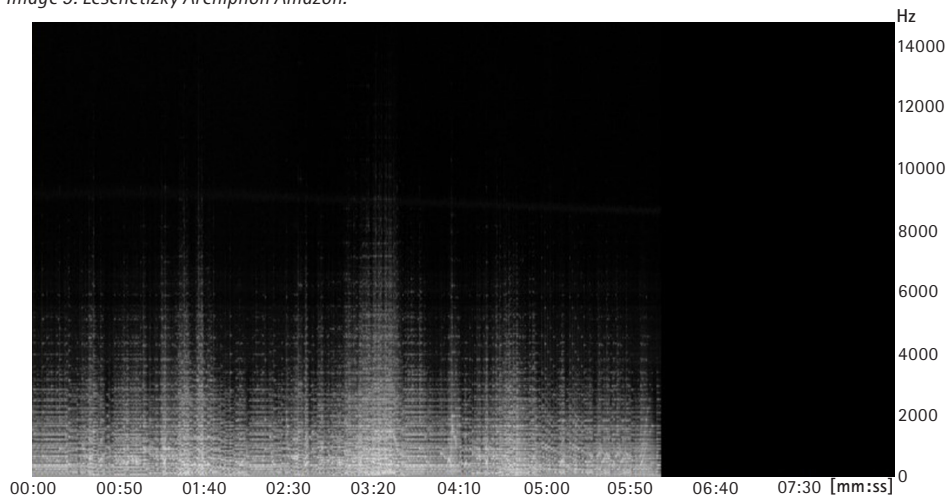




Image 10. Leschetizky *Bechstein-Welte* YouTube.

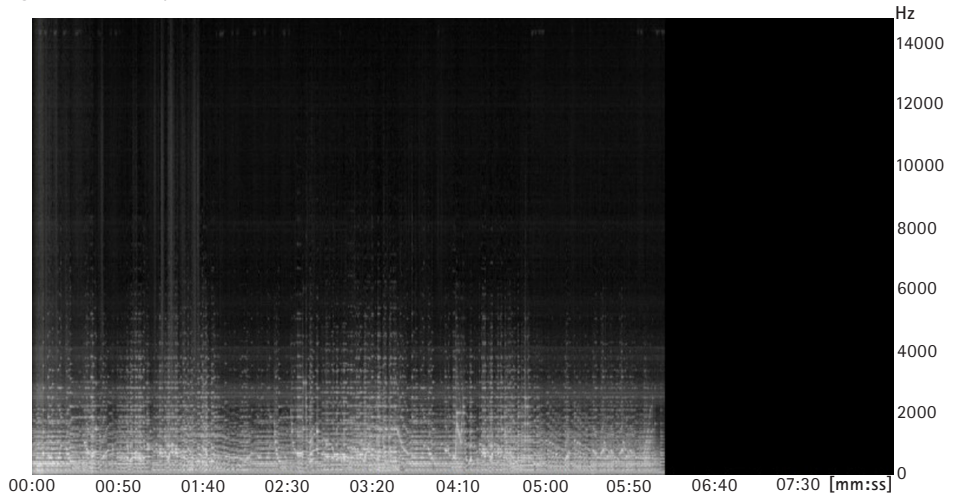
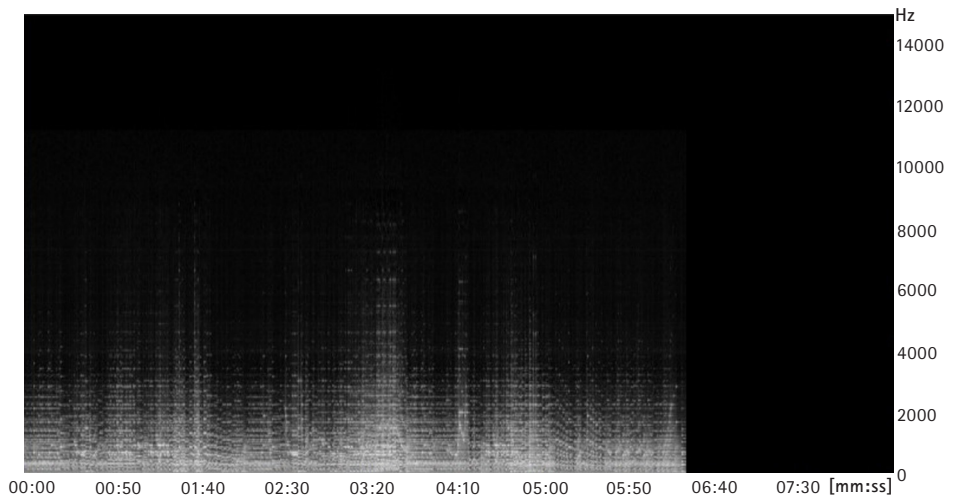


Image 11. Leschetizky *Denis Hall*.



Once again, these images offer more than a description could hope to achieve. It is worth drawing attention to the passage of time, however; although we can see the same shape in all of the various recordings, some are substantially more elongated than others. Beyond this, the *Stitcher*, *Archiphon* and *Tacet* are very similar in terms of their spectral clarity; the central melodic lines are brighter, and therefore, offset from the other piano material, and there is very little background noise. *Denis Hall's* digitisation is very clear, but there is much less in the top end of the recording; either the piano is not as bright in the upper regions, or this was removed when the file was compressed to MP3. The *Bechstein-Welte* digitisation is much noisier; it is still easy to see the main melodic and

Image 12. Leschetizky Steinway-Welte YouTube.

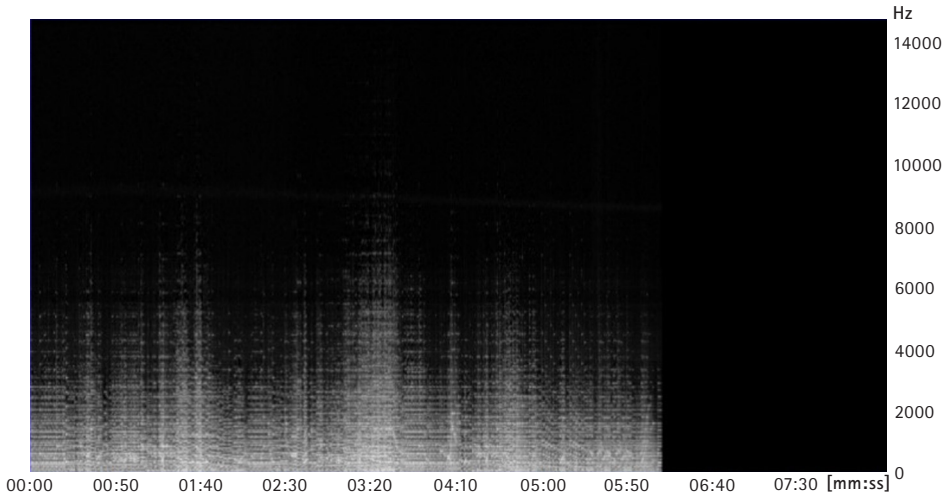
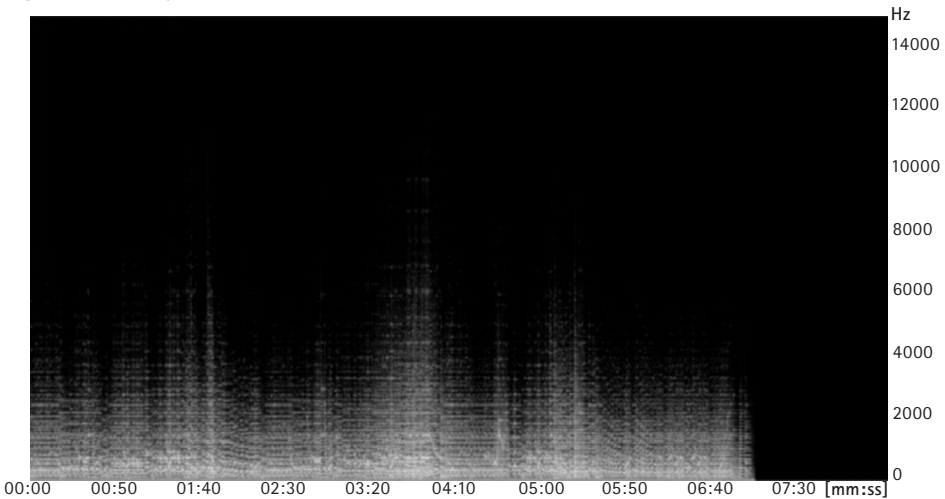
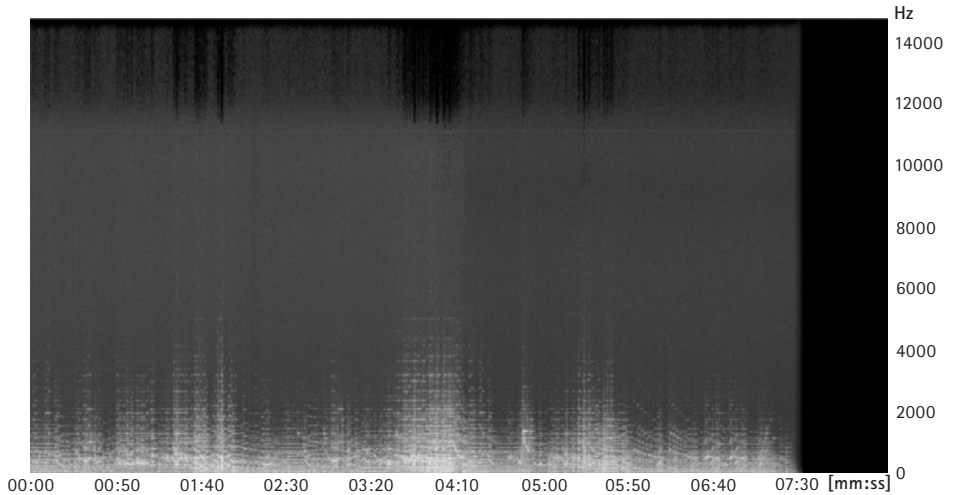


Image 13. Leschetizky Tacet.



harmonic materials but there is also clearly some background noise, and some acoustic artefacts at very specific spectral bands that permeate the whole. This implies that they were recorded in a space with something buzzing or humming; the fan from a computer, for example, might produce this kind of high-frequency band. The Opal recording is, however, again the one that stands out; there is a very substantial amount of noise, and the performance itself will most certainly be drowned out at key moments. Importantly, however, there is no 'consistent' image here, since the digitisations all differ, and the method of recording differs.

Image 14. Leschetizky Opal.



## Conclusion

The case study introduced two different sets of problems when dealing with reproducing piano rolls. Firstly, complications which arise from the roll itself, which will influence the quality of reproduction considerably. These circumstances would include the choice of instrument and speed of running the pneumatic mechanism, for example. The study showed various sonic results in the context of pitch. The Nocturne Op. 27 No. 2 starts on Db, but only two transfers actually started on that note (Stitcher Radio and Denis Hall). Other instruments are so differently tuned that the range goes from C (which is only a semitone down), to Bb (Bechstein-Welte YouTube), A (Archiphon) and even F (Steinway-Welte YouTube) (although this particular instance may be incorrect). Unsurprisingly, these differences severely impact the recordings in context of timbre. The duration of recordings was considerably different, and varied from 5'14" to 6'21". This is an incredible difference in playing time and, since all of the digitisations present different times, one must question which is the most reliable in this context.

Secondly, there are the choices of recording techniques when registering the performance of the instrument, which will make a smaller impact on the overall picture. As we could see from this case study, the various transfers differ in numerous key respects: Format – although ostensibly uniform, several recordings turned out to be mono rather than stereo. Furthermore, several turned out to be the same digitisation. The pitches of the first note, and therefore the whole piece, differ; sometimes by as much as a whole tone. The spectral clarity is widely divergent, with some containing more background noise than others, and some prioritising different parts of the spectrum; this is particu-

larly significant in the context of tone and timbre, since these are things that one is particularly drawn to when listening to the different rolls.

From this, we must conclude that the overall influencing factors on production of digitised files are numerous, and will have a greater or lesser impact upon how one intends to use them. In this sense, sonic evidence is invaluable in research, as they directly show the changes in performing fashions through time. However, it is extremely important to understand the extent to which the transfers or digitisations influence the primary source. In short, we are not dealing with a primary source at all; rather, with a secondary one. To rely upon them, therefore, requires that we understand what they are, how they are produced, and ultimately how they can be used within research. It is paramount that we understand all these points, since reproducing piano rolls are an invaluable resource, and will remain sources of evidence long into the future.

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## Abstract

### **Back to the future: the digitisation of reproducing piano rolls as a rendering of the past**

In the digital age, reproducing piano rolls are increasingly hard to hear; the original playback technologies are rare, and many have deteriorated since their construction. Thankfully, a vast archive of digitisations has enabled performances, captured on such rolls, to become increasingly available for use within musical research. These digitisations preserve historic performance practices that have, in many cases, since disappeared from use and, as a consequence, they have an extremely valuable role to play in numerous research fields. The nature of this role may, however, be questioned; digitisations are often taken to be primary sources of evidence, seemingly offering direct and immediate

access to once-upon-a-time performances. The processes involved in their production, however, suggest that they may be more appropriately understood as secondary sources. To demonstrate this point, this article offers a case study through which the production of digitisations is scrutinised; a range of visualisation tools are used to examine nine digitisations of a single piano roll and, although one may expect uniformity among the digitisations, visualisations reveal significant and substantial differences. Some of these differences may be attributed to the piano roll technologies, particularly in terms the voicing and balance of the piano. Others are a consequence of the digitisation process itself; specific recording techniques, room acoustics, and microphone selection are but some of the many variables that determine the nature of the digital result. As the article develops, it becomes increasingly clear that digitisation profoundly influences what we hear. It is paramount that we understand the variables involved in the production of digitisations, since their capacity to take us back to the past ensures that they remain invaluable sources of evidence long into the future.

### **Keywords**

Digitisation; reproducing piano rolls; recording technologies; historic performance practices.

### **The author**

Croatian pianist Inja Stanović was born in Zagreb and is currently living in Sheffield. She completed her first degree at the Ino Mirkovic School of Music, licensed under the P.I. Tchaikovsky Moscow State Conservatory. She went on to complete two postgraduate programmes at the Schola Cantorum, Paris, before undertaking a masters at The Boston Conservatory. She completed a Ph.D. at The University of Sheffield focusing on nineteenth-century performance practice relating to the works of Chopin. Following several lecturing positions at the University of Sheffield and Birmingham Conservatoire, she recently started a Leverhulme Trust Early Career Fellowship at the University of Huddersfield.

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